The immediate effect of sham laser and three different spinal manipulative protocols on the throwing speed of baseball players in the Kwa-Zulu Natal Baseball Union.

By

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Dissertation submitted in partial compliance with the requirements for the Masters degree in Technology: Chiropractic

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I, Michael Robson, do declare that this dissertation is a representation of my own work in both concept and execution

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DEDICATION

To my family, thank you for being my emotional, technical and financial support through all these years. Without your love and guidance I would not have been able to complete this journey.

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ABSTRACT

Background:

Baseball pitching is a whole body ballistic movement that requires transfer of energy from the lower extremity to the upper extremity via the trunk. Adverse changes can occur within the surrounding ligaments, tendons and muscular tissue of the trunk when immobilization or restricted motion within a joint segment occurs. Improper transfer of energy is thought to cause abnormal stresses on the joints and may lead to injury and/or decreased performance. Spinal manipulation therapy (SMT) was the focus of this study, aimed to improve flexibility and joint mobility (Range of motion), thereby allowing for a more efficient closed kinetic chain movement, which could result in a faster speed of the baseball pitch.

Objective:

To determine and compare the immediate effect of placebo and SMT of the thoracic and lumbar spines in respects of range of motion (ROM) and the velocity of the pitching participants.

Methods:

Fourty asymptomatic baseball players were divided randomly into four groups. Group A received thoracic spine manipulation, Group B received lumbar spine manipulation, Group C received combined thoracic and lumbar spine manipulation and Group D received the sham laser intervention as a placebo controlled group. Pre- and post-intervention trunk flexion and lateral flexion ROM and pitching speeds were measured, using a digital inclinometer and a radar gun respectively. A subjective measurement of the participant's perception of a change in pitching speed post-intervention was also recorded. SPSS version 23 was used to analyse the data.

Results:

There was a significant increase in pitching speed in the SMT interventions groups ($p<0.05$). However, between the SMT and placebo groups they were not considered significantly different at 5% ($p>0.05$). A significant increase in Thoracic RLAT ROM was noticed on the inter-group analysis ($p<0.05$). There was no correlation seen between subjects' perception of change in throwing speed post-intervention and the objective results obtained.

Conclusion

The immediate effect of SMT on baseball pitching speed was inconclusive. The outcome of this study suggests that SMT results in an increase in the average speed of baseball pitching but not at a level of statistical significance.

Key words:

Baseball, Baseball Pitching, Biomechanics, Chiropractic, Chiropractic Adjustment, Performance, Pitching Biomechanics, Spinal Manipulation Therapy, Spine, Throwing, Sport Biomechanics

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LIST OF DEFINITIONS

Trunk:

The piece of the body, barring the head and appendages. For this investigation, it incorporates the thoracic and lumbar spine (Moore, Dalley and Agur 2010)

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 and Peterson 2011).

Joint play:

This term describes the degree of end movement or distention allowed passively that cannot be achieved through voluntary effort of the patient (Schafer and Faye, 1990).

LIST OF ABBREVIATIONS

AVE	Average
ANOVA	Analysis of variance
Cm	Centimetres
FF	Forward flexion
Kg	Kilograms
Km/h	kilometres an hour
Kzn	KwaZulu Natal
LLAT	Left Lateral Flexion
L1- L5	Lumbar vertebra with corresponding number
m	Meters
N/A	Not available
n	Sample size
RLAT	Right lateral flexion
ROM	Range of motion
SD	Standard deviation
SMT	Spinal manipulative therapy
T 1 – T 12	Thoracic vertebra with corresponding number

CHAPTER ONE

INTRODUCTION

1.1 Introduction

In baseball it is has been thought for many years that the force behind the speed of pitching originated from the shoulder complex (Burkhart, Morgan and Kibler 2003). However, recent literature indicates that in throwing athletes, the forces produced by the shoulder are not sufficient for achieving a high speed movement (Burkhart, Morgan and Kibler 2003). The lower extremity, pelvis, and trunk are responsible for initiating the kinetic force and establishing a base of support that transfers potential energy to the subsequent segments (Werner *et al.* 2008; Seroyer *et al.* 2010; Wassinger and Myers 2011; Urbin *et al.* 2013). Redwood (2003); Gatterman (2005) believe that when an immobilized or restricted joint segment is present, an adverse change may occur in the surrounding ligaments, tendons, muscular tissue and vascular elements. The implications of these changes may result in loss of tensile strength, adhesion formation, loss of flexibility and range of motion, and muscle atrophy (Gatterman 2005). All of these changes can lead to a loss of functional ability (Redwood 2003; Lederman 2005). To counteract these changes, this study will focus on spinal manipulation as it has been shown to be an effective way of increasing spinal joint mobility (Gatterman 1990; Herzog 2000; Gatterman 2005; Herzog 2010; Bergmann and Peterson 2011).

1.2 Aims and objectives of the study

The primary aim of this study was:

To determine via a controlled, prospective, investigative trial the effect of thoracic, lumbar and combined thoracic and lumbar manipulation on the pitching speed of asymptomatic baseball players registered in the KwaZulu Natal Baseball Union.

Several specific objectives were identified and these included:

Objective One

To determine the immediate effect (pre- and post-intervention) of thoracic spine manipulation on thoracic range of motion and the throwing speed of baseball players.

Objective Two

To determine the immediate effect (pre- and post- intervention) of lumbar spine manipulation on lumbar range of motion and the throwing speed of baseball players.

Objective Three

To determine the immediate effect (pre- and post- intervention) of a combination of thoracic and lumbar spine manipulation on thoracic and lumbar range of motion and the throwing speed of baseball players.

Objective Four

To determine the immediate effect (pre- and post- intervention) of sham laser technique on the thoracic and lumbar spine range of motion and the throwing speed of baseball players.

Objective Five

To determine the immediate subjective change in speed post manipulation for each participant.

1.3 Hypotheses of the study

For the objectives, the Null Hypotheses (Ho) were set as follows:

- There would be no statistically significant increases in pitching speed post-intervention for any of the four groups.
- There would be no statistically significant increases in range of motion in any of the four groups.
- There would be no statistically significant relationships between change in pitching speed immediately post-intervention and change in range of motion of the lumbar and thoracic spines.

- There would be no statistical relationship between change in pitching speed immediately post-intervention and the participant’s perception of change in their pitching speed.

1.4 Scope of the study

The results of 40 healthy, asymptomatic, non-contraindicated to spinal manipulation baseball players, who all met the inclusion criteria, are reported in this dissertation. The participants were divided into four groups. Group A received thoracic manipulation, Group B received lumbar manipulation, Group C received a combined manipulation of both the thoracic and lumbar spines and Group D received a sham laser intervention. Pre-intervention objective testing included flexion and lateral flexion of the lumbar and thoracic spines along with pitching speed measurement. These objective measurements were then recorded again post-intervention along with the participant’s subjective measurement of perception of change in speed of their pitching.

1.5 Flow of the dissertation

- Chapter one

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

- Chapter two

Review of the literature: anatomy of the lumbar and thoracic spines, the baseball pitch and mechanics involved in pitching, and SMT.

- Chapter three

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

- Chapter four

Results of the statistical analysis.

- Chapter five

Discussion of the results and how they relate to the existing literature. Conclusions drawn from the study and recommendations for future research due to these findings.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

In this chapter the literature relevant to this research is covered. The basics of baseball are covered with the relevant anatomy and biomechanics of the thoracic and lumbar spine and how these relate to the baseball pitch. This chapter also covers asymptomatic joint dysfunction and its possible effect on the performance of asymptomatic amateur baseball players.

The search engines used to review the literature included: DUT Summon, Google, Google Scholar, medlinePlus, Ebscohost, Science Direct, Proquest, Springer Link and PubMed. The following key words were used: Baseball, Spinal manipulation, Chiropractic, Baseball Performance, Pitching, Throwing, Thoracic spine, Lumbar spine, Performance.

2.2 Baseball

2.2.1 Introduction to baseball

Baseball is a bat and ball team game played by two opposing teams, each consisting of nine on-field players (MLB 2017). The goal of baseball is to score more runs than the opposition, with each team taking turns at playing offense (known as batting) and defence (known as fielding)(MLB 2017). Each game consists of nine innings, during which each team gets an opportunity to field and bat nine times (MLB 2017). Local teams in KwaZulu-Natal however, due to resources and time constraints, play seven innings or games with time constrictions.

2.2.2 The playing field

The playing field consists of both an infield and an outfield (MLB 2017). The infield is designed to be a square shape but is commonly called the “diamond”, which has a base at each corner, thus making four bases (first base, second base, third base and a fourth base known as home plate) (MLB 2017). The distance between each base is 27,4m perpendicular from the next (MLB 2017). In the middle of the infield - 18,4m away from the home plate - is the pitchers plate (MLB 2017).

Outside the diamond there is an area known as the outfield, which can sometimes be surrounded by a wall between 97 to 140m away from the home plate (MLB 2017). There are two foul lines that extend from each side of home plate to the outfield boundary, that dissect the first and third bases (MLB 2017). The area that lies between these foul lines is known as fair territory and any balls hit outside of these lines are known as foul balls (MLB 2017).

