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How to cite this thesis
THE IMMEDIATE EFFECT OF CHIROPRACTIC
LUMBOSACRAL MANIPULATIVE THERAPY ON
POWER OUTPUT IN ELITE CYCLISTS

A dissertation submitted to the Faculty of Health Sciences, University of
Johannesburg, in fulfilment of the requirements for the degree of Master of
Technology: Chiropractic

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UNIVERSITY OF
JOHANNESBURG

Supervisor: ___________________________ Date: ________________
Dr. Irmarie Landman

Johannesburg, 2015
DECLARATION

I, Michelle Lisa Ross, declare that this dissertation is my own, unaided work. It is being submitted as partial fulfilment for the Master’s degree of Technology, in the program of Chiropractic, at the University of Johannesburg. It has not been submitted before any degree or examination in any other University or Technikon.

________________________________________

Michelle Lisa Ross

On this day the __________ of the month of ____________________ 2015.
ABSTRACT

The purpose of this study was to determine whether chiropractic spinal manipulative therapy had an immediate effect on athletic performance in the elite cyclist. Changes in performance were quantified using objective data from power measurements (in Watts) recorded while the participants were cycling.

The study was a pre-test-post-test control group design. Eighty participants were randomly allocated into either the treatment group or the control group. Data was collected using the air-braked cycle ergometer, the Wattbike Trainer. The test protocol comprised of a ten-minute warm up followed by three six-second sprint efforts, each sprint at a different resistance level. The test protocol was repeated after a thirty-minute rest period. During the rest period the treatment group received chiropractic manipulative therapy to the lumbar spine and sacroiliac joints and the control group received no intervention.

Both the treatment and control group increased their mean power output, possibly due to a learned response. However the treatment group had a noticeably greater increase in mean power output across all three sprint efforts, post chiropractic spinal manipulative therapy. This improvement in performance of asymptomatic, elite cyclists could possibly be attributed to the effects of the chiropractic spinal manipulative therapy.
DEDICATION

To my family and my friends who have been by my side throughout my years of study, thank you for your support and understanding.

A special thank you to my parents, Adele and Ian Ross, who have been my pillars of strength and provided constant encouragement. Your unconditional love is the foundation on which all my achievements have been built.
ACKNOWLEDGEMENTS

Dr. Irmarie Landman, my supervisor, thank you for your guidance, hard work and time throughout this study.

Steve Saunders, thank you for your advice and time spent assisting me with formulating the basis to which the methodology of this study was constructed. Your willingness to share your extensive knowledge and expertise of the intricacies of the Wattbike is greatly appreciated.

Elizabeth Harrison, my remarkably efficient editor, thank you.

Juliana Van Staden, from STATKON, thank you for your assistance in the statistical analysis of the data and willingness to help me fully understand the results.

Staff of Virgin Active Bryanpark and Virgin Active South Africa, thank you for the use of the facilities and continuous patience and support during the trial period.

Dr. Lisa Dickerson, thank you for your advice, support and the many hours spent at the gym supervising the treatment of participants, even when heavily pregnant.

To all the participants who took part in this study, thank you for your time and interest. Without you it would not have been possible.
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CHAPTER 1
Introduction

1.1 Introduction

A cyclist’s performance ability can be assessed and analysed using the quantifiable measurement of power output. The ability of a cyclist to produce a high power output is essential for competitive races, as adequate power is needed during climbing phases, when sprinting to the finish, when passing other cyclists and when starting in mass or individual time trialling. Most successful cyclists, irrespective of the race discipline, have a high maximal aerobic power output measured with an incremental test, and an ability to work at relatively high power outputs for extended periods (Atkinson, Davidson, Jeukendrup and Passfield, 2003).

Monitoring power output is of particular importance when working with elite cyclists, where improvements in performance are small but may still be considered worthwhile in a competitive sport setting (Driller, Argus and Shing, 2013). Monitoring minor changes in the cyclist’s performance, in response to altered training loads and evaluating the effects of different training programs, has become a critical facet of sports performance management (Driller, Argus, Bartram, Bonaventura, Martin, West and Halson, 2014).

Usabiaga, Crespo, Iza, Aramendi, Terrados and Poza (1997) found that a cyclist’s position involves a change from normal lumbar lordosis when standing to lumbar kyphosis when sitting on a bicycle. Slumped sitting (as in lumbar kyphosis) has been associated with greater intradiscal pressure in the lumbar spine and the prolonged sitting has been associated with creep deformation in the lumbar viscoelastic tissues (Muyora, Lo’pez-Minarob and Alacidc, 2013). Cyclists spend a large amount of time training
on their bicycles to elicit a physiological training effect, and this training may influence lumbar spinal curvature over time.

According to Gatterman (2004), spinal manipulative therapy can be defined as any chiropractic procedure that utilises controlled force, leverage, direction, amplitude and velocity directed at specific joints or anatomic regions. Chiropractors commonly use such procedures to influence joint mechanics and neurophysiologic function (Gatterman, 2004). For this particular study the researcher assessed the lumbar vertebrae and sacro-iliac joints.

By assessing and treating the lumbar spinal segments and sacroiliac joints, the researcher aimed to reduce fixations located in these specific joints with the intention of improving their biomechanical function. In addition the researcher intended, by influencing neurological function, to have a positive effect on the nerves supplying the main muscle groups of the lower limb.

To the researcher’s knowledge there is presently no research that addresses the possible effects of pre-event chiropractic spinal manipulative therapy and specifically, its possible immediate effects on power output in the cyclist.

1.2 Aims

The aim of the study was to determine whether chiropractic spinal manipulative therapy had an immediate effect on athletic performance in the elite cyclist. Changes in performance were quantified using power measurements (in Watts) taken while the participant was cycling. Comparing the two groups (the treatment and control group) served to determine whether the improvement was due to the chiropractic spinal manipulative therapy, or whether the observed improvements were
perhaps due to a learned response after having completed the identical test protocol a second time.

1.3 Benefits of the Study

If chiropractic spinal manipulative therapy was found to be of benefit, the researcher would be able to quantify the difference in the power output of the cyclists, due to the correction of faulty biomechanics and improved neurological function. This would serve as evidence that chiropractic treatment may be able to improve the cyclist’s athletic performance and perhaps also have an effect on reducing injury during the competitive cycling season. The study may create a better understanding of the biomechanics of the pedal stroke and production of power, which would enable chiropractors to provide a treatment protocol to help cyclists achieve their full potential. The information gained would add to current knowledge and understanding of the benefits of chiropractic spinal manipulative therapy.
CHAPTER 2
Literature Review

2.1 Introduction

This chapter looks at the relevant literature needed to fully understand the topic and establish a platform from which the reader can comprehend and put into context the results of this study.

In all sports at an elite level the difference between winning and losing is often measured in fractions of a second. This is particularly so with cycling. In this highly competitive team sport each team and indeed each athlete, will develop a training regimen specific to the role that the individual rider will play in the team structure. Accurate performance measurement is therefore key to developing team capabilities and maximizing individual athletic functioning.

Miners (2010) questioned “How is ‘performance’ and therefore ‘performance enhancement’ defined from a chiropractic treatment perspective? Is it winning the race, lifting a heavier weight or scoring more points? Is performance related to individual athletic variables such as speed, strength, agility, or sport technique?” Miners (2010) went on further to question how one can go about measuring performance. He asked if a subjective report of improvement or injury recovery from a coach, trainer or individual athlete was sufficient to deem performance improved.

Chiropractic can be considered a form of manual medicine (along with physiotherapy and biokinetics). The main goals of manual medicine are to restore maximal, pain-free movement of the musculoskeletal system, enhance neuromuscular function, and improve biomechanical balance (Brolinson, Smolka, Rogers, Sukpraprut, Goforth, Tilley and Doolan, 2012). Greenstein (1997) suggested that a “multidisciplinary approach that applies spinal manipulative therapy, as well as soft-tissue techniques, physical therapy, rehabilitation, innovative training techniques, nutritional
counseling, plyometrics and education on injury prevention” should form the basis of a model for chiropractic care and treatment of the given athlete.

2.2 Lumbosacral Anatomy

2.2.1 Lumbar and Sacral Osteology

The lumbar spine is a secondary spinal curve, with the function to resist high compressive loads. The five lumbar vertebrae are situated in the lower back between the thoracic vertebrae and the sacrum.

A typical vertebra is divided into an anterior and posterior part. The anterior part is the vertebral body. The posterior part is the neural arch composed of the pedicle and the posterior elements, namely, the laminae, transverse-, articular- and spinous-processes (Levangie and Norkin, 2005).

Osteology of the Lumbar Spine

Each lumbar vertebra has a large kidney shaped vertebral body (when viewed superiorly) that increases in size from cephalad to caudad; the transverse diameter of the vertebrae is more than the mid-sagittal diameter.

There are two transverse processes (TVP) for each vertebra. These transverse processes are long and slender. There are four articular processes per vertebra. The two superior facets are concave and directed posteromedially (or medially). The inferior facets are convex and directed anterolaterally (or laterally). The lumbar vertebrae are unique amongst the rest of the spinal vertebrae as they also have an accessory process
(mammillary process) on the posterior surface of each superior facet (Moore and Dalley, 2010).

![Figure 2.1 Anatomy of the Lumbosacral Spine (Netter, 2014)](image)

The mammillary processes serve as muscle attachment sites. Each vertebra has a posterior spinous process that is short, thick, broad and hatchet shaped (Moore and Dalley, 2010). The triangular lumbar vertebral foramen is larger than the thoracic but smaller than the cervical vertebral foramen (Levangie and Norkin, 2005).
The fifth lumbar vertebra is an atypical lumbar vertebra since it is a transitional vertebra; it is the point at which the lumbar spine characteristics and movements change to that of the sacrum. The lumbosacral articulation is composed of the fifth lumbar vertebra and the first sacral segment and forms the lumbosacral angle (Levangie and Norkin, 2005).

Osteology of Sacral Region

The sacrum is composed of five fused sacral vertebrae in adults and forms a triangular structure, with a base and apex (Levangie and Norkin, 2005). The sacrum contains four pairs of sacral foramina, for the exit of the anterior and posterior rami of the four sacral spinal nerves. The base (superior aspect) of the sacrum has two articular facets to articulate with the inferior facets of the fifth lumbar vertebra (Levangie and Norkin, 2005). The function of the sacrum is to provide strength and stability to the pelvis and transmit the weight of the upper body to the pelvic girdle. The pelvic girdle is the bony ring formed by the hipbones and the sacrum (Thompson, 2002).

2.2.2 Lumbar Joints and Sacroiliac Joints

The lumbosacral spine contains two types of articulations:

- cartilaginous/symphysis joints which are observed at the intervertebral articulations (Levangie and Norkin, 2005),
- synovial joints which are observed at the facet/zygapophyseal and sacroiliac articulations (Forst, Wheeler, Fortin and Vilensky, 2006; Levangie and Norkin, 2005)

The Lumbar Spine Joints

The joints of the lumbar vertebral bodies are secondary cartilaginous joints designed for weight bearing and strength. The articulating surfaces of the
adjacent vertebral bodies are called the intervertebral joints and are connected by fibro-cartilage intervertebral discs (Moore and Dalley, 2010). The intervertebral discs are divided into two parts, the Annulus Fibrosus and the Nucleus Pulposus (Levangie and Norkin, 2005). The posterior third of the Annulus Fibrosus is innervated by the ventral primary ramus of the spinal nerve (Moore and Dalley, 2010).

Lumbar facet joints are true synovial joints consisting of articular cartilage of adjacent articular surfaces, an inner synovial membrane (synovium), synovial fluid, an outer ligamentous capsule and a fibroadipose meniscoid structure (Levangie and Norkin, 2005; Thompson, 2002). The lumbar facet joints are innervated by articular branches that arise from the medial branches of the dorsal primary rami of the spinal nerves. Each articular branch supplies two adjacent joints, one above and one below. Therefore each joint is supplied by two nerves from two adjacent spinal segments (Moore and Dalley, 2010).

Movement does not occur independently in the lumbar spine, but coupled motion occurs that produces simultaneous lateral flexion and rotation.

Movements that occur in the Lumbar Spine:

- Flexion= 40-60 degrees
- Extension= 20-35 degrees
- Lateral Flexion=15-20 degrees
- Rotation=45 degrees (Magee, 2008)

Table 2.1: Articulations of Lumbar Spine (Martini, Nath and Bartholomew, 2015)

<table>
<thead>
<tr>
<th>Element</th>
<th>Joint</th>
<th>Type of Articulation</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The vertebrae</td>
<td>Intervertebral (Between vertebral bodies)</td>
<td>Amphiarthrosis (Symphysis)</td>
<td>Slight movement</td>
</tr>
<tr>
<td></td>
<td>Zygapophyseal (Between articular processes)</td>
<td>Gliding diarthrosis</td>
<td>Slight rotation and flexion/extension</td>
</tr>
</tbody>
</table>
Sacroiliac Joints

Two sacroiliac joints are formed on each side between the sacrum (first to third sacral segment) and the iliac bones (Levangie and Norkin, 2005). The sacrum and the ilium’s C-shaped articular surfaces are irregular with many depressions (Forst et al., 2006; Levangie and Norkin, 2005).

The joint surfaces are unique in that they are covered with hyaline cartilage and fibrocartilage (Forst et al., 2006). Stability is attributed to the adjacent ligaments, which connect the lateral borders of the sacrum with the iliac crest. Various ligaments are found from the lumbar spine to the ilia, which add to the stability of the pelvis (Moore and Dalley, 2010). The surrounding musculature also influences movement and stability. The most notable muscle of which is the Latissimus dorsi muscle via the thoracolumbar fascia, the Gluteus maximus and the Piriformis muscle (Slipman, Whyte and Chow, 2001).

The sacroiliac joint (SIJ) is innervated by the fourth and fifth lumbar ventral rami (L4 & L5), superior gluteal nerve and the fifth lumbar to the second sacral dorsal rami (L5 to S2) (Forst et al., 2006). Histological analysis of the SIJ revealed the presence of paciniform encapsulated and non-paciniform mechanoreceptors suggesting pain and proprioception are transmitted from this joint (Fortin, Kissling and O’Connor, 1999).

The movement in the SIJ is commonly considered to be between three and five degrees. The motion at the sacroiliac joint is, however, affected by a number of factors, including age, gender of the individual and the inherent congruence of the joint surface. The movement of the sacroiliac joint can be monitored by observing the change in distance between the posterior superior iliac spines with the patient seated and prone (Levangie and Norkin, 2005). The movement of the pelvis can be described by two broad patterns of movement, namely nutation and the opposite, counter nutation:
**Nutation:** The sacral promontory moves inferiorly and anteriorly and the apex of the sacrum and the tip of the coccyx move posteriorly in the sagittal plane. The sacrotuberous and sacrospinous ligaments limit the movement of nutation. The iliac crests approximate and the ischial tuberosities move apart, widening the base of support when assuming a seated position (Kapandji, 2008)

**Counter-nutation:** The sacral promontory moves posteriorly and superiorly and the apex of the sacrum moves inferiorly and anteriorly. The anterior and posterior sacroiliac ligaments limit movement. The iliac crests move apart and the ischial tuberosities approximate, narrowing the base of support as when lying down (Kapandji, 2008)

Other possible movements include anterior and posterior pelvis tilting, lateral tilting and rotation (Harrison, Harrison and Troyanovich, 1997). If the lumbar spine becomes hypomobile, the spine compensates for the loss of motion by developing hypermobility somewhere else (Gatterman, 2004). This applies in the case of the SIJ, with hypermobility occurring at the sacroiliac joint when the lumbar spine is hypomobile (Levangie and Norkin, 2005).

