# The immediate effect of thoracic spine manipulation on power output, speed and stroke rate in paddlers

**By**

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I, Thornton Vivier, do declare that this dissertation is representative of my own work in both conception and execution.

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M.Tech: Chiropractic

# Dedication

I consider it the greatest joy to dedicate this dissertation to my Lord and Saviour, Jesus Christ, without whom I would never have come this far and through whom I have found the strength to conquer every mountain that has risen before me.

To Mom, Bruce, Stu, Oums and Oups for being my emotional, technical and financial support through all these years. Without your love and guidance I would surely have failed to complete this journey. Thank you for being my rudder when I needed guidance, my anchor when I needed stability and the wind in my sales when I could not go on.

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# Abstract

**Background:** Kayaking performance can be improved either through reducing drag of the boat or increasing propulsion (Michael *et al.*, 2009). In order to increase propulsion, biomechanical efficiency is required. The trunk muscles have been highlighted as having an important role in the paddler's stroke. Due to their relationship with the thoracic spine, dysfunction of the movement of the thoracic vertebrae could negatively impact the ability of the trunk muscles to work effectively. Spinal manipulation is used to restore joint range of motion and this has been shown to have a positive effect on the surrounding muscles. Limited studies have investigated the effect of spinal manipulation on performance outcomes, specifically in paddlers.

**Objective:** To determine the effect of lower thoracic spine manipulation, of T7 - T12 vertebrae, compared to sham laser, on the mean power (watts) of a paddler's stroke, the time taken (seconds) to paddle a 200m distance and stroke rate (strokes/min).

**Method:** This study was designed as a pre-test, post-test experiment, involving 30 asymptomatic, male paddlers from Durban. Participants were divided into an intervention group, receiving spinal manipulation to the lower thoracic spine between T7 - T12 or a control group receiving sham laser. Participants performed a 200m sprint on a kayak ergometer followed by a timed five minute break, during which, the interventions were administered. This was followed by a second 200m sprint on the kayak ergometer post-intervention. Outcome measures were average power (watts), time taken to paddle a 200m sprint on a kayak ergometer (seconds) and stroke rate (strokes per minute).

**Results:** Although a trend of an effect was seen in terms of improved power output and time taken to paddle 200m in the intervention group, no statistically significant treatment effect was found for power ($p$ = 0.557), time ($p$ = 0.122) or stroke rate ($p$ = 0.889) when compared to the sham group.

**Conclusion:** Lower thoracic spine manipulation did not result in a significant change in average power, time taken to paddle 200m on a kayak ergometer or stroke rate. Future studies are necessary to investigate the trends observed.

Key words: Kayaking, kayaking, spinal manipulation, chiropractic, thoracic spine

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# List of Abbreviations

| | | |
|---|---|---|
| ACJ | – | Acromioclavicular Joint |
| CSF | – | Cerebro-spinal Fluid |
| DUT | – | Durban University of Technology |
| EMG | – | Electromyograph |
| GHJ | – | Glenohumeral Joint |
| GTO | – | Golgi Tendon Organ |
| ICF | – | International Canoe Federation |
| KCC | – | Kingfisher Canoe Club |
| KZN | – | KwaZulu-Natal |
| LBP | – | Low Back Pain |
| MVC | – | Maximum Voluntary Contraction |
| m | – | Metres |
| ROM | – | Range of Motion |
| SCJ | – | Sternoclavicular Joint |
| STJ | – | Scapulothoracic Joint |
| SMT | – | Spinal Manipulative Therapy |
| TLF | – | Thoracolumbar Fascia |
| UKZN | – | University of KwaZulu-Natal |

# Definitions

Adjustment: A Chiropractic therapeutic procedure that uses controlled force, leverage, direction, amplitude and velocity directed at specific joints or anatomic regions. Chiropractors commonly use such procedures to influence joint and neurophysiologic function (Gatterman, 2005).

End Feel: Discreet, short range movements of a joint independent of voluntary muscle action, determined by springing each vertebra at the end range of its passive movement (Bergmann *et al.*, 2002).

Fixation: A state in which an articulation has become temporarily immobilized in a position that it may normally occupy during any phase of physiological movement (Haldeman, 2005).

Joint Dysfunction: The disturbance of function without structural change, affecting range of motion. It can present as a change in motion, be it an increase or decrease (Bergmann *et al.*, 2002).

Joint Play: Discreet, short range movements of a joint independent of the action of voluntary muscles, determined by springing each vertebra in the neutral position (Bergmann *et al.*, 2002).

Joint Subluxation: A theoretical model of articular spinal lesions that incorporates the complex interaction between inflammatory, degenerative and pathologic changes in nerve, muscle, ligamentous, vascular and connective tissues and may influence organ system function and health (Leach, 2004).

Kayaking: An event where the competitor, known as a paddler (McDonell, et al., 2012), is seated within the deck of the kayak with their legs extended anteriorly, using a double-bladed paddle to propel the kayak through the water with maximal effort (Michael *et al.*, 2009).

Manipulation: A therapeutic procedure that delivers a high-velocity, low-amplitude thrust into the direction of joint restriction (Haldeman, 2005).

Motion Palpation: A mechanism for determining the location and characteristics of altered or restricted joint movement where the examiner guides the patient through particular movements and at the end range of motion, passively pushes the bony lever (e.g. spinous process), thereby assessing the quality of resistance, known as end play or end feel (Redwood and Cleveland, 2003).

Placebo Effect: The positive physiological or psychological changes associated with the use of inert medications, sham procedures or therapeutic symbols within a healthcare encounter (Miller *et al*., 2005)

Average Power: Power output of each stroke (watts) divided by the number of strokes

Time: For this study time refers to how long it took to complete the 200m sprint on the kayak ergometer recorded in seconds.

Stroke Rate: is the number of strokes taken divided by the time, multiplied by 60 seconds, resulting in stroke rate per minute.

Performance: The ultimate measure of performance in flat-water kayaking is the time taken to paddle the competing distance. Performance in a kayak requires a powerful and skilled paddler in order to minimize drag forces and maximize propulsion (Michael *et al.*, 2008).

# Chapter 1 : Introduction

## 1.1 Background

It is widely accepted that athletes are constantly in search of ways to improve and increase levels of performance. Kayaking is no exception. In a sport where centimetres and milliseconds count and can make the difference from first to last place, finding ways to optimize performance without turning to illicit drugs or "doping" is important. Like other sports, kayaking athletes have been at the receiving end of charges for doping, as seen in July 2014 when an Olympic gold medal winning paddler tested positive for doping at a training camp in Hungary (Meyn, 2014).

KwaZulu-Natal (KZN) has the largest number of registered paddlers in the country with the KZN Canoe Union hosting over 3800 registered paddlers (KwaZulu-Natal Canoe Union, 2014). The province plays host to some of the most prestigious kayaking events in the country such as The Dusi Canoe Marathon, which has been running since 1951 (Dusi Canoe Marathon, 2015) and The Drak Challenge. It is also home to some of the biggest names in canoeing.

Flat-water kayaking is an Olympic event, which is competed over distances of 200m, 500m and 1000m (Van Someren and Howatson, 2008). The athlete, known as a paddler, is seated in a boat and paddles on both sides with a double bladed paddle to propel the boat across a straight course of calm water (Hume *et al.*, 2012). The ultimate measure of performance in the event is the time taken to complete the allocated distance (Michael *et al.*, 2009) and this can be affected by various factors (Michael *et al.*, 2008). Kayaking performance can be improved via two mechanisms: reducing drag of the boat and increasing propulsion (Michael *et al.*, 2009).

The velocity of a flat-water kayak is dependent on force production within the kayak stroke (Brown *et al.*, 2010). The upper body musculature is important in force production, with flat-water kayak paddlers displaying larger upper body dimensions than the average population (Akca and Muniroglu, 2008). The lower limb musculature, although less important than upper body musculature, has also shown to be correlated with prediction of stroke performance (Akca and Muniroglu, 2008). The kayak stroke can be broken down into three phases. The first is the pull-through phase consisting of the movement of the blade through the water from the most forward position to the most backward position; the second is the exit phase, consisting of the movement of the blade from the most backward position, leaving the water and moving through the air until it reaches a horizontal position; the last phase is the recovery phase, consisting of the movement of the paddle through the air from a horizontal position until it makes contact with the water in the most forward position (Trevithick *et al.*, 2007).

The kayak stroke is complex. Research into the recruitment of shoulder muscles during a kayak stroke tested eight muscles, five of which (upper trapezius, supraspinatus, lattisimus dorsi, serratus anterior and rhomboid major) showed fair to high consistency of activation during at least one of the phases of the kayak stroke (Trevithick *et al.*, 2007). The lattissimus dorsi muscle produces adduction and medial rotation of the arm (Moore and Dalley, 2006), a movement described as being the same as that used to paddle a kayak (Moore and Dalley, 2006). The lattissimus dorsi muscle attaches to the thoraco-lumbar region, an area of the spine found to be central to kayaking efficiency (Brown *et al.*, 2010; Limonta *et al.*, 2010). This region is the centre for the generation of forces within the kayak stroke (Brown *et al.*, 2010) and plays an important role in the transmission of forces from the pelvis to the contra-lateral shoulder (Vleeming *et al.*, 2014). This region facilitates the majority of the movement which occurs in the kayak stroke (Limonta *et al.*, 2010) and the structures which attach here aid balance and co-ordination through the course of the movement (Akuthota, 2004). It is postulated that dysfunction in this area of the spine may lead to reduced kayaking performance.

The spine is susceptible to joint dysfunction resulting from biomechanical overload, neurological irritation, environmental stress and injury (Gatterman, 2005). Spinal manipulative therapy (SMT) addresses joint dysfunction by using various techniques, one being the high velocity low amplitude thrust (HVLA) (Gatterman, 2005). Although the mechanisms of SMT are not fully understood (Potter *et al.*, 2005) it has been found to result in biomechanical and neurophysiological effects. The biomechanical effects result from the mechanical force of the SMT which changes the segmental biomechanics, leading to changes in range of motion. While the neurophysiological effects result in stimulation of the mechanoreceptors in and around the joint, resulting in a change to the sensory inflow of information to the spinal cord altering the motor neuron pools affecting the motor output (Pickar, 2002). The use of spinal manipulation to affect sporting performance based on these effects has been proposed yet is under-investigated.

Sood (2008) and Deutschmann *et al.* (2015) found that there were significant increases in bowling speeds ($p$ = <0.001) in action cricket fast bowlers and kicking speeds ($p$ = <0.001) in soccer players, respectively, after SMT. Both studies found increased range of motion post manipulation, when compared to control groups, but only Sood (2008) found a correlation between the increased range of motion and improved performance. It was theorized by the authors of the studies that changes such as decreased muscle hypertonus and increased range of motion within the spine lead to the improvements observed. The effect of SMT of the lower thoracic spine on a paddler's performance in terms of power output, speed and stroke rate have not been investigated. This study sought to determine if spinal manipulative therapy of the lower thoracic spine resulted in improved performance in paddlers kayaking a 200m sprint compared to a placebo group, using a kayak ergometer. According to Van Someren *et al*. (2000), a kayak ergometer adequately simulates open water kayaking and is capable of measuring power (watts), stroke rate (strokes/min) and time (seconds) to paddle 200m sprint in kayak paddlers when compared to a placebo group.

## 1.2 Aim and objectives

### 1.2.1 Aim

The aim of this study was to determine the effect of lower thoracic spine manipulation of T7 - T12 vertebrae, compared to sham laser, on the mean power (watts) of a paddler's stroke, the time taken (seconds) to paddle a 200m distance and stroke rate (strokes/min).

### 1.2.2 Objectives

1. To determine the effect of lower thoracic spine manipulation of T7 - T12 vertebrae on the mean power of a paddler's stroke, the time taken to paddle a 200m distance and stroke rate.
2. To determine the effect of sham laser on the mean power of a paddler's stroke, the time taken to paddle a 200m distance and stroke rate.

3. To compare the effects of lower thoracic spine manipulation of T7 - T12 vertebrae and sham laser on the mean power of a paddler's stroke, the time taken to paddle a 200m distance and stroke rate.

## 1.3 Hypothesis

### 1.3.1 Null hypothesis

1. The null hypothesis stated that there would be no significant difference between manipulation of the lower thoracic spine and sham laser in terms of mean power of a paddler's stroke over a 200m sprint on a kayak ergometer
2. The null hypothesis stated that there would be no significant difference between manipulation of the lower thoracic spine and sham laser in terms of mean stroke rate over a 200m sprint on a kayak ergometer.
3. The null hypothesis stated that there would be no significant difference between manipulation of the lower thoracic spine and sham laser in terms of time over a 200m sprint on a kayak ergometer.

### 1.3.2 Alternate hypothesis

1. The alternate hypothesis stated that manipulation of the lower thoracic spine would result in a statistically significant improvement ($p < 0.05$), when compared to sham laser, in terms of mean power of a paddler's stroke over a 200m sprint on a kayak ergometer.
2. The alternate hypothesis stated that manipulation of the lower thoracic spine would result in a statistically significant improvement ($p < 0.05$), when compared to sham laser, in terms of mean stroke rate over a 200m sprint on a kayak ergometer.
3. The alternate hypothesis stated that manipulation of the lower thoracic spine would result in a statistically significant improvement ($p < 0.05$), when compared to sham laser, in terms of time over a 200m sprint on a kayak ergometer.

## 1.4 Flow of the dissertation

- Chapter one

Overview of the dissertation and presentation of the aims, objectives and hypotheses of the study.

- Chapter 2

Review of the literature: anatomy of the shoulder and thoracic spine and other major structures involved in the kayak stroke; kayaking, kayak ergometry and SMT.

- Chapter 3

Methodology of the study, including the study design, methods, clinical procedures, measurement tools and manipulative procedures.

- Chapter 4

Results of the statistical analysis.