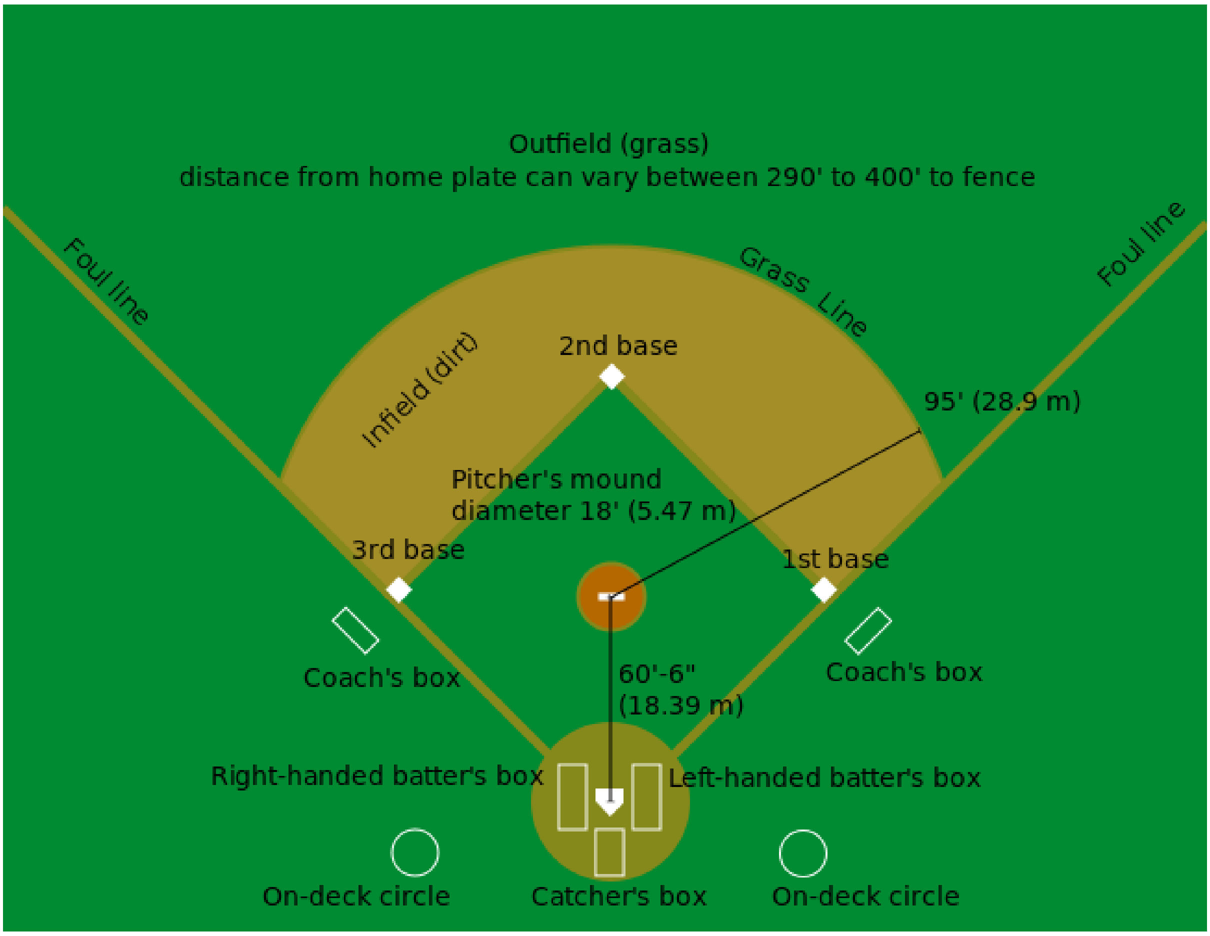


Figure 2.1 Baseball Diamond

(Adapted from https://commons.wikimedia.org/wiki/File%3ABaseball_diamond.svg, 2006)

2.2.3 Playing of the game

The offensive players achieve runs by circling all four bases, in a counterclockwise manner, set at the corners of the square-shaped baseball diamond (MLB 2017). The offensive team will continue batting until three outs have occurred (MLB 2017).

The team that is on defence has the goal of preventing the batting team from scoring runs by recording three outs per an inning (MLB 2017). When three outs have been recorded, it is time for the teams to swap roles (MLB 2017). The fielding team can be broken down into the outfield players and infield players. There are three outfielders and six infielders (MLB 2017). The outfielders consist of three players - the left fielder, centre fielder and right fielder (MLB 2017). The infielders consist of six players - the first baseman, second baseman, third baseman, shortstop, catcher and the pitcher (MLB 2017).

2.2.4 Baseball pitching

2.2.4.1 Introduction

In the game of baseball one of the most important players is the pitcher, who is solely responsible for delivery of the ball to the batter to begin a play (MLB 2017). Barrett and Burton (2002); Whiteley (2007) found that during college level baseball games the pitchers were responsible for making 51% of the total number of throws in the game themselves; compared to the 49% shared between the eight other players on the field.

The pitcher stands on the pitching mound and throws the ball to the catcher who is positioned behind home plate in a manoeuvre known as pitching (Calabrese 2013). The pitcher throws the baseball towards the catcher with the objective of getting a strike. A strike can occur when (MLB 2017):

- A pitch is thrown through the strike zone and the batter does not swing.
- The batter swings at a pitch and misses.
- The batter makes contact with a pitch but does not enter the field of play.

An area known as the strike zone begins above the batters knees to below the midpoint on their waist and shoulders and only exists over the home plate (MLB 2017). Pitches that do not enter the strike zone while the batter doesn't swing are known as balls (MLB 2017). When a pitcher throws four balls to a batter, the batter may proceed to first base and this is commonly known as a "walk" or "base on balls" (MLB 2017).

Pitchers have different ball variations that they can use in order to try strikeout a batter or get an out from a field play (MLB 2017). These include the fastball, changeup, slider, curveball and knuckle ball (Bernier 2014). The most commonly used and important pitch in baseball is the fastball (Fleisig *et al.* 2006). A baseball pitchers ability to throw the ball at a high speed with accuracy is regarded as a valuable asset to a team (Werner *et al.* 2008).

2.2.4.2 Stages and Biomechanics of Baseball Pitching

Chu *et al.* (2016) described the baseball pitching motion as a sequence of coordinated movements of the body, which aims to produce a pitch with high speed and accuracy. The sequence of pitching occurs when the pitcher lifts their front foot, progresses through a linked motion in the hips and trunk, that ends with a ballistic motion of the shoulder complex and arm thrusting the baseball forward towards the target (Werner *et al.* 2008; Weber *et al.* 2014).

The six phases of pitching include (Werner *et al.* 2008; Weber *et al.* 2014):

- Wind-up
- Stride (Early cocking)
- Late cocking
- Acceleration
- Deceleration
- Follow through

2.2.4.2.1 The Wind Up Phase

The wind up phase of throwing occurs when the player first initiates movement from the stationary position of facing home plate and the batter (Calabrese 2013). The movement starts when the player first stands with both feet in contact with the pitching plate and ends with the player's lead leg (left leg on a right handed pitcher) reaching the highest point of hip and knee flexion (Calabrese 2013).

2.2.4.2.2 The Stride Phase (Early Cocking)

The stride phase continues on from the wind up and begins from the highest point of hip and knee flexion and ends with the lead leg's contact with the ground (Calabrese 2013). The lower extremity moves down the mound towards home plate while separation of the hand from the glove occurs (Calabrese 2013). The chest of the pitcher remains closed and rotated away from the target during the stride phase (Calabrese 2013). The stride phase plays a vital role in the positioning of the trunk and the lower extremity (Calabrese 2013). This phase allows for the transfer of energy from the lower half of the body to the upper extremity by increasing the time and distance the trunk can rotate (Calabrese 2013). Force is developed due to the lower extremity/pelvis and transfered by trunk rotation through the development of muscular tension (Pink 2001).

2.2.4.3 The Late Cocking Phase

The late cocking phase begins when the front leg makes contact with the surface and ends with the throwing shoulder in a maximum external rotation position (Calabrese 2013; Chu *et al.* 2016). The trunk rotates towards home plate with subsequent lumbar spine hyperextension and rotation of the upper torso occurring with eccentric contraction of the abdominal obliques to prevent excess hyperextension of the lumbar spine (Young *et al.* 1996; Seroyer *et al.* 2010; Chu *et al.* 2016). The trunk rotates due to the activation of the lead side internal oblique and erector spinae muscles while the opposite external oblique contracts (Calabrese 2013). The front leg of the pitcher move from the previous flexed position during foot contact to a more extended position during the rotation of the trunk (Calabrese 2013). This occurs so that a solid support is avalible for the trunk to begin the forward flexing motion towards the target (Calabrese 2013).

2.2.4.4 The Acceleration Phase

The acceleration phase of the pitching motion continues from the point of maximum external rotation of the throwing shoulder and terminates when the pitcher releases the ball (Calabrese 2013). During the acceleration phase, the trunk continues to rotate and laterally flex towards the contralateral shoulder, as to transfer energy through to the upper extremity (Seroyer et al. 2010; Chu et al. 2016) . The trunk moves from a hyperextended position to a forward laterally flexed position with a controlled lordosis being present (Kibler, Wilkes and Sciascia 2013; Weber et al. 2014).

During the acceleration both the lead and stance foot are in contact with the groud which provides a strong supportive base (Whiteley 2007 ; Weber *et al.* 2014). The forward flexion angle of the trunk ranges between 32º and 55º prior to ball release (Matsuo et al. 2001). The abdominal obliques, rectus abdominis, and lumbar paraspinal musculature of the nonthrowing side appear to have greater activity compared with the throwing side during acceleration, and are important in accentuating lateral truncal movement (Seroyer et al. 2010).

2.2.4.5 The Deceleration Phase and Follow Through

The deceleration phase initiates at the time of ball release. It terminates when the throwing shoulder reaches a maximal internal rotation with 35º of horizontal adduction with the back foot off the ground (Calabrese 2013). The trunk rotates and flexes towards the plate over the now extended lead leg as the pitcher descends the mound (Calabrese 2013). The pitcher then assumes a ready fielding position following the termination of the throwing mechanism (Calabrese 2013; Chu *et al.* 2016).

2.3 Bony anatomy of the thoracic and lumbar spine

2.3.1 Thoracic Spine

The thoracic spine makes up the upper back and provides an area in which the ribs can attach posteriorly (Moore, Dalley and Agur 2010).

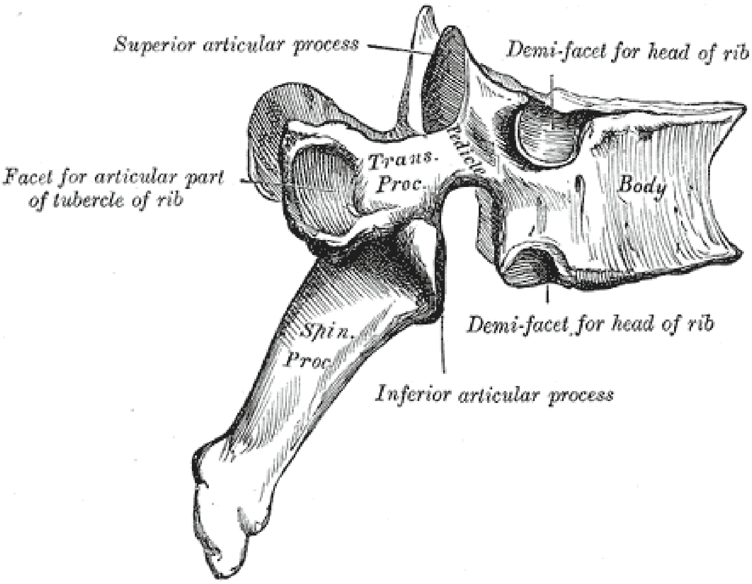


Figure 2.2 Anatomy of the thoracic vertebra (Gray 1918)

The thoracic portion of the spine begins after the cervical spine, at C7, and ends before the Lumbar spine, at L1 (Moore, Dalley and Agur 2010). The thoracic spine is made up of 12 vertebrae, which is the most of any spinal segment (Moore, Dalley and Agur 2010). The thoracic spine normally has a concave anterior curve known as a khyphotic curve (Gatterman 2005; Moore, Dalley and Agur 2010). The kyphotic curve of the thoracic spine can range between 20º and 50º with an average of 45º (Bergmann and Peterson 2011). The thoracic spine mainly plays a role of protection of the thoracic viscera and loses intersegmental mobility due to this protection role (Gatterman 2005; Moore, Dalley and Agur 2010; Bergmann and Peterson 2011). The spinous processes of the thoracic spine are long and inferiorly facing, which causes overlapping of the spinous processes in the mid-thoracic region which then limits extension (Gatterman 2005).