**Table 2.2: The Articulation of L5 and the Sacrum (Martini, Nath and Bartholomew, 2015)**

<table>
<thead>
<tr>
<th>Element</th>
<th>Joint</th>
<th>Type of Articulation</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>L5/sacrum</td>
<td>Between body of L5 and sacral body</td>
<td>Amphiarthrosis (Symphysis)</td>
<td>Slight movement</td>
</tr>
<tr>
<td></td>
<td>Between inferior articular processes of L5 and articular processes of sacrum</td>
<td>Gliding diarthrosis</td>
<td>Slight flexion and extension</td>
</tr>
</tbody>
</table>
Table 2.3: The Articulation of the Sacrum and the Iliac Bones (Martini, Nath and Bartholomew, 2015)

<table>
<thead>
<tr>
<th>Element</th>
<th>Joint</th>
<th>Type of Articulation</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacrum/ Ilium</td>
<td>Sacroiliac joints</td>
<td>Gliding diarthrosis</td>
<td>Slight movement</td>
</tr>
</tbody>
</table>

2.2.3 Musculature Associated with Cycling

According to Ericson, Bratt, Nisell, Arborelius and Ekholm (1986), the mean peak concentric power output of the main muscle groups while cycling on an ergometer was found to be as follows: for the hip extensors, 74.4 W; hip flexors, 18.0 W; knee extensors, 110.1 W; knee flexors, 30.0 W and ankle plantar flexors, 59.4 W. At the ankle joint, energy absorption through eccentric plantar flexor action was observed; with a mean peak power of 11.4 W and negative work of 3.4 J for each limb and complete pedal revolution. Ericson et al. (1986) stated that the total positive work for each of the different major muscle groups as a percentage of the total work done per pedal revolution was: hip extensors, 27 %; hip flexors, 4 %; knee extensors, 39 %; knee flexors, 10 %; and ankle plantar flexors 20 %. No more recent research of this nature was found. Each of these muscle groups will be discussed further below.

_Lumbopelvic Musculature_

The function of the lumbopelvic musculature is to control movement of the trunk and provide stability to the trunk when the lower extremities are in motion (Levangie and Norkin, 2005).

Posterior back muscles can be divided into three groups; the superficial group (only present in the cervical and thoracic spine), the intermediate group (together forming the extrinsic back muscles) which produce and control movements, and finally the deep group (intrinsic back muscles) that provide vertebral column movements and postural control.
The intermediate layer of back muscles are also referred to as the sacrospinalis group or erector spinae, which are further divided into the iliocostalis, longissimus and spinalis muscles (refer to Table 2.4).

**Table 2.4 Summary of Anatomy of the Erector Spinae Muscles (Moore and Dalley, 2010)**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Main action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erector spinae</td>
<td>Posterior iliac crest, posterior surface of sacrum, sacroiliac ligaments, sacral and inferior lumbar spinous processes and supraspinous ligament.</td>
<td>Iliocostalis: Angles of lower ribs and cervical transverse processes.</td>
<td>Posterior rami of spinal nerves.</td>
<td>Extends vertebral column when acting bilaterally. Laterally flexes the vertebral column when acting unilaterally.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longissimus: Mastoid process of temporal bone, thoracic and cervical transverse processes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spinalis: Spinous processes of upper thoracic vertebrae and cranium.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hip Musculature**

The main hip flexors include the iliopsoas (psoas and iliacus), rectus femoris, sartorius and tensor fascia latae muscles (Levangie and Norkin, 2005). A summary of the anatomy of the hip flexors can be found in Table 2.5.
Table 2.5 Summary of Anatomy of Hip Flexors (Moore and Dalley, 2010)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psoas</td>
<td>T12-L5 vertebral</td>
<td>Lesser trochanter</td>
<td>Ventral rami of lumbar nerves (L1 – L3)</td>
<td>Flexes hip and stabilises hip joint</td>
</tr>
<tr>
<td>Iliacus</td>
<td>Iliac fossa</td>
<td>Lesser trochanter</td>
<td>Femoral (L2 – L4)</td>
<td>Flexes hip and stabilises hip joint</td>
</tr>
<tr>
<td>Tensor fascia latae</td>
<td>Iliac crest, anterior superior</td>
<td>Iliotibial band</td>
<td>Superior Gluteal (L4 – S1)</td>
<td>Abducts, flexes, internally rotates thigh, steadies trunk on lower limb</td>
</tr>
<tr>
<td></td>
<td>iliac spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectus femoris</td>
<td>Anterior inferior iliac spine</td>
<td>Patella/tibial tubercle</td>
<td>Femoral (L2 – L4)</td>
<td>Flexes thigh, extends leg</td>
</tr>
<tr>
<td></td>
<td>and superior rim of acetabulum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sartorius</td>
<td>Anterior superior iliac spine</td>
<td>Proximal medial tibia (Pes anserinus)</td>
<td>Femoral (L2 – L4)</td>
<td>Adbucts, flexes, externally rotates hip, flexes leg at knee joint</td>
</tr>
</tbody>
</table>

The main extensors of the hip are the one-joint gluteus maximus muscle (largest of the hip extensor muscles) and the two-joint Hamstring muscle group, which is comprised of the semitendinosus, semimembranosus and bicep femoris muscles. These primary extensors receive support from the
posterior fibers of the gluteus medius, adductor magnus and piriformis muscles (Levangie and Norkin, 2005).

The gluteus medius muscle is not a hip extensor but is in close relation to the hip extensors. It is important as a pelvic stabilizer whilst the opposite leg is in use. The summary of the hip extensor anatomy is found in Table 2.6.

**Table 2.6 Summary of Anatomy of the Hip Extensors and Knee Flexors (Moore and Dalley, 2010)**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Main action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluteus maximus</td>
<td>Posterior ilium, dorsal surface of the sacrum and coccyx and sacrotuberous ligament</td>
<td>Lateral condyle of tibia</td>
<td>Inferior gluteal nerve (L5, S1, and S2)</td>
<td>Extends thigh</td>
</tr>
<tr>
<td>Gluteus medius</td>
<td>External surface of ilium</td>
<td>Lateral surface of greater trochanter of femur</td>
<td>Superior gluteal nerve (L5, S1)</td>
<td>Abducts and medially rotates the thigh</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>Ischial tuberosity</td>
<td>Proximal medial tibia (Pes anserinus)</td>
<td>Sciatic (tibial division) (L5 – S2)</td>
<td>Extends thigh, flexes leg</td>
</tr>
<tr>
<td>Semimembranosus</td>
<td></td>
<td>Posterior medial tibial condyle</td>
<td>Sciatic (peroneal) (L5 – S2)</td>
<td>Extends thigh, flexes leg</td>
</tr>
<tr>
<td>Biceps femoris: Long Head</td>
<td></td>
<td>Head of fibula</td>
<td></td>
<td>Extends thigh, flexes leg</td>
</tr>
<tr>
<td>Biceps femoris: Short Head</td>
<td>Linea aspera and supra condylar line</td>
<td>Fibula, lateral tibia</td>
<td>Sciatic (peroneal) (L5 – S2)</td>
<td>Extends thigh, flexes leg</td>
</tr>
</tbody>
</table>
**Thigh Musculature**

The main knee extensors are made up of the four Quadriceps muscles, namely: the rectus femoris, vastus lateralis, vastus intermedius and vastus medialis (Levangie and Norkin, 2005; Moore and Dalley, 2010). The summary of the anatomy of the knee extensors is found in Table 2.7.

**Table 2.7 Summary of Anatomy of the Knee Extensors (Moore and Dalley, 2010)**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Main action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus femoris</td>
<td>Anterior inferior iliac spine and superior rim of acetabulum</td>
<td>Patella/tibial tubercle</td>
<td>Femoral (L2 – L4)</td>
<td>Flexes hip, extends knee</td>
</tr>
<tr>
<td>Vastus lateralis</td>
<td>Greater trochanter and lateral lip of linea aspera of femur</td>
<td>Lateral patella, tibial tubercle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vastus intermedius</td>
<td>Anterior and lateral aspect of femoral shaft</td>
<td>Patella; tibial tubercle</td>
<td>Femoral (L2 – L4)</td>
<td>Extends leg at knee joint</td>
</tr>
<tr>
<td>Vastus medialis</td>
<td>Intertrochanteric line and medial lip of linea aspera of femur</td>
<td>Medial patella, tibial tubercle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The knee is flexed by means of the hamstring muscle group, which consists of three muscles that span the hip and knee joints; namely, semitendinosus, semimembranosus and biceps femoris. The anatomy of these muscles has been discussed above in Table 2.6.
**Leg Musculature**

The posterior leg muscles are divided into superficial and deep muscle groups.

The superficial group is composed of the gastrocnemius, soleus and plantaris muscles. The gastrocnemius and soleus are the main plantar flexors of the ankle and through the achilles tendon provides a large moment arm for plantar flexion (Levangie and Norkin, 2005; Moore and Dalley, 2010).

The deep group is composed of the popliteus, flexor hallucis longus, flexor digitorum longus and tibialis posterior muscles. These muscles only produce 5% of the total plantar flexion force at the ankle (Moore and Dalley, 2010). Table 2.8 provides a summary of the anatomy of all the leg muscles.

**Tables 2.8 Summary of Anatomy of the Leg Musculature (Moore and Dalley, 2010)**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Innervation</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrocnemius</td>
<td>Lateral head: lateral aspect of lateral condyle of femur</td>
<td>Posterior surface of calcaneus via calcaneal tendon</td>
<td>Tibial (S1 - S2)</td>
<td>Plantar flexes ankle with extended knee, raises heel at running, flexes leg at knee</td>
</tr>
<tr>
<td></td>
<td>Medial head: popliteal surface of femur; superior to medial condyle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Popliteus</td>
<td>Lateral surface of lateral condyle of femur and lateral meniscus</td>
<td>Posterior surface of tibia, superior to soleal line</td>
<td>Tibial (L4 - S1)</td>
<td>Flexes knee and unlocks it</td>
</tr>
<tr>
<td>Muscle</td>
<td>Origin</td>
<td>Insertion</td>
<td>Innervation</td>
<td>Action</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Soleus</td>
<td>Posterior aspect of head of fibula; superior quarter of posterior surface of fibula soleal line and medial border of tibia</td>
<td>Posterior surface of calcaneus via calcaneal tendon</td>
<td>Tibial (S1 - S2)</td>
<td>Plantar flexes ankle independent of knee position and stabilises ankle</td>
</tr>
<tr>
<td>Plantaris</td>
<td>Inferior end of lateral supracondylar line of femur and oblique popliteal ligament</td>
<td></td>
<td></td>
<td>Assists Gastrocnemius</td>
</tr>
<tr>
<td>Flexor hallucis longus</td>
<td>Inferior two thirds of posterior surface of fibula and inferior part of interosseous membrane</td>
<td>Base of distal phalanx of hallux</td>
<td>Tibial (S2 - S3)</td>
<td>Flexes hallux for improved toe off at jump and run, weakly plantar flexes ankle</td>
</tr>
<tr>
<td>Flexor digitorum longus</td>
<td>Medial part of posterior surface of tibia inferior to soleal line and fascia covering tibialis posterior</td>
<td>Bases of distal phalanges of the lateral four digits</td>
<td>Tibial (S2 - S3)</td>
<td>Flexes lateral four digits, and plantar flexes ankle</td>
</tr>
<tr>
<td>Tibialis posterior</td>
<td>Posterolateral surface of tibia, medial 2/3 of fibula and interosseous membrane</td>
<td>Tuberosity of navicular, cuneiform and cuboid and bases of 2nd to 4th metatarsals</td>
<td>Tibial (L4 - L5)</td>
<td>Plantar flexes ankle, inverts foot</td>
</tr>
</tbody>
</table>
2.2.4 Lumbosacral Neuroanatomy and Neurophysiology

The lumbar and sacral plexus’ supply the lumbopelvic, hip and leg musculature with motor innervation, and obtain sensory input from these muscles and associated structures. Primary afferent fibres from various receptor organs within the surrounding tissues detect sensory input. These afferent fibres are neurons, which form part of the peripheral nervous system (Haldeman, 2005).

There are various types of receptor endings, but for the purpose of this study the focus will lie on mechanoreceptors. Mechanoreceptors are designed to detect changes in balance, touch, proprioception (joint angle, rate of movement, and muscle stretch and force) and pain (Esposito and Philipson, 2005; Haldeman, 2005). They are present in joints, muscles and the skin. The different types of mechanoreceptors of importance to this study are the Pacinian corpuscle, Ruffini’s end organ, free nerve endings, Golgi tendon apparatus and muscle spindles (Haldeman, 2005).

- Pacinian corpuscles located in joints, are rapidly adapting dynamic receptors and are active during joint movement. They signal the onset and offset of a mechanical event (Haldeman, 2000).
- Ruffini’s end organs are slow adapting, low threshold receptors found in joints. They react to minor changes in ligament tension and capsular pressure (Hopkins and Ingersoll, 2000).
- Free nerve endings located in joints are non-encapsulated receptors. They function as pain receptors and the polymodal free nerve endings respond to mechanical stimuli (Haldeman, 2005).
- The Golgi tendon organ located at the musculotendinous junction, detects changes in muscle tension and force produced. These receptors are also present within joints. Golgi tendon organs are innervated via Group Ib afferent fibres (Haldeman, 2000).
- Muscle spindles are slow adapting low threshold receptors located in almost all skeletal muscle and appear parallel to extrafusal
muscle fibres. Muscle spindles are sensitive to muscle tension and changes in muscle length (Haldeman, 2005). Each muscle spindle is innervated by a spindle nerve. Muscle spindles receive dual motor innervation from the fusimotor and the skeletomotor system; both have dynamic and static axons. Muscle spindles are exceedingly important in controlling muscle movement (Hansen and Koepen, 2002).

The input from these receptors determines the muscle output, and is regulated by proprioceptors. Proprioception is defined as the afferent input of internal stimuli from proprioceptive fibers within the body, screened from the external environment, which are responsible for body segment stability, posture control and certain conscious sensations (Riemann and Lephart, 2002).

Proprioception is a key component of the sensorimotor system and is responsible for providing the central nervous system with afferent information used for neuromuscular control, while contributing to dynamic joint stability (Lephart, Pincivero, Giraldo and Fu, 1997; Riemann and Lephart, 2002).

2.3 Lumbo-Sacral Manipulation

Chiropractic therapy makes use of many diverse manipulation techniques, which can be described as specific, short lever, high-velocity, low-amplitude thrusts, with the intention of influencing joint mechanics and neurophysiologic function (Gatterman, 2004). With this particular study the researcher assessed and manipulated the lumbar vertebrae and the sacro-iliac joints.

The chiropractic manipulation is said to open a joint by increasing the space between articulating surfaces or by stretching the tissue in close
proximity to that particular joint which may be causing a restriction of movement. This provides local and remote mechanical and neurological effects (Esposito and Philipson, 2005; Triano, 2001).

By manipulating the lumbar spinal segments and sacroiliac joints, the researcher aimed to reduce restrictions located in these areas with the intention of improving the biomechanical function of these specific joints, as well as possibly affecting the neurological function of the nerves supplying the main muscle groups of the lower limb.

2.4 The Effect of Chiropractic Spinal Manipulative Therapy on Asymptomatic Subjects

According to the WHO (2005), a fixation is defined as: “The state whereby an articulation has become fully or partially immobilized in a certain position, restricting physiological movement”.