- Chapter 5

Discussion of the results and how they relate to the existing literature.

- Chapter 6

Conclusions drawn from the study and recommendations for future research arising therefrom.

# Chapter 2 : Literature Review

## 2.1 Introduction

Flat-water kayaking is one of the best known kayak disciplines (Michael *et al.*, 2008). From a stationary start paddlers paddle their kayaks with maximal effort along a designated competition distance, with time taken to complete the designated distance being the ultimate criterion of performance (Michael *et al.*, 2008). Upper body strength and flexibility conditioning are major components of the training programmes of elite flat-water paddlers, however little is known about the relationship between strength, joint range of motion (ROM) and performance (McKean and Burkett, 2010). This chapter will discuss the anatomy of the shoulder and thoracic spine, including the muscles involved in the kayak stroke as well as review kayaking and kayak ergometry. Spinal manipulative therapy and how it may affect kayaking performance will be discussed.

The search engines used to review the literature included: DUT Summon, Google, Google Scholar, CINAHL, medlinePlus, ebscohost, Science Direct, Proquest, Springer Link, PubMed. The following key words were used: Kayaking, kayaking, spinal manipulation, Chiropractic, kayak ergometer, thoracic spine, neurophysiological, performance.

## 2.2 Overview of the anatomy of the shoulder

The shoulder is the proximal part of the upper limb and includes the pectoral, scapular and lateral supraclavicular regions. The shoulder girdle is an incomplete ring formed by the scapulae posteriorly and the clavicles and the manubrium of the sternum anteriorly (Moore and Dalley, 2006). The shoulder complex, along with the other joint complexes of the upper limb, is primarily responsible for positioning and controlling movement of the hand in front of the body (Peat, 1986). The shoulder complex is made up of three bones: the humerus, clavicle and scapula as seen in Figure 2.1. These bones articulate to make the three of the four joints of the shoulder complex, namely the acromioclavicular (ACJ), sternoclavicular (SCJ), glenohumeral (GHJ). The fourth joint, or rather articulation is the scapulothoracic joint (STJ). The shoulder complex is stabilized by both passive (capsule, labrum and ligaments) and dynamic stabilizers (rotator cuff, deltoid and scapular stabilizer muscles) (Terry and Chopp, 2000).

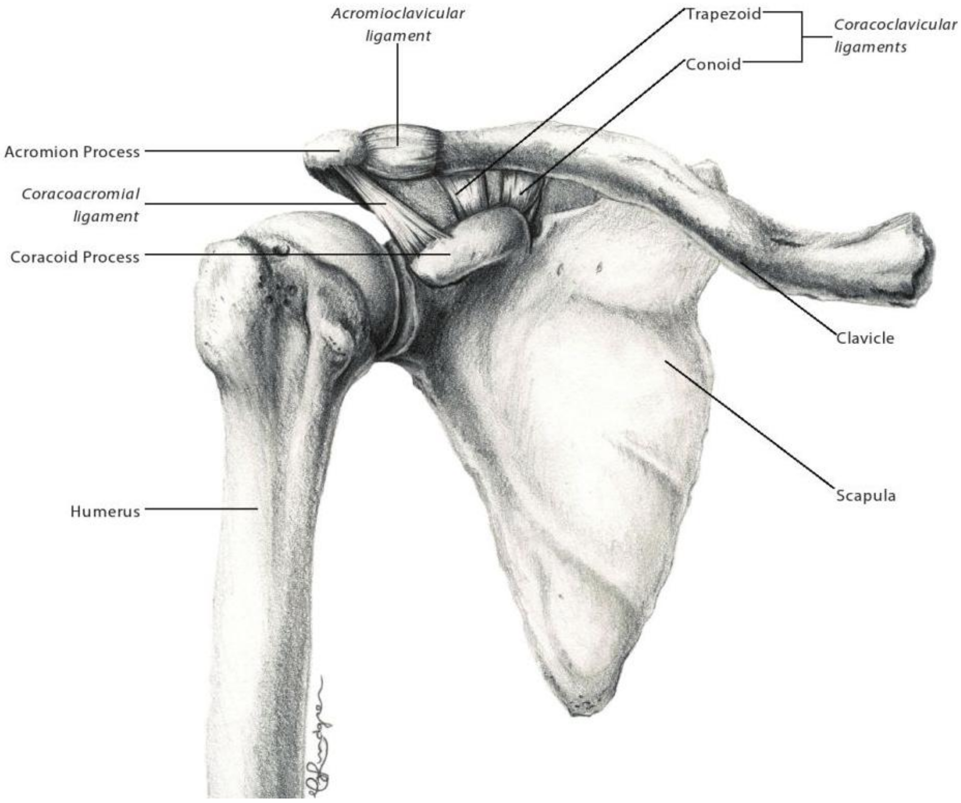


**Figure 2.1: Bony anatomy of the shoulder complex**
Source: (Lundgren, 2011)

The SCJ is the only attachment of the upper limb to the axial skeleton and is responsible for transmission of forces from the upper limb to the axial skeleton. Despite the limited joint surface, this joint is rarely dislocated due to the re-enforcement of its joint capsule by peri-articular ligaments.

The position of the STJ on the thorax depends on the shape of the thorax as well as the resting tone of the muscles surrounding it (levator scapulae, trapezius, rhomboids, subscapularis, serratus anterior and pectoralis minor). The movement of the scapula on the thorax is facilitated by a soft-tissue interface between the ventral surface of the scapula and the dorsal aspect of the thorax (Hurov, 2009).

The ACJ is a diarthrodial joint between the lateral clavicle and the acromion of the scapula. This small joint experiences high axial load, resulting in early degeneration from contact stresses. Stability of this joint is primarily due to passive stabilizers: capsule, intra-articular disc and ligaments (Terry and Chopp, 2000).

The GHJ is a ball and socket joint, consisting of a large round humeral head, fitting into a narrow glenoid fossa, this allows for a high level of mobility but means the shoulder is heavily reliant on static (ligaments and joint capsule) and dynamic (muscles) soft tissue structures, proprioceptive co-ordination of the dynamic stabilizers and negative intra-articular pressure for stability (Nguyen, 2008).

The glenoid labrum also serves to increase the surface area of the glenoid fossa in contact with the humeral head by up to 50 percent (Hurov, 2009). In the mid-range of upper limb motion the shoulder is stabilized by dynamic stabilizers such as the muscles of the rotator cuff, the long head of the biceps and scapular musculature (lattissimus dorsi, trapezius, serratus anterior, levator scapulae and rhomboids) (Nguyen, 2008). The co-ordination of the muscles acting on the joint is a vital part of kayaking performance (McKean and Burkett, 2010).

Movement of the shoulder represents a complex and dynamic interrelationship between bony anatomy and biomechanics, static ligamentous and tendonous restraints and dynamic muscular forces. Dysfunction of any one of these components disrupts this complex relationship and can cause sub-optimal function of the whole system (Terry and Chopp, 2000).

### 2.2.1 Relevant muscles of the shoulder complex

For the purposes of this study only those muscles that were found by Trevethick *et al.* (2007) in a study investigating muscle activation during a paddler's stroke (n = 9) will be discussed. Trevethick *et al.* (2007) assessed nine asymptomatic paddlers for muscle activation patterns while kayaking on a kayak ergometer. The lattissimus dorsi, subscapularis, supraspinatus, infraspinatus, serratus anterior and rhomboid major muscles were assessed using fine wire electromyography (EMG), while the upper trapezius and middle deltoid muscles were assessed using surface EMG. It was found that only three of the muscles, the lattissimus dorsi, upper trapezius and supraspinatus muscle as described in Table 2.1, showed consistent activation during phase one, the "pull-through phase", of the kayak stroke. This phase is when the paddle on the side of the test arm is moving through the water from the most anterior to the most posterior position. It is when the propulsive force is generated to move the kayak through the water (Trevethick *et al.*, 2007), and is the phase that would have the most impact on kayaking performance.

**Table 2.1: Anatomy of shoulder muscles involved during phase one of a kayak stroke**

| Muscle | Origin | Insertion | Action | Innervation |
|---|---|---|---|---|
| Trapezius | Medial third of superior nuchal line, external occipital protuberance, nuchal ligament, SP's of C7 - T12 | Lateral third of clavicle, acromion and spine of scapula | Descending part elevates, ascending part depresses and all parts acting together retract the scapula; descending and ascending parts act together to rotate glenoid fossa superiorly | Accessory nerve (CN XI) (motor) and C3 and C4 spinal nerves (pain and proprioception) |
| Lattissimus dorsi | T7 - 12 SP's, TLF, iliac crest and inferior 3 or 4 ribs | Floor of intertubercular groove of humerus | Extends, adducts and medially rotates humerus; raises body towards arms during climbing | Thoracodorsal nerve (C6, C7, C8) |
| Supraspinatus | Supraspinous fossa of the scapula | Superior facet on the greater tubercle of the humerus | Suprascapular nerve | Abduction of the arm, pulls the humeral head into the glenoid fossa providing stability during upper limb movements |

(C = cervical; CN = cranial nerve; SP = spinous process; TLF = thoracolumbar fascia)
Source: Moore and Dalley, 2006

## 2.3 Overview of the anatomy of the thoracolumbar region

According to Limonta *et al.* (2010) trunk flexion and rotation are key movements in the kayak stroke. These movements occur predominantly in the lower part of the thoracic spine (Moore and Dalley, 2006). Figure 2.2 provides an overview of the bony anatomy of typical thoracic vertebrae.

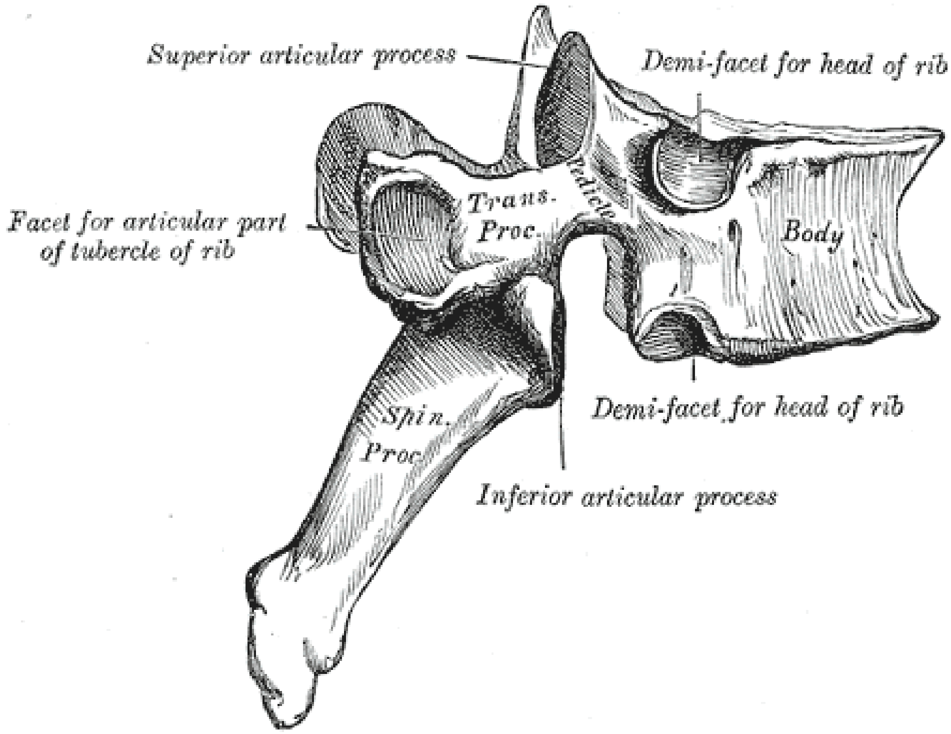


**Figure 2.2: Anatomy of the thoracic vertebra**
Source: (Gray, 1918)

The four articular processes of the thoracic vertebrae and their relation to the articular processes of adjacent vertebrae form facet joints otherwise known as the zygapophyseal joints. They are responsible for intersegmental movement and maintaining vertebral alignment, preventing anterior slippage or listhesis of one vertebra on another (Moore and Dalley, 2006). The normal range of motion for the thoracic spine is tabulated in Table 2.2.

**Table 2.2: Normal range of motion of the thoracic spine**

| Thoracic Region | Flexion | Extension | Lateral Flexion | Rotation |
|---|---|---|---|---|
| Upper (T1-T4) | ±4º | ±4º | ±6º | ±8º |
| Middle (T5-T8) | ±6º | ±6º | ±7-9º | ±8º |
| Lower (T9-T12) | ±12º | ±12º | ±7-9º | ±2º |

Source: Bergmann and Peterson, 2002

The primary distinguishing feature of thoracic vertebrae is the presence of superior and inferior costal facets, located on the supero-lateral and infero-lateral surfaces of each pedicle. These costal facets, together with an articular surface on the tip of each transverse process, serve as attachment points for the ribs. The transition from thoracic characteristics to lumbar characteristics happens over one vertebra, namely T12, with its superior half having facets orientated to allow rotation and its inferior facets allowing primarily flexion and extension (Moore and Dalley, 2006).

### 2.3.1 Innervation of zygapophyseal joints and joint mechanoreceptors

The posterior ramus of each spinal nerve is divided into a lateral and a medial branch. The medial branch gives rise to articular nerves which supply the facet joints of the corresponding level and the level below (Moore and Dalley, 2006). Hilton's law states that a joint is innervated by the same nerves that innervate the muscles that act on the joint as well as the skin surrounding the joint (Herbert-Blouin *et al.,* 2013). Wyke (1972) describes the make-up of articular nerves as being comprised of various myelinated and un-myelinated nerve fibres of varying diameters and function, as seen in Table 2.3.