Table 2.1 Global range of motion for the thoracic spine (Bergmann and Peterson 2011)

Movement	Degrees
Flexion	25-45º
Extension	25-45º
One Sided Lateral Flexion	20-40º
One Sided Rotation	30-45º

The thoracic vertebrae feature costovertebral and costotransverse joints (Moore, Dalley and Agur 2010; Bergmann and Peterson 2011). On either side of the vertebral body a costovertebral joint in present which allows the head of the associated rib level to articulate with the vertebral body (Bergmann and Peterson, 2011). On the anterior portion of the transverse processes a costotransverse joint exists which articulate with the tubercules of the rib (Bergmann and Peterson, 2011). The articular facets of the thoracic spine are positioned at 60º from the transverse to the coronal plane and 20º from the coronal to sagittal plane (Gatterman, 2005). The superior and inferior articular facets have different orientations to each other. The inferior articular processes originate from the laminae and face anteriorlly while being inferomedially in orientation (Gatterman 2005). The superior articular processes originate from the laminae-pedicle junction and face posteriorly while being superolaterally orientated (Gatterman 2005).

Table 2.2 Characteristics of thoracic vertebrae (Moore, Dalley and Agur 2010)

Part	Characteristics
Body	Heart shaped; has two costal facets for articulation of the rib
Vertebral Foramen	Circular and small (compared to cervical and Lumbar spine)
Articular Processes	Superior facets face posterorlaterally; inferior facets face more anteromedially.
Transverse Processes	Two with one each side of body; Long and strong which extend in the posterolaterally direction; length of TVP decreases further down the thoracic spine.
Spinous Processes	Posteroinferiorly facing long Spinous process with level of tip of Sp below associated vertebra.

There are also vertebrae in the thoracic spine known as atypical vertebrae (T1,T9, T10-T12) (Moore, Dalley and Agur 2010). The T1 vertebral body resembles that of a cervical vertebra which has a whole facet for first rib articulation (Bergmann and Peterson 2011). The T9 vertebra has no demifacets below it, or sometimes has two demifacets on either side (Bergmann and Peterson 2011). The T10 vertebra has one full rib facet located partially on the body of the vertebra and partially on the tubercle (Bergmann and Peterson 2011). The T11segment has complete costal facets but no facets on the transverse processes for the rib articulation (Bergmann and Peterson 2011). The T11 vertebra also begins to transition to characteristics similar to those of lumbar vertebrae (Bergmann and Peterson 2011). The spinous process is shorter than a typical thoracic vertebra and faces more horizontally. The T12 vertebra has complete facets for articulation with the ribs (Bergmann and Peterson 2011).

2.3.2 Lumbar Spine

The normal lumbar spine consists of five vertebrae (L1-L5), and is located between the thoracic (T12) and sacral regions (S1) of the spine (Moore, Dalley and Agur 2010).

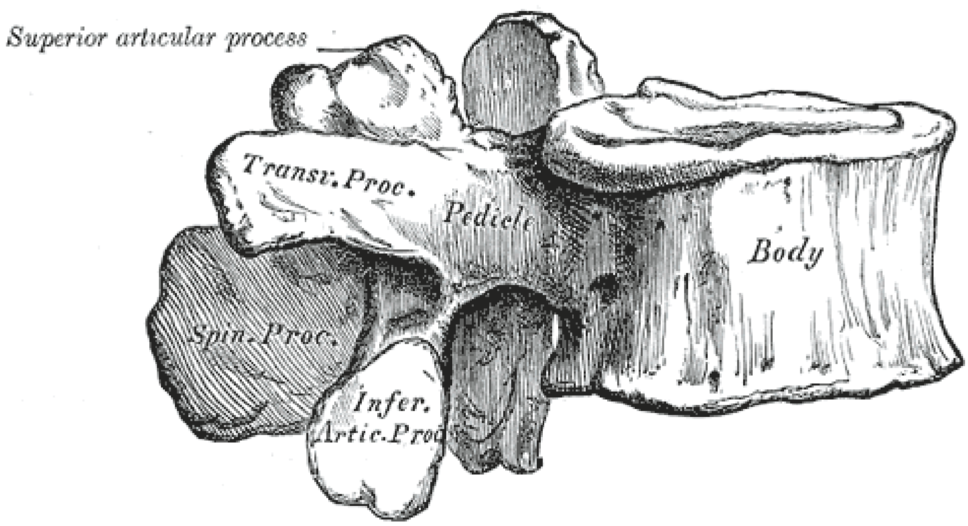


Figure 2.3 Anatomy of a lumbar vertebra (Gray, 1918)

The lumbar vertebrae differ from the thoracic vertebrae in the following ways (Moore, Dalley and Agur 2010)

- No transverse foramina
- No costal facets
- Larger in size
- Vertebral foramina are larger and more triangular in shape
- Superior articular facets have mamillary processes
- Vertebrae join to form a lordotic curve
- Vertebral bodies are deeper and wider

Table 2.3 Characteristics of the lumbar spine (Moore, Dalley and Agur 2010).

Part	**Characteristics**
Body	Large and kidney shaped.
Vertebral Foramen	Triangular in shape and larger than the thoracic vertebrae.
Transverse Processes	Long and slender, with an accessory process on the posterior surface of the base of each process.
Articular Processes	Superior facets face posteromedially, inferior facets face anterolaterally, maxillary processes on posterior surface of each superior articular process.
Spinous Processes	Short, thick, broad and sturdy

Due to the heavy weight that the lumbar spine is required to support, the bodies of the vertebrae are larger than the thoracic spine (Moore, Dalley and Agur 2010). The lumbar spine has a concave posteriorly orientated curve known as a lordotic curve which ranges from 20 to 40 degrees (Bergmann and Peterson 2011). The facets of the lumbar spine lie mainly in the sagittal plane but become more coronally facing as one moves down the lumbar spine towards the sacral junction (Bergmann and Peterson 2011). The facets orientation allows for greater movement in flexion and extension, but limits rotational movements (Bergmann and Peterson 2011).

Table 2.4 Global movement of the lumbar spine (Moore, Dalley and Agur 2010).

Movement	Degrees
Flexion	40-60°
Extension	20-35°
One Sided Lateral Flexion	15-25°
One Sided Axial Rotation	5-18°

2.4 The role of the lumbar and thoracic spines in the baseball pitch

Young *et al.* (1996); Burkhart, Morgan and Kibler (2003) hypothesized that the shoulder complex alone is incapable of generating the required force to propel a ball at high velocities. The spine is responsible for transmitting forces produced distally in the lower body to the shoulder complex (Young *et al.* 1996; Calabrese 2013; Weber *et al.* 2014; Chu *et al.* 2016) thus, the spine is a key component of the kinematic chain in throwing.

The thoracic spine has a further influence on glenohumeral motion and scapulothoracic position (Crosbie *et al.* 2008). Kebaetse, McClure and Pratt (1999) showed that the position of the thoracic spine can have an effect on scapular kinematics and a resultant decreased muscle force. This connection can be made by the fact that there are numerous muscular connections between the spine, scapula, clavicle, and humerus (Crosbie *et al.* 2008; Moore, Dalley and Agur 2010). Bony position will influence muscle length and therefore influence the ability to generate tension, which is commonly known as scapulohumeral rhythm, with there being a consistent and synchronous interaction between the scapular, humerus and thoracic segments (Crosbie *et al.* 2008) . Crosbie *et al.* (2008) believed that the physical link between the shoulder girdle and the trunk is responsible for the coupling of scapular external rotation and upper thoracic axial rotation.

The thoracic spine contributes to 80 percent of total spinal rotation (McGill and Hoodless 1990). The facet joints not only play a role in the motion of the spine and function as important load bearing structures, but also distribute the ground reaction forces up the kinematic chain in the throwing athlete (Young et al., 1996).

During stride phase of the throwing motion, the chest of the pitcher remains closed away from the target (Young *et al.* 1996; Calabrese 2013). By this positioning, the distance and time of trunk rotation and lateral flexion can be increased in the opposite direction (Calabrese 2013). The force of contraction of the throwing side external oblique could have an increased force of contraction by this counter movement away from the target (McGill and Hoodless 1990), possibly allowing a pitch that is more forceful. In the arm cocking phase, extension of the thoracic spine maximises shoulder external rotation relative to the erect body axis (Young et al., 1996).

During the throwing motion, the lumbar spine provides a level base that remains stable (Calabrese 2013). Lateral flexion of the lumbar spine has an influence on shoulder movement (Calabrese 2013). In the throwing action, the combination of lateral flexion away from the throwing arm and trunk rotation, serves as the major contributor to the abduction force upon the humerus, thus helping the arm achieve a fully cocked position (Calabrese 2013; Chu *et al.* 2016).

The trunk rotates towards home plate with subsequent lumbar spine hyperextension and rotation of the upper torso occurring with eccentric contraction of the abdominal obliques to prevent excess hyperextension of the lumbar spine (Young *et al.* 1996; Seroyer *et al.* 2010; Chu *et al.* 2016). The trunk moves from a hyperextended position to a forward flexed position, and a controlled lordosis should be present (Kibler, Wilkes and Sciascia 2013; Weber et al. 2014).

According to Young et al. (1996), the ability or inability of the lumbar spine to laterally flex is the determining factor in its influence on the shoulder. Altered shoulder biomechanics, energy dissipation, and loss of pitching control throughout the motion can potentially occur if the lumbar spine has reduced mobility (Young et al., 1996).

Aguinaldo, Buttermore and Chanmbers (2003), compare professional pitchers to college and youth pitchers (n =38), found that trunk rotation began significantly later (34% ± 5%) in the biomechanics of professionals pitchers when compared to the nonprofessional's.

Escamilla *et al.* (2002) investigated a group of American and Korean pitchers and found there to be an increase in forward trunk tilt at ball release (32 ± 8° vs. 26 ± 9°) in those who threw with higher velocities.

Oyama *et al.* (2013) investigated the relationships of speed and lateral trunk lean on high school–aged pitchers (n=73). Motion analysis was done to asses trunk lean at the moment of maximum external rotation of the shoulder joint. The results showed that increased contralateral trunk lean in baseball pitchers resulted in a statistically significant increase in both ball speed, and shoulder and elbow joint moments that were tracked.

Solomito *et al.* (2015) found that there is a statistically significant association between contralateral trunk lean and increased ball speed (P = .003), stating that for every 10° increase in contralateral lean that a pitcher gained, ball speed would increase by 108 km/h. This is due to the distance of the pitchers trunk axis away from the pitching arm allowing the pitcher more time to increase the forward velocity of their arm which is transferred to the ball which results in a higher speed (Solomito *et al.* 2015).