It is important to note that athletes may be pain free but this does not mean the athlete is fixation free. Gatterman (2004) stated that spinal fixations might be present in asymptomatic patients.

The aim of chiropractic spinal manipulative therapy is to address the restricted movement of a joint segment and restore optimum function (Gatterman, 2004). The two main effects of such therapy are mechanical and neurological.

2.4.1 Mechanical Effects of Chiropractic Spinal Manipulative Therapy

The mechanical force of the manipulation delivered to the dysfunctional joints may alter the segmental biomechanics. The breakdown of contractile and collagen adhesions in the local soft tissue through mechanical force application will aid the release of possible scar tissue and provide an increase in the available active and passive range of
motion (Kirkaldy- Willis, 1992; Pickar and Wheeler, 2001).

Colloca and Keller (2001) purposed that the mechanical forces provided by chiropractic spinal manipulative therapy to the fixated joint stimulates the somatosensory system, inhibits nociception, improves functional ability of muscles, and/or improves dorsolumbar range of motion. The thrust of chiropractic spinal manipulative therapy also improves the function of muscle tone regulation (Peterson and Bergmann, 2002).

**2.4.2 Neurological Effects of Chiropractic Spinal Manipulative Therapy**

Chiropractic spinal manipulative therapy affects primary afferent neurons from paraspinal tissues, the motor control system and pain processing (Pickar, 2002). The biomechanical changes caused by chiropractic spinal manipulative therapy affect the neural activity by removing the aberrant sensory input or providing new input through the manipulative therapy procedures (Leach, 2004). These changes induced by the manipulation may affect the central neural integration within nociceptive, autonomic and/or motor neuronal pools thereby producing changes in the afferent somatomotor and visceromotor activity (Pickar and Wheeler, 2001).

*The effects on sensory receptors in paraspinal tissues*

Changes in the sensory input may elicit changes in efferent somatomotor and visceromotor activity (Pickar, 2002).

*The effects on neural tissue within the intervertebral foramen*

The tissue properties of neural tissue within the intervertebral foramina may render it vulnerable to effects of mechanical compression produced by changes in the intervertebral disc or facet joints (Pickar, 2002). Only slight mechanical compression applied to the dorsal root ganglia (DRG) and dorsal roots (DRs) is sufficient to produce large, prolonged increases in the discharge of Groups I, II, III and IV afferents (Howe, Loeser and
Calvin, 1977). Mechanical compression of the DRs or DRG may alter both impulse-based neural transmission (e.g. action potentials) and non–impulse-based mechanisms (e.g. axoplasmic transport). According to Esposito and Philipson (2005), chiropractic spinal manipulative therapy can alter neural function by mechanically changing compressional pressures in the intervertebral foramen.

The effects on central facilitation

Central facilitation (central sensitisation) refers to the increased excitability or enhanced responsiveness of dorsal horn neurons to afferent input (Pickar, 2002).

Pickar (2002), stated that reflex erector spinae muscle activity, evoked by pressure placed against paraspinal tissues, varied between subjects and between vertebral segments. Thus alpha motor neurons could be held in a facilitated state due to the sensory bombardment from segmentally related paraspinal structures. These motor reflex thresholds also correlated with the pain thresholds, suggesting that some sensory pathways were also sensitised or facilitated in the abnormal segment.

The phenomenon of central facilitation increases the receptive field of central neurons and allows innocuous mechanical stimuli access to central pain pathways (Woolf, 1994). This means sub-threshold mechanical stimuli may initiate pain because central neurons have become sensitized, and removal of these sub-threshold stimuli should be clinically beneficial. Chiropractic spinal manipulative therapy provides removal of these stimuli through the changes in joint movement or joint play (biomechanical) and through the gate control theory proposed by Melzack and Wall (1965).

The effects on somatosomatic reflexes

There is substantial evidence demonstrating that spinal manipulation induces paraspinal muscle reflexes and modifies motor neuron excitability (Pickar, 2002). In a study conducted by Herzog, Scheele and Conway
(1999), increased paraspinal EMG activity was observed in a pattern related to the region of the spine post application of chiropractic spinal manipulative therapy. Suter, McMorland, Herzog and Bray (2000) studied symptomatic patients with SIJ dysfunction, anterior knee pain and evidence of motor inhibition to knee extensor muscles. Chiropractic manipulative therapy applied to the SIJ resulted in a significantly decreased inhibition of the knee extensors.

Pickar (2002) indicated that chiropractic spinal manipulative therapy improves muscle function either through facilitation or disinhibition of neural pathways. In a study done by Pickar (2002) EMG activity from the Gastrocnemius muscle, caused by direct activation of descending corticospinal tracts using transcranial magnetic stimulation, was larger in patients after lumbar manipulation, compared to that in patients set up in the manipulation position but with no application of manipulative therapy. Changes in muscle spindle input produced by the manipulation could also contribute to the inhibition of somatosomatic reflexes (Pickar, 2002).

Pickar and Wheeler (2001) describe the following hypothetical mechanism for the neurological effect of chiropractic spinal manipulative therapy on muscle:

Gamma motor neuron activity is increased to muscles of fixated vertebral segments. This impairs joint mobility by allowing the muscle stretch reflex to detect minute changes in muscle length. The manipulation increases the joint mobility by producing a barrage of impulses in muscle spindle afferents decreasing the activity of facilitated gamma motor neurons, and reducing the gain of the gamma-loop through an undetermined neural pathway.

Pickar (2002) stated that gamma motor neuron mechanoreceptors reset muscle spindles, restoring muscle tonus. This resets the gamma-bias by producing a high frequency discharge in the muscle spindle and Golgi tendon organs. The reactions of the muscle spindles and Golgi tendon
organs evoke a monosynaptic potential in all alpha-motoneurons going to the associated muscle (Pickar and Wheeler, 2001).

The stimulation of mechanoreceptors present at the lumbar facet joints is one of the proposed mechanisms of providing the clinical effects of chiropractic spinal manipulative therapy (Esposito and Philipson, 2005). Herzog et al. (1999) proposed that this stimulation of joint mechanoreceptors exerts a regulating function on the muscle tone of the associated musculature of the joints. The manipulation stretches the adjacent musculature of the particular vertebral level being treated; this stretch activates muscle spindle and Golgi-tendon reflexes, which decrease the state of hypertonicity and remove myofascial trigger points in these associated muscles. Thus better regulation of reflex responses in muscles occurs (Peterson and Bergmann, 2002; Esposito and Philipson 2005; Herzog et al., 1999; Pickar and Wheeler, 2001).

Herzog et al. (1999) proposed that the manipulation would produce a reduction in muscle electrical activity and tension. Removal of muscle hypertonicity is achieved via a basic reflex whereby an aberrant stimulation initiates the stimulation of signals from the muscle spindles. These signals enter the spinal cord through the dorsal nerve root. The interneuronal connections allow signal transmission to adjacent spinal levels and efferent components of the alpha motor neuron. This reflex can be excitatory or inhibitory, which can result in either increased or decreased muscle contraction or force production (Esposito and Philipson, 2005).

The effect on the alpha motor neuron is also the proposed mechanism of producing a greater muscle power output in muscles biomechanically distant to the adjusted segment. Pickar (2002) also found that there is substantial evidence that chiropractic spinal manipulative therapy evokes paraspinal muscle reflexes and alters motor neuron excitability. These somatosomatic reflexes may be quite complex, producing excitatory and inhibitory effects.
The effect on nociception

The phenomenon of central facilitation is known to increase the receptive field of central neurons, enabling either sub-threshold or innocuous stimuli to access central pain pathways.

In a review by Pickar (2002) it was found that numerous studies have shown that spinal manipulation increases pain tolerance or pain threshold. One mechanism underlying this ability to alter pain threshold or tolerance is the manipulation therapy’s ability to alter central sensory processing by removing sub-threshold mechanical or chemical stimuli from paraspinal tissues. Spinal manipulative therapy causes an increase in proprioceptive input, which has a reflex inhibition on the transmission of pain (Kirkaldy-Willis and Bernard, 1999).

In conclusion the review done by Pickar (2002) demonstrates that chiropractic spinal manipulative therapy theoretically alters the inflow of sensory signals from paraspinal tissues in a manner that improves physiological function.

2.5 Chiropractic and Athletic Performance

During the 2010 Olympic Winter Games, chiropractic as a profession showcased its unique and specialised techniques. Chiropractors involved in sport gained recognition and played an important role in establishing chiropractic in the Olympic medical services model (Uchacz, 2010).

Greenstein (1997) stated that performance in a sport could be determined by a variety of factors, including but not limited to biomechanical, neurophysiologic and psychological components.

According to Yeoman (2001), the immediate effects of chiropractic manipulations are an increase in joint range of motion in all planes, reduction in pain, increased skin pain tolerance level, increased paraspinal
muscle pressure pain tolerance, increased blood flow as well as reduced muscle electrical activity and tension. Other noteworthy basic scientific studies suggest that high velocity, low amplitude thrust techniques (which are used when administering chiropractic spinal manipulative therapy) may improve performance because they facilitate motor neuron pool excitability for 20–60s (Dishman, Ball and Burke, 2002); produce a significant increase in surface EMG, measured in erector spinae isometric maximum voluntary contraction when performed on the joints of the lumbar spine (Ernst, 2003); and are effective in producing short-term pain relief (Winters, Sobel, Groenier, Arendzen and Meyboom-de Jong, 1997).

Brolinson (2003) stated that pre-competition manipulative therapy seems to make biomechanical and physiologic sense. The soft tissue is being “warmed up”, and joint function is being “optimised,” which may enhance musculoskeletal function.

Lauro and Mouch (1991) conducted a study to determine the effect that various chiropractic manipulations had on athletic ability. After six weeks of treatment both groups had an increase in reaction time, but the group who received chiropractic manipulations had an 18% improvement whereas the control group had an increase of 1%. The authors, Lauro and Mouch (1991) concluded that fixation-free athletes reacted faster, were better coordinated and executed finer movements with more precision, resulting in an increased athletic performance.

A number of studies on asymptomatic participants have shown improved function due to chiropractic procedures, which include increased hip range of motion (Pollard and Ward, 1998), increased ankle range of motion (Fryer, Mudge and McLaughlin, 2002) and increased muscle strength (Perle, 2002). It is proposed that this improved function of asymptomatic participants can be attributed to the maintenance of joint function, correction of restrictive joint fixations and subsequent improvement of
conditions in the arthrokinematic chain. This leads to improved muscle balance and an increase in speed of neuromuscular reflexes as a result of chiropractic spinal manipulative therapy (Costa, Chibana, Giavarotti, Compagnoni, Shiono, Satie and Bracherg, 2009; Sandell, Palmgren and Björndahl, 2008).

Lauro and Mouch (1991) state that it had been shown that there may be a potential for enhancing athletic ability through chiropractic treatment, when the goal of treatment is to diagnose and correct existing joint dysfunction complexes whether symptomatic or not.

2.6 Power Output as a Measurement of Performance in the Cyclist

For elite athletes, small changes in performance can be the difference between winning and losing (Jeukendrup, Craig and Hawley, 2000), and as such, testing needs to have the precision to detect small but meaningful changes in performance over time (Driller et al., 2013). Within a research setting, highly reliable testing protocols allow researchers to determine with greater confidence and accuracy, the effects of various interventions on performance and ensure any resulting changes are real and not the result of measurement or biological error (O’Hara, Thomas, Cooke and King, 2012).

Elite cyclists’ performance ability can be assessed and analysed using power output as a quantifiable measurement of performance ability. Balmer, Davison and Bird (2000) state that to evaluate the performance of athletes, it is necessary to use laboratory based tests that are reliable, valid, and sensitive to small changes in an athlete’s fitness level. Faria, Parker and Faria (2005) state that a few of the physiological markers found to be predictive of cycling performance include the following:
• Power output at the lactate threshold
• Peak power output, which can be used to calculate a power/weight ratio (typically in an elite cyclist this should be approximately ≥5.5 W/kg)
• Power output during a maximal cycling test

For simplicity’s sake, to enable the reader to understand the basics of power metres and how power output (Watts) on a bicycle is determined, the following simplified formula is used: Power = force x velocity (Macdougall and Sale, 2014). Power output is an objective and constant snapshot of the work rate done by the cyclist at any given moment. Cadence (rate at which cyclist turns the pedals) and pedal forces measured by a strain gauge (how much physical effort is needed by the cyclist to pull and push the pedals each revolution) are varied inversely to maintain constant power (Redfield and Hull, 1986). Thus, in order to increase power output on a stationary bicycle, one would need to increase the resistance load on the bike to increase the force required to turn over the pedals or one would need to increase the number of times the pedal goes around in one minute. Speed and strength are the most important elements of a cyclist’s skill set as these factors enable them to increase power output (Friel, 2009).
Figure 2.2 The Interaction of Various Skills in Cycling (Friel, 2009)

Most successful cyclists, irrespective of the race discipline, have a high maximal aerobic power output measured from an incremental test, and an ability to work at relatively high power outputs for extended periods (Atkinson et al., 2003).

According to Driller et al. (2013), sprint performance in the laboratory has been closely related to field sprint performance in elite cyclists in race settings. This further substantiates the fact that laboratory assessment of variables such as anaerobic peak power and mean power provides meaningful data for assessing and monitoring performance. Thus, monitoring power output is of particular importance when working with elite cyclists, where improvements in performance are small but may still be considered worthwhile in a competitive sport setting (Driller et al., 2014).
Monitoring minor changes in the cyclist’s performance due to altered training loads and evaluating the effects of different training programs has become a critical facet of sports performance (Driller et al., 2014).

Balmer et al. (2000) mention that instead of using heart rate response and/or average cycling speed in km/hr., a cyclist using a power meter could ride to a predetermined power output based on a percentage of peak power output recorded during an anaerobic power test. It is worth noting that the relationship between heart rate and power output can be detached and distorted from one another during prolonged exercise, in that heart rate may be disproportionately high for the relatively low power output. This detachment can be caused by changes in the cyclist’s position, psychological state and environmental conditions, amongst other factors (Balmer et al., 2000). Thus one can infer that power output, rather than heart rate, measured during training and racing could be used to provide a more reliable assessment of exercise intensity as an objective measure of the work done, as it is not as easily affected by the cyclist’s surroundings, state of mind, emotions or cycling position.

However, heart rate data still has important value in assessing exercise activity, as it shows the physiological cost of the activity. Quantitative tracking of fitness levels over time (when combining objective power output data with physiological data – heart rate etc) provides conclusive evidence of training adaptations.

Driller et al. (2014) make the point that the use of regular performance testing may allow coaches and scientists to track athletic performance improvements or even detect athletes who are overreaching or overtraining.
2.7 Biomechanics of Cycling and the Effects of Chiropractic Manipulative Therapy

The principal posture adopted in cycling involves sitting on the bicycle. This cycling posture, if held over prolonged periods, produces specific variations in lumbar curvature when trunk flexion postures are achieved. Cyclists exhibit greater lumbar flexion than non-athletes in maximal trunk flexion and while sitting on the bicycle (Muyora et al., 2013). Sagittal spinal curvature may adapt gradually to sports during long-term intensive training. Muyora et al. (2013) explain that exposure to years of intense training may influence sagittal spinal curvature and range of motion by increasing the spine’s exposure to particular mechanical loading. Burnett, Cornelius, Dankaerts and O’Sullivan (2004) postulate that the causative factors of the change in sagittal spinal curvature, based on current understanding of biomechanics and physiology theories, are thought to be prolonged forward flexion, flexion–relaxation or over activation of the erector spinae, mechanical creep and generation of high mechanical loads when in a flexed and rotated position while cycling.