**Table 2.3: Description of articular nerve composition**

| Diameter | Function | % of nerve |
|---|---|---|
| Narrow | Articular pain sensation, vasomotor function of articular blood vessels | 45 |
| Medium | Mechanoreceptors, innervate small corpuscular endorgans found in the fibrous joint capsule, which help produce reflexogenic and kinaesthetic responses to mechanical stress | 45 |
| Large | Mechanoreceptors, only innervate large, high-threshold corpuscular endorgans found in joint ligaments, purely reflexogenic. | 10 |

Source: Wyke, 1972

The nerve endings found in the zygapophyseal joint capsule generate three kinds of outcomes. Firstly, postural and kinaesthetic sensation, i.e. sensation of joint position and movement i.e. proprioception (Lanuzzi *et al.*, 2011). Secondly, arthrokinetic reflexes at the spinal and brainstem levels. Thirdly, pain sensation (Wyke, 1972). Table 2.4 describes the mechanoreceptors, otherwise known as the Wyke receptors, found in the capsule surrounding the zygapophyseal joints.

**Table 2.4: Description of Wyke Receptors**

| Type | Morphology | Location | Function |
|---|---|---|---|
| I | Globular or ovoid shape, surrounded by thin capsule | Superficial layers of the joint capsule | • Low-threshold, slowly adapting receptors<br>• Active in any joint position<br>• Static and dynamic |

| | | | |
|---|---|---|---|
| II | Conical shape, with a thick multi-layered capsule | Deep layers of the joint capsule | • Low-threshold, rapidly adapting<br>• Only active at the start of mechanical stress on joint capsule<br>• Dynamic<br>• Sense acceleration and deceleration |
| III | Largest of the four, fusiform shape, surrounded by film-like layer of connective tissue | Longitudinally along the superficial fibers of joint ligaments near their bony attachments | • Dynamic, high-threshold, slowly adapting<br>• Only active when large forces applied to ligaments |
| IV | A lattice of nerve plexi or free nerve endings | Throughout fibrous capsule, adjacent periosteum and articular blood vessels as well as ligaments surrounding joints | • Nociceptors<br>• Only active when joints are exposed to extreme mechanical or chemical stress |

Source: Wyke, 1972

Although the patients in this study were asymptomatic with regards to pain, good proprioception and arthrokinetic reflexes are vital in a sport which takes place in such an unstable environment as kayaking. When the joints of the spine are subject to pain, injury, inflammation or become restricted in normal range of motion (otherwise known as joint dysfunction) the mechanoreceptors of the zygapophyseal joints may alter their firing patterns (Henderson, 2012) affecting proprioception, arthorkinetic reflexes and pain (Pickar, 2012). Thereby modalities such as spinal manipulation may aid in restoring the mechanoreceptor firing to normal and enhancing performance.

### 2.3.2 Muscles of the trunk

Brown *et al.* (2010) found activation of the muscles of the trunk and lower limbs as well as the lattissimus dorsi muscle during the kayak stroke. Eight international level paddlers (six male and two female), were fitted with surface electrodes over the muscle bellies of lattissimus dorsi, rectus abdominis, external oblique, rectus femoris, biceps femoris, and gastrocnemius bilaterally in order to measure muscle activation. Each paddler used their own paddle which was fitted with a strain gauge to determine force production as the blade travelled through the water. Each participant performed five sprints over a distance of 75m, broken up into a 50m acceleration sector, a 5m measuring sector and a 20m run off phase. The peak activation for each muscle and the peak and mean force production for each stroke were measured.

A significant positive relationship was found between the muscles of the lower abdomen and force production, primarily the ipsilateral external oblique ($r$ = 0.801, $p$ < 0.05) and the contralateral rectus abdominus ($r$ = 0.855, $p$ < 0.05). The ipsilateral lattissimus dorsi displayed significantly higher levels of activation than the contralateral lattissimus dorsi; however, it was found that the muscles of the abdomen played a more important role in force production than the ipsilateral lattissimus dorsi. The contralateral rectus abdominus was seen to contract isometrically to provide a stable platform, against which force could be generated in a largely unstable environment. The anatomy of these muscles is described in Table 2.5.

**Table 2.5: Muscle attachments, actions and innervation of selected muscles of the trunk**

| Muscle | Origin | Insertion | Action | Innervation |
|---|---|---|---|---|
| Rectus Abdominis | Pubic symphisis and pubic crest | Xiphoid process and costal cartilages 5-7 | Flexes trunk and compresses abdominal viscera, stabilizes and controls pelvic tilt | Thoracoabdominal nerves (anterior rami of inferior six thoracic nerves) |
| Transverse Abdominus | Internal surfaces of costal cartilages 7 - 12, TLF, iliac crest and lateral half of inguinal ligament | Linea alba with aponeurosis of internal oblique, pubic crest and pecten pubis via conjoint tendon | Compresses and supports abdominal viscera | Thoracoabdominal nerves and first lumbar nerves |
| External Obliquus | External surfaces of ribs 5 - 12 | Linea alba, pubic tubercle and anterior half of iliac crest | Compresses and supports abdominal viscera, flex and rotate trunk | Thoracoabdominal nerves (anterior rami of thoracic nerves 5 - 7) and subcostal nerve |

(TLF = Thoracolumbar Fascia)

Source: Moore and Dalley, 2006

Although this study illustrates the role of the rectus abdominus and the external oblique muscles in the kayak stroke, the findings support the role of the latissimus dorsi muscle as a contributor to the kayak stroke and as such are in agreement with Trevethick *et al.* (2007).

### 2.3.3 Mechanoreceptors found in muscles

Muscle spindles and golgi tendon organs provide mechanoreceptor feedback from muscles to allow muscle tone to be monitored (Gatterman, 2005).

#### 2.3.3.1 Muscle spindles

These proprioceptors can be found lying parallel to the fibers of skeletal muscle (extrafusal fibers). They contain specialized fibers called intrafusal fibers that are responsible for velocity and length information about the muscle. These spindles contain type Ia afferent nerve endings which communicate with the dorsal root and ultimately with the alpha-efferents supplying the muscle in which they are found as well as surrounding muscles. Efferent control of the muscle spindles is by the central nervous system through the gamma motor neuron network. These neurons originate alongside the alpha-motor neurons in the anterior horn of the grey matter in the spinal cord; they descend and innervate the polar (contractile) ends of the intrafusal fibers. Gamma activity causes shortening of the poles of the intrafusal fibers and thus lengthening of their central region causing stimulation of Ia afferent nerve endings which in turn communicate via alpha-efferent motor neurons with the extrafusal muscle fibers, causing contraction/shortening of the muscle (Gatterman, 2005).

#### 2.3.3.2 Golgi tendon organs

These encapsulated receptors can be found in the musculotendinous junction and are stimulated by muscle tension. When the muscle contracts, tension in the tendon increases, causing stretching of the golgi tendon organ (GTO), which then sends impulses via sensory neurons to the central nervous system (CNS). This results in excitation of inhibitory neurons, which inhibit alpha motor neuron activity and thereby reduces muscle contraction. If a sudden, large increase in tension occurs, a rapid, reflex relaxation of the muscle occurs. This is known as the tendon reflex and is a protective mechanism to prevent tearing of muscle or tendon and avulsion of bone (Gatterman, 2005).

## 2.4 Thoracolumbar fascia

The thoracolumbar fascia is a laminated combination of aponeurotic and fascial tissue that weaves the deep abdominal and paraspinal muscles into a complex matrix from the sacral to thoracic regions and helps to stabilize the lumbopelvic region via co-ordinated concentric and eccentric contractions of the transverse abdominus, external oblique and paraspinal muscles. It plays an important role in load transfer, posture and respiration (Vleeming *et al.*, 2014). The superficial layer of the posterior component of the thoracolumbar fascia is closely attached to the lattissimus dorsi and gluteus maximus muscles and less closely related to the trapezius and external oblique muscles. The majority of the superficial fibers originate from the aponeurosis of the lattissimus dorsi muscle and are attached to the supraspinal ligament and spinous processes of C1 - L4. The fibers originate caudomedially and run craniolaterally. Contraction of the muscular attachments of the superficial layer of the thoracolumbar fascia has been shown to cause increased tension in the lattissimus dorsi and the contra-lateral gluteus maximus. This implies that these muscles and the fascia connecting them are involved in rotational movements of the trunk as well as transmission of forces from the pelvis, over the trunk, to the contra-lateral shoulder (Vleeming *et al*.1995).

Improved activation and co-ordination between these muscles, as one may expect to find following thoracic spine manipulation, will improve the efficacy of the fascia in force transmission and rotation of the trunk and pelvis, both of which are important in the kayak stroke (Limonta *et al.*, 2010). The thoracolumbar fascia also plays a proprioceptive role during contraction of its muscular attachments (Akuthota, 2004), a function which is very important in an unstable environment such as the one in which paddlers must perform**.**

## 2.5 Kayaking

The ultimate measure of performance in flat-water kayaking is the time taken to paddle the competing distance. Performance in a kayak requires a powerful and skilled paddler in order to minimize drag forces and maximize propulsion (Michael *et al.*, 2008). Flat-water kayaking has seen drastic changes in performance through engineering, professional coaching and sports science (Ackland *et al*., 2003).

### 2.5.1 Phases and biomechanics of the kayaking stroke

The kayak stroke is broken down into phases, with the definition of these phases differing among researchers (McDonnell *et al.*, 2012). Table 2.6 displays the phases of the kayak stroke as defined by Trevithick *et al.* (2007).

**Table 2.6: Phases of the kayaking stroke**

| **Phase** | **Movement** |
|---|---|
| Pull-through | Paddle moves through the water from the most forward position to the most backward position |
| Exit | From the most backward position the paddle leaves the water and moves through the air until it reaches a horizontal position |
| Recovery | Paddle moves through the air from horizontal until it makes contact with the water in the most forward position |

Source: Trevithick *et al.,* 2007

McDonnell *et al.* (2012) sought to provide a standardized framework for the description and analysis of the kayak stroke by formulating a clear observational model for the definition of the stroke phases. They found that the water-contact-defined positions of catch, immersion, extraction and release were most suitable for use by researchers. These positions were used to define the start and end points of phases and sub-phases of the kayak stroke. They postulated that the kayak stroke should be broken into two phases, namely the aerial phase (between release and catch) and the water phase (between catch and release) and that for more detailed description, the water phase should be broken up into three sub-phases: entry (between catch and immersion), pull (between immersion and extraction) and exit (between extraction and release).

Limonta *et al.* (2010) were the first to describe the kinematics of the kayak stroke using three dimensional analyses. This allowed for a more detailed analysis of the kinematics of a paddlers stroke (Michael *et al.*, 2009). They found that as the left sided paddle exits the water the pelvis is rotated in the transverse plane with the left hip situated posteriorly. The paddler then flexes the trunk forward, the right shoulder flexes and the right elbow extends to allow optimal paddle advancement. As soon as the paddle enters the water the right shoulder begins to extend and the elbow begins to flex, drawing the paddle through the water from front to back. At the same time, trunk rotation occurs through the thoracic spine and shoulder girdle. The right knee extends and the pelvis rotates, moving the right hip from anterior to posterior to enhance and assist the second part of shoulder extension. Once the wrist reaches the level of the pelvis, retraction of the paddle from the water begins. This occurs in a diagonal movement with the paddle moving away from the kayak due to right shoulder abduction. In this phase the trunk should not extend beyond the vertical. From here the cycle of the left side begins (Limonta *et al.,* 2010).

They further describe the stroke by discussing the movement of the wrist which was characterized by an elipse with the lower half of the ellipse representing the in-water phase and the upper half representing the out of water phase. The study found that the more this trajectory extended in the X-axis i.e. the greater the amplitude of the stroke, the longer the pull-through phase, which is the phase in which the paddle is in the water (Limonta *et al.,* 2010).

The study found that the more experienced paddlers showed greater movement amplitude with regard to trunk flexion and hip rotation, and increased range of motion with regards to elbow flexion and knee extension, when compared to less experienced participants, suggesting that increased mobility of the trunk means a more efficient stroke. Increased trunk flexion means that a paddler can catch water further forward than their less experienced counterparts (Limonta *et al.,* 2010).

Trunk rotation was described as the main contributor to increasing amplitude of the stroke, supplemented by pelvis rotation, which was decreased in less experienced paddlers as a result of weaker abdominal, lower back and upper leg muscles (Limonta *et al.,* 2010). They further noted that all participants displayed asymmetries in dominant verses non-dominant sides. These asymmetries increased as experience decreased and were more evident in the upper limbs than the lower limbs. The authors emphasized the importance of addressing asymmetries, such as those which may be caused by joint dysfunction, as they can lead to overuse injuries and contribute to a decrease in efficiency of movement as balanced forces lead to increased stability and forward trajectory of the paddler without dispersion of forces.

### 2.5.2 Factors affecting kayak performance

A successful kayaker requires high aerobic capacity and anaerobic yield as well as exceptional upper body strength. Factors such as kayak velocity, power, technique, fitness and force are key to determining paddler performance (Michael *et al.*, 2008).

Improvements in performance can be achieved by improving propulsion or by diminishing the drag generated by the water on the boat. Propulsion can be improved by increasing the power output of the paddler and by improving efficiency through better technique (Michael *et al.*, 2009). Research indicates that a one percent increase in power output will lead to a 0.33% increase in boat velocity (Van Someren and Howatson, 2008).

Mobility and co-ordination of the thoraco-lumbar region are important factors in a sport such as kayaking, where paddlers are required to repeatedly make large, rapid trunkal movements as well as co-ordinated cross body actions in a largely unstable environment (Limonta *et al.*, 2010). An unstable, uncoordinated paddler is seen to lose propulsive power as a proportion of the force of their stroke is dedicated to maintaining balance rather than focusing as much of their output as possible on forward movement (Michael *et al.*, 2009). The importance of the abdominal muscles (Brown *et al.*, 2010) and the TLF (Vleeming *et al.*, 2014) in bracing the spine as well as proprioception and transmission of forces from the pelvis to the upper limbs has been noted.