Werner *et al.* (2008) found athletes (n=54) who showed greater amounts of forward fexion of the trunk (average 55± 9º) when throwing exhibited greater amounts of ball speed, compared to pitchers who threw with a more extended trunk while pitching. This is with correlation to Stodden *et al.* (2005) where increased trunk tilt at release was one of three kinetic, and five kinematic, parameters linked to an increased ball speed. The explanation for this is that forward flexion of the trunk will allow for the ball to gain increased speed during the acceleration phase of throwing due to the increased time and force gained due to the trunks involvement in propeling the ball (Stodden *et al.* 2005).

2.5 Spinal manipulation

The aim when applying spinal manipulative therapy (SMT) is to improve joint movement and restore normal physiology within the neuromusculoskeletal system (Henderson 2012).

The most common form of spinal manipulation used by chiropractic practitioners is the short-lever, high-velocity, low amplitude thrust (Bergmann and Peterson 2011). The chiropractor will make contact over the paraspinal tissue (spinous, transverse or mamillary process) and perform a dynamic short thrust to the vertebrae being manipulated (Bergmann and Peterson 2011). Spinal manipulation then is a direct input to tissues of the vertebral column (Pickar 2002).

There is a theoretical model for joint dysfunction of a motion segment called a Vertebral Subluxation (Gatterman 2005). This Vertebral Subluxation may present as pathological changes to the neural, vascular, muscular, ligamentous and connective tissue components of the motion segment (Redwood 2003; Gatterman 2005).

The presence of these joint dysfunctions within the spine is found through motion palpation (Bergmann and Peterson 2011). Motion palpation is defined as a palpatory diagnostic procedure used to assess both the active and passive motions of segments within a joint (Bergmann and Peterson 2011).Bergmann and Peterson (2011) describes local pain, tissue hypersensitivity, altered alignment, increased or decreased joint motion, altered joint play, altered end feel and local muscle rigidity as clinical features of joint dysfunction.

It is noted by Haldeman (2005) that pain is not required for joint dysfunction to be present. Pain is regarded as one of the possible clinical symptoms of the underlying joint dysfunction and not all symptoms are required for dysfunction to be present (Haldeman 2005). It can also be noted that joint dysfunction may be present for a period of time before reaching a painful stage (Gatterman 2005).

Gatterman (2005) outlined several benefits to a joint post spinal manipulation. These included diminished weight-bearing of the 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 of intervertebral foramen stenosis caused by reduced kyphosis and decreased tension on joint capsule.

This increased neurological input, flexibility and mobility of the manipulated joints (Herzog, 2000; Gatterman, 2003) may result in increased performance of pitching as the ease and speed that the pitcher may rotate their trunk is increased post-SMT (Sood, 2008; Le Roux, 2008; Costa and Chibana et al., 2009; Miners, 2010; Deutschmann, 2015).

Any deficits or areas in the kinetic chain that are not functioning optimally may result in an injury or decreased performance (Seroyer *et al.* 2009; Kibler, Wilkes and Sciascia 2013; Chu *et al.* 2016). When the balance is lost between the structures of the body, from trauma, over activity, or ongoing compensatory shifting, stress is accumulated and a decrease in functional ability occurs (Redwood 2003). The spine functions as one unit as dysfunction occuring at one level may cause compensatory changes to occur at another level or area such as the shoulder, elbow or wrist (Redwood 2003). Immobilization of a joint segment may result in unfavorable changes in the surrounding; ligaments, tendons, muscular tissue and vascular elements described by Lederman (2005). Functional implications of these changes are loss of tensile strength, adhesions, loss of flexibility and range of motion and muscle atrophy leading to a loss of functional ability (Lederman 2005).

Studies done on spinal manipulation have theories that manipulation can:

- Cause a change in the orientation and/or positioning of various anatomical structures (Leach 2004)
- Return normal motion segment function (Triano *et al.* 2003)
- Breaking of adhesions (Leach 2004)
- Increase range of motion of motion segments (Triano *et al.* 2003)
- Increase neurological input (Haldeman 2005)
- Unbuckling ligaments and releasing trapped meniscoids(Bergmann and Peterson 2011)

The increased neurophysiological (Pickar 2002; Haldeman 2005; Bicalho *et al.* 2010; Clark *et al.* 2011) and biomechanical (Triano *et al.* 2003; Leach 2004; Gatterman 2005; Bergmann and Peterson 2011) input to the manipulated joints may result in increased speed of the lateral flexion and flexion of the trunk and arms. This gained mechanism may improve players' performance in their respective motion and thus, the baseball pitching motion (Sood 2008; Costa *et al.* 2009; Deutschmann 2015). Costa *et al.* (2009) believed that SMT plays a role in the optimizing sporting performance. Due to the improvement of joint function, muscle balance, and the speed of neuromuscular reflexes that are gained from SMT it is possible that one or all of these mentioned can lead to increased sporting performance (Costa *et al.* 2009).

Le Roux (2008) and Costa *et al.* (2009) determined that SMT enhanced golf swing performance. Deutschmann (2015) investigated kicking speed and range of motion in soccer player's post-spinal manipulative therapy. Asymptomatic soccer players were found to have improved range of motion in the lumbar spine and sacro-iliac joints following spinal manipulative therapy when compared to a control group. All three manipulation intervention groups displayed statistically significant improvements in kicking speed.

Similarly, Sood (2008) conducted a pre-test post-test study on the effect of spinal manipulation on cricket players' bowling speed. The results found immediate increased trunk flexion and lateral flexion movements, together with increased bowling speed following manipulation. A significant correlation was found between bowling speed, trunk flexion and lateral flexion range of motion, indicating that spinal manipulation improved range of motion and that these improvements appeared to affect bowling speed. 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 generated.

These studies, although limited, show that there is a possible connection between SMT and improved performance. Due to the similarity between the movements tested in Sood (2008), and their correlation to improved bowling speed, and those biomechanics described by various authors on pitching mechanics in terms of biomechanics, propose that SMT of the spine will produce similar effects on baseball players' throwing speed.

2.6 Placebo and Hawthorne effect

Wall and Wheeler (1996) state that the word placebo is derived from the term ‘I shall please’. The placebo effect is used as a control intervention or blinding of the participants to prove the efficacy of a drug or treatment modality that is being given to research participants (Draper 2002). The research participants that fall into these placebo or deception groups are unaware whether they are receiving the active treatment or not (Draper 2002). With spinal manipulation, just like all other treatment modalities, the placebo effect can occur (Maigne and Vautravers 2003; Bergmann and Peterson 2011).

Miller, Wendler and Swartzman (2005) suggest that certain safeguards be put in place to help with the deception of patients. These include the review and approval of research projects by a specified independent ethics committee, an informed consent document detailing the study description and a full understanding of the procedures which may include a deception, and debriefing the research participants after the study has been completed.

The Hawthorne effect as described by Mouton (1996) states that participants in research studies often make themselves “fit in” as they don’t want to be considered as an outlier or an abnormality. This will make participants go out their way to please the researcher so that they may achieve the desired results necessary (Mouton 1996). This is important when conducting research that has a subjective measurement outcome as participants may over report any findings (Mouton 1996).

The placebo and Hawthorne effect act through psychological means that are created through the participant’s perceptions. The Hawthorne effect works due to the participant being aware that they are being studied (Mouton 1996). The placebo effect works by the participant’s belief that they are being subjected to an inactive form of treatment (Mouton 1996).

2.7 Conclusion

Based on the above literature, the aim of this study is to investigate whether SMT has an effect on baseball pitching speed.

CHAPTER THREE

METHODOLOGY

3.1 Study design

This was a quantitative, randomised, controlled, prospective, investigative trial (Salkind 2010).

3.2 Advertising and participant recruitment

Participants were recruited either by direct contact, word of mouth or by advertisements. Direct contact was done by approaching players at various baseball clubs in the Durban area and informing them about the upcoming research being done. Those who expressed interest were then recruited if they met the inclusion criteria of the study. Those who knew about the research, were able to communicate to others whom they knew of who might have been interested in the study and met the criteria to be a participant. Advertisements **(Appendix C)** were placed at the local clubs participating in the study on their respective notice boards. Potential participants were requested to contact the researcher telephonically for more information.

3.3 Permissions

Appointments at the Durban University of Technology Chiropractic Day Clinic required gatekeeper's permission which was granted in **Appendix K.** Permission was also obtained to use the premises at the Queensmead Sports Arena at Umbilo for appointments on the day of data collection **(Appendix J)**. Participants who wanted to take part in this study were required to complete an informed consent form **(Appendix B)** which allowed participation in this study and permission for use of data.

3.4 Sampling recruitment

3.4.1 Inclusion criteria

1. Participants had to be male to keep the sample homogeneous.
2. Participants had to be between the ages of 18 to 40 years as this reduced the risk of participants with degenerative changes in the spine (Zhang and Jordan 2010).
3. The participants had to sign the Informed Consent Form **(Appendix B).**
4. The participants had to be registered with the KwaZulu-Natal Baseball Union.
5. Participants had to be asymptomatic for musculoskeletal pain although pain is not required for joint dysfunction to be present (Haldeman 2005).

3.4.2 Exclusion criteria

1. Participants that had contraindications to spinal manipulation, including – but not limited to – stress fractures, cauda equina syndrome, hyper mobility of vertebral segments, previous lower back surgery, tumours and bone infections (Bergmann and Peterson 2011)
2. Those who had an injury which occurred between the initial screening examination and the day of data collecting.
3. Those who were currently receiving treatment to either their thoracic or lumbar spines.

3.4.3 Population and sample size

With approximately 100 baseball players in the KZN baseball Union senior league, a sample size of 80 participants is deemed statistically significant (Heckard and Utts 2012). However for this research a sample of 40 participants was used via a non-probability convenience sampling technique (Salkind 2010). It is estimated that there are roughly 50 pitchers in the league. By testing 40 participants it would be a good representation of the league. This sample was used mainly due to budgetary constraints as well as similarities in sample size of Sood (2008) and Deutschmann (2015).

3.4.4 Sampling method

The participants were randomly placed into one of four groups by the hat method upon presentation of the participant to the study. An independent party was asked to blindly draw a piece of paper from an opaque envelope. In the envelope were four pieces of paper, with either an A, B, C or D on them. These letters indicated the group allocations. Once a number was drawn from the envelope, it was placed back to ensure an equal chance of the participants being placed into any of the intervention groups. Those who drew the letter A were allocated to Group A and received thoracic manipulation. Those who drew the letter B were in Group B and received lumbar manipulation. Those who drew the letter C were placed into Group C and received both lumbar and thoracic manipulation and those who drew the letter D were placed in Group D and received the sham laser technique.