Usabiaga et al. (1997) found that a cyclist’s position involves a change from lumbar lordosis in standing to lumbar kyphosis while sitting on a bicycle. Slumped sitting has been associated with greater intradiscal pressure in the lumbar spine and the prolonged sitting has been associated with creep deformation in the lumbar viscoelastic tissues (Muyora et al., 2013). Cyclists spend a large amount of time training on their bicycles to elicit a physiological training effect, and this training may influence lumbar spinal curvature. Rajabi, Freemont and Doherty (2000) found significantly greater standing thoracic curvature in cyclists than in sedentary subjects.

In addition to the position and biomechanics of the spine, Guillaume, Guenette, Sheel and Sanderson (2008) conducted a study which
examined in detail the pedalling action of the cyclist while on the bike, and took note of the fact that the overall moment arm of the lower limb was made up of the following: the ankle contributed on average 21 %, the knee 29 % and the hip 50 % of the total moment. According to Guillaume et al. (2008), the results of this study showed that the relative ankle moment of force remained at 21 % despite manipulation of the cyclists’ position or perceived effort or physiological load. The relative hip moment was reduced on average by 4 % with increased cadence and increased on average by 4 % with increased power output whereas the knee moment responded in the opposite direction. These results suggest that the coordinative pattern in cycling is a dominant characteristic of cycling biomechanics and remains fairly consistent. It is thus important to ensure that the researcher is able to alter the ergometer’s set up to establish the cyclist’s geometry and lower limb kinematics that most closely replicate the cyclist's position on his or her own bike, as this is proven to improve cycling economy and increase the accuracy of the outcome of a given performance test (Driller et al., 2014).

The Subluxation complex (vertebral) is defined as: “A theoretical model and description of the motion segment dysfunction, which incorporates the interaction of pathological changes in nerve, muscle, ligamentous, vascular and connective tissue” (WHO, 2005).

A dysfunctional vertebral subluxation complex can cause a decrease in performance. The decreased performance may be due to dysfunctional biomechanics and altered neurological functioning of the lumbar spine and sacroiliac joints. It has been proven that dysfunction at the sacroiliac joint may cause lower limb weakness and neurological deficit (Magee, 2008). According to studies conducted by Herzog et al. (1999) and Sher (2002), a statistically significant increase in gluteus maximus and quadriceps muscle output can be achieved by manipulating the lumbar spine and sacroiliac joint respectively.
Previous studies have also shown the effect of chiropractic manipulation of the sacroiliac joint alone on quadriceps muscle strength. An immediate reduction in knee extensor muscle inhibition has been observed after sacroiliac dysfunction has been treated with chiropractic manipulation (Maris, 2003).

The chiropractic manipulation provides optimum muscle function and optimum stability to the spine (Panjabi and White, 1990) by improving the ability of the muscle to contract and stretch which subsequently provides a biomechanical advantage (Colloca and Keller, 2001). Studies have shown that pre-competition manipulations have improved biomechanical and physiological factors; with soft tissue and joint function being optimised and musculoskeletal function enhanced (Brolinson, 2003). Sacroiliac joint motions rely on hip and trunk motion and a restricted movement of one will result in a decrease of the other (Schafer and Faye, 1990).

Gatterman (2004) suggested that if one area of the spine becomes hypomobile, an area of hypermobility has to develop elsewhere to compensate for the loss of motion. Thus if the Sacroiliac joints show decreased range of motion, it is projected that the lumbar spine will compensate by showing an increased range of motion (Levangie and Norkin, 2005).
CHAPTER 3
Methodology

3.1 Introduction

This chapter serves to explain the methodology of the study i.e. how the participants were selected, the treatment approach utilised, the relevance of the data obtained, the ethical considerations and the chosen methods for the analysis of the data.

3.2 Study Design

The study was a pre-test-post-test control group design. Participants were randomly allocated into either the treatment group (Group A) or the control group (Group B).

3.2.1 Aim of Study

The aim of the study was to determine whether chiropractic spinal manipulative therapy had an immediate effect on athletic performance of the elite cyclist. Changes in performance were quantified by use of power output measurements (in Watts) obtained while the participants were cycling. The study was designed to attempt to establish if a change in performance was due to the intervention itself (chiropractic spinal manipulative therapy), or was primarily due to a learned response occurring because the subject had completed the identical test protocol for a second time. A learned response would have involved participants anticipating the level of effort needed, during the second attempt, to improve their results.
3.2.2 Participant Recruitment

Participants were recruited using purposive and snowball sampling techniques and were selected from the local cycling community and professional cycling teams. They were informed about the study by means of word of mouth and an advertisement (Appendix A). The advertisement was placed in cycling stores that have clubs and emailed to the registered applicable club members.

3.2.3 Sample Selection and Size

The sample size consisted of a total of 80 cyclists. 40 cyclists were allocated to the treatment group (Group A) and the other 40 cyclists were allocated to the control group (Group B). Of the 40 cyclists in each group, an equal number were male and female. Thus in each group, 20 cyclists were male and 20 cyclists were female.

Screening of participants was done to determine suitability. The researcher took note of and selected participants based on their capabilities to meet the inclusion and exclusion criteria. If the cyclist chose to participate in the study, the procedure of the trials was then explained, after which the participants were required to sign the information and consent forms (Appendices B and C) specific to this study. The first 80 participants, who met the inclusion criteria and were willing to take part in the study after it had been fully explained to them, were assigned to a group via random allocation.

3.2.4 Inclusion Criteria

The following inclusion criteria were set out in order to assist the researcher in selecting suitable participants for the study:
• All participants had to be between the ages at 16 and 50 years; after the age of 50 years degeneration of the musculoskeletal system begins, and may produce a change in expected normal biomechanics (Battie, Viderman and Parent, 2005).

• Gender: Male or female. An equal number of males and females were included in the study (40 male and 40 female).

• Participants had to have the ability to complete the 94.7 cycle race (or a route of similar difficulty and distance) within 3.5 hours with an average speed of 26 km/hr. This total race time of 3.5 hours was chosen as a benchmark fitness requirement to establish the cyclists’ fitness levels and race performance capabilities. A cyclist who was able to achieve the above mentioned criteria would have been sufficiently fit so as not to suffer from fatigue during the second test protocol. This ensured that their pedal technique and efficiency were maintained; thereby limiting the number of variables that may have caused discrepancy between the first and second power tests.

• To further ensure an adequate current fitness level, participants had to have adhered to the following training session guidelines:
  o Participant had to have trained 3 days per week, for 3 months prior to taking part in study.
  o The duration of a training session had to have been between 60-90 minutes per session, 3 days per week.
  o One training session per week had to include a minimum of a 60 km cycle on a road bike or a 40 km cycle on a mountain bike.
  o Participants had to have had consistent, regular cycling training for more than 2 years prior to the study. This is to ensure that the participants have acquired their own habitual pedal technique so that it did not vary during the second test protocols.
Participants had to have completed a minimum of 5 cycle races within a 12-month period prior to trial dates; to ensure that each cyclist had an adequate base line fitness level.

- Participants had to have been pain free and have had no major lower limb or spinal injuries during the past 6 months.

### 3.2.5 Exclusion Criteria

Participants meeting the below criteria were deemed unfit for the purposes of this study:

- Participants who demonstrated any contra-indications to the application of Chiropractic Spinal Manipulative Therapy (Gatterman, 2004) see (Appendix D).
- Participants with a history of lumbar spine surgery or musculoskeletal disease.
- Participants with a current musculoskeletal injury or systemic illness that was likely to affect the outcome of the study or the performance of the athlete.
- Participants must not have used analgesics, anti-inflammatories or muscle relaxant drugs for the duration of the study.
- Participants must not have received any other form of treatment that may have interfered with the results of the study.
- Participants were instructed not to participate in any heavy training or physical activity 24 hours prior to the trials.

### 3.3 Random Group Allocation

Participants were randomly assigned to the treatment (Group A) and the control group (Group B). This was done using two boxes with small pieces of paper numbered 1 - 40 in them. One box was used for females and the other for males.
Randomization of group allocation was achieved by the participants selecting a numbered piece of paper from a box; those who selected an odd number were part of the treatment group (Group A) and those who selected an even number were part of the control group (Group B).

3.4 Treatment Approach

3.4.1 Once off Visit

The participants were required to make themselves available for a single trial session, as this was a once-off study that measured the immediate effect of chiropractic spinal manipulative therapy.

During the trial, participants had a case history taken (Appendix E) as well as a physical examination (Appendix F) and a lumbar spine regional examination (Appendix G) to ensure suitability for the study. In addition, a SOAP note (Appendix H) was completed to record the summarized information pertaining to the participant. All participants were required to comply with the inclusion criteria stated above. An experienced elite cyclist would have the least amount of variance in pedal stroke and cycling technique once fatigue was induced, thus making the retest as similar as possible when the inclusion criteria were met.

Both the control (Group B) and the treatment (Group A) groups completed an identical warm up and test protocol. The trials were performed on Wattbike Trainer bikes.

The warm up consisted of a ramp test for 10 minutes. The men had a starting point of 90 watts; and were then instructed to increase their power output by 25 watts with each minute that passed. The bike console provided prompts to the participant for the new target wattage required each minute. The women participants followed the same protocol,
however their starting point was 70 watts, which increased by 20 watts each minute. By the final minute the men had reached a total power output of 340 watts and the women had reached 270 watts.

After the warm up was completed, the participants were asked to perform three sprint efforts. Each sprint was 6 seconds long. These efforts had a 54 second recovery interval between each sprint. The first sprint was done at level 1 wind resistance. The second sprint was done at level 5 wind resistance. The third and final sprint was conducted at wind resistance level 10. The magnetic resistance was kept at level 1 for the duration of the trials.

Both groups then had a rest period of approximately half an hour; and all participants were given the same refreshments (Energade, nuts and banana/apple) and encouraged to only consume what was provided. This was done to eliminate any advantage due to the consumption of different supplements and food/drinks that could have influenced the participant’s performance. During the 30-minute rest interval, the treatment group (Group A) was motion palpated for restrictions in the lumbar spine and sacroiliac regions. The restrictions noted were manipulated. This procedure was done under the supervision of a qualified Chiropractic practitioner, Dr Lisa Dickerson (Appendix I).

Once the half an hour recovery period had come to an end, the participants repeated the same protocol as before; a 10-minute warm up using a ramp test followed by 3 sprint efforts at different resistance levels.

Power output while cycling was increased by either pedalling faster or by increasing the resistance. Either of these two strategies would have increased the number of watts the cyclist was able to produce.
The participant’s RPM (number of revolutions of the pedal crank arm per minute) was greatest at a low resistance; in this case the lowest resistance occurred during the first sprint effort. A high RPM required the greatest co-ordination and control of the cyclists’ pedal stroke. At a high resistance the participants had a decreased RPM, which required less co-ordination but greater muscle strength.

The trials aimed to measure any possible change to the cyclists’ ability to either pedal faster or increase muscle recruitment to increase strength during the second test phase.
Figure 3.1: A Flow Diagram to Summarise the Research Design of this Study.
3.5. Assessment and Intervention

3.5.1 Assessment - Palpation

Participants’ lumbar spines and sacro-iliac joints were palpated statically and in motion prior to receiving chiropractic spinal manipulative therapy, in order to screen for possible fixations. Please see Appendix J for further detail.

Static palpation of the lumbar spine was done with the participant prone, while motion palpation of rotation, lateral flexion and flexion/extension was done with the participant seated.

The sacro-iliac joints were first assessed using static palpation with the participant prone. The findings of which were then confirmed by motion palpation of the joints, with the participant standing.

Positions of malposition of the sacro-iliac joints could be identified with the aid of palpation and observation. Table 3.1 lists the clinical findings associated with pelvic distortion (Peterson and Bergmann, 2002).

Table 3.1 Clinical findings associated with pelvic distortion (Peterson and Bergmann, 2002)

<table>
<thead>
<tr>
<th>Posterior Innominate Flexion Malposition</th>
<th>Anterior Innominate Extension Malposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prominent medioinferior PSIS</td>
<td>Anterolateral and superior PSIS</td>
</tr>
<tr>
<td>Low gluteal fold</td>
<td>High gluteal fold</td>
</tr>
<tr>
<td>Elevated ASIS</td>
<td>Lowered ASIS</td>
</tr>
<tr>
<td>Contralaterally deviated sacral apex</td>
<td>Ipsilaterally deviated sacral apex</td>
</tr>
<tr>
<td>Anteroinferior sacral base</td>
<td>Posterosuperior sacral base</td>
</tr>
<tr>
<td>Ipsilateral posteroinferiorly rotated L5</td>
<td></td>
</tr>
<tr>
<td>Ipsilateral convexity of the lateral curve</td>
<td></td>
</tr>
<tr>
<td>Functional leg length deficiency</td>
<td></td>
</tr>
</tbody>
</table>
3.5.2 Intervention - Spinal Manipulative Therapy

Diversified techniques were used in the trial. The techniques were used on the fixated spinal segments that were located using motion and static palpation. Please see Appendix K for further detail.

3.6 Objective Data

3.6.1 Wattbike, air-braked cycle ergometer

Participants were assessed using the air-braked cycle ergometer, the Wattbike (Wattbike Ltd, Nottingham, UK). The study took place at the Wattbike Studio at Bryanpark Virgin Active (Appendix L).

Power readings, measured in watts, were used to measure the performance of the participants. All participants that participated in the study had to use SPD cleats and rigid soled cycling shoes, so as to enable them to effectively make use of all muscle groups during the trial session.

The Wattbike calculated power output by measuring the chain tension over a load cell (sampled at 100 Hz) and the angular velocity of the crank arms (twice per revolution) (Driller et al., 2013). The Wattbike is factory calibrated and did not need recalibrating. By measuring the sum of all the forces applied to the chain through the cranks, the Wattbike was able to calculate absolute mechanical power produced by the participant.

The reliability of the Wattbike cycle ergometer has been reported previously over a range of power outputs (50–300 W), with a coefficient of variation of 2.6 % (95 % CI 0.7–2.0 %) in trained cyclists (Driller et al., 2013). The mean accuracy of the Wattbike is typically within 2 % (~0.42 %
+/- 1.21 %) with retest variance typically better than 1 % (0.42 % +/- 0.46 %) (Driller et al., 2013).

The Wattbike cycle ergometer appeared to have been highly reliable when compared to other isokinetic cycle ergometers, as it was equipped with racing handlebars, saddle and toe clips and was configured to closely match the dimensions of the participant’s bicycle (Faria et al., 2005). This provided an appropriate and more readily available alternative to that of setting up participants’ own bikes on various indoor trainers.

3.7 Data Analysis

The researcher collected objective data for the duration of the trials. The data was analysed by Juliana Van Staden of STATKON (located at the University of Johannesburg Kingsway Campus). Parametric tests were used for inter- and intra-group analysis. Independent samples t-test was used to measure differences between the two groups (inter-group analysis). A paired samples t-test was used to analyse any differences between the participants within the group (intra-group analysis).

3.8 Ethical Considerations

All participants that wished to partake in this particular study were requested to read and sign the information form (Appendix B) and consent form (Appendix C). The information and consent form outlined the name of the researcher, purpose of the study and benefits of partaking in such a study. The participant assessment, cycling protocol and treatment procedure were explained in full. Any risks, benefits and possible expected discomforts pertaining to the treatments involved were also outlined and the participant’s safety was ensured (prevention of harm).