### 2.5.3 Kayak ergometry

In order to objectively assess a paddler's performance a kayak ergometer can be used (Donne *et al.*, 2012). A kayak ergometer is a device which has been used for winter training by kayakers. It works by transmitting force from the paddle via a wire to a flywheel which spins and creates wind turbulence which produces the resistance necessary to simulate the water resistance of open water kayaking (Larsson *et al*. 1988). The ergometer is connected to a computer which uses software to produce a stroke by stroke analysis of each run, giving readings for power, time and the number of strokes completed.

According to Van Someren *et al.* (2000) a kayak erometer accurately simulates the physiological demands of short term, high intensity kayaking. It also accurately simulates the posture and musculature involved in the kayaking stroke, while reproducing the path travelled by the wrist, elbow and shoulder joints in on-water kayaking (Campagna *et al.,* 1986). It does not perfectly replicate the bio-mechanics of flat-water kayaking, however it is a useful tool for objectively testing paddlers (Donne *et al.*, 2012).

## 2.6 Spinal manipulative therapy

Manual movement and mobilization of joints has been used as a therapeutic technique for centuries (Pickar, 2002). The aim when applying spinal manipulative therapy (SMT) is to improve joint movement and restore normal physiology within the neuromusculoskeletal system (Henderson, 2012).

### 2.6.1 Joint dysfunction

The theoretical model for motion segment dysfunction is the vertebral subluxation. A vertebral subluxation presents as an interaction of pathologic changes within neural, vascular, muscular, ligamentous and connective tissue components of the motion segment (Redwood and Cleveland, 2003), and can be defined as a motion segment in which alignment, movement integrity and/or physiological function are altered although contact between the joint surfaces remains partially intact (Gatterman, 2005). The presence of joint dysfunction is found through motion palpation – a palpatory diagnostic tool used to assess active and passive segmental joint range of motion (Bergmann *et al.* 2002). Bergmann *et al.* (2002) describe the clinical features of joint dysfunction found on examination as being:

1. Local pain
2. Local tissue hypersensitivity
3. Altered alignment
4. Decreased, increased or aberrant joint movement
5. Altered joint play
6. Altered end feel
7. Local palpatory muscle rigidity

Pain is not a requisite for joint dysfunction to be present (Haldeman, 2005). Pain is a symptom of the underlying dysfunction which, like any disease process, can be present for long periods of time, developing and progressing insidiously before producing symptoms. It is therefore inappropriate to use pain as a gauge of severity of a condition. In much the same way that the absence of pain does not mean dysfunction has not begun, the disappearance of pain does not indicate the removal or resolution of dysfunction (Gatterman, 2005).

The causes of joint dysfunction can be categorized into four groups as shown in Table 2.7.

**Table 2.7: Potential causes of joint dysfunction**

| | |
|---|---|
| Biomechanical | • Vertebral malposition<br>• Adhesion<br>• Fragmentation of the nucleus pulposis<br>• IVD deformation due to tissue creep<br>• Meniscoid entrapment<br>• Hypermobility<br>• Mechanical joint locking<br>• Motion segment buckling |
| Neurological | • Nerve, nerve root or dorsal root ganglion compression or traction<br>• Spinal cord compression or traction<br>• Reflex response<br>• Motor system degeneration<br>• Psychoneuroimmunology |
| Trophic | • Aberrant axoplasmic transport<br>• Ischaemia<br>• Altered flow of cerebrospinal fluid |
| Psychosocial | • Placebo<br>• Stress<br>• Lifestyle |

(IVD = Intervertebral Disc)

Source: Gatterman, 2005

Korr (1975 as cited in Leach, 2004; Potter *et al.*, 2005) proposed that joint dysfunction occurs as a result of the muscle spindle being more concerned with the extra-fusal to intrafusal length ratio rather than the absolute muscle length. Korr suggested that the CNS is able to regulate the level of background gamma activity in response to the needs of a muscle, this phenomenon is known as "gamma gain". In muscles which involve large rapid contractions, such as those involved in a kayaking stroke, the gamma gain is set low and in muscles involved in short sharp contractions, such as those responsible for maintaining balance in a kayak, the gamma gain is set high.

In this way the CNS is able to control the sensitivity of the length regulating activity within the spindle system. It is possible for the CNS to incorrectly adjust the sensitivity of the spindle system, leading to hypersensitivity. For example, when someone holds a load on one side of the body, the muscles on the contralateral side of the spine are contracting isometrically to keep the spine vertical. If the person then drops the load, an act similar to a paddler attempting to maintain balance while producing large unilateral forces in an unstable environment, the muscles which were contracting isometrically suddenly shorten. This causes slack within the spindle system, and silencing of the Ia impulses from the spindle occurs as the tension on the poles decreases. This drop in Ia input is sensed by the CNS and interpreted as the gamma gain being too low for the Ia nerve fibers to transmit the proprioceptive information needed to regulate muscle length and velocity so it increases gamma gain which leads to contraction of the poles of the intra-fusal fibers in an attempt to take up the slack. Once normal posture is resumed the muscle fiber is stretched but the increased gamma gain persists and there is resistance to lengthening of the muscle and it remains contracted, this results in increased muscle resistance to free joint range of motion and a hard end feel on palpation (as cited in Leach, 2004; Potter *et al.*, 2005). Thus, joint dysfunction is found on clinical examination. In such a case, clinician would generally utilise a method of SMT to remove the joint dysfunction and restore the joint to normal joint play and range of motion (Henderson, 2012).

There are various techniques that make up SMT with a high velocity, low amplitude (HVLA) thrust manipulation being a commonly utilized technique, used typically, but not exclusively, by chiropractors (Potter *et al.,* 2005). Gatterman (2005) describes two methods of delivering HVLA SMT commonly used by chiropractors:

1. The joint is held in its neutral position, specific contacts are made and tissue slack is removed and the thrust is delivered.
2. The joint is moved through its active and passive ranges of motion in the direction, in which the adjustment is to be delivered. The thrust is delivered at the end range of movement beyond the elastic barrier and into the paraphysiological space, as illustrated in Figure 2.3.

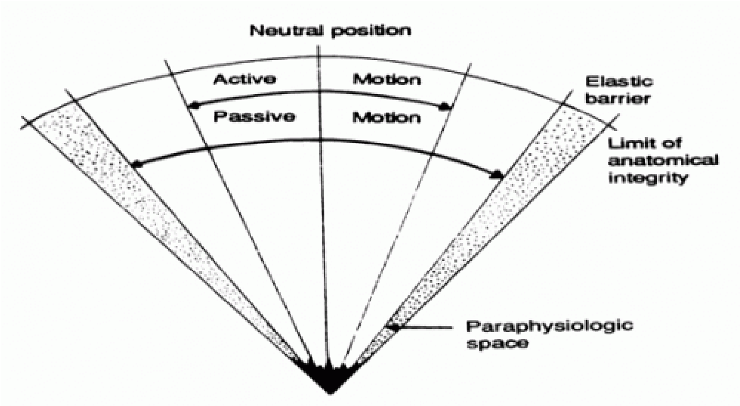


**Figure 2.3: Anatomical and paraphysiological ranges of motion**
Source: Gatterman, 2005

While SMT may not address all the components of the subluxation it addresses the motion component of the dysfunction directly and as such is believed to indirectly impact the other components (Hyde and Gengenbach, 2007; Pickar, 2002). The precise mechanism through which SMT is effective is unclear, with early theories suggesting the therapeutic effects seen were facilitated by the nervous system (Pickar and Bolton, 2012; Potter *et al.*, 2005).

### 2.6.2 Benefits of SMT

Gatterman (2005) outlined several post spinal manipulative benefits:

- Diminished weight-bearing of facet joints
- Unlocking of osseous restrictions
- Reduced stasis in local vasculature
- Freeing of entrapped meniscoids
- Release of capsular adhesions
- Breakdown of links formed by immobilization
- Diminished pain sensation
- Reduction in articular cartilage displacement by chronically entrapped meniscoids
- Reduction of intervertebral foramen stenosis caused by reduced kyphosis
- Decreased tension on joint capsule

### 2.6.3 The effect of SMT

The exact mechanism through which SMT produces its therapeutic effects is unclear (Dishman *et al.*, 2002; Potter *et al.,* 2005; Pickar and Bolton, 2012). Evidence suggests that SMT is an effective treatment modality; however, more mechanism-based and clinical research is required, particularly with regards to long-term effects of SMT and over longer courses of treatment (Henderson, 2012). There are two main theories as to the therapeutic effectiveness of SMT (Potter *et al.*, 2005), as described below.

#### 2.6.3.1 Biomechanical

The biomechanical effect is as a result of changes in joint alignment and increased joint ROM (Gatterman, 2005). When SMT is applied to joint dysfunction vertebral movement is produced and this alters the biomechanics of the affected segment, which in turn reduces strain on the surrounding tissues and helps restore joint mobility and joint play (Pickar, 2002). The resultant improvement in range of motion is due to increased joint space, which may or may not be accompanied by an audible click or "cavitation", when compared to the maximum forced gapping of facet joints (Potter *et al.,* 2005).

#### 2.6.3.2 Neurophysiologic

The biomechanical effects produced by SMT have the ability to change the flow of sensory information to the CNS. The neurophysiological effects of SMT may result in excitation of inhibited muscles or inhibition of overactive muscles (Pickar, 2002). A reflexic response has been shown in the muscles surrounding and distal to a fixated joint following SMT, using EMG. This muscular reflexogenic response is thought to produce a reduction in pain, hypertonicity and increased functional ability (Potter *et al.*, 2005). Herzog *et al*. (1995) found that muscles in the immediate vicinity of a spinal segment receiving SMT as well as muscles distal to the site of manipulation displayed reflex activation as determined by surface EMG readings. This research holds little power due to the small sample size but the authors found consistent elcetromyographical activity (50 msec - 100 msec) of the target muscles occurred following SMT, this was the first study to demonstrate that there was increased muscle activity following SMT, the authors attributed this to a reflex reaction originating in the muscle spindles.

Korr's theory allows for two possible mechanisms through which spinal manipulation may reduce joint dysfunction; both mechanisms centre around decreasing the muscle hypertonus surrounding a fixated joint. Firstly, the HVLA thrust will apply a stretch to the already stretched intra-fusal system causing a barrage of afferent input, forcing the CNS to lower the gamma activity within the muscle spindle system. Secondly, stimulation of the golgi tendon organs in an already hypertonic muscle will result in decreased alpha and gamma motorneuron activity causing a reduction in muscle contraction thereby reducing resistance to movement of the fixated vertebral segment, allowing it to move more freely and naturally (Leach, 2004).

Researchers have found somatomotor changes following SMT. Bicalho *et al.* (2010) (N = 40) found elevated surface EMG readings of the paraspinal muscles in patients with chronic lower back pain at rest and during a flexion-extension cycle. Following spinal manipulation (n = 20) these readings were significantly reduced in the static phase ($p < 0.001$) as well as the extension phase ($p = 0.028$) when compared to a control group (n = 20). Similarly, patients, with (n =10) and without (n = 10) chronic LBP showed significant decreases ($p < 0.05$) in stretch reflex excitability in the erector spinae muscles following spinal manipulation where an audible cavitation was heard (Clarke *et al.*, 2011). The authors attributed the changes to a reduction in muscle sensitivity caused by lowering of the gamma gain in the intrafusal system or at various intersegmental sites of the Ia reflex pathway, as a result of the spinal manipulation, as described by Korr (1975 as cited in Leach, 2004). This study is in disagreement with previous studies, which suggest that audible cavitation is not necessary to illicit the beneficial effects of spinal manipulation, however the sample sizes in this study were quite small and a control group, receiving a placebo intervention or no SMT at all should have been used.

Harvey and Descarreaux (2013) performed a study to determine the longevity of neuromuscular changes in the trunk following SMT of Low Back Pain (LBP) patients. Thirty minutes post-intervention the control group was seen to have significantly higher surface EMG readings (associated with spasm) and subjective pain rating scores, while performing repeated flexion-extension movements of the trunk, when compared to those participants who received SMT. The authors concluded that SMT may lead to decreased sensitization or muscle fatigue resulting from repetitive trunk motion (such as those seen in kayaking). These studies support Korr's theory that SMT leads to normalization of the neurophysiology around a subluxated joint following SMT. As with most studies involving SMT true participant blinding is difficult and standardized force of SMT is nearly impossible, thus potentially contributing to bias toward the intervention group. In addition participants in this study all received manipulation at the same spinal segment (L3) regardless of pain location. This does not accurately reflect clinical practice and may have lead to skewed results.

When assessing the effect of SMT on muscle maximum voluntary contraction (MVC), Keller and Calloca (2000) found a significant increase ($p < 0.001$) in post-manipulative surface EMG readings in patients (n = 20) with LBP during isometric MVC when compared to two control groups (n = 20), one receiving sham SMT and one receiving no SMT. This showed that increased isometric strength of the muscles related to joint dysfunction may be an effect of SMT. This study used an activator gun, not HVLA thrust, to administer SMT to those in the intervention group. The use of the two control groups in this study gives the study more power as it contributes to patient blinding and decreases the likelihood that the favourable results following SMT were as a result of placebo.

The idea that SMT has a central mechanism for the relief of vertebral fixation is supported by Haavik and Murphy (2012) who reviewed the effects of SMT on sensory processing, motor output, functional performance and sensorimotor integration and they found that many studies support the use of SMT to affect long-lasting changes to sensorimotor integration within the central nervous system. Whether these findings are due to correction of spinal dysfunction and therefore normalization of sensorimotor integration or a barrage of afferent input following spinal manipulation is unclear (Haavik and Murphy, 2012).

### 2.6.4 Spinal manipulation and performance

As promising as the neuromuscular and biomechanical responses mentioned above appear to be, it cannot be assumed that these changes translate to improved performance in a sport such as kayaking. There are limited studies investigating the effect of SMT on sporting performance outcomes.