3.5 Procedure

If the participant met the inclusion criteria for the research, they were required to attend an appointment the week prior to the data collection days. The participant read the letter of information for the study **(Appendix A)** which introduced the potential participant to the study. The research procedure was explained in detail by the researcher to every prospective participant. The participant then signed an informed consent form (Appendix B) stating that they had been informed about the research topic and were willing to partake in the research.

Participants then underwent a physical examination at the Durban University of Technology Chiropractic Day Clinic, ruling them fit for participation in the study within one week prior to data collection. This was done to reduce the amount of time spent on the day of data collection, screening participants and then collecting data. All participants provided a medical case history (**Appendix E),** and underwent a physical examination **(Appendix F)** and a thoracic spine (**Appendix G)** and Lumbar spine orthopaedic examination **(Appendix H).** Those who were unable to attend the appointment at the university were screened on the day of data collection at the Queensmead Sports Arena where a qualified Chiropractor was present to oversee the procedures. For the appointments at the arena, the treatment and examination areas were curtained-off to provide the participants with privacy. Once the examinations had been completed, each participant was allocated to a group as discussed previously. A research assistant was present on the day of data collection to help with the screening of participants who were not able to attend the appointments at the clinic. The research assistant was able to decrease the time taken to do all participating individuals' clearance physical on the day.

Participants were instructed to warm up prior to throwing, to guard against injuries and ensure adequate performance. Each individual was responsible for his own warm up to ensure the participant was at his most confident and ready at the time of testing. The participant then stood on the mound and threw three baseball pitches as hard as he could while being measured by a radar gun set up two metres behind home plate. The average of the three pitches was calculated and used as the pre-intervention baseline. Range of motion measurements were taken with the Digital Inclinometer for the thoracic and lumbar spines once the participant had completed the initial three pitches. Participants received the intervention performed on them depending on their group allocation.

All manipulation was performed by the researcher to keep the variables of manipulation constant. A maximum of two adjustments was performed per one region being measured. Motion palpation was performed to the relative area in order to locate those areas of spinal fixation (Bergmann and Peterson 2011). The area of most perceived fixation will be the level at which the adjustment was performed. For all manipulations in the study the Diversified techniques described by Bergmann and Peterson (2011) were used.

Group A received thoracic manipulation in the form of the Bilateral Hypothenar Transverse adjustment. The patient was positioned prone, face down on the chiropractic bed. The researcher stood alongside the bed in a fencer stance facing cephalad and contacted the transverse processes on either side of the fixated segment with the hypothenar aspect of both hands. Tissue slack was removed and a short sharp impulse in a posterior to anterior direction was applied (Bergmann and Peterson 2011).

Group B received lumbar spine manipulation in the form of the lumbar roll described by Bergmann and Peterson (2011). The patient was positioned on his side with the transverse process of the fixated segment facing up off the bed. The transverse process was contacted with the pisiform of the researcher. Skin slack was removed and a short sharp body drop was done, creating a posterior to anterior rotational force to the fixated segment.

Group C received a combination of the two techniques described previously.

Group D received the placebo laser technique. The placebo intervention was performed with the participant in a prone position on the treatment table. The laser unit was switched on and the red colour created by the laser was demonstrated on the participant's hand so that he believed he was receiving a treatment protocol. The participant was instructed to keep his head face-down onto the bed as the laser could be dangerous and damaging to the eyes of the participant. The researcher wore protective goggles to authenticate the process. The laser unit was then switched off and applied to the lumbar spine's paraspinals bilaterally for 5 minutes.

The participant then had their ROM measured again post intervention by the researcher. Once the final range of motion data had been collected, the participant had the opportunity to pitch three more times and an average was calculated, representing the post-intervention measurement for speed. Once done with the final post intervention objective measurements, the participant's subjective data was collected. The participant was asked if he had any subjective change in speed post intervention with the following question "Did you feel that your throwing speed increased, decreased or remained the same following the treatment?" **(Appendix D).**

3.6 Controlling variables

- The same ball was used for all participants in this study as it was the standard size and weight.
- All players threw from the same mound to ensure all the angles and distances were the same for each participant.
- Each participant was asked to throw his own preferred style to minimize the effect of using a different technique to satisfy the collection of data.
- Testing took place on various days due to varying availability of participants, thus weather and humidity could have impacted on the performance of the participants.

3.7 Measurement Tools

3.7.1 Objective measurement tools

3.7.1.1 Saunders Digital Inclinometer (ROM)

This measurement tool was the same make and model used both by Sood (2008) and Deutschmann (2015) in their studies of similar content. This allowed more consistent measurements, allowing for comparison between them. Czaprowski (2012) conducted a study where the aim was to evaluate the intra- and interobserver repeatability of measurements of the anterior-posterior spinal curvatures using the Saunders digital inclinometer. Czaprowski (2012) concluded that the assessment of anteroposterior curvatures of the spine by one investigator provided good repeatability and reliability of measurements ($p>0.05$).

The digital inclinometer (The Saunders Group) consists of a sensor with a digital display. If inclinometer is tilted in any direction, it will read the relevant ROM. If it is then zeroed at the current ROM and then moved again e.g. to 20 degrees in any direction, then it will read 20 degrees. This allows the inclinometer to be used in any direction as it is always able to be zeroed.

3.7.1.2 Thoracic flexion and lateral flexion

The participant stood upright and a mark was made at the level of the T6 spinous process of the spine. The sensor of the inclinometer was placed over the mark of T6 with the Velcro strap secured around the waist. The inclinometer was then zeroed. The participant was then asked to forward flex their spine as far as possible with the knees straight. At the limit of forward flexion a reading was taken in degrees. The participant then stood up straight and the inclinometer was zeroed. The participant was then asked to bend laterally to the side without bending out of the Coronal plane. A reading was taken and the participant was returned to neutral where the inclinometer was zeroed once more. The participant was then asked to laterally bend towards the opposite side following the same instructions as the previous side.

3.7.1.2 Lumbar flexion and lateral flexion

With the participant standing upright, a mark was made at the L2/L3 interspace. The inclinometer was then placed on the mark made between L2 and L3 with the Velcro straps around the participant’s waist. The inclinometer was zeroed before asking the participant to forward flex as far as possible, keeping the knees straight. At the point of maximum flexion, the reading was taken. The participant was asked to return to a neutral position again. The unit was once more zeroed and the participant was asked to laterally bend to one side as far as possible in the coronal plane. At maximum lateral flexion, the reading was taken. The participant was then asked to return to neutral. The participant was asked to bend towards the opposite side and the reading taken.

3.7.1.2 Stalker Pro II Radar Gun (Speed)

The Stalker Pro II is a Stationary Doppler Radar with a digital processor capable of processing speeds of 1 to 800 KPH with an accuracy ± 3% (Applied Concepts 2016).

Applied Concepts (2016) state that the Stalker PRO II radar is able to send out high frequency radio waves which are measured after they bounce off a moving object which is commonly known as doppler radar. The Radar gun converts the reflected microwave signals into a digital stream of data which the computer inside the hand held device processes to interpret, filter, and measure the speeds (Applied Concepts 2016).

The speed was recorded in km/h by the Radar gun. The gun was set up directly behind the catcher, within two meters, to get the most accurate reading possible while standing behind a net for safety. This was to ensure that there was 0º to the line of the throw. The Radar gun was provided by the KwaZulu-Natal Baseball Union as it is often used to test the performance of players in the league.

3.8.2 Subjective measurement tools

3.7.2.1 Perception of pitching speed

Once done with the objective measurements, the participant's perception on change in speed was recorded with the following question "Did you feel that your throwing speed increased, decreased or remained the same following the treatment?" **(Appendix D).**

3.8 Ethical considerations

3.8.1 Autonomy

Participants received a letter of information **(Appendix A)** explaining the study as well as the potential risks involved in participation. They also received an informed 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.

3.8.2 Non-Maleficence

To protect the identity of the participants their names were coded and their information stored in the chiropractic department. All patient files were stored in the DUT Chiropractic Day Clinic. All participants involved in this study were thoroughly examined, by means of a full medical history **(Appendix E)**, physical examination **(Appendix F)**, thoracic (**Appendix G)** and lumbar regional examination **(Appendix H)** for contraindications to spinal manipulation. A qualified chiropractor was present on-site to supervise the entire procedure for all consultations.

3.8.3 Justice

Each participant who volunteered to participate in the research study and who met the inclusion criteria was enrolled. All participants were given fair and equal opportunity to participate in the research. To maintain fairness to all participants in the study, all participants who fell into the control group were offered a free treatment at the Durban University of Technology Chiropractic Day clinic.

3.8.4 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 baseball discipline.

3.9 Statistical Analysis

SPSS version 23 was used to analyse the data. A *p* value of 0.05 was used to assess the significance of the statistical tests. Two-tailed tests were used in all cases.

Intra-group analysis was tested using paired t-tests to compare the change from pre- to post- within each group. Inter-group analysis involved comparison of mean absolute change and percentage change between the four intervention groups, using one-way ANOVA testing, and post-hoc Bonferroni adjusted multiple comparison tests.

Pearson’s correlation analysis was used to examine the presence and strength of any relationships between changes in outcome variables. The association between subject perception of change in throwing speed and mean throwing speed change was assessed using the Pearson chi square test.