During this study, the following risks and discomforts may have occurred. Discomfort may have occurred after the chiropractic manipulative therapy
had been delivered. This is considered a possible normal response and may be experienced by some participants. Another possible adverse reaction was delayed onset of muscular soreness a few days post participation in the trial. This is again considered a normal response to a moderate to intense period of physical activity. The aforementioned risks and discomforts were explained to the participant in full prior to the commencement of the study. If the need arose, participants were referred to an appropriate health care professional when necessary.

The information and consent forms also explained that strict doctor-patient confidentiality was adhered to at all times. All information that was given to the researcher during the study was converted into data and, therefore, could not be traced back to any individual thus, ensuring the participants’ anonymity and confidentiality when compiling the research dissertation. The participants were informed that their participation was on a voluntary basis and that they were free to withdraw from the study at any stage.

Should the participant have had any further questions, contact details of the researcher would have been made available. The participants were required to sign the information and consent form, signifying that they understood all that was required of them for this particular study. Results of the study were made available on request. Those participants that did not receive spinal manipulative therapy during the study were afforded the opportunity to receive treatment after the trials had taken place. This was at no cost to the participant.

This study was approved and registered with the Research Ethics Committee (REC-241112-035) and Higher Degrees Committee of the University of Johannesburg (Appendix M and Appendix N respectively). The study was submitted to Turnitin, refer to Appendix O for report.
4.1 Introduction

Data collected during the study is analyzed and compared in this chapter.

The objective data for this study was recorded on the Wattbike. Each Wattbike was equipped with a console, which recorded all data for the individual participant as they underwent testing. The data set consisted of the average power readings over three sprint efforts at different resistance levels, each effort lasting 6-seconds. This was repeated twice.

80 participants took part, with 40 participants in each of the two groups (control and treatment). Both groups had equal distribution of female and male participants. As both groups were larger than 30, statistical analysis could invoke the Central Limit Theorem. The sample size of each group was large enough that one can regard the sampling distribution of the mean to be normally distributed, even though the underlying population distributions may not be. This in turn means that one can rely on the results of the parametric tests and assumptions can be made with respect to the population as a whole.

Parametric exploratory data analysis was performed on the values collected. This was done on values from the first set of sprint efforts (pre-intervention) to determine if any non-experimental anomalies existed. Analysis was repeated on the second set of sprint efforts to explore the possible effects after treatment was administered (post intervention). The watts produced by the two groups of participants (control and treatment group) at all three resistance levels were separately analyzed.
The Levene’s Test for equality of variances was used to determine whether the underlying distributions have similar variances.

The T-test for equality of means was used to establish whether the means of the two groups were statistically significantly different from each other. A T-test for independent groups is useful when the same variable has been measured in two independent groups. By comparing the means of the two groups, one can easily detect a change within the group, thus the test is more specific and sensitive than that of the equivalent non-parametric test. The T-test for equality of means was conducted on the first set of values to determine whether the two groups’ physical performances were comparable at the onset of the study. It was repeated on the second set of values to establish if the change in mean power output was statistically significant.

The p-value determined the significance of the statistics, which indicated how likely it was that a given result had occurred by chance. If the p-value was less than or equal to 0.05 (p ≤ 0.05) the findings were deemed to be statistically significant (i.e. a less than 5% chance that the results had occurred by chance). If the p-value was greater than 0.05 (p > 0.05) the inverse was true.

Descriptive Statistics were used in order to compare the power output of the treatment and control group, with particular attention paid to the means, standard deviations, medians and ranges of each of the groups. The standard deviation is a measure of the dispersion (statistical variability or variation) of a set of values.

The analyses included:
  - Demographic data analysis based on age and type of cyclist
Inter-group and intra-group analysis was performed on participants' average power output (watts) over a 6-second sprint effort, at three different resistance levels for the two test efforts.

The test used for inter-group analyses was the Independent Samples T-test, while the test used for intra-group analyses was the Paired Samples T-test.

4.2 Demographic Data Analysis

The total sample of this study consisted of eighty participants (n=80). The treatment group (Group A) consisted of forty participants (n=40), of which twenty were female and twenty were male. Group A performed the test protocol before and then again after they received chiropractic manipulative therapy to the lumbar and sacroiliac joints. The control group (Group B) consisted of forty participants (n=40) of which twenty were female and twenty were male. Group B served to determine if there was a learned response elicited by performing the objective test for a second time and received no intervention. Group B repeated the test protocol after a thirty-minute rest period.

4.2.1 Age

All eighty participants' ages were analyzed. A minimum age of 18 years and a maximum of 50 years were included in the study. The mean value for the treatment group was 31 years. The control group was slightly older with a mean of 35 years. The median for the treatment group was 30 years and the control group was 32 years. Table 4.1 compares the variables for age between the groups.
Table 4.1 Descriptive statistics of age in years between groups

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Std. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>31,05</td>
<td>30,00</td>
<td>7,93</td>
<td>18</td>
<td>50</td>
</tr>
<tr>
<td>Control</td>
<td>35,24</td>
<td>32,00</td>
<td>8,42</td>
<td>18</td>
<td>50</td>
</tr>
</tbody>
</table>

The p-value of the independent samples T-test for age was 0,02. The value is less than 0.05 which indicates that the average age difference between the treatment and control group was large enough to be found statistically significant. This disparity between the groups, with an average age difference of just over 4 years, occurred due to the random allocation of cyclists into the control and treatment groups. However the p-value for Levene’s test for equality of variances is greater than 0,05, thus the population variances in a group are equal (i.e. the ranges of ages are equal) and the groups are thus comparable. Table 4.2 illustrates these findings.

Table 4.2 Levene’s Test for Equality of Variance & T-test for equality of means for age between groups

<table>
<thead>
<tr>
<th></th>
<th>Levene’s Test for Equality of Variances</th>
<th>T-test for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-value</td>
<td>P-value</td>
</tr>
<tr>
<td>Age</td>
<td>Equal variances assumed</td>
<td>0,49</td>
</tr>
</tbody>
</table>

4.2.2 Type of Cyclist

Participants from four different cycling disciplines took part in the study. Mountain biking had the largest representation with 46,25% (37 participants) of the total sample. 36,25% (29 participants) of the total
sample were road cyclists. Triathletes made up 12,5% (10 participants) and track cyclists only 5% (4 participants) of the total sample. Table 4.3 demonstrates a cross tabulation of the frequency of cyclist types between Group A and Group B.

**Table 4.3 Cross tabulation of frequency of cyclist type between groups**

<table>
<thead>
<tr>
<th>Cyclist type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Road cyclist</td>
</tr>
<tr>
<td>Group A (Treatment)</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>% within Group A</td>
</tr>
<tr>
<td>Group B (Control)</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>% within Group B</td>
</tr>
<tr>
<td>Total count</td>
<td>29</td>
</tr>
<tr>
<td>Total percentage</td>
<td>36,25%</td>
</tr>
</tbody>
</table>

Group A consisted of 15 (37,5%) road cyclists, 15 (37,5%) mountain bikers, 6 (15%) triathletes and 4 (10%) track cyclists. Group B consisted of 14 (35%) road cyclists, 22 (55%) mountain bikers, 4 (10%) triathletes and no track cyclists. The above distribution of type of cyclist between the two groups was a direct result of random group allocation.

4.3 Inter-group Analysis

4.3.1 Pre-intervention Analysis

Analysis of data collected for the pre-intervention test protocol should not have been markedly different, as one would anticipate that the two groups are comparable and their physical performance similar at the onset of the study. As the groups were larger than 30 participants, statistical analysis
could invoke the Central Limit Theorem, thus one can assume sample normality.

The descriptive statistics, seen in Table 4.4, indicated a similar trend between Group A and Group B over the three resistance levels. The mean difference between Group A and Group B at resistance level 1 was 61.52 watts, at resistance level 5 it was 93.23 watts and at resistance level 10 the mean difference was 84.72 watts.

**Table 4.4 Intergroup descriptive statistics of watts achieved for given resistance levels for first test protocol (pre-intervention)**

<table>
<thead>
<tr>
<th>Resistance level</th>
<th>Treatment</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance level 1</td>
<td>Treatment</td>
<td>873.33</td>
<td>827.5</td>
<td>269.93</td>
<td>372</td>
<td>1356</td>
<td>984</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>811.8</td>
<td>737</td>
<td>248.91</td>
<td>437</td>
<td>1300</td>
<td>863</td>
</tr>
<tr>
<td>Resistance level 5</td>
<td>Treatment</td>
<td>960.6</td>
<td>951</td>
<td>283.23</td>
<td>431</td>
<td>1464</td>
<td>1033</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>867.37</td>
<td>812</td>
<td>260.71</td>
<td>425</td>
<td>1333</td>
<td>908</td>
</tr>
</tbody>
</table>
Having compared the two groups, the p-value of Levene’s test for equality of variances for all three resistance levels was greater than 0.05, indicating that there was no statistically significant difference between the two groups.

The p-value of the T-test for equality of means for all three resistance levels was greater than 0.05, indicating that there was no statistically significant difference when comparing the mean power output of both groups at the three resistance levels for the first protocol. Thus one can say the pre-intervention values and thus the treatment versus control groups were not significantly different at the onset of the study. Refer to Table 4.5.

<table>
<thead>
<tr>
<th>Resistance level 10</th>
<th>Treatment</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>996.68</td>
<td>Median</td>
<td>977.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>280.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>446</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>1577</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>1131</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Control             | Mean        | 911.95| Median| 810   |       |
|                     | Std. Deviation | 264.09|       |       |       |
|                     | Minimum     | 468   |       |       |       |
|                     | Maximum     | 1422  |       |       |       |
|                     | Range       | 954   |       |       |       |
Table 4.5 Levene’s Test for Equality of Variance & T-test for equality of means for intergroup analysis of given resistance levels for first test protocol (pre-intervention)

<table>
<thead>
<tr>
<th>Resistance level</th>
<th>Levene’s Test for Equality of Variances</th>
<th>T-test for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-value</td>
<td>P-value</td>
</tr>
<tr>
<td>Resistance level 1</td>
<td>Equal variances assumed</td>
<td>0,52</td>
</tr>
<tr>
<td>Resistance level 5</td>
<td>Equal variances assumed</td>
<td>0,63</td>
</tr>
<tr>
<td>Resistance level 10</td>
<td>Equal variances assumed</td>
<td>0,50</td>
</tr>
</tbody>
</table>

4.3.2 Post-intervention Analysis

After a thirty-minute interval in which both groups were allowed to recover, the entire protocol; including the identical warm up procedure; was repeated. Within this thirty-minute recovery period Group A (treatment) received chiropractic manipulative therapy and Group B (control) did not. Refer to table 4.6 for descriptive statistics of second protocol.

The mean difference in power output between Group A and Group B was greatly increased throughout the second protocol. At resistance level 1 it was 114,65 watts, at resistance level 5 it was 140,44 watts and at resistance level 10 the mean difference was 128,84 watts. The difference between the average increase in power output of the treatment group and that of the control group during the second test protocol is statistically significant, i.e. The increase in performance of the treatment group was of a great enough magnitude to be statistically significant when compared to that of the control group.
Table 4.6 Intergroup descriptive statistics of watts achieved for given resistance levels for second test protocol (post-intervention)

<table>
<thead>
<tr>
<th>Resistance level</th>
<th>Treatment</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean</td>
<td>958,5</td>
<td>1008,5</td>
<td>263,09</td>
<td>480</td>
<td>1371</td>
<td>891</td>
</tr>
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<td>309,64</td>
<td>465</td>
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<tr>
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<tr>
<td>10</td>
<td>Mean</td>
<td>1050,5</td>
<td>992</td>
<td>307,97</td>
<td>496</td>
<td>1676</td>
<td>1180</td>
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<tr>
<td>Control</td>
<td>Mean</td>
<td>921,66</td>
<td>848</td>
<td>267,93</td>
<td>435</td>
<td>1409</td>
<td>974</td>
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</table>
When comparing the two groups’ data for the second test protocol, the p-value of Levene’s test for equality of variances for all three resistance levels was greater than 0.05. This indicates that there was no statistically significant difference with regard to the equality of sample variances.

The p-values of the T-test for equality of means were equal to 0.05 for resistance level 1 and level 10. The results are then said to have been 5% likely to have occurred by chance, thus they are said to be statistically significant. At resistance level 5, p was equal to 0.03 thereby indicating a greater statistical significance than the other two resistance levels. These findings are illustrated in Table 4.7.

Table 4.7 Levene’s Test for Equality of Variance & T-test for equality of means for intergroup analysis of given resistance levels for second test protocol (post-intervention)

<table>
<thead>
<tr>
<th>Resistance Level</th>
<th>Levene’s Test for Equality of Variances</th>
<th>T-test for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-value</td>
<td>Equal variances assumed</td>
</tr>
<tr>
<td>Resistance level 1</td>
<td>0.77</td>
<td>Equal variances assumed</td>
</tr>
<tr>
<td>Resistance level 5</td>
<td>0.07</td>
<td>Equal variances assumed</td>
</tr>
<tr>
<td>Resistance level 10</td>
<td>0.28</td>
<td>Equal variances assumed</td>
</tr>
</tbody>
</table>
4.4 Intra-group Analysis

The Paired Samples T-test was used to determine whether there was a statistical significance when comparing the first and second test protocols within each group separately, seen in Table 4.8.

Analysis of data collected for the treatment group at all three resistance levels, found the p-value to be 0,00. This signified that the change in power output for the treatment group at all three resistance levels is statistically significant as it is less than 0,05. Thus the observed change, namely the increase in mean power output from the first test protocol to the second test protocol, was very unlikely to have occurred due to chance.

For the control group, the p-value is greater than 0,05 at resistance levels 1 (0,06) and 10 (0,23). This indicates that there is no statistical significance with regard to the change in mean power output at these given resistance levels. At resistance level 5, the control group had a p-value of 0,02, indicating this finding was statistically significant.

Table 4.8 Paired samples T-test for intra-group analysis at different resistance levels

<table>
<thead>
<tr>
<th></th>
<th>Paired Differences</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std.</td>
<td>Deviation</td>
<td>P-value</td>
</tr>
<tr>
<td>Treatment</td>
<td>Resistance level 1</td>
<td>-85,18</td>
<td>103,13</td>
<td>0,00</td>
</tr>
<tr>
<td></td>
<td>Resistance level 5</td>
<td>-71,35</td>
<td>87,09</td>
<td>0,00</td>
</tr>
<tr>
<td></td>
<td>Resistance level 10</td>
<td>-53,83</td>
<td>64,70</td>
<td>0,00</td>
</tr>
<tr>
<td>Control</td>
<td>Resistance level 1</td>
<td>-32,05</td>
<td>104,64</td>
<td>0,06</td>
</tr>
<tr>
<td></td>
<td>Resistance level 5</td>
<td>-24,15</td>
<td>61,98</td>
<td>0,02</td>
</tr>
<tr>
<td></td>
<td>Resistance level 10</td>
<td>-9,71</td>
<td>50,38</td>
<td>0,23</td>
</tr>
</tbody>
</table>
4.5 Percentage Change

The mean values of the power output for the first and second test protocol of both groups were analysed, and the difference between mean wattage at each resistance over the two efforts was calculated as a percentage, illustrated in Table 4.9.