Sood (2008) in a pre-test post-test experimental study (N = 40) comparing the effect of thoracic spine manipulation compared to a control group, found immediate increased trunk flexion and lateral flexion (movements similar to those required during a kayaking stroke [Limonta *et al.*, 2010]) movements together with increased bowling speed in action cricket fast bowlers. A significant correlation ($p$= 0.003; $r$ = 0.451) was found between bowling speed, trunk flexion and lateral flexion ROM, indicating that thoracic spine manipulation, at least in the short-term, improved range of motion and that these improvements appeared to affect bowling speed. Due to the similarity between the movements tested in Sood (2008), and their correlation to improved bowling speed, and those described by Limonta *et al.* (2010) involved in the kayaking stroke it is proposed that SMT of the lower thoracic spine will produce similar effects on the kayak stroke as those seen on bowling speed in action cricket fast bowlers. Sood (2008) suggested a biomechanical mechanism for the improvements in bowling speed in that greater thoracic facet mobility meant improved transmission of forces along the kinematic chain and greater torque in a throwing athlete. Based on the findings of the studies mentioned above with regards to the effects of SMT on muscle function it could also be speculated that the increased bowling speed was due, in part, to better muscle function. Deutschmann *et al.* (2015) investigated kicking speed and ROM in soccer players post-SMT. Asymptomatic soccer players (N = 40) from local premier league soccer teams were found to have improved range of motion in the lumbar spine and sacro-iliac joints following SMT when compared to a control group. All three intervention groups also displayed statistically significant improvements in kicking speed. There was however, no correlation between the increased kicking speed and improved range of motion. This finding differs from Sood (2008). The authors suggested that improved co-ordination, post-SMT, between the structures involved in kicking, resulted in the improvements seen in the kicking speed, suggesting a neurophysiological response to SMT. The authors recommended that further studies be conducted to assess the effects observed. The sample sizes in these studies were small to begin with, this coupled with the fact that they were each divided into four smaller groups (n=10) limits the power rather dramatically. Both studies included SMT of more than one spinal region and had a combination group this may have diluted the data somewhat. Future studies should either aim to be more focused, by testing one spinal region at a time, or have larger sample sizes.

These studies, although limited, show that there is a possible connection between SMT and improved performance based on the biomechanical and neurophysiological effects of SMT. Flatwater kayakers are required to generate large cross body movements through combined rotation, flexion and lateral flexion of the trunk (Limonta *et al.*, 2010) at maximal effort (Michael *et al.*, 2008) in an unstable environment and as such increased torque and improved muscle function and co-ordination (Deutschmann *et al.* 2015) may well lead to improvements in kayak performance. In light of this, the current study investigated the effect of SMT of the thoracolumbar spine regarding its effect on a paddlers performance in terms of power output, time taken to paddle 200m and stroke rate.

### 2.7 The placebo effect

The physiological effect of SMT may not be fully understood (Potter *et al.*, 2005; Pickar, 2002) but it is certain that, as with any form of treatment, the placebo effect will play a role in therapeutic outcomes (Bergmann and Peterson, 2002; Gatterman, 2005) and for this reason a control group is vital in order to understand the effects of SMT beyond placebo (Edmond, 2006). Research that involves the placebo effect generates ethical concerns due to the deception of participants. It is important to put measures in place when conducting research involving such deception of participants as there exists a delicate balance between the value of the information which may be gleaned from such research and the risk to the individuals involved in these types of research. Such safeguards may include (Miller *et al.*, 2005):

- Review and approval of such research by an independent ethics committee
- Signing of an informed consent document, which discloses that the research may involve some level of deception
- Debriefing of participants at the end of their participation in such research.

The thoracolumbar region is where the majority of trunkal rotation and flexion occurs (Moore and Dalley, 2006). These movements are repeated at maximal effort in an unstable environment during a flat-water sprint (Michael *et al.*, 2009; Limonta *et al.*, 2010) and they are seen to increase and be more symmetrical in elite paddlers (Limonta *et al.*, 2010). Thus, this study hypothesizes that the effects of SMT, as discussed in this chapter, will lead to improved performance in the kayak stroke.

# Chapter 3 : Methodology

## 3.1 Introduction

This chapter details the study design and research procedure that was followed and the statistical analysis performed on the data collected.

## 3.2 Study design

This study was designed as a pre-test, post-test experiment. This design allowed for two groups: an experimental group and a control group, with measurements being taken before and after the application of the intervention (Bell, 2010). Permission to conduct this study was obtained from the Durban University of Technology (DUT) Research and Higher Degrees Committee (RHDC) and Institutional Research Ethics Committee (IREC) (IREC 042/15) (Appendix L).

## 3.3 Study population and location

The study population included male paddlers, living in the greater Durban area, between the ages of 20 and 40 years of age. Research was conducted at the DUT Chiropractic Day Clinic (CDC) and at the Kingfisher Canoe Club (KCC), after permission to conduct research at these sites was obtained (Appendix H and J respectively).

## 3.4 Participant recruitment

Participants were recruited either by approaching paddlers directly at various kayaking clubs in the Durban area or via word of mouth. Direct contact with potential participants occurred by the researcher approaching paddlers at the paddling club daily during the data collection period. Those expressing interest were then recruited if they met the inclusion criteria of the study. Word of mouth recruitment allowed for those who had taken part in the study to invite friends and family who were eligible to take part.

## 3.5 Sampling procedure

An initial interview was performed with the potential participant either face to face or via telephone. The researcher asked the potential participant the following questions:

- Are you male or female? Candidates had to be male in order to maintain homogeneity amongst the sample population.
- Are you between the ages of 20-40? In order to reduce the likelihood of chronic degenerative change in the musculoskeletal system (Jordan and Zhang, 2010).
- Are you currently kayaking at least three times per week or a minimum of four hours per week? In order for there to be a base level of fitness across the participants (Cunninghame, 2009).

If the potential participant met the above criteria an appointment was made either at the DUT CDC or the KCC. At the appointment the research procedure was explained to the participant and they were provided with a letter of information (Appendix A) and allowed to ask any questions they may have had about the study. Following this they were asked to sign an informed consent form (Appendix B). They then underwent a full case history (Appendix C) and physical examination (Appendix D) together with a thoracic spine regional examination (Appendix E) to determine if they met the study inclusion criteria.

### 3.5.1 Inclusion and exclusion criteria

#### 3.5.1.1 Inclusion criteria

1. Aged 20-40 years of age to reduce risk of degenerative changes in the spine (Jordan and Zhang, 2010).
2. All participants had to be male for sample homogeneity.
3. In order to have a baseline level of fitness all participants had to have been training a minimum of three days a week or four hours a week for the past three months (Cunninghame, 2009).
4. All participants had to have fixations present within the lower six thoracic vertebrae.
5. Participants had to be asymptomatic with regards to musculoskeletal pain.
6. Participants were required to sign an informed consent form (Appendix B).

#### 3.5.1.2 Exclusion criteria

1. History of trauma or surgery to the spine
2. Contra-indications to thoracic manipulation identified on case history or patient examination such as (Gatterman, 2005 and Bergmann and Peterson, 2002):
    a. Osteoarthritis
    b. Any other arthritides
    c. Spinal fractures
    d. Sprains
    e. Clotting disorders
    f. Osteoporosis
3. Blood pressure > 160/100 mmHg in the absence of heart or vascular disease or 140/90 if there is a history of heart disease or vascular disease (Longmore *et al.*, 2009), as the participants were required to paddle a 200m sprint on a kayak ergometer.
4. Metabolic disorders such as Diabetes or Hypoglycaemia as these conditions may have affected performance during testing.
5. Received chiropractic treatment within the last three months.

### 3.5.2 Sample size

The sample size was 30 paddlers. This number was selected based on Cunninghame's (2009) study, and feasibility. The first 30 paddlers who met the inclusion criteria were included in the study.

### 3.5.3 Sample allocation

If the participant met the inclusion criteria they were randomly allocated into one of two groups by the hat method, a probability sampling technique, whereby, upon presentation of the participant to the study, an independent party was asked to blindly draw from a hat, filled with 15 number one's and fifteen number two's. Once the group number had been drawn it was discarded so that it could not be redrawn.

- Group One - intervention group (SMT).
- Group Two - control group (sham laser).

### 3.6 Study interventions

#### 3.6.1 Spinal manipulative therapy intervention

Thoracolumbar spinal manipulation was utilized in this study. The manipulation administered followed the diversified method of spinal manipulative therapy and consisted of a high velocity, low amplitude thrust into the direction of joint restriction (Haldeman, 2005). All of the participants in Group One received manipulation of all the fixated segments that were found between T7 - T12 using motion palpation. All manipulations were administered in the prone position to allow for consistency between the groups, with one of the following techniques being utilized depending on which technique was most suited to the participant. All manipulations were performed by the researcher.

##### 3.6.1.1 Bilateral Thenar Transverse

The patient was positioned prone with their face on the headrest. The practitioner stood on one side of the bed in the fencer stance, facing either cephalad or caudad and contacted the transverse processes on either side of the fixated segment with the thenar aspect of both hands and, after removing tissue slack, applied a posterior to anterior impulse thrust using the arms and trunk (Bergmann *et al.*, 2002).

- Bilateral Hypothenar Transverse

The patient was positioned prone with their face on the headrest. The practitioner stood on one side of the bed in the fencer stance, facing either cephalad or caudad and contacted the transverse processes on either side of the fixated segment with the hypothenar aspect of both hands and, after removing tissue slack, applied a posterior to anterior impulse thrust using the arms and trunk (Bergmann *et al.*, 2002).

##### 3.6.1.2 Hypothenar Thenar Transverse

The patient was positioned prone with their face on the headrest. The practitioner stood on the fixated side of the patient in the fencer stance making a hypothenar contact on the transverse process with the contact hand and a thenar contact on the opposite transverse process with the indifferent hand. Once tissue slack was removed an impulse thrust was applied through the contact hand, using the arms and trunk (Bergmann *et al.*, 2002).

#### 3.6.1.3 Hypothenar Spinous - Thenar Transverse

The patient was positioned prone with their face on the headrest. The practitioner stood on the fixated side of the patient in the square stance making a hypothenar contact on the ipsilateral side of the spinous process with one hand and a thenar contact on the opposite transverse process with the other hand. Once tissue slack was removed an impulse thrust was applied from medial to lateral and posterior to anterior, through both hands, using the arms and trunk (Bergmann *et al.*, 2002).

#### 3.6.1.4 Unilateral Hypothenar Spinous

The patient was positioned prone with their face on the headrest. The practitioner stood on the fixated side of the patient in the square stance making a hypothenar contact on the ipsilateral side of the spinous process with one hand and the other hand reinforcing the contact. Once tissue slack was removed an impulse thrust was applied from medial to lateral and posterior to anterior, through the contact hand, using the arms and trunk (Bergmann *et al.*, 2002).

### 3.6.2 Sham laser

A patient who has received chiropractic treatment before is aware of what spinal manipulation feels like, making it difficult to perform a placebo manipulation without the patient knowing, thus a sham laser was utilized in this study. All of the participants in Group two received a sham laser treatment, applied in the prone position, by contacting the skin with the detuned laser for one minute over each of the fixated facet joints of the lower thoracic spine.

## 3.7 Measurement tool

All testing was conducted on a K1 Ergo (Australian Sports Comission, Garran, Australia) kayak ergometer, a device which has been used for winter training by kayakers. It works by transmitting force from the paddle via a wire to a flywheel which spins and creates wind turbulence which produces the resistance necessary to simulate the water resistance of open water kayaking (Larsson *et al*. 1988). The ergometer is connected to a computer, which uses the “K1 Ergo” software to produce a stroke by stroke analysis of each run, providing readings for power (watts), time (seconds) and the number of strokes completed.

## 3.8 Research procedure

Once the participant was recruited and eligible for the study they performed a five minute warm up on the kayak ergometer to allow them to become familiar with the machine. After a five minute break they then performed a 200m sprint on the kayak ergometer. The average power (watts), the time taken to complete the 200m sprint (seconds) and the average stroke rate (strokes per minute) were recorded. The participant was then allowed a timed five minute break, during which time the manipulation/sham laser was administered. After the five minute break, participants performed a second 200m sprint on the kayak ergometer. The average power over the second 200m sprint, the time taken for them to complete the second 200m sprint and the average stroke rate was recorded. All testing was done by the researcher and there was no blinding, barring the randomization process for sample groups. It is unlikely that this affected the results as they were not subjective and were generated by the ergometer, not the researcher.

## 3.9 Data reduction and analysis

### 3.9.1 Data reduction

The raw data consisted of a stroke by stroke breakdown of power (measured in watts), the time taken to complete the 200m sprint (measured in seconds) as well as the number of strokes it took to complete the 200m sprint.

- Average power was determined by adding up the power produced per stroke over the 200m sprint, then dividing it by the number of strokes.
- Average stroke rate was calculated by taking the number of strokes, dividing it by the time taken to complete the 200m sprint and multiplying that figure by 60, resulting in the number of strokes per minute.
- Body mass index was calculated by dividing the weight (kg) by the height (m) squared (Longmore *et al.*, 2009).

### 3.9.2 Statistical analysis

IBM Statistical Package for Social Sciences version 23 was used to analyse the data. A p value of $< 0.05$ was considered as statistically significant. Independent samples t-tests were used to compare demographic and baseline variables between the two randomized groups. Paired t-tests were used to compare power and time between pre- and post-test measurements within groups. Repeated measures Analysis of Variance (ANOVA) tests were used to compare the change between pre- and post-test measurements between the two treatment groups. A significant time by group interaction effect signified a significant intervention effect. Profile plots were used to visualize the trends.

## 3.10 Ethical considerations

### 3.10.1 Autonomy

Participants received a letter of information (Appendix A) explaining the study as well as the potential risks involved in participation. They also received a consent form (Appendix B), which they were required to sign before participation. They were made aware that they may withdraw from the study at any point without experiencing any negative consequences as a result of their withdrawal.