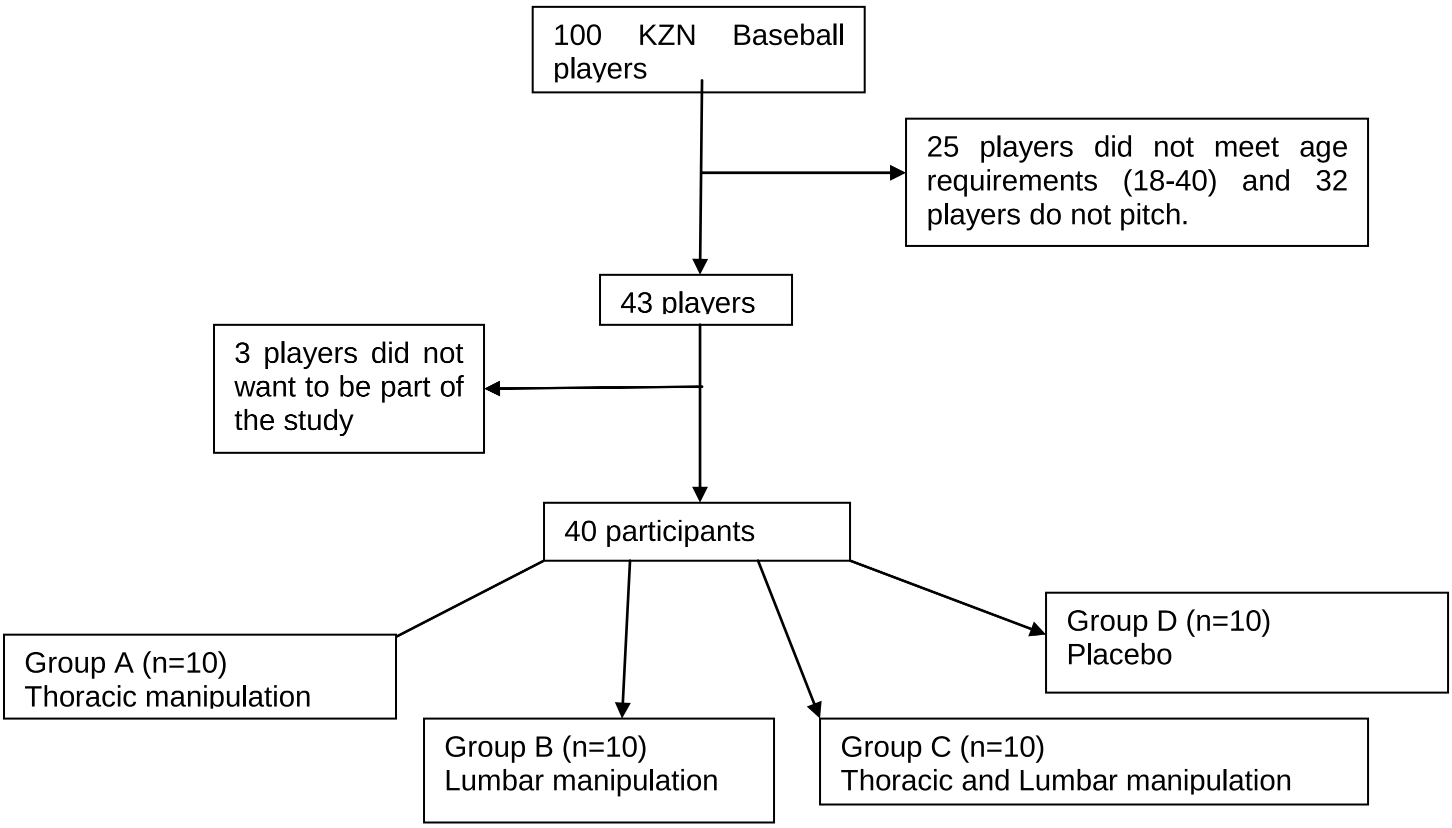
CHAPTER 4

RESULTS

4.1 Introduction

This chapter includes the data that was gained as per the methodology outlined in the previous chapter three. The data that is presented in this section of the thesis includes the representation of the demographic data (age, height and body mass) and the results of statistical analysis from the subjective (participants perception of change of speed post intervention) and objective (thoracic and lumbar range of motion pre and post intervention, throwing speed pre and post intervention) results. All calculations were based on n=40.

4.2 Flow diagram of participants



4.3 Results

4.3.1 Physical characteristics

The minimum, maximum, mean and standard deviation of the physical characteristics which include age, body mass and height of the participants who participated in this study are shown in **Table 4.1** to **4.4**

Table 4.1 Descriptive Statistics of Group A

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	10	18	27	22.10	2.807
Body mass (kg)	10	69	95	78.90	7.505
Height (cm)	10	163	180	171.00	6.733

Table 4.2 Descriptive Statistics of Group B

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	10	18	30	21.30	3.802
Body mass (kg)	10	73	95	82.60	8.208
Height (cm)	10	157	198	174.60	11.404

Table 4.3 Descriptive Statistics of Group C

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	10	18	37	22.80	5.432
Body mass (kg)	10	67	106	80.90	12.801
Height (cm)	10	159	192	174.20	8.779

Table 4.4 Descriptive Statistics of Group D

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	10	18	26	20.80	2.860
Body mass (kg)	10	68	104	82.40	11.834
Height (cm)	10	155	201	174.50	14.872

A total of 40 male participants were included in the study with each group consisting of 10 participants. The age of the subjects ranged from 18 to 37 years old. The mass of the participants ranged from 67 to 105 kg and the height of the players ranged from 155 to 201cm tall. An ANOVA was done to determine if there were any differences in means between groups for age, body mass and height. No statistical significance between groups was found for any of the three variables (age [p-value =.673], body mass [p-value= .844] and height [p-value= .860]) showing that there were no significant differences in means for age, body mass and height.

4.3.2 Intra-group analysis

Intra-group analysis was carried out on each of the variables measured using paired t-tests to compare the change from pre- to post- within each group. The differences were calculated by subtracting the Post-value from the Pre-value. The negative values occur due to the post values being higher than the pre values.

4.3.2.1 Intra-group analysis for Group A

The Intra-group analysis of Group A is shown in **Tables 4.5** to **4.7**. The mean, standard deviation and standard error of the mean are given in Table 4.5, while **Table 4.6** shows the correlations between pre and post readings for the variables.

Table 4.7 gives the results of the paired t-test, with t-statistic value, p-value and a 95% confidence interval for the difference in the means for pre and post readings.

Table 4.5 Paired Sample Statistics of Group A – Thoracic Manipulation

	Mean	N	Std. Deviation	Std. Error Mean
Pre Average Speed	108.04533	10	12.797392	4.046891
Post Average Speed	110.28333	10	12.416568	3.926464
Thoracic FF Pre	31.70	10	10.264	3.246
Thoracic FF Post	39.10	10	13.527	4.278
Thoracic LLAT Pre	30.00	10	8.589	2.716
Thoracic LLAT Post	37.30	10	8.757	2.769
Thoracic RLAT Pre	32.60	10	9.264	2.930
Thoracic RLAT Post	39.40	10	7.834	2.477
Lumbar FF Pre	36.70	10	11.275	3.565
Lumbar FF Post	39.70	10	11.176	3.534
Lumbar LLAT Pre	21.60	10	3.978	1.258
Lumbar LLAT Post	26.00	10	3.528	1.116
Lumbar RLAT Pre	21.00	10	3.464	1.095
Lumbar RLAT Post	27.00	10	3.300	1.043

Table 4.6 Paired Samples Correlations of Group A – Thoracic Manipulation

	N	Correlation	Sig.
Pre Average Speed & Post Average Speed	10	.989	**.001***
Thoracic FF Pre & Thoracic FF Post	10	.959	**.001***
Thoracic LLAT Pre & Thoracic LLAT Post	10	.815	**.004***
Thoracic RLAT Pre & Thoracic RLAT Post	10	.855	**.002***
Lumbar FF Pre & Lumbar FF Post	10	.817	**.004***
Lumbar LLAT Pre & Lumbar LLAT Post	10	.760	**.011***
Lumbar RLAT Pre & Lumbar RLAT Post	10	.437	.206
All statistically significant values indicated by bold with (*).			

Table 4.7 Paired Sample Test for Group A – Thoracic Manipulation

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre Average Speed – Post Average Speed	-2.238	1.877211	.593626	-.895124	-3.580876	-3.770	9	**.004***
Thoracic FF Pre – Thoracic FF Post	-7.400	4.695	1.485	-10.759	-4.041	-4.984	9	**.001***
Thoracic LLAT Pre – Thoracic LLAT Post	-7.300	5.272	1.667	-11.071	-3.529	-4.379	9	**.002***
Thoracic RLAT Pre – Thoracic RLAT Post	-6.800	4.803	1.519	-10.236	-3.364	-4.477	9	**.002***
Lumbar FF Pre – Lumbar FF Post	-3.000	6.799	2.150	-7.863	1.863	-1.395	9	.196
Lumbar LLAT Pre – Lumbar LLAT Post	-4.400	2.633	.833	-6.284	-2.516	-5.284	9	**.001***
Lumbar RLAT Pre – Lumbar RLAT Post	-6.000	3.590	1.135	-8.568	-3.432	-5.285	9	**.001***
All statistically significant values indicated by bold and (*).								

The *p-values,* indicated in bold in **Table 4.7** are statistically significant at the 0.05 level. A significant difference exists between the Pre and Post measurements within the thoracic manipulation group for all thoracic movements and lateral flexion of the lumbar spine while there was also a significant increase in speed.

4.3.2.2 Intra-group analysis for Group B

The Intra-group analysis of Group B is shown in **Tables 4.8** to **4.10**. The mean, standard deviation and standard error of the mean are given in **Table 4.8**, while **Table 4.9** shows the correlations between pre and post readings for the variables.

Table 4.10 gives the results of the paired t-test, with t-statistic value, p-value and a 95% confidence interval for the difference in the means for pre and post readings.

Table 4.8 Paired Samples Statistics for Group B– Lumbar Manipulation

	Mean	N	Std. Deviation	Std. Error Mean
Pre Average Speed	113.68333	10	9.910865	3.134091
Post Average Speed	115.77667	10	10.164257	3.214220
Thoracic FF Pre	29.20	10	7.815	2.471
Thoracic FF Post	35.40	10	9.082	2.872
Thoracic LLAT Pre	30.40	10	5.777	1.827
Thoracic LLAT Post	35.40	10	4.648	1.470
Thoracic RLAT Pre	29.90	10	5.087	1.609
Thoracic RLAT Post	37.50	10	4.035	1.276
Lumbar FF Pre	40.90	10	7.666	2.424
Lumbar FF Post	48.40	10	11.227	3.550
Lumbar LLAT Pre	19.20	10	3.293	1.041
Lumbar LLAT Post	24.40	10	3.169	1.002
Lumbar RLAT Pre	18.50	10	5.104	1.614
Lumbar RLAT Post	26.40	10	4.326	1.368

Table 4.9 Paired Samples Correlations for Group B – Lumbar Manipulation

	N	Correlation	Sig.
Pre Average Speed & Post Average Speed	10	.992	**.001***
Thoracic FF Pre & Thoracic FF Post	10	.907	**.001***
Thoracic LLAT Pre & Thoracic LLAT Post	10	.920	**.001***
Thoracic RLAT Pre & Thoracic RLAT Post	10	.777	**.008***
Lumbar FF Pre & Lumbar FF Post	10	.876	**.001***
Lumbar LLAT Pre & Lumbar LLAT Post	10	.726	**.017***
Lumbar RLAT Pre & Lumbar RLAT Post	10	.403	.249
All statistically insignificant values indicated by bold and (*).			

Table 4.10 Paired Samples Test for Group B – Lumbar Manipulation

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre Average – Post Average	-2.093333	1.256666	.397393	-1.194369	-2.992298	5.268	9	**.001***
Thoracic FF Pre – Thoracic FF Post	-6.200	3.853	1.218	-8.956	-3.444	-5.089	9	**.001***
Thoracic LLAT Pre – Thoracic LLAT Post	-5.000	2.357	.745	-6.686	-3.314	-6.708	9	**.001***
Thoracic RLAT Pre – Thoracic RLAT Post	-7.600	3.204	1.013	-9.892	-5.308	-7.501	9	**.001***
Lumbar FF Pre – Lumbar FF Post	-7.500	5.836	1.845	-11.675	-3.325	-4.064	9	**.003***
Lumbar LLAT Pre – Lumbar LLAT Post	-5.200	2.394	.757	-6.913	-3.487	-6.868	9	**.001***
Lumbar RLAT Pre – Lumbar RLAT Post	-7.900	5.195	1.643	-11.616	-4.184	-4.809	9	**.001***
All statistically significant values indicated by bold and (*).								