Table 4.9 Increase in wattage as a percentage at different resistance levels

<table>
<thead>
<tr>
<th>Resistance level</th>
<th>Group</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Treatment</td>
<td>11,50%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>4,70%</td>
</tr>
<tr>
<td>5</td>
<td>Treatment</td>
<td>7,60%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>3,90%</td>
</tr>
<tr>
<td>10</td>
<td>Treatment</td>
<td>5,30%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1,20%</td>
</tr>
</tbody>
</table>

The percentage change in wattage, when comparing the first and second test protocols, was consistently greater in the treatment group (Group A) than the control group (Group B). At resistance level 1, Group A increased their average wattage by 11,5 %, Group B by 4,7 %. At resistance level 5, Group A increased their average wattage by 7,6 %, Group B by 3,9 %. At resistance level 10, Group A increased their average wattage by 5,3 %, Group B by 1,2 %. The above percentage change is illustrated in figure 4.1.
Figure 4.1 Bar Graph Representing the Percentage Change in Power Output at different resistance levels.

The discussion of these statistical findings will be found in Chapter Five.
CHAPTER 5
Discussion

5.1 Introduction

The results of this study will be discussed with reference to the statistical analysis performed in Chapter 4. The researcher will substantiate the findings with evidence presented from other literature sources, presented in Chapter 2.

As previously discussed, the lumbar spine is a secondary spinal curve, with the function to resist higher compressive loads (Levangie and Norkin, 2005) provided its lordotic curvature is maintained. Usabiaga et al. (1997) observed that the typical position of a cyclist while seated on the bicycle induced a lumbar kyphosis, instead of the normal lumbar lordosis seen when the cyclist was standing. Cyclists exhibit greater lumbar flexion than non-athletes in maximal trunk flexion and while sitting on the bicycle (Muyora et al., 2013).

Slumped sitting has been associated with greater intradiscal pressure in the lumbar spine and the prolonged sitting has been associated with creep deformation in the lumbar viscoelastic tissues (Muyora et al., 2013). This can influence the optimal functioning of lumbar spinal nerves, as the tissue properties of neural tissue within the intervertebral foramina may render it vulnerable to effects of mechanical compression produced by changes in the intervertebral disc or facet joints.

Elite cyclists spend a large amount of time training on their bicycles to elicit a physiological training effect. Muyora et al. (2013) explain that exposure to years of intense training may influence sagittal spinal curvature and range of motion by increasing the spine’s exposure to particular mechanical loading.
It could be proposed that chiropractic spinal manipulative therapy may thus assist the elite cyclist to function at their peak level by minimising biomechanical and neurological shortfalls caused by their prolonged abnormal cycling posture are kept to a minimum.

5.2 Demographic Data

Eighty participants took part in the study, 40 men and 40 women.

5.2.1 Age

The average age for the treatment group was older (31 years) than the control group (35 years). Analysis of the data by means of the Independent Samples T-test for age showed a significant difference when comparing the two groups. This was due to the random allocation of cyclists into the control and treatment groups, thus designation of participants according to their age was not possible. It was still deemed better to use random sampling despite this finding, as the random sampling removed researcher bias when choosing groups. Also, as neither mean was close to 50 years of age, after which degeneration of the musculoskeletal system begins, and may produce a change in expected normal biomechanics (Battie et al., 2005), the mean ages of both groups were comparable.

5.2.2 Type of Cyclist

Participants from four different cycling disciplines took part in the study. Mountain biking had the largest representation of 46,25% (37 participants) of the total sample. 36,25% (29 participants) of the total sample were road cyclists. Triathletes made up 12,5% (10 participants) and track cyclists only 5% (4 participants) of the total sample. The overall distribution of type of cyclist between the two groups was unequal. Designation of participants
was completely random, which resulted in the unequal number of each type of cyclist between the groups.

Each discipline of cycling has cyclists with particular strengths and weaknesses that are a direct result of the specific discipline’s requirements. For example, track cyclists may, on average, be physically stronger than mountain bike cyclists. Road cyclists may, on average, have greater endurance than track cyclists. This is due to the fact that track cyclists need a large amount of explosive power to accelerate as quickly as possible from a standing start. However each race only lasts a few seconds up to a maximum of a few minutes, thus their endurance capabilities are not as well developed as that of cyclists spending a greater time on the bike with each race, such as road cyclists.

With this in mind, cyclists from different disciplines may be better suited to different test protocol designs. The test protocol of this particular study was thus conducted over three different resistance levels; a low, medium and high resistance. The reasoning behind this was that the researcher attempted to consider the different skill sets displayed by each group of elite cyclists that participated in the study. Cyclists who predominantly relied on strength to produce power (track cyclists) would have excelled at the high resistance (level 10), and those who favoured speed and increased co-ordination (road cyclists) would have excelled at the low resistance (level 1).

5.3 Inter-Group Analysis

Inter-group analysis looks at similarities and differences between the two groups in this study. With this analysis the researcher aims to compare the results, at various stages of testing, of the treatment group against that of the control group. The data from the first set of sprint efforts (pre-intervention) was used to determine if any non-experimental anomalies
existed and to ensure that the two groups were comparable. This was done to verify that the two group’s physical performance was similar at the onset of the study.

The post-intervention data was used for further inter-group analysis and it was conducted using the values collect from the second sprint efforts. This was done to see if there was any significant change in power output when only one group had received chiropractic spinal manipulative therapy.

Pre-intervention
Levene’s test for equality of variances revealed that there was no statistically significant difference in variance at any of the three resistance levels. The t-test for equality of means indicated that there was no statistically significant difference when comparing the mean power output for both groups at the three resistance levels. Thus one could conclude that the pre-intervention values and thus treatment versus control group were not significantly different, making the basis for the study legitimate as both groups started at a similar performance level.

Post-intervention
Levene’s test for equality of variances again showed that there was no statistically significant difference in terms of equality of sample variances at each of the three resistance levels.

The t-test for equality of means for analysis of the average power output of the treatment (post chiropractic spinal manipulative therapy) versus the control group for resistance level 1 and resistance level 10, had a p-value that was equal to 0,05. The observed results are then said to have a 5% likelihood of having occurred by chance, thus making the findings statistically significant. At resistance level 5, p was equal to 0,03 thereby indicating greater statistical significance than the other two resistance levels.
Therefore, after the administration of the chiropractic spinal manipulative therapy to the treatment group, the results of the repeated test protocol showed a significant statistical difference in the increased magnitude of mean power output. The treatment and control groups were no longer comparable and statistical findings indicated that the results were unlikely to have occurred by chance.

This improvement in function of asymptomatic, elite cyclists could be attributed to the effects of the chiropractic spinal manipulative therapy. Costa et al. (2009) and Sandell et al. (2008) suggest that the participants that had chiropractic spinal manipulative therapy observed an improvement in function due to the maintenance of joint function, correction of restrictive joint dysfunctions and thereby improved conditions in the arthrokinematic chain, which then resulted in improved muscle balance and an increased in speed of neuromuscular reflexes.

As stated in Chapter 2, a number of studies on asymptomatic participants have also shown improved function due to chiropractic procedures, which include increased hip range of motion (Pollard and Ward, 1998), increased ankle range of motion (Fryer et al., 2002; Perle, 2002) and increased muscle strength (Perle, 2002). A change in biomechanics could lead to an alteration in the lever system of the muscle and promote a more efficient contraction.

The stimulation of mechanoreceptors present at the lumbar facet joints is one of the proposed mechanisms of providing clinical effects of chiropractic spinal manipulative therapy (Esposito and Philipson, 2005). It has also been proven that dysfunction at the sacroiliac joint may cause lower limb weakness and neurological deficit (Magee, 2008). Herzog et al. (1999) and Sher (2002) stated that by adjusting the lumbar spine and SIJ respectively, an increase in Quadriceps and Gluteus maximus muscle output could be achieved. One can thus draw similarities and link the findings of the above studies with that of the one being presented, as in...
the above studies chiropractic manipulative therapy produced an observable and measurable difference in performance and/or function for various participants in a range of conditions.

5.4 Intra-group Analysis

The Paired Samples T-Test was used to determine whether there was a statistical significance when comparing the first and second test protocols within each group separately. The use of these tests enables the researcher to delve into the specific performance results within each group over the repeated sprint efforts and see how they changed over time.

When examining the data collect for the treatment group at all three of the resistance levels, statistical analysis found that there were significant differences within the group when comparing the data collected from the first test protocol to that which was collected from the second test protocol. At all three resistance levels the treatment group showed a p-value of 0.00 for the Paired Samples T-Test. Therefore the results in the treatment group were not at all likely to have occurred due to chance. As only one variable had been changed between the first and second protocols (the use of chiropractic spinal manipulative therapy) one can suggest that the improvement was due to the chiropractic manipulative therapy administered during the thirty-minute break.

For the control group, at resistance level 1 and resistance level 10 there was no statistically significant difference between the first and second protocols with regard to the change in mean power output. However, at the medium resistance, level 5, the data collected for the control group indicated that there was statistically significant difference (p=0,02).

The inconsistency of findings at resistance level 5 for the intra-group analysis of the control group could be due to the fact that it is a medium
resistance. A medium resistance would have allowed the participants opportunity to increase power by making use of either or both strategies, namely increasing cadence or increasing force on the pedals. As stated by Redfield and Hull (1986), cadence and pedal forces are varied inversely to maintain constant power. In order to increase power output on a stationary bicycle, one would need to increase the resistance level on the bike to increase the force required to turn over the pedals, or one would need to pedal faster. Speed and strength are very important elements of a cyclist’s skill set as these factors enable them to increase power output (Friel, 2009).

Thus the observed change in power output in the control group for the second protocol was significantly greater at resistance 5 due to participants exhibiting a learned response and then increasing cadence/leg speed (as would be the main reason for increased power output at resistance level 1) and/or increasing pedaling force (as would be the case at resistance level 10).

However, it must be noted that only one of the three resistance levels had significant findings for the control group. Thus the results for the control group’s increase in mean power output over the two test protocols was less convincing than that of the consistent significant findings for the treatment group at all three resistance levels.

Berg and Lundin (2002) stated that alterations in the central nervous system resulting from practice (repeated efforts) lead to improved skill performance. Therefore the increase in mean power output for both groups after the second sprint effort could be due to the ability of the participant to anticipate the upcoming needed effort, and thereby physically push themselves harder during the second attempt. The researcher acknowledges the possible contribution that practice/acquired familiarity over the two efforts could have had to the increase in
performance of the cyclists. However the fact that the control group did not increase performance as greatly as the treatment group during the second protocol, leads one to speculate that whilst learning may play a role, the chiropractic manipulative therapy serves to create the larger improvement in the treatment group.

The researcher also acknowledges that the psychological effect of receiving chiropractic manipulative therapy may have had an effect on the treatment group i.e. the cyclists’ performance was improved due to the fact that they believed they received an intervention to assist them in performing better (the “placebo effect”). The understanding of the placebo effect has recently shifted in emphasis from a focus on the physical placebo agent, such as a pill, to the overall simulation of a therapeutic intervention and its effects on the brain and body (Price, Finniss and Benedetti, 2008). However, a change in performance mainly due to a placebo effect seems unlikely, as the degree of improvement in the treatment group was statistically significant. Without a change in study design, placebo responses cannot be fully discounted (administering a known, true placebo to the control group).

5.5 Percentage Change

The mean values of the power output for the first and second test protocol were analysed, and the difference between mean wattage at each resistance level over the two efforts was calculated as a percentage.

As a percentage, it is easy for one to comprehend the change in wattage. The treatment group had a consistently greater increase in power output than that of the control group. At resistance level 1, the treatment group increased their average wattage by 11,5 %, the control group by 4,7 %. At resistance level 5, the treatment group increased their average wattage by 7,6 %, the control group by 3,9 %. At resistance level 10, the treatment
group increased their average wattage by 5.3%, the control group by 1.2%.

The average increase in power output of the treatment group was 8.1% and the control group was 3.3%. Therefore the chiropractic treatment may have created as much as a 4.8% improvement on performance in the elite cyclist after negating the effect of familiarization with the test protocol. However this figure cannot necessarily be regarded as accurate, as there are other variables and confounding factors that could not be standardized or avoided and they too may be playing a role in the percentage calculated e.g. the treatment group contained 4 track cyclists, whereas the control group contained 0 track cyclists.

For elite athletes, small changes in performance can have monumental effects on the outcome of a competition, be it winning or losing (Jeukendrup et al., 2000). Monitoring small, objective changes in performance, such as improved power output, is of particular importance when working with elite cyclists (Driller et al., 2013). Scrutinising minor changes in the cyclist’s performance due to altered training loads and evaluating the effects of different training programs has become a critical facet of sports performance management (Driller et al., 2014). Evaluating the effects of various treatment approaches can contribute to forming the overall winning formula for an elite athlete. Hence a 4.8% improvement, whilst it may appear small, could possibly make a significant difference when one considers that some races are won by fractions of a second.

Greenstein (1997) stated that performance could be determined by a variety of factors, including but not limited to biomechanical, neurophysiologic and psychological components. The psychological aspect of this study is that of the familiarization to the test protocol, which aided in the improvement in performance of the second sprint efforts. This factor is however true for every competitive sports person, as practice is
key to success. This psychological component of familiarization was however accounted for in this study, by making use of both a treatment and a control group. This then leaves the biomechanical and neurophysiologic components, which we can speculate, are improved by the chiropractic manipulative therapy and therefore, allow improved performance.

The chiropractic manipulation provides optimum muscle function and optimum stability to the spine (Panjabi and White, 1990) by improving the ability of the muscles to contract and stretch which subsequently provides a biomechanical advantage (Colloca and Keller, 2001). Sacroiliac joint motions rely on hip and trunk motion and a restricted movement of one will result in a decrease in motion of the other (Schafer and Faye, 1990).

Gatterman (2004) also suggested that if one area of the spine becomes hypomobile, an area of hypermobility has to develop elsewhere to compensate for the loss of motion. Thus if the Sacroiliac joints show decreased range of motion, it is projected that the lumbar spine will compensate by showing an increased range of motion (Levangie and Norkin, 2005). Thus the interdependence of the SIJ and lumbar spine dictate, that for optimum function to occur, both need to be biomechanically sound.

When the researcher attempted using chiropractic manipulative therapy to improve the biomechanical functioning of the lumbar spine and sacroiliac joint, a difference in performance of the treatment group when compared to that of the control group was noted.
CHAPTER 6
Conclusion and Recommendations

6.1 Conclusion

The aim of the study was to determine whether chiropractic spinal manipulative therapy had an immediate effect on athletic performance in the elite cyclist. Changes in performance were quantified by use of power output measurements (in watts) while cycling.

Statistical data revealed that inter-group analysis of the first test protocol values had no statistically significant differences at all three resistance levels; thus treatment versus control group were similar at the onset of the study. A comparison of the average power output of the two groups after the second test protocol resulted in a p-value of 0.05 or less for all three resistance levels, thus a statistically significant difference was observed throughout. The treatment group had a noticeably increased improvement in mean power output. This improvement in performance of asymptomatic, elite cyclists could possibly be attributed to the effects of the chiropractic spinal manipulative therapy.

Intra-group analysis found that the treatment group, at all three of the resistance levels, had statistically significant differences in the mean power output when comparing the data collected from the first test protocol to that collected from the second test protocol. This was not the case when analyzing the data for the control group, as there was no statistically significant difference in power output at two resistance levels (1 &10). At resistance level 5, the control group saw a statistically significant increase in performance, which is possibly due to the participants’ greater ability to influence factors contributing to increased power output at a medium resistance level.
Comparing the two groups, treatment and control, determined whether the improvement was due to chiropractic adjustments, or whether completing the test protocol a second time was perhaps due to a learned response. The average increase in power output of the treatment group was 8.1 % and the control group was 3.3 %. Therefore the chiropractic treatment may have had as much as a 4.8 % improvement to performance in the elite cyclist after negating the effect of familiarization.