### 3.10.2 Non-Maleficence

In order to ensure the participants were protected their names were coded and their information was stored on an external hard drive which was stored in the chiropractic department. All patient files are stored in the DUT Chiropractic Day Clinic.

### 3.10.3 Justice

**3.10.4 Each participant who volunteered to participate in the research study and who met the inclusion criteria was enrolled, resulting in fairness. There was no discrimination against paddlers. They were all given equal opportunity to participate in the research. However, in order to maintain sample homogeneity only male paddlers between the ages of 20 and 40 years of age who had been kayaking for at least three months for a minimum of four hours per week were allowed to take part in the study. In an attempt to maintain fairness to all participants in the study, all participants who fell into the control group were offered a free, voluntary, follow up consultation, on completion of testing, where they would be entitled to Chiropractic treatment, should they wish to receive such treatment. Beneficence**

Participants could expect to benefit from improvements in performance as well as the benefits of spinal manipulation. The result of this study can benefit the chiropractic profession and the kayaking discipline.

### 3.10.5 Permission

The researcher was granted permission to conduct research by the DUT RHDC and the IREC (Appendix L) prior to commencement of data collection. Permission to use the DUT CDC was obtained from the clinic director (Appendix M) and permission to use the KCC was obtained from the club chairperson (Appendix J). Permission was obtained from UKZN for the use of the kayak ergometer for the duration of the study (Appendix G).

# Chapter 4 : Results

## 4.1 Introduction

This chapter will present the results of the data that was analysed.

## 4.2 CONSORT flow diagram

Figure 4.1 shows the flow of participants from recruitment to termination of the study.

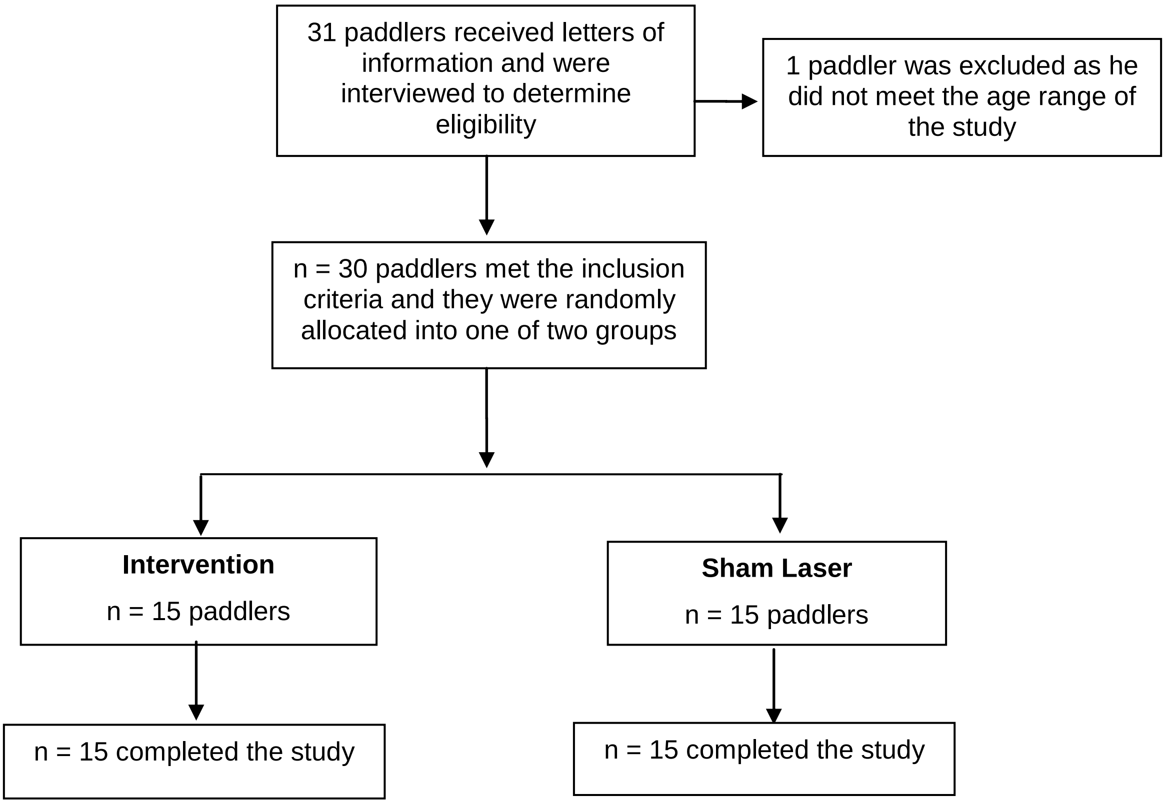


**Figure 4.1: CONSORT flow diagram**

## 4.3 Demographic and anthropometric characteristics of the participants

### 4.3.1 Age

The age range for the total sample was 20 - 38 years of age. There was no statistically significant difference ($p$ = 0.305) in mean age between the intervention group (28.53; SD± 4.97) and placebo group (26.73; SD± 4.45) (independent sample t-test).

### 4.3.2 Weight, height and body mass index (BMI)

Using independent sample t-tests there was no statistically significant difference found between the two groups for weight ($p$ = 0.406), height ($p$ = 0.890) or BMI ($p$ = 0.124), indicating that the groups were comparable at baseline. Table 4.1 shows the mean weight, height and BMI for the two groups.

**Table 4.1: Weight, height and BMI for the placebo and intervention groups**

| | n | Weight | | Height | | BMI | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD± | Mean | SD± | Mean | SD± |
| Intervention | 15 | 80.40 | 6.72 | 1.80 | 0.05 | 24.85 | 1.35 |
| Placebo | 15 | 78.00 | 8.73 | 1.80 | 0.08 | 24.01 | 1.54 |

## 4.4 Kayak ergometry

### 4.4.1 Power output (W)

At baseline there was no statistically significant difference ($p$ = 0.751) detected between the mean power output achieved by the participants in the intervention (235.15; ± 62.79 W) and the placebo (228.91; ± 41.61 W) groups, indicating that the groups were comparable. Intra-group analysis, using paired sample t-test, showed no statistically significant difference between pre- and post-measurements for the intervention ($p$ = 0.086; CI -28.981 to 2.181) or the sham group ($p$ = 0.567; CI -27.785 to 15.859).

Figure 4.2 shows the change over time in power output for the two groups; the intervention group shows a steeper gradient indicating increased power output, and a trend of a treatment effect. This effect was not supported by the statistical analysis using repeated measures analysis of variance (ANOVA), where no statistically significant difference was found between the groups over time ($p$ = 0.557).

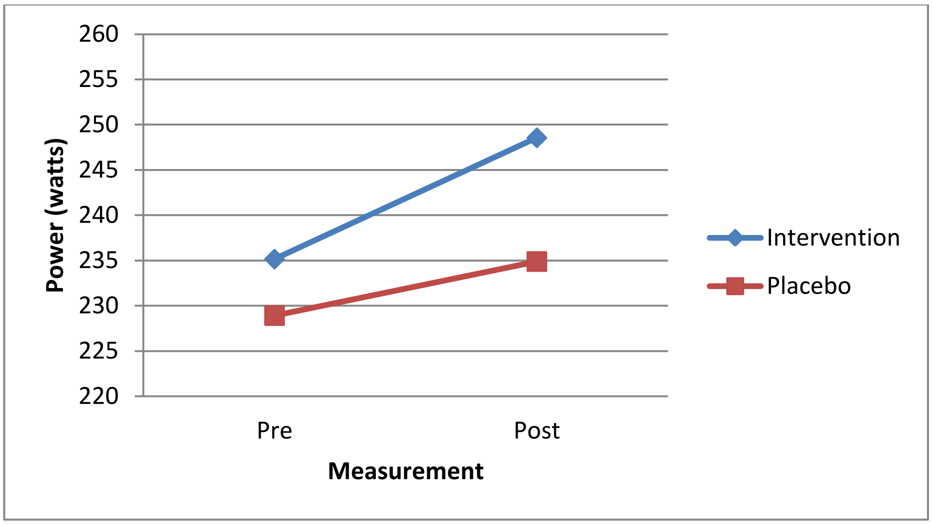


**Figure 4.2: Pre- and post-measurements for mean power output per group**

### 4.4.2 Time taken to complete a 200m sprint (seconds)

At baseline, no statistically significant difference ($p$ = 0.833) was found between the time taken to complete a 200m sprint in the intervention (36.86; ± 3.60 sec) and the placebo (36.63; ± 1.79 sec) groups, indicating that the groups were comparable at entry. Intra-group analysis, using paired sample t-test, revealed a statistically significant difference between pre- and post-measurements for the intervention group ($p$ = 0.018; CI 0.228 to 2.118) but not for the placebo group ($p$ = 0.817; CI -0.947 to 1.180).

This effect was not supported by the statistical analysis using repeated measures ANOVA, where no statistically significant difference was found between the groups over time ($p$ = 0.122). However, a difference of 0.8 seconds in the context of flatwater kayaking could mean the difference between first and last place and does represent a clinically significant result. Figure 4.3 shows the change over the duration of the study for time taken to complete the 200m sprint in the two groups; the intervention group shows a steeper gradient indicating improved time, and a trend of a treatment effect.

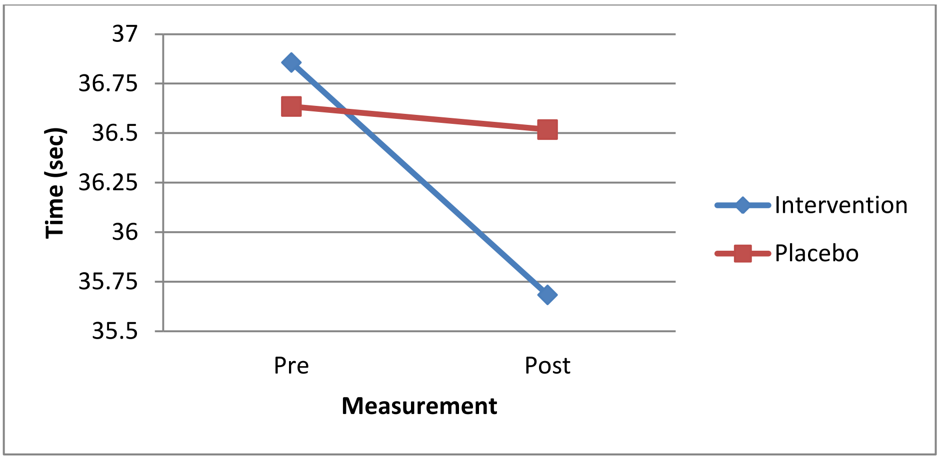


**Figure 4.3: Pre- and post-measurements for time taken to paddle a 200m sprint per group**

### 4.4.3 Stroke rate (strokes per minute)

At baseline, there was no statistically significant difference ($p$ = 0.330) detected between the stroke rate of the intervention (56.54; ± 6.02 strokes/min) and the placebo (54.24; ± 6.64 strokes/min) groups, indicating that the groups were comparable. Intra-group analysis, using paired sample t-test, revealed no statistically significant difference between pre- and post-measurements for the intervention ($p$ = 0.170; CI -5.793 to 1.129) or the placebo group ($p$ = 0.080; CI -5.621 to 0.358).

Figure 4.4 shows the change over time in stroke rate for the two groups; the intervention group and the placebo group show almost parallel increases in stroke rate, indicating no treatment effect. This was supported by the statistical analysis using repeated measures ANOVA, where no statistically significant difference was found between the groups over time ($p$ = 0.889).

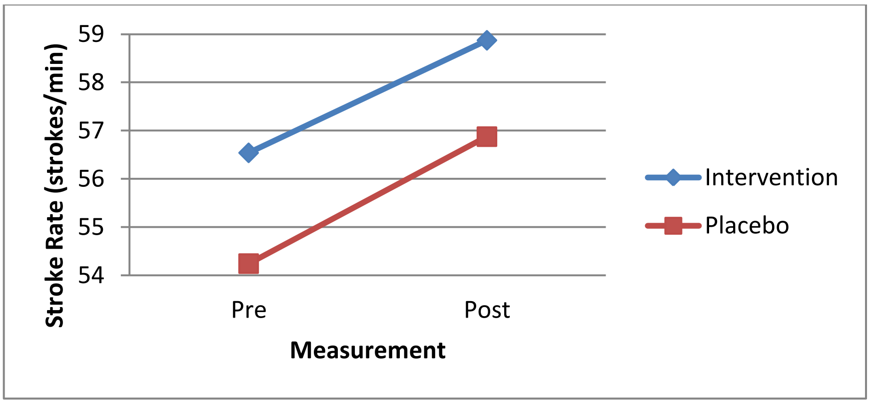


**Figure 4.4: Pre- and post-measurements for mean stroke rate per group**

# Chapter 5 : Discussion

## 5.1 Introduction

This chapter will discuss the results of this study in the context of the relevant literature.

## 5.2 Sample recruitment

The sample consisted of thirty male paddlers, divided equally and randomly into two groups. The participants tested were from KwaZulu-Natal, the province with the highest number of registered paddlers in the country, a total of 3800 (KwaZulu-Natal Canoe Union, 2014). Only one respondent was excluded due to not meeting the age range requirements. Difficulties were experienced in recruiting participants due to a lack of their availability to attend the consultation which lasted approximately one hour. In order to overcome thisthe KCC club was used as an additional data collection site making it more accessible to the participants to try and improve recruitment.

## 5.3 Demographic characteristics

### 5.3.1 Age

Performance has been shown to diminish drastically in athletes older than 55 years of age due to a variety of factors such as speed, changes in body composition, muscle composition changes, decreased testosterone and psychology of aging (Ransdell *et al.*, 2009). The age range of the participants allowed to take part in the study was controlled at 20 - 40 years of age to eliminate the effect that age has on performance, however Canoeing South Africa (2010) acknowledges competition from under 10 years of age up to 69 years of age. No significant differences were found between the groups indicating that age would not have influenced the study outcomes.