The Intra-group analysis of Group B is shown in **Table 4.8** to **4.10**. The *p-values* indicated in bold in **Table 4.10** are statistically significant at the 0.05 level. A significance difference exists between the Pre and Post measurements within the lumbar manipulation group for all lumbar and thoracic movements measured, while there was also a significant change in speed.

4.3.2.3 Intra-group analysis for Group C

The Intra-group analysis of Group C is shown in **Tables 4.11** to **4.13**. The mean, standard deviation and standard error of the mean are given in **Table 4.11** while **Table 4.12** shows the correlations between pre and post readings for the variables.

Table 4.13 gives the results of the paired t-test, with t-statistic value, p-value and a 95% confidence interval for the difference in the means for pre and post readings.

Table 4.11 Paired Samples Statistics for Group C – Thoracic & Lumbar Manipulation

	Mean	N	Std. Deviation	Std. Error Mean
Pre Average Speed	113.60667	10	12.079498	3.819873
Post Average Speed	115.75333	10	11.998500	3.794259
Thoracic FF Pre	30.40	10	6.883	2.177
Thoracic FF Post	34.70	10	7.617	2.409
Thoracic LLAT Pre	29.20	10	5.940	1.879
Thoracic LLAT Post	34.90	10	5.131	1.622
Thoracic RLAT Pre	29.30	10	7.181	2.271
Thoracic RLAT Post	33.80	10	5.808	1.837
Lumbar FF Pre	35.90	10	9.769	3.089
Lumbar FF Post	40.40	10	10.211	3.229
Lumbar LLAT Pre	25.60	10	6.753	2.135
Lumbar LLAT Post	30.00	10	5.437	1.719
Lumbar RLAT Pre	24.30	10	6.701	2.119
Lumbar RLAT Post	30.50	10	4.790	1.515

Table 4.12 Paired Samples Correlations of Group C – Thoracic & Lumbar Manipulation

	N	Correlation	Sig.
Pre Average Speed & Post Average Speed	10	.980	**.001***
Thoracic FF Pre & Thoracic FF Post	10	.897	**.001***
Thoracic LLAT Pre & Thoracic LLAT Post	10	.806	**.005***
Thoracic RLAT Pre & Thoracic RLAT Post	10	.867	**.001***
Lumbar FF Pre & Lumbar FF Post	10	.974	**.001***
Lumbar LLAT Pre & Lumbar LLAT Post	10	.708	**.022***
Lumbar RLAT Pre & Lumbar RLAT Post	10	.767	**.010***
All statistically significant values indicated by bold and (*).			

4.13 Paired Samples Test of Group C – Thoracic & Lumbar Spine Manipulation

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre Average Speed – Post Average Speed	2.146667	2.392643	.756620	.435073	3.858260	2.837	9	**.019***
Thoracic FF Pre – Thoracic FF Post	-4.300	3.368	1.065	-6.709	-1.891	-4.037	9	**.003***
Thoracic LLAT Pre – Thoracic LLAT Post	-5.700	3.529	1.116	-8.225	-3.175	-5.107	9	**.001***
Thoracic RLAT Pre – Thoracic RLAT Post	-4.500	3.598	1.138	-7.074	-1.926	-3.955	9	**.003***
Lumbar FF Pre – Lumbar FF Post	-4.500	2.321	.734	-6.161	-2.839	-6.130	9	**.001***
Lumbar LLAT Pre – Lumbar LLAT Post	-4.400	4.812	1.522	-7.842	-.958	-2.892	9	**.018***
Lumbar RLAT Pre – Lumbar RLAT Post	-6.200	4.315	1.365	-9.287	-3.113	-4.543	9	**.001***
All statistically significant values indicated by bold and (*).								

The Intra-group analysis of Group C is shown in **Table 4.11** to **4.13**. The *p-values* indicated in bold in **Table 4.13** are statistically significant at the 0.05 level. A significance difference exists between the Pre and Post measurements within the combined thoracic and lumbar manipulation group for all lumbar and thoracic movements measured, while there was also a significant increase in speed.

4.3.2.4 Intra-group analysis for Group D

The Intra-group analysis of Group D is shown in **Tables 4.14** to **4.16**. The mean, standard deviation and standard error of the mean are given in **Table 4.14**, while **Table 4.15** shows the correlations between pre and post readings for the variables.

Table 4.16 gives the results of the paired t-test, with t-statistic value, p-value and a 95% confidence interval for the difference in the means for pre and post readings

Table 4.14 Paired Samples Statistics for Group D – Sham Laser

	Mean	N	Std. Deviation	Std. Error Mean
Pre Average Speed	108.55333	10	10.810742	3.418657
Post Average Speed	109.08333	10	10.575586	3.344294
Thoracic FF Pre	30.20	10	5.940	1.879
Thoracic FF Post	33.70	10	6.533	2.066
Thoracic LLAT Pre	30.40	10	5.522	1.746
Thoracic LLAT Post	33.50	10	6.346	2.007
Thoracic RLAT Pre	33.10	10	5.087	1.609
Thoracic RLAT Post	36.20	10	4.917	1.555
Lumbar FF Pre	34.10	10	7.810	2.470
Lumbar FF Post	38.70	10	8.538	2.700
Lumbar LLAT Pre	21.70	10	5.498	1.739
Lumbar LLAT Post	24.20	10	5.245	1.659
Lumbar RLAT Pre	20.80	10	4.290	1.356
Lumbar RLAT Post	26.30	10	4.900	1.550

Table 4.15 Paired Samples Correlations of Group D – Sham Laser

	N	Correlation	Sig.
Pre Average Speed & Post Average Speed	10	.998	**.001***
Thoracic FF Pre & Thoracic FF Post	10	.949	**.001***
Thoracic LLAT Pre & Thoracic LLAT Post	10	.942	**.001***
Thoracic RLAT Pre & Thoracic RLAT Post	10	.754	**.012***
Lumbar FF Pre & Lumbar FF Post	10	.965	**.001***
Lumbar LLAT Pre & Lumbar LLAT Post	10	.877	**.001***
Lumbar RLAT Pre & Lumbar RLAT Post	10	.791	**.006***
All statistically significant values indicated by bold and (*).			

Table 4.16 Paired Samples Test for Group D – Sham Laser

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre Average Speed– Post Average Speed	-.530000	.772754	.244366	-.022795	-1.082795	-2.169	9	.058
Thoracic FF pre – Thoracic FF Post	-3.500	2.068	.654	-4.980	-2.020	-5.351	9	**.001***
Thoracic LLAT Pre – Thoracic LLAT Post	-3.100	2.183	.690	-4.662	-1.538	-4.490	9	**.002***
Thoracic RLAT Pre – Thoracic RLAT Post	-3.100	3.510	1.110	-5.611	-.589	-2.793	9	**.021***
Lumbar FF Pre – Lumbar FF Post	-4.600	2.271	.718	-6.224	-2.976	-6.406	9	**.001***
Lumbar LLAT Pre – Lumbar LLAT Post	-2.500	2.677	.847	-4.415	-.585	-2.953	9	**.016***
Lumbar RLAT Pre – Lumbar RLAT Post	-5.500	3.028	.957	-7.666	-3.334	-5.745	9	**.001***
All statistically significant values indicated by bold and (*).								

The Intra-group analysis of Group D is shown in **Table 4.13** to **4.15**. The *p-values* indicated in bold in **Table 4.15** are statistically significant at the *0.05* level. A significance difference exists between the Pre and Post measurements within the Placebo control group for all lumbar and thoracic movements measured. The p-value for average speed is 0.058 which is just less than 0.05 and although not quite significant still reflect an increase in speed.

4.3.3 Intergroup analysis

Inter-group analysis involved comparison of mean change between the four intervention groups using a one way ANOVA testing, and post-hoc Bonferroni adjusted multiple comparison tests. Pearson's correlation analysis was used to examine the strength of any linear relationships between changes in outcome variables.

An ANOVA test was conducted on the variables to test whether there is a difference in means across the four groups. The Null hypothesis (Ho) is that the means are equal and the Alternative hypothesis (H_a) is that at least two means differ.

Table 4.17 One way ANOVA test for comparison of mean change between intervention groups

		Sum of Squares	df	Mean Square	F	Sig.
Diff Average Speed	**Between Groups**	20.018	3	6.673	2.336	.090
	Within Groups	102.825	36	2.856		
	Total	122.843	39			
Diff Thoracic FF	**Between Groups**	94.500	3	31.500	2.399	.084
	Within Groups	472.600	36	13.128		
	Total	567.100	39			
Diff Thoracic LLAT	**Between Groups**	90.875	3	30.292	2.396	.084
	Within Groups	455.100	36	12.642		
	Total	545.975	39			
Diff Thoracic RLAT	**Between Groups**	128.600	3	42.867	2.926	**.047***
	Within Groups	527.400	36	14.650		
	Total	656.000	39			
Diff Lumbar FF	**Between Groups**	106.200	3	35.400	1.559	.216
	Within Groups	817.400	36	22.706		
	Total	923.600	39			
Diff Lumbar LLAT	**Between Groups**	39.475	3	13.158	1.224	.315
	Within Groups	386.900	36	10.747		
	Total	426.375	39			
Diff Lumbar RLAT	**Between Groups**	32.600	3	10.867	.642	.593
	Within Groups	609.000	36	16.917		
	Total	641.600	39			

All significant values indicated by bold and (*)

From **Table 4.17** Difference in Average Speed, Thoracic FF, Thoracic RLAT and Thoracic LLAT were found to be significant at *a 10% level,* but only Diff Thoracic RLAT was significant at a 5% level.

- Thoracic RLAT (p-value= 0.047)
- Thoracic LLAT (p-value =0.084)
- Thoracic FF (p-value = 0.084)
- Average Speed (p-value = 0.09)

There were insignificant differences between all the groups for all other outcomes as indicated in **Table 4.17.** The Bonferroni Post Hoc tests were run to identify which sets of treatments are significantly different from each other.