Therefore it can be postulated that fixations of the lumbar spine and sacroiliac joint may inhibit the performance of elite cyclists, even if they are asymptomatic. The research can thus serve as evidence that chiropractic spinal manipulative therapy may be able to enhance performance in elite cyclists.

6.2 Recommendations

- Repeat the study as above with an increased warm up period. A number of participants commented that a longer, more gradual warm up may be beneficial to performance testing where maximum effort is required.
- Perform the study using an indoor trainer with a power metre, which will enable each participant to take part on his or her own bicycle. This has the benefit of the participants having the bike set up in the way to which they are accustomed and thus less chance of variability in results due to a change of normal cycling posture.
- Perform the study using a placebo treatment (e.g. a tablet) in the control group so that the result of the “placebo effect” in the treatment group can be negated or at least assessed.
- Make use of cyclists from the same cycling discipline, thus using the same “type” of cyclist e.g. track cyclist, mountain biker or road cyclist. Each cycling discipline has its particular strengths and weakness as discussed previously, which may influence results
depending on study design and how that relates to a particular sample group.

- Design a study that specifically tests the strengths and weaknesses of a given type of cyclist, and then attempt to quantify changes in these factors post chiropractic manipulative therapy.

- Perform study on specific cycling teams with the same activity level, training schedule and race calendar. This will ensure a greater similarity in chosen sample and one can draw more accurate findings.

- Perform comparative studies of other manual therapy approaches to determine which has the most beneficial effect on performance, i.e. comparing mobilization techniques to chiropractic manipulative therapy.

- Perform comparative studies between the manipulations of different areas of the spine to that of lower limb joints and its influence on a chosen aspect of cycling performance.

- Include a combination of interventions that encompass chiropractic care, such as manipulative therapy, soft tissue massage, myofascial needling or active release and recording data from different treatment groups.

- Different performance indicators could be employed as objective measurement to obtain the spectrum that chiropractic spinal manipulative therapy enhances sport performance, i.e. testing spinal flexibility, balance on the bike, strength or endurance which are specific performance indicators for certain cycling disciplines.

- Making use of the polar view on the Wattbike (or similar software on other ergometers), whereby one can record the amount of force being produced between right and left leg during each pedal revolution. In this manner one can attempt to determine whether there is an influence post chiropractic manipulation on biomechanics i.e. is a greater equality of force production elicited
and/or is there greater symmetry demonstrated between the activity of the right and left leg.

- A larger sample, recording demographic parameters such as age, gender and frequency of training could be utilized and a model constructed to not only indicate whether there is improvement, but also be able to predict the size of improvement based on these factors.

- A study should be done to test the long-term effects of regular chiropractic manipulative therapy on a cycling team throughout an entire racing season to determine whether chiropractic should be included in the teams’ training regimen and medical support structures, thereby enhancing performance and possibly reducing the risk of injury.
REFERENCES


Are you able to complete the 94.7 cycle race (or a race of similar length and difficulty) within 3.5 hours and maintain an average speed of 26 km/hr?

Are you between the ages of 16 – 50 years old?

Do you have an interest in power output as a measurement of cycling performance?

Come take part in a research study that takes a look at the immediate effect of Chiropractic manipulative therapy on power output in the elite cyclist

Please contact Michelle Ross 084 510 2267
Appendix B

DEPARTMENT OF CHIROPRACTIC
FACULTY OF HEALTH SCIENCES
Telephone: (011) 559 6218

Date: ____________________

INFORMATION FORM

Dear Participant,

My name is Michelle Ross, and I am doing my Master’s Degree at the University of Johannesburg. I would like to invite you to consider participating in my research study entitled The Immediate Effect of Chiropractic Lumbosacral Manipulation Therapy on Power Output in the Elite Cyclist.

Before agreeing to participate, it is important that you read and understand the following explanation of the purpose of the study, the study procedures, benefits, risks, discomforts, and precautions as well as the alternative procedures that are available to you, and your right to withdraw from the study at any time.

Purpose of the study

The purpose of this study is to try determine the effects of the chiropractic adjustment on elite cyclists. I will observe and attempt to measure a
change in the your ability to increase power output through the correction
of faulty biomechanics. This could possibly have an effect on reducing
injury during the competitive cycling season and it could potentially allow
chiropractors to understand better the biomechanics of the pedal stroke
and production of power. This information could allow chiropractors to
provide a treatment protocol to help cyclists’ achieve their full potential.
This will further add to current knowledge and understanding of the
benefits of chiropractic spinal manipulative therapy.

Procedure

Should you decide to partake in this study a full assessment will be done,
by way of a full physical examination as well as relevant regional
examinations. The inclusion and exclusion criteria will also be explained in
detail. This is done to ensure that you comply with the specifications
needed and that it is safe for you take part in the study. You will be
required to attend a once off visit. You will be randomly placed in one of
two groups, the treatment group or the control group. This is done by
selecting a numbered piece of paper from a box allocated to your gender,
with papers numbered 1-40. If you draw an odd number, you will be part of
the treatment group (Group A) and if you draw an even number, you will
be part of the control group (Group B).

The control group (Group B) will be asked to complete the predetermined
power test on the Wattbike. Following a rest period of approximately half
an hour, the you will be asked to complete the same power test again.

The treatment group (Group A) will do the same predetermined power test
as the control group, however during the 30 minute rest interval you will be
palpated for spinal fixations in the lumbar spine and sacroiliac regions.
The restrictions noted will be manipulated under the supervision of a
qualified chiropractic practitioner and then you will be asked to complete the same power test again, post chiropractic manipulative therapy.

Participants in the control group will be offered Chiropractic treatment if they so wish, once the study is completed.

80 cyclists will participate in this study and it will only be performed in South Africa. The entire study, including all treatments will take place at the VIRGIN ACTIVE Bryanpark – Wattbike Studio.

Spinal manipulation is a standard procedure that is performed as part of a routine chiropractic treatment and may present a slight risk of discomfort. You may or may not hear a popping sound associated to the treatment. If you do hear this sound it is completely normal and is as a result of a normal physiological response. It is possible that you may feel some discomfort, although this is uncommon.

As your participation in this study is entirely voluntary you can decline to participate, or stop at any time, without stating any reason. Your withdrawal will not affect your access to other medical care. If you decide not to take part in this study you may still receive the best current care, from your usual practitioner, this may or may not include this study treatment. If it is deemed to be in your best interest, I retain the right to withdraw you from the study.

If you want any information regarding your rights as a research participant, or complaints regarding the research study, you may contact Prof Marie Poggenpoel; Chairperson of the University of Johannesburg Academic Ethics Committee; which is an independent committee established to help protect the rights of research participants. Tel: (011) 559 2860.
Confidentiality

All information obtained during the course of this study will be kept strictly confidential. Recorded data will be used for the statistical analysis by STATKON. STATKON provides a professional, goal-orientated statistical consultation service to postgraduate students and researchers at UJ in respect of research design and methodology, experimental and questionnaire design, and statistical analysis of data. Recorded data will not include any information that identifies you as a participant in this study. Data that may be reported in scientific journals will not include any information that identifies you as a participant in this study.

Any information uncovered regarding your test results or state of health as a result of your participation in this study will be held in strict confidence. You will be informed of any finding of importance to your health or continued participation in this study but this information will not be disclosed to any third party without your written consent. The only exception to this rule will be cases of communicable diseases were a legal duty of notification of the Department of Health exists. In this case, you will be informed of my intent to disclose such information.

Thank you for taking the time to read this form and consider participation in this study.

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

Researcher: Michelle Ross 084 510 22 67
Supervisor: Dr Irmarie Landman 011 559 6820

UJ Ethics clearance number: REC-241112-035
Appendix C

DEPARTMENT OF CHIROPRACTIC

CONSENT FORM

I have been fully informed as to the procedures to be followed and have been given a description of the discomforts, risks and benefits expected from the treatment. In signing this consent form, I agree to this form of treatment and understand my rights and that I am free to withdraw my consent and participation at any time without any reason. I understand that if I have any questions during the study, they will be answered.

Date: ___________________  Researcher: ___________________

Date: ___________________  Participant: ___________________
Appendix D

Contraindications to Chiropractic Spinal Manipulative Therapy
(Gatterman, 2004)

- Space-occupying lesions

- Vascular complications
  - Vertebral-basilar artery insufficiency
  - Atherosclerosis of major blood vessels
  - Aneurysms

- Tumours
  - Primary tumours of the bone
  - Secondary tumours (metastasis to bone)

- Bone infections
  - Tuberculosis
  - Osteomyelitis

- Traumatic injuries
  - Fractures
  - Joint instability
  - Severe sprains or strains
  - Unstable spondylolisthesis

- Arthritis
  - Rheumatoid arthritis
  - Ankylosing spondylitis
  - Psoriatic arthritis
  - Osteoarthritis
  - Reiter’s syndrome
• Psychological consideration
  o Malingering
  o Hystgria
  o Hypochondriasis
  o Pain Intolerance

• Metabolic disorders
  o Clotting disorders
  o Osteopaenia

• Neurologic complications
  o Cauda equina syndrome
  o Disc lesion (advancing neurological deficits)
UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Date: ______________

Patient: ________________________ File No: __________

Age: ______ Sex: ________ Occupation: ________________

Student: ________________________ Signature: __________

Complies with Inclusion criteria of the research:

Clinician: ______________________
Signature: ______________________

Examination:
Previous: UJ Other
Current: UJ Other

X-ray Studies:
Previous: UJ Other
Current: UJ Other

Clinical Path. Lab:
Previous: UJ Other
Current: UJ Other

Case status:
PTT: Conditional: Signed off: Final sign out:

Recommendations:
**Students case history**

1. *Source of history:*

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

3. *Present illness:*

   - Location
   - Onset
   - Duration
   - Frequency
   - Pain (character)
   - Progression
   - Aggravating factors
   - Relieving factors
   - Associated Sx’s and Sg’s
   - Previous occurrences
   - Past treatment and outcome
4. *Other complaints:*

5. *Past history*
   - General health status
   - Childhood illnesses
   - Adult illnesses
   - Psychiatric illnesses
   - Accidents/injuries
   - Surgery
   - Hospitalisation

6. *Current health status and lifestyle*
   - Allergies
   - Immunizations
   - Screening tests
   - Environmental hazards
   - Safety measures
   - Exercise and leisure
   - Sleep patterns
   - Diet
   - Current medication
   - Tobacco
   - Alcohol
   - Social drugs
7. Family history:
   Immediate family:

   Cause of death

   DM

   Heart disease

   TB

   HBP

   Stroke

   Kidney disease

   CA

   Arthritis

   Anaemia

   Headaches

   Thyroid disease

   Epilepsy

   Mental illness

   Alcoholism

   Drug addiction

   Other

8. Psychosocial history:

   Home situation
   Daily life
   Important experiences
   Religious beliefs

9. Review of systems:

   General
Skin
Head/Eyes
Ears
Nose/sinuses
Mouth/throat
Neck
Breasts
Respiratory
Cardiac
Gastrointestinal
Urinary
Genital
Vascular
Musculoskeletal
Neurological
Haematological
Endocrine
Psychiatric
Appendix F

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

PHYSICAL EXAMINATION

(Note: only if Lumbar Regional is complete)

Underline abnormal findings in RED. Date: ________________

Patient: __________________ File No: ____________

Clinician: _______________ Signature: ____________

Student: ________________ Signature: ____________

Height: __________ Weight: __________ Temp: __________

Rates: Heart: __________ Pulse: __________ Respiration: __________

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<th>Blood pressure:</th>
<th>Arms:</th>
<th>L</th>
<th>R</th>
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<tbody>
<tr>
<td></td>
<td>Legs:</td>
<td>L</td>
<td>R</td>
</tr>
</tbody>
</table>

General Appearance:

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________
STANDING EXAMINATION

1. Posture: Erect
   Adam’s
5. Romberg’s sign
6. Pronator drift
7. Trendelenburg’s sign
9. Scapular winging
10. Muscle tone
11. Spasticity/Rigidity
12. Shoulder: skin symmetry
    ROM
    - glenohumeral
    - scapulo-thoracic
    - acromioclavicular
    - elbow
    - wrist

14. Chest measurement:
    - inspiration
    - expiration

15. Visual acuity

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

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<tr>
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<th>R</th>
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<td>cm</td>
<td>cm</td>
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</tbody>
</table>

SEATED EXAMINATION

1. Spinal posture
2. Head
   - hair
   - scalp
   - skull
   - face
   - skin
3. Eyes:
   Observation
   - conjunctiva
   - sclera
   - eyebrows
   - eyelids
   - lacrimal glands
- nasolacrimal duct
- position and alignment
- corneas and lenses

- corneal reflex

- ocular movement
  
<table>
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<th>L</th>
<th>III</th>
<th>IV</th>
<th>VI</th>
<th>R</th>
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</thead>
</table>

- visual fields
- accommodation
- Ophthalmoscopic Examination
  - iris
  - pupils
  - red reflex
  - optic disc
  - vessels
  - general background
  - macula
  - vitreous
  - lens

4. Ears:
- auricle
- ear canal
- drum

- auditory acuity
- Weber test
- Rinne test

5. Nose:
- External
- Internal
  - septum
  - turbinates
  - olfaction

6. Sinuses (frontal & maxillary):
  - tenderness
  - transillumination

7. Mouth and pharynx:

- lips
- buccal mucosa
- gums and teeth
- roof
- tongue
  - inspection
  - movement
- taste
- palpation

- pharynx
  - CN X
  - inspection

9. Neck

- posture
- size
- swelling
- scars
- discolouration
- hair line

Ranges of motion (cervical spine)

The following are normal ranges of motion:

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

- lymph nodes
- trachea
- thyroid
- carotid arteries (thrills, bruit)
- Cranial Nerves
  - CN V
  - CN VII
  - CN VIII (nystagmus)
  - CN IX
  - CN XI
  - CN XI1
9. **NEUROLOGICAL EXAMINATION (CERVICAL SPINE)**

<table>
<thead>
<tr>
<th>DERMATOMES</th>
<th>Left</th>
<th>Right</th>
<th>MYOTOMES</th>
<th>Left</th>
<th>Right</th>
<th>REFLEXES</th>
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<tr>
<td>C2</td>
<td>Neck Flexion</td>
<td>C1/2</td>
<td>Biceps</td>
<td>C5</td>
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<tr>
<td>C3</td>
<td>Lat. Neck Flexion</td>
<td>C3</td>
<td>Brachio – radialis</td>
<td>C6</td>
<td></td>
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<tr>
<td>C4</td>
<td>Shoulder Elevation</td>
<td>C4</td>
<td>Triceps</td>
<td>C7</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>C5</td>
<td>Shoulder Abduction</td>
<td>C5</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>C6</td>
<td>Elbow Flexion</td>
<td>C5</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>C7</td>
<td>Elbow Extension</td>
<td>C7</td>
<td></td>
<td></td>
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<tr>
<td>C8</td>
<td>Elbow Flexion at 90°</td>
<td>C6</td>
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<tr>
<td>T1</td>
<td>Forearm Pronation</td>
<td>C6</td>
<td></td>
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<tr>
<td></td>
<td>Forearm Supination</td>
<td>C6</td>
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<tr>
<td></td>
<td>Wrist Extension</td>
<td>C6</td>
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<tr>
<td></td>
<td>Wrist Flexion</td>
<td>C7</td>
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<tr>
<td></td>
<td>Finger Flexion</td>
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<td></td>
<td>Finger Abduction</td>
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<td></td>
<td>Finger Adduction</td>
<td>T1</td>
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</table>