### 5.3.2 Height, weight and BMI

According to a study on the morphology of the paddlers who competed at the 2000 Sydney Olympic Games the average height (cm), weight (Kg) and BMI of the male competitors was 184.3 (SD ± 5.8), 85.2; (SD ± 6.2) and 24.9 respectively (Ackland *et al.*, 2003). These findings are not dissimilar from the findings within this study. This indicates that the sample population was representative of kayakers in terms of basic morphology. The mean BMI of the sample population is at the upper end of the normal weight range. This is most likely due to a large upper body structure offset by a lean body composition (Ackland *et al.*, 2003; Akca and Muniroglu, 2008). Akca and Muniroglu (2008) found a strong correlation between the large upper body mass of flatwater kayakers and performance in sprint events. In this study there were no significant differences between groups for BMI, indicating that BMI would have had little impact on the findings.

## 5.4 Kayak ergmoetry

### 5.4.1 Power

The mean power output showed no statistically significant difference between the two groups either pre-test or post-test, however the intervention group showed a trend of an effect over the placebo group (Figure 4.2), indicating a greater degree of improvement post-intervention. Exactly how this improvement was achieved is not clear as spinal manipulation has a variety of effects, as described in Chapter 2. It is possible that following spinal manipulation there was an improvement in truncal ROM allowing a more efficient stroke, as Limonta *et al.* (2010) described the role of trunk mobility in the kayak stroke. A limitation of the study is that ROM was not recorded as the focus of the study was an overall improvement in performance, rather than physiological outcomes. Sood (2008) found a correlation between improved ROM and bowling speed, indicating that ROM may be a significant factor in performance.

The role of power output in performance has been questioned. McKean and Burkett (2010) found little correlation to dry-land strength and endurance to on-water performance, indicating that brute strength is not enough to ensure performance in a kayak. These findings indicate that an increase in power may not, in itself, be enough to significantly improve performance. It should also be noted at this point that this study did not control whether or not participants had already paddled on the day of testing, meaning fatigue could have potentially been a factor in the outcome. As there was no significant intervention effect it cannot be ruled out that chance played a part in the trends seen in the intervention group.

### 5.4.2 Time taken to paddle 200m

Performance i.e. the time taken to paddle 200m is a product of a number of factors, as mentioned previously, such as power and stroke rate (Michael *et al.*, 2008). Thus, an improvement in average power is not, in itself, a guarantee of improved time and hence not a guarantee of improved performance. For example, several of the participants displayed improvements in average power over their second 200m sprint but conversely displayed a slower time and vice versa. It is postulated that this phenomenon can be attributed to an improvement or lowering of the stroke rate.

The roughly 0.8 sec improvement in the intervention group post-intervention represents a great improvement in the context of the sport. It is not uncommon to see an entire field of paddlers separated by less than a second, especially over a short distance such as the 200m event (www.canoeicf.com, 2014). It is possible that familiarization affected the findings of this study as the participants varied in their level of experience on a kayak ergometer.

Training on kayak ergometers is not a prolific practice in KwaZulu-Natal. This may be due to the favourable climate for "on the water" training. However, in many countries, in Europe especially, kayak ergometer training is a necessity owing to the freezing temperatures in winter. Whilst the majority of the participants in this research had had no prior experience on a kayak ergometer, there were a few of the more advanced paddlers who had a certain level of experience and even a few who had lived in Europe for a period and had actually trained on similar equipment. This meant that as testing progressed, the participants who had little or no prior experience on a kayak ergometer gained experience and were able to improve their technique, becoming more proficient in the use of the machine, thereby producing better results.

The researcher attempted to account for this phenomenon by giving patients a warm-up run, however this may have been insufficient. In the context of the research the improvements seen represented a trend and were not seen to be significant when compared to the control group and therefore chance cannot be ruled out as a factor and SMT cannot be confirmed to have increased performance over a 200m sprint on a kayak ergometer.

Spinal Manipulative Therapy is purported to improve the efficiency of the neuromuscular-skeletal system by normalising aberrant joint motion and altering sensory flow to the central nervous system (Pickar, 2002). The trend of improved time taken to paddle 200m in the intervention group could be associated with the improved function of the muscles and joints in the thoracolumbar spine, allowing improved co-ordination and performance, similar to that observed by Sood (2008) and Deutschmann *et al.* (2015) regarding performance following SMT.

### 5.4.3 Stroke rate

Both groups showed a roughly equal improvement in stroke rate post-intervention as can be seen by the almost parallel trajectory of the graphs in Figure 4.3. These findings support that familiarization with the kayak ergometer may have played a part in the trends toward improved performance. Familiarization may have also been affected by level of experience. Whilst an attempt was made to maintain a baseline level of experience it should be noted that the participants varied dramatically with regards to fitness and level of experience, ranging from national and provincial representatives to social paddlers.

There was, however a relatively equal distribution between the two groups with both test groups being representative of the whole spectrum of fitness and experience. It should also be noted that the vast majority of paddlers in KwaZulu-Natal are predominantly marathon paddlers. To the researcher’s knowledge there was only one sprint focused paddler who took part in the study. He cannot however be described as strictly a sprint paddler as he took part in numerous marathon events and underwent a significant amount of marathon training. Although he showed a significantly higher average power than the rest of the participants, in both his first and second sprints, his times were no better than the marathon paddlers with the same level of fitness and experience.

When kayaking on the water there are a wide variety of factors that affect the paddlers style and technique such as the shape of the paddle blade used and what material the paddle is constructed from as certain materials are lighter and more rigid, such as carbon fiber, whilst other materials, like plastic and fiber glass, are heavier and more flexible (Robinson *et al.*, 2002). Factors such as boat weight, design and dimensions will also affect the paddler's individual style and technique (Michael *et al.*, 2009). In this study all the participants were forced to paddle on the same equipment, namely the kayak ergometer and it is possible that some of the participants may have adopted a style that was unfavourable for kayak ergometry.

The majority of a paddler's power output is dedicated to maintaining kayak velocity (power = drag force x kayak velocity) (Michael *et al.*, 2009). The force applied by the paddler to propel the kayak forward is intermittent and as such the kayak experiences periods of acceleration, during pull-through, and deceleration, during the brief period between the paddle exiting the water and entry of the opposite paddle into the water. The acceleration causes increased drag on the hull of the boat and deceleration reduces average velocity, therefore good technique and a rapid stroke rate are vital in achieving good performance i.e. a quick time (Michael *et al.*, 2009).

Unlike "on the water" kayaking the kayak ergometer has no water resistance, however it uses a fly wheel to generate air resistance (Larsson *et al*. 1988), which will show intermittent increases and decreases, not unlike like those seen in water resistance during an "on the water" kayak stroke, as the fly wheel experiences acceleration during pull-through and deceleration during recovery. Technique and efficiency were not quantified or measured in this study, however stroke rate was. Improved performance is a product of both stroke rate and power output (Michael *et al.*, 2009). In this study there was a trend of increased power output in the SMT group with intra-group analysis showing a statistically significant improvement in time taken to paddle a 200m sprint. Yet the stroke rate did not significantly differ from the sham group. Indicating that independent of stroke rate power output appeared to affect time. It is therefore plausible that the SMT may have affected power output yet the effect was not large enough to detect with the small sample size.

# Chapter 6 : Conclusions and Recommendations

## 6.1 Conclusion

The purpose of this study was to determine the immediate effect of spinal manipulation of the lower thoracic spine of male paddlers on average power output, time taken to paddle 200m and stroke rate. No statistical evidence was found that the intervention improved power, time or stroke rate compared to the control group, resulting in the null hypothesis being unable to be rejected. Future research should be conducted using the recommendations as outlined below.

## 6.2 Limitations

1. The participants in the study were not homogenous with respect to on water paddling experience as well as kayak ergometer experience.
2. It was not controlled whether or not participants had paddled prior to testing, which could have resulted in muscle fatigue during testing.
3. The study was limited to male paddlers and therefore the results cannot be extrapolated to female paddlers
4. Age was restricted to 20-40 years of age and as such cannot be extrapolated to older or younger populations

## 6.3 Recommendations

1. A study using a larger sample size in order to increase the power of the study.
2. Adding a practice-run after the participants' initial warm-up and before actual testing begins, to further reduce the learning effect on the outcome of the results.
3. Future studies should control fitness and level of experience more strictly, perhaps by testing only elite athletes who are competing in flat-water sprint events, by using elite flatwater kayakers who have similar training routines, such as a team of kayakers

4. Surface Electromyography and range of motion testing would strengthen the study results as they would allow for a greater appreciation of the effect of SMT on muscles and joint mobility.
5. Future studies should control for activity on the day of testing as fatigue may play a role in the outcome of testing.
6. A crossover study design would make for a more robust study.
7. Future studies should be conducted on female paddlers.
8. A broader age range should be used in future studies.

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# Appendices

## Appendix A: Letter of Information

### LETTER OF INFORMATION

**Title of the Research Study:** The immediate effect of thoracic spine manipulation on power output and speed in paddlers

**Principal Investigator/s/researcher:** Thornton Vivier

Contact: 0780770655

**Co-Investigator/s/supervisor/s:** Dr Neill Gomes [M.Tech Chiropractic, M. Med. Sc. (Sports Med), C.C.S.P]

Contact: 0824399027

**Brief Introduction and Purpose of the Study:** You have been selected to take part in a study to investigate the effect of thoracic spine manipulation on the power of the kayaking stroke. Thirty people will be required to complete this study. You will be required to attend one consultation lasting approximately two hours for assessment and testing. All participants, including you, will be split into two equal groups. Each of the groups will receive a standard clinical assessment of their thoracic spines. One group will receive spinal manipulative therapy and the other group will receive laser therapy of their thoracic spine. <u>All testing will take place at one of two research sites namely the Durban University of Technology Chiropractic Day Clinic and KCC.</u>

**Outline of the Procedures:** *Please try not to alter your normal lifestyle or daily activities in any way*, as this could interfere with the results of the study. Those taking part in the study must be between the ages of 20 and 40. Any kayakers who do not meet the required number of days training per week (3) or the number of hours training per week (4) would be excluded. Kayakers would also be excluded if they have had any surgery or previous trauma to the shoulder, thoracic or lumbar region. Kayakers who are found to have contraindications to manipulation, such as arteriosclerosis, vertebrobasilar insufficiency, fractures, severe sprains, osteoarthritis, clotting disorders or osteoporosis. Other contraindications would include any arthritides, severe trauma to the thoracic region or metabolic disorders such as Diabetes or Hypoglycaemia.

**Research process:**
At the consultation participants will be placed, randomly into one of two groups. Those in Group 1 will receive manipulation of the thoracic spine and those in Group 2 will receive laser therapy. Once participants have been allocated to a group they will be screened for suitability as a participant using a case history, physical examination and thoracic spine regional examination. They will then perform

a 5 minute warm up on a kayak ergometer followed by a 200m sprint on the ergometer. After this they will have a 5 minute break, during which they will undergo manipulation or laser therapy, depending on which group they are allocated to. Finally, they will perform a second 200m sprint on the kayak ergometer.

**Risks or Discomforts to the Participant:** Participants in test group 1 will receive spinal manipulation, which may include side effects such as local or radiating discomfort which is generally transient and rarely lasts more than 24 hours. In order to minimize any serious side effects a thorough physical (Appendix C) and regional examination (Appendix D) will be performed on each patient before treatment is administered. Participants may also experience some muscle stiffness as a result of testing however this should not last longer than 48 hours. Patients will also be made aware of potential side effects beforehand and maintain the right to withdraw from the study at any point without any consequences. Participants will be encouraged to contact the researcher telephonically, post-testing, should they have any questions or concerns regarding any side-effects they may be experiencing after testing. The researcher will attempt to allay any concerns and answer any questions the participant may have and, if needed or at the participant's request, may schedule a follow-up consultation or refer the participant to a suitable healthcare practitioner.

**Benefits:** Your full co-operation will assist the Chiropractic profession in expanding its knowledge on the immediate effects of spinal manipulation. The manipulative treatment that will be given is a common treatment intervention in the treatment of Thoracic Facet Dysfunction. All treatments are free of charge.

**Reason/s why the Participant May Be Withdrawn from the Study:** Participants may be withdrawn from the study for non-compliance, illness, adverse reactions and are free to withdraw at any stage without fear of adverse consequences.

**Remuneration:** Subjects taking part in the study will not be offered any form of remuneration for taking part in the study. Upon completion of the research process, the normal cost of consultations will be charged for those patients wanting further treatment. All patient information is confidential and the results of the study will be made available in the Durban University of Technology library in the form of a mini-dissertation.

**Costs of the Study:** Participation in this study is completely free of charge and no monetary contribution will be required by the participant.

**Confidentiality:** All patient information will be kept confidential and will be stored, under lock and key, in the Chiropractic Day Clinic for 5yrs, after which it will be shredded or erased. It should be noted that there is a possibility of being allocated to a control/placebo group, where you will receive a sham treatment, which you will only be made aware of after testing is completed. Please don't hesitate to ask questions on any aspect of this study. Should you wish, you can contact my research supervisor at the above details.