9. **Peripheral vasculature:**
   - **Inspection**
     - skin
     - nail beds
     - pigmentation
     - hair loss
   - **Palpation**
     - pulses:
       - femoral
       - dorsalis pedis
       - popliteal
       - radial
       - post. Tibial
       - brachial
     - lymph nodes
       - epitrochlear
       - femoral (horizontal & vertical)
     - temperature (feet and legs)
   - **Manual compression test**
• Retrograde filling (Tredelenburg) test
• Arterial insufficiency test

10. Musculoskeletal:
   (i) ROM
   • hip
     | L | R |
     |---|---|
     | flex. 90/120 |
     | ext.    15   |
     | abd.    45   |
     | add.    30   |
     | int rot 40  |
     | ext rot 45  |
     | flex.    130  |
     | ext.    0/15 |
     | plantar Flex 45 |
     | dorsiflex 20 |
     | inversion 30 |
     | eversion 20 |
     | Apparent |
     | Actual  |

   • knee
   • ankle

(ii) leg length
   • Co-ordination - point to point
     - dysdiachokinesia

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

11. Thorax
   • Inspection - skin
     - shape
     - respiratory distress
     - rhythm (respiratory)
     - depth (respiratory)
     - effort (respiratory)
     - intercostals-supraventricular retraction

   • Palpation - tenderness
- masses
- respiratory expansion
- tactile fremitus

• Percussion
  - lungs (posterior)
  - diaphragmatic excursion
  - kidney punch

• Auscultation
  (i) breath sounds
  - vesicular
  - bronchial
  (ii) adventitious sounds
  - crackles (rales)
  - wheezes (rhonchi)
  - rubs
  (iii) voice sounds
  - broncophony
  - whispered pectoriloquy
  - egophony

• Cardiovascular
  - auscultation (aortic murmurs)
  - Allen’s test

SUPINE EXAMINATION

1. JVP
2. PMI
3. Auscultation heart
   (L. lat. Recumbent)
4. respiratory excursion
5. percussion chest
   (anterior)
6. breast palpation
7. Abdominal Examination
   • Inspection
     - skin
     - umbilicus
     - contour
     - peristalsis
     - pulsations
     - hernias (umbilical/incisional)
   • Auscultation
     - bowel sound
     - bruit
   • Percussion
     - general
     - liver
     - spleen
   • Palpation
     - superficial reflexes
     - cough
     - light
     - rebound tenderness
- deep
- liver
- spleen
- kidneys
- aorta
- intra-retro-abdominal wall mass
- shifting dullness
- fluid wave

• Acute abdomen
  - where pain began and now
  - cough
  - tenderness
  - guarding/rigidity
  - rebound tenderness
  - rosving’s sign
  - psoas sign
  - obturator sign
  - cutaneous hyperaesthesia
  - rectal exam
  - Murphy’s sign

MENTAL STATUS

(i) Appearance and behaviour
  - level of consciousness
  - posture and motor behaviour
  - dress, grooming, personal hygiene
  - facial expression
  - affect

(ii) Speed and language
  - quantity
  - rate
  - volume
  - fluency
  - aphasias (pm)

(ii) Mood

(v) Memory and attention
  • orientation (time, place, person)
  • remote memory
  • recent memory
  • new learning ability

(vi) Higher cognitive functions
  • information and vocabulary
  • (general and specialised knowledge)
  • abstract thinking
Appendix G

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

REGIONAL EXAMINATION
LUMBAR SPINE AND PELVIS

Date: 

Patient: ________________________ File No: ________________

Clinician: ________________________ Signature: ________________

Student: ________________________ Signature: ________________

A. STANDING

1. BODY TYPE
2. POSTURE
3. OBSERVATION: -

• Muscle Tone
• Bony + Soft Tissue Contours
• Skin
• Scars
• Discolouration
• Step deformity

4. SPECIAL TESTS

• Schober’s Test
• Spinous Percussion
• Treadmill
• Minor’s Sign
• Quick Test
• Trendelenburg Test
5. RANGE OF MOTION

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

/ = Pain free limitation
// = Painful limitation

6. GAIT

- Rhythm, pendulousness
- On Toes (S1)
- On Heels (L4, 5)
- Halt Squat on one leg (L2, 3, 4)
- Tandem Walking

7. MOTION PALPATION – sacroiliac joints

B. SITTING

01. SPECIAL TESTS

- Tripod Test
- Kemp’s Test
- Valsalva Maneuvre
2. MOTION PALPATION

<table>
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<td>L5</td>
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<td>U</td>
<td>L</td>
<td>S1</td>
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</table>

C. SUPINE

01. OBSERVATION

- Hair, Skin, Nails
- Fasciculations

2. PULSES

- Femoral
- Popliteal
- Dorsalis Pedis
- Posterior Tibial

3. MUSCLE CIRCUMFERENCE

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<thead>
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4. LEG LENGTH

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5. ABDOMINAL EXAMINATION

- Observation
- Abdominal Reflexes
- Auscultation Abdomen and Groin
- Palpation Abdomen and Groin

Comments: 

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NEUROLOGICAL EXAMINATION

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<td>Hip Int. Rot (L4/L5)</td>
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<td>Hip Adduction (L2, 3, 4)</td>
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<td>Hip Abduction (L4/L5)</td>
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<td>Hip Extension (L5/S1)</td>
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7. **SPECIAL TESTS**

- SLR
- WLR
- Braggard’s
- Bowstring
- Sciatic Notch Pressure
- Sign of the Buttock
- Bilateral SLR
- Patrick Faber
- Gaenslen’s Test
- Gapping Test
- “Squish” Test
- Gluteus Maximus Stretch
- Thomas’ Test
- Rectus Femoris Contracture Test
- Hip Medial Rotation
- Psoas Test

**LATERAL RECUMBENT**

- Sacroiliac Compression
- Ober’s Test
- Femoral Nerve Stretch Test
- Myotomes: - Quadratus Lumborum Strength
- - Gluteus Medius Strength
PRONE

- Facet joint challenge
- Myofascial Trigger points:
  - Quadratus Lumborum
  - Gluteus Medius
  - Gluteus Maximus
  - Piriformis
  - Tensor Fascia Lata
  - Hamstrings
- Skin Rolling
- Eichsen’s Test
- Sacroiliac Tenderness
- Pheasant’s Test
- Gluteal Skyline
- Myotomes:
  - Gluteus Maximus strength

NON-ORGANIC SIGNS

- Pin-point pain
- Axial Compression
- Trunk Rotation
- Burn’s Bench Test
- Flip Test
- Hoover’s Test
- Ankle Dorsiflexion Test
- Pin-point pain
## CHIROPRACTIC DAY CLINIC
### SOAP NOTE:

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29/10/2014

To Whom it May Concern;

This letter confirms that I, Dr. Lisa Dickerson, have agreed to oversee and supervise Michelle Ross’ clinical trial due to take place at the Bryan Park Virgin Active Gym.

Relevant dates and times as to when the trials will take placed will be discussed between me and Michelle Ross.

For any further questions please feel free to contact me on 083 653 5094.

Kind Regards

Dr. Lisa Dickerson MTC (SA), ICSSD
Appendix J – Palpation Techniques

Static palpation of the lumbar spine

Evaluation of the bony and soft tissue structures of the lumbar spine was done with the patient in a prone position. The region was scanned for potential areas of tenderness, misalignment, or asymmetry (Peterson and Bergmann, 2002).

The pads of the fingers or the thumbs were used to scan for bony landmarks and palpate the spinous processes, interspinous spaces and mammillary processes of the lumbar spine

Motion palpation of the lumbar spine

The method whereby the patient was seated for evaluation was used. The patient was placed on an adjusting table with their arms across the chest. The researcher stood beside the patient and controlled the movement through contact on the patient's shoulders (Peterson and Bergmann, 2002).

Rotation

• A thumb contact was taken on the ipsilateral aspect of the two adjacent spinous processes. The patient was rotated ipsilaterally to end range of motion. Segmental motion should have been felt while springing the spinous process further into rotation.
• The spinous process should have approximated the palpating thumb and have a springy end feel. Loss of these motions indicated restricted motion. The entire lumbar spine was palpated in this manner from cephalad to caudad (Peterson and Bergmann, 2002).

Lateral flexion

• A thumb contact was taken on the lateral aspect of each interspinous space with a contact on the spinous processes of the
vertebra above and below.

- The researcher then laterally flexed the patient about the thumb contact until all joint slack had been removed.
- The joint was stressed further by laterally flexing the patient and simultaneously applying a counter pressure with the thumb contact to palpate for a springy end feel as the top segment moved away from the bottom segment.
- Coupled motion was induced using movements of lateral flexion and rotation which caused the top segment to move ipsilaterally toward the palpating thumb relative to the segment below.
- If the end feel of the joint was not springy or felt blocked, there may have been a problem with the elastic barrier of resistance indicating a problem with the movement of that joint relative to the one below (Peterson and Bergmann, 2002).

**Flexion and Extension**

- The index finger and the second finger were placed above and below the spinous process of L1.
- The patient was extended and the closing of the interspinous space was felt for at the contact points.
- The patient was then flexed and the opening of the interspinous space was felt for at the contact points (Peterson and Bergmann, 2002).

**Static palpation of the Sacroiliac joints**

Palpation of the pelvic bones and soft tissue structures was mostly conducted with the patient in a prone position. For the evaluation of bony landmarks, a bilateral thumb or fingertip contact was taken. The contour and alignment of the iliac crests, posterior superior iliac spine (PSIS), sacral base and sacral apex were compared. The palpatory depth of the sacral base just medial to the PSIS, as well as the distance between the PSIS and the second sacral tubercle were evaluated and compared on
each side. Indications of pelvic dysfunction could be seen by flexion (posteriorinferior) or extension (anterosuperior) malpositions of one innominate as compared with the other.

**Motion palpation of the Sacroiliac joints**

*Upper Sacroiliac mobility*

- Patient stood facing a wall, supporting himself or herself against the wall.
- The researcher knelt behind the patient and took a thumb contact on the patient's posterior superior iliac spine (PSIS) and the second sacral tubercle or ipsilateral sacral base.
- The patient was asked to flex his or her ipsilateral hip. In normal movement, the thumbs would approximate as the PSIS moved posteriorly and inferiorly toward the stationary sacral tubercle. When the pelvis rotates obliquely around the opposite hip and the thumbs do not approximate, a Sacroiliac flexion restriction should be suspected (Peterson and Bergmann, 2002).
- For extension palpation the contralateral hip was flexed with the same contact as above. This induced posterior nodding of the sacral base on the palpation side.
- Normal movement was evident when the researcher's thumbs moved apart as the PSIS moved anteriorly and superiorly away from the second sacral tubercle (Peterson and Bergmann, 2002).

*Lower Sacroiliac mobility*

- Patient was asked to stand facing a wall, supporting himself or herself against the wall.
- The researcher knelt behind the patient and took a thumb contact on the patient's sacral apex and the adjacent ischium.
The patient flexed the ipsilateral hip. In normal movement the researcher’s thumbs would separate as the ischium moves anteriorly and superiorly when compared to the sacral apex (Peterson and Bergmann, 2002).
Appendix K - Spinal Manipulative Therapy Techniques

Thigh-ilio-deltoid technique

Patient Position: Side-lying with the restricted side uppermost. The arms were placed across the chest so as to balance the patient. The dorsum of the upper foot was placed in the popliteal fossa of the lower limb. The lower limb was kept straight.

Researcher Position: Faced the patient and grasped the patient's knee between the thighs. At the point where the correct amount of hip flexion was achieved, adduction of the patient's thigh and a fencer stance was assumed.

Contact Hand: Caudad hand contacted with specific pisiform contact on the inferomedial aspect of the PSIS. The elbow was flexed and the forearm was kept perpendicular to the contact hand.

Indifferent Hand: Cephalad hand took a contact on the upper shoulder and provided cephalad traction.

Thrust: Inominate rotated anteriorly into extension. The Chiropractic spinal manipulative therapy was delivered at the end of expiration as a body drop with an impulse. The line of drive was posterior to anterior and slightly superior. The contact hand drove the PSIS anteriorly with a slight ulnar torque (States, 1985)

Spinous hook pull technique

Patient position: The patient was in a side-posture position, with the dorsum of the upper foot placed in the popliteal fossa of the lower leg and the arms crossed over the chest as to balance the patient.

Researcher Position: Square stance to the patient with the researcher's knee placed on the patient’s upper knee.
**Contact Hand:** Reinforced fingertip contact of the first three fingers of the caudad hand on the downside of the restricted spinous process. The forearm placed along the patient's posterolateral iliac crest.

**Indifferent Hand:** The cephalad hand contacted the patient's upside shoulder and overlapping hand.

**Thrust:** Researcher’s forearm rotates the patient's pelvis anteriorly. The Chiropractic spinal manipulative therapy was delivered as a body drop at end of expiration. The line of drive was anteriorly with the forearm, upwards with the contact hand and downwards with the knee. These movements all occurred simultaneously (Peterson and Bergmann, 2002).
Appendix L

Virgin Active South Africa (Pty) Ltd
305 Main Road, Kenilworth, 7708, Cape Town, South Africa
P.O. Box 379, Rondebosch, 7701
Tel: +27 (0)21 710 8500, Fax: +27 (0)21 710 8800
www.virginactive.co.za

To whom this may concern

This letter serves acknowledgement that a group of NON members will be using Bryan Parks Watt Bike facility for the period November-December, 2014 and January-February 2015. All non-members will not pay a guest fee for their once-off visit for the period stipulated above. All non-members using Bryan Parks Watt Bike facility must adhere to all our club rules, a copy will be available on the day of access. Our guest register must be completed in full before gaining access.

Regards,

Ashley Paul
Club General Manager
Bryan Park Virgin Active
011 463-6610

Directors: R C Andersen, M W Bucknall*, N M Field, P C K McCall*, Prof W L Nkulu, P M R Norris*, F A Reed*, M Poole*, S Gordon*
Company Secretary: K M W Sandra • “British • Registration No: 2005/041060/07
TO WHOM IT MAY CONCERN:

STUDENT: ROSS, ML
STUDENT NUMBER: 201007375

TITLE OF RESEARCH PROJECT: “The Immediate Effect of Chiropractic Lumbosacral Manipulative Therapy on Power Output in Elite Cyclists”

DEPARTMENT OR PROGRAMME: CHIROPRACTIC
SUPERVISOR: Dr I Landman
CO-SUPERVISOR:

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

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

Yours sincerely,

[Signature]
Prof M Poggenpoel
Chair: Faculty of Health Sciences REC
Tel: 011 559 6686
Email: mariep@uj.ac.za
Appendix N

FACULTY OF HEALTH SCIENCES
HIGHER DEGREES COMMITTEE

HDC-01-88- 2014
01 December 2014

TO WHOM IT MAY CONCERN:

STUDENT:  ROSS, ML
STUDENT NUMBER:  201007375

TITLE OF RESEARCH PROJECT:  The Immediate Effect of Chiropractic Lumbosacral Manipulative Therapy on Power Output in Elite Cyclists.

DEPARTMENT OR PROGRAMME:  CHIROPRACTIC

SUPERVISOR:  Dr I Landmann  
CO-SUPERVISOR:

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

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

Yours sincerely,

[Signature]

Prof Y Coopoo
Chair: Faculty of Health Sciences HDC
Appendix O

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

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Word count: 15,091
Character count: 84,157
Submission date: 06-Nov-2015 12:47AM
Submission ID: 595924079

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