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

(Supervisor and details) Please contact the researcher (0780770655), my supervisor (0824399027) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

**Appendix B: Consent Form**

**CONSENT**

**Statement of Agreement to Participate in the Research Study:**

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

____________________ __________ ______ _______________

**Full Name of Participant Date Time Signature / Right Thumbprint**

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

| | | |
|---|---|---|
| **Full Name of Researcher** | **Date** | **Signature** |
| **Full Name of Witness (If applicable)** | **Date** | **Signature** |
| **Full Name of Legal Guardian (If applicable)** | **Date** | **Signature** |

## Appendix C: Chiropractic Day Clinic Case History

**CHIROPRACTIC PROGRAMME**

DUT
DURBAN UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

# CHIROPRACTIC DAY CLINIC CASE HISTORY

Patient:______________________________ Date: __________

File #: ______________ Age: __________

Sex: __________ Occupation: ______________________

Student: ______________________ Signature ______________________

**FOR CLINICIANS USE ONLY:**

Initial visit

Clinician: Signature:

| **Case History:** |
|---|
| |

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

**CASE STATUS:**

| PTT: | Signature: | Date: |
|---|---|---|

| |
|---|
| **CONDITIONAL:**<br>Reason for Conditional: |
| |
| |
| Signature: Date: |

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

| |
|---|
| Case Summary signed off: Date: |

**Student's Case History:**

1. **Source of History:**

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

3. **Present Illness:**

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

| | | |
|---|---|---|
| Outcome: | | |

### 4. Other Complaints:

### 5. Past Medical History:

General Health Status Childhood Illnesses Adult Illnesses Psychiatric Illnesses Accidents/Injuries Surgery Hospitalizations

### 6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication

Analgesics/week:
Other (please list):

Tobacco Alcohol Social Drugs

### 7. Immediate Family Medical History:

Age of all family members Health of all family members Cause of Death of any family members

| | Noted | Family member | | Noted | Family member |
|---|---|---|---|---|---|
| Alcoholism | | | Headaches | | |
| Anaemia | | | Heart Disease | | |
| Arthritis | | | Kidney Disease | | |
| CA | | | Mental Illness | | |

| | | | | | |
|---|---|---|---|---|---|
| DM | | | Stroke | | |
| Drug Addiction | | | Thyroid Disease | | |
| Epilepsy | | | TB | | |
| Other (list) | | | | | |

## 8. Psychosocial history:

Home Situation and daily life Important experiences, Religious Beliefs

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

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

## Appendix D: Senior Physical Examination

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

**CHIROPRACTIC PROGRAMME**

PHYSICAL EXAMINATION: SENIOR

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

**Student:** **Signature:**

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

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

**SYSTEM SPECIFIC EXAMINATION:**

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

**Clinician:** **Signature:**

Page 1

**Appendix E: Thoracic Spine Regional Examination**

# THORACIC SPINE REGIONAL EXAMINATION

Patient:________________________________________File:__________ Date:__________

Intern:__________________________________Signature:_____________________________

Clinician: ______________________________Signature:_____________________________

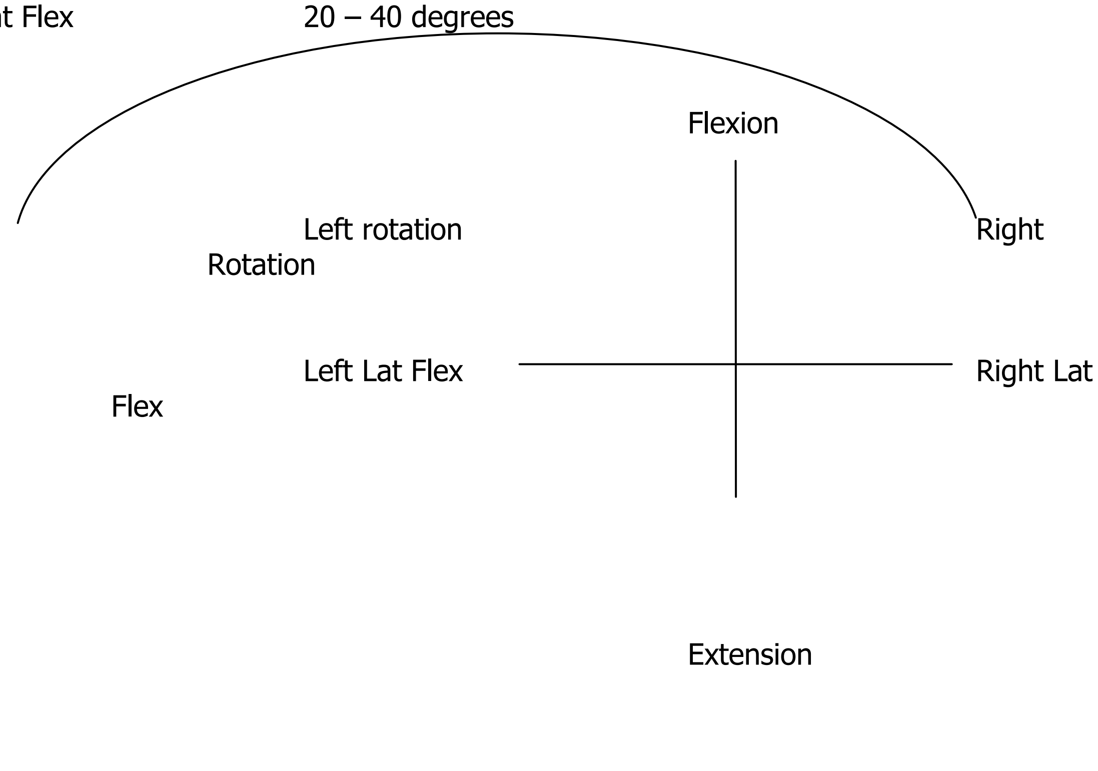
**STANDING:**

Posture ( incl. L/S & C/S ) | Scars
Muscle tone | Chest deformity

Skyline view – Scoliosis | (pigeon, funnel, barrel)
Spinous Percussion
Breathing (quality, rate, rhythm, effort)
Deep Inspiration

**RANGE OF MOTION:**

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



**RESISTED ISOMETRIC MOVEMENTS:** (in neutral)

Forward Flexion
Extension
L/R Rotation
L/R Lateral Flexion

**SEATED:**

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

**SUPINE:**

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

**PRONE:**

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

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

COMMENTS:____________________________________________________________

**NEUROLOGICAL EXAMINATION:**

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

**Basic LOWER LIMB neuro:**

| | |
|---|---|
| Myotomes | |
| Dermatomes | |
| Reflexes | |

**KEMP'S TEST:**

**MOTION PALPATION:**

<table>
<tr><th colspan="3"></th><th>Right</th><th>Left</th></tr>
<tr><td colspan="3">Thoracic Spine</td><td></td><td></td></tr>
<tr><td rowspan="3">Ribs</td><td colspan="2">Calliper (Costo-transverse joints)</td><td></td><td></td></tr>
<tr><td rowspan="2">Bucket Handle</td><td>Opening</td><td></td><td></td></tr>
<tr><td>Closing</td><td></td><td></td></tr>
<tr><td colspan="3">Lumbar Spine</td><td></td><td></td></tr>
<tr><td colspan="3">Cervical Spine</td><td></td><td></td></tr>
</table>

| BASIC EXAM | History | ROM | Neuro/Ortho |
|---|---|---|---|
| LUMBAR | | | |
| CERVICAL | | | |

## Appendix F: SOAPE Note

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

**CHIROPRACTIC PROGRAMME**

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

*Date:* *Visit:* *Student:*

*Attending Clinician:* *Signature:*

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

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

**0:** **P:**

**E:**

*Special attention to:* *Next appointment:*

*Date:* *Visit:* *Student:*

*Attending Clinician:* *Signature:*

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

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

**O:** **P:**

**E:**

*Special attention to:* *Next appointment:*

*Date:* *Visit:* *Student:*

*Attending Clinician:* *Signature*

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

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

**O:** **P:**

**E:**

*Special attention to:* *Next appointment:*

## Appendix G: Permission to Use the K1 Ergo Kayak Ergometer

**Appendix F**

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

18th November 2014

Chairperson
Department Research Committee

**Re: Use of the K1 Ergometer for research project: Mr Thorn Vivier**

This letter serves to notify the Research Committee that Mr Vivier has permission to use the K1 Ergometer for the duration of his research project. Once his data collection is completed, he will return the Ergometer to the Discipline of Biokinetics, Exercise and Leisure Sciences, UKZN, Westville Campus.

He will take full responsibility for the maintenance and repair of the equipment should there be any issues whilst under his care.

Please feel free to contact me should you require any additional information.

Yours sincerely,

Andrew McKune, DTech
Associate Professor Exercise Science
Discipline of Biokinetics, Exercise and Leisure Sciences
School of Health Sciences
University of KwaZulu-Natal

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

**Biokinetics, Exercise & Leisure Sciences**
Postal Address: Private Bag X54001,
Durban, 4000, South Africa
Telephone: +27 (0) 31 260 7985
Facsimile: +27 (0) 31 260 7903
Email: mckunea@ukzn.ac.za

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**Appendix H: Permission to Use the Chiropractic Day Clinic**

# MEMORANDUM

To : Prof Puckree Chair : RHDC
Prof Adam Chair : IREC

From : Dr Charmaine Korporaal
Clinic Director: FoHS Clinic

Date : 24.02.2015

Re : Request for permission to use the Chiropractic Day Clinic for research purposes

Permission is hereby granted to :

**<u>Mr Thornton Vivier (Student Number: 20803864)</u>**
**<u>Research title</u>** : "The immediate effect of thoracic spine manipulation on power output and speed in paddlers".

Mr Vivier, is requested to submit a copy of his RHDC / IREC approved proposal along with proof of his MTech:Chiropractic registration to the Clinic Administrators before he starts with his research in order that any special procedures with regards to his research can be implemented prior to the commencement of him seeing patients.

In terms of his request for vouchers: these need to be in line with the DUT PR policy and it is suggested that he contact Ms P. Redmond (Design Unit) in regard of setting up the vouchers. The vouchers (15 required), will need to state:

1. The purpose of the voucher: i.e. what the patient is entitled to.
2. Who may treat the patient (the researcher, other students) and what conditions the voucher enables the patient to be treated for. [this needs to be outlined in the research methods or ethics checklist sections of the proposal]
3. That the voucher is applicable and useable only by the research participant.
4. Whether a set time frame will be allowed within which the voucher is redeemable.
5. Space for the student and clinicians signature on that date that the participant participated in the research, enabling the participant to receive the voucher.
6. Any additional RHDC or IREC requests /requirements in terms of the use of vouchers in research.

In terms of your request to store the kayak ergometer in the rehabilitation room and to utilize this as the room for your data collection, please make arrangements with Mrs Twiggs once your research has been approved by IREC. Please bear in mind that you must allow for the room to still be utilized for outpatients in the clinic, so you may need to set it up in a manner that allows for you to complete your research concurrently with clinic operations. Your assistance would be appreciated.

Thank you for your time.
Kind regards

[redacted]

Dr Charmaine Korporaal
Clinic Director: FoHS Clinic

Cc: Chiropractic Day Clinic : Mrs Pat van den Berg
Chiropractic Day Clinic: Mrs Linda Twiggs
Supervisor: Dr Neil Gomes

**Appendix I: Data Collection Sheet**

# Data Collection

Patient Name: ..........................................................................

Group No.: ..................................................................................

| Power (watts) | Time (seconds) | Levels Adjusted |
|---|---|---|
| | | |

## Appendix J: Permission to Use Kingfisher Canoe Club

P O Box 364
HYPER-BY-THE-SEA
DURBAN
4053

Tel (031) 3032740
Fax 086 293 4791
E-Mail secretary@kingfishercc.co.za

KINGFISHER CANOE CLUB

20th July 2015

To whom it may concern

Access to Kingfisher Canoe Club for Chiropractic Research

Thornton Vivier will be granted access to the Kingfisher Canoe Club for the purposes of conducting Chiropractic Research on paddlers for the duration of his data collection process, so long as his research does not interfere with club activities.

An area for testing which allows for privacy of both the participant and the researcher throughout the examination and testing process will be available.

The researcher may recruit both club members and non-members for the purposes of his research.

Regards

[redacted]

Terry Drummond (Chairman)
**KINGFISHER CANOE CLUB**

**Appendix K: Off-campus Clinician Agreement**

## Off-Campus Clinician Agreement

Dr. A. Docrat

Department Head: Chiropractic and Somatology

Re: Research

The research supervisor and the off-campus clinician hereby agree that they have gone through and understood the PG2a as pertinent to: The immediate effect of thoracic spine manipulation on power output and speed in paddlers.

In signing this document the off campus clinician agrees that they understand that special attention must be paid in terms of the following:

- Data collection must occur as specified in the PG2a document and any deviations must be reported to the HoD, Dr. A. Docrat
- Participant inclusion and exclusion criteria must be strictly adhered to eg: age, gender, etc. as stipulated in the PG2a
- Operation of any relevant equipment. (as per PG2a)
- Time parameters for the study's intervention protocol. (as per PG2a)

Off-campus Clinician details:

Name:______________________________________________________

Qualification:_________________________________________________

Registration No.:____________________ Practice No.:______________________

Tel.:________________________________________________________

email:_______________________________________________________

Practice Address:_____________________________________________

______________________________________________________

Sign:_______________________________________

(off-campus clinician)

Name:_____________________________

Sign:_______________________________

(supervisor)

Name:_____________________________

Sign:_______________________________

(Researcher)

## Appendix L: Permission from IREC to conduct study

DUT
DURBAN
UNIVERSITY OF
TECHNOLOGY

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

P O Box 1334, Durban, South Africa, 4001

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

**www.dut.ac.za**

21 May 2015

IREC Reference Number: **REC 44/15**

Mr T F Vivier
1 Candytuft Grove
Glen Anil

Dear Mr Vivier

**The immediate effect of thoracic spine manipulation on power output and speed in paddlers**

I am pleased to inform you that Full Approval has been granted to your proposal REC 44/15.

The Proposal has been allocated the following Ethical Clearance number **IREC 042/15**. Please use this number in all communication with this office.

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

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

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

Yours Sincerely

[redacted]

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY
2015 -05- 21
INSITUTUTIONAL RESEARCH ETHICS COMMITTEE
P O BOX 1334 DURBAN 4000 SOUTH AFRICA