Table 4.18 Bonferroni post-hoc tests for multiple comparisons between groups for Diff Thoracic RLAT

Dependent Variable		(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Diff Thoracic RLAT	Bonferroni	A	B	.80000	1.71172	1.000	-3.9791	5.5791
			C	-2.30000	1.71172	1.000	-7.0791	2.4791
			D	-3.70000	1.71172	.224	-8.4791	1.0791
		B	A	-.80000	1.71172	1.000	-5.5791	3.9791
			C	-3.10000	1.71172	.471	-7.8791	1.6791
			D	-4.50000	1.71172	.075	-9.2791	.2791
		C	A	2.30000	1.71172	1.000	-2.4791	7.0791
			B	3.10000	1.71172	.471	-1.6791	7.8791
			D	-1.40000	1.71172	1.000	-6.1791	3.3791
		D	A	3.70000	1.71172	.224	-1.0791	8.4791
			B	4.50000	1.71172	.075	-.2791	9.2791
			C	1.40000	1.71172	1.000	-3.3791	6.1791

No significant pair wise was found by Bonferroni in **Table 4.18.** However, Duncan's Multiple Range Test **(Table 4.19)** did pick up a few differences which showed Group A and Group B being different from Group D. This means that the change in Thoracic RLAT for Groups A and B was significantly higher than group D.

Table 4.19 Duncan's Multiple Range test for Diff Thoracic RLAT.

Group		N	Subset for alpha = 0.05	
			1	2
Duncan	B	10	**-7.6000**	
	A	10	**-6.8000**	
	C	10	-4.5000	-4.5000
	D	10		**-3.1000**
	Sig.		.095	.419

4.3.4 The Association between Changes in throwing Speeds Pre- Post-Intervention and the Subjects' Perception of Change in throwing Speed

A cross tabulation of the perceived change for the groups, indicated that there was no significant differences in the percentage subjective change by intervention group using a Pearson Chi-Square test ($\chi^2 = 9.903, p = 0.129$). There is however, a trend shown in **Table 4.20** that suggests that the lumbar Manipulation group showed the highest perception (60%) of subjective percentage change while the placebo group showed the lowest percentage of subjective change (20%).

Table 4.20 Participants perception of change in throwing speed by group

			Subjective change		
			decreased	increased	No change
Group	A	Count	3	5	2
		% within Group	30.0%	50.0%	20.0%
	B	Count	0	6	4
		% within Group	0.0%	60.0%	40.0%
	C	Count	0	4	6
		% within Group	0.0%	40.0%	60.0%
	D	Count	2	2	6
		% within Group	20.0%	20.0%	60.0%
Total		Count	5	17	18
		% within Group	12.5%	42.5%	45.0%

4.3.5 The correlation between the change in throwing speed Pre- post-intervention and the change in trunk flexion and lateral flexion ROM pre- post-intervention.

There were no significant correlations between any of the Thoracic and Lumbar ROM movements and change in the throwing speed as seen in **Table 4.21**

Table 4.21 Pearson's correlation coefficients between throwing speed change and change in other outcomes

Correlations								
		Diff Thoracic FF	Diff Thoracic LLAT	Diff Thoracic RLAT	Diff Lumbar FF	Diff Lumbar LLAT	Diff Lumbar RLAT	Diff Ave Speed
Diff Thoracic FF	Pearson Correlation	1	.333*	.031	.264	.240	.122	-.092
	Sig. (2-tailed)		.036	.849	.099	.135	.454	.571
Diff Thoracic LLAT	Pearson Correlation	.333*	1	.233	-.010	-.046	-.310	-.108
	Sig. (2-tailed)	.036		.148	.953	.776	.052	.506
Diff Thoracic RLAT	Pearson Correlation	.031	.233	1	-.006	-.266	-.176	-.131
	Sig. (2-tailed)	.849	.148		.969	.098	.278	.421
Diff Lumbar FF	Pearson Correlation	.264	-.010	-.006	1	.210	-.038	-.195
	Sig. (2-tailed)	.099	.953	.969		.194	.815	.229
Diff Lumbar LLAT	Pearson Correlation	.240	-.046	-.266	.210	1	.587**	-.219
	Sig. (2-tailed)	.135	.776	.098	.194		.000	.174
Diff Lumbar RLAT	Pearson Correlation	.122	-.310	-.176	-.038	.587**	1	.002
	Sig. (2-tailed)	.454	.052	.278	.815	.000		.988
Diff Ave Speed	Pearson Correlation	-.092	-.108	-.131	-.195	-.219	.002	1
	Sig. (2-tailed)	.571	.506	.421	.229	.174	.988	

CHAPTER 5

DISCUSSION AND CONSLUSION

5.1 Introduction

This chapter will discuss the results of the statistical analysis of Chapter Four in terms of the review of the literature and conclude the study findings.

5.2 Flow of participants

The KZN Premier Baseball League has a population size of 100 players, 43 of whom can pitch and were therefore eligible for the study. Forty of the 43 that were eligible for the study were able to participate, while three players declined for various reasons (e.g. time, availability or not interested).

The 40 participants were divided into one of four groups randomly.

- Group A (Thoracic SMT)
- Group B (Lumbar SMT)
- Group C (Lumbar and Thoracic SMT)
- Group D (Placebo in the form of Sham Laser)

A total of 10 participants were allocated into each group. Each of the 40 participants completed the full research process with no adverse effects reported.

5.3 Physical characteristics

All 40 male participants used in this study were asymptomatic. There were no statistically significant differences ($\alpha = 0.05$) between the four intervention groups with regards to any of the three physical characteristics recorded (age [*p-value=.673*], body mass [*p-value=.844*], height [*p-value=.860*]) indicated in **Table 4.1** to **Table 4.4,** thus ensuring any demographic bias towards a particular group potentially present was eliminated (Salkind 2010).

This would eliminate one of the four groups having a greater advantage in mean characteristics which could affect the performance analysis between the intervention groups (Van den Tillaar and Ettema 2004). It is relevant that there is no significant difference between the groups for demographics, as discussed by Dun *et al.* (2007), the subjects' age, experience level and physical size are all factors that could affect a baseball players pitching speed.

The demographics of the participants in the studies by Escamilla et al. (2002); Werner et al. (2008); Oyama et al. (2013); Solomito et al. (2015) are similar in terms of age, body mass and height. Based on the similarities of the above mentioned studies, it could be suggested that the expected outcomes of the data discussed below would be similar.

5.4 Thoracic and Lumbar Range of Motion

The baseline means (±SD) indicated in **Table 4.5, 4.8, 4.11** and **4.14** shows the variability in the measurements of Thoracic FF, Thoracic LLAT, Thoracic RLAT, Lumbar FF, Lumbar LLAT and Lumbar RLAT ROM. The baseline thoracic spine and lumbar spine ROM (±SD) indicated in these tables are within the normal ROM limits for asymptomatic individuals described by Moore, Dalley and Agur (2010) in **Table 2.1** and **Table 2.2** respectively. The results in **Table 4.7, 4.10, 4.13** and **4.16** indicate that there were statistically significant increases in ROM within each of the intervention groups with only lumbar forward flexion of Group A not increasing at a significant level (*p-value = 0.196*).

The ROM findings in this study are similar to Sood (2008); Deutschmann (2015); Wiggett (2015) who also used the Saunders Digital Inclinometer in objective ROM measuring. This validates the claim by Czaprowski *et al.* (2012) that the Saunders digital inclinometer is a measuring device that has intra- and inter-observer repeatability of measurements.

When comparing the ROM changes across the four intervention groups in **Table 4.17**, it was found that there was only a statistical significant difference for Thoracic RLAT (*p-value= 0.047*) between Groups A, B and D. The mean Thoracic RLAT change was shown to increase in the thoracic and lumbar manipulation groups more than the placebo group.

Most overhead athletes have excessive amounts of external rotation with decreased amounts of internal rotation at 90° of abduction in the throwing shoulder (Kibler, Sciascia and Thomas 2012). The eccentric contraction of the muscles around the dominant shoulder can cause a rise in muscular tension which results in a loss of ROM (Proske and Morgan 2001). The thoracic spine has a close relationship with the shoulder due to the scapulothoracic joint and various muscle connections between the spine and the shoulder (Crosbie *et al.* 2008; Moore, Dalley and Agur 2010). A reason for the increased Thoracic RLAT ROM can be that 39 out of the 40 participants were right handed. Thus the decreased ROM, due to the eccentric muscle bulk (Proske and Morgan 2001) of the isipilateral side of the throwing shoulder, may have been corrected by SMT.

SMT to the lumbar spine may have caused an increase in RLAT of the Thoracic spine due to the close relationship of the Latissimus dorsi between the two regions. The muscle originates from the spinous processes of T7 to L5 (including the thoracolumbar fascia), iliac crest, inferior 3 to 4 ribs and inferior angle of scapula (Moore, Dalley and Agur 2010). The muscle then inserts into the intertubecular groove of the humerus (Moore, Dalley and Agur 2010). Bergmann and Peterson (2011) states that the lower thoracic levels tend to have more degrees lateral flexion when compared to the superior thoracic segments. The lower thoracic segments have a tendency to follow the coupling movement patterns of the lumbar spine (Bergmann and Peterson 2011). Due to the Latissimus dorsi running across those lower thoracic segments and the lumbar spine it is possible that there is a relationship between the two. A change to the joints describe by Triano *et al.* (2003); Leach (2004); Haldeman (2005); Bergmann and Peterson (2011) may have occurred due to SMT which then affected the thoracic and lumbar spines. Nagda *et al.* (2011) states that the Latissimus dorsi tends to be active in the late cocking through to follow through phase of baseball pitching suggesting this muscle plays a vital role in the biomechanics of pitching.

Any combination of following theorises may be possible explanations for the increased ROM findings obtained for Thoracic RLAT in this study.

- A change in the orientation and/or positioning of various anatomical structures (Leach 2004)
- Increased range of motion of motion segments (Triano *et al.* 2003)

- Increasing neurological input (Haldeman 2005)
- Unbuckling of ligaments and the release of trapped meniscoids (Bergmann and Peterson 2011)
- Breaking of adhesions (Leach 2004)
- Return of normal motion segment function (Triano *et al.* 2003)

Dun *et al.* (2007) found that older groups of pitchers tend to exhibit less forward trunk flexion at ball release. Due to the younger age of the participants in this study, forward flexion of the trunk may not have been affected by SMT. In a future study SMT can be done to pitchers with an older age than the ones tested in this present study to see if there is an increased trunk flexion post SMT.

According to Millan *et al.* (2012), the biomechanical effect of SMT is influenced by a reduction in pain. So by reducing pain in a patient an increase in ROM is possible (Millan *et al.* 2012). Now as this study was done on pain free participants it could be understood that no reduction in paid occurred so then no ROM increased would have occurred.

Millan *et al.* (2012) showed that SMT had the greatest effect of the cervical region, which was not tested in this preset study. This can be due to the fact that the atlanto-axial joint is responsible for more than 50% of total cervical rotation (Moore, Dalley and Agur 2010; Bergmann and Peterson 2011) and by targeting that joint during a manipulation it is possible that a greater measureable effect is possible (Millan *et al.* 2012). By contrast the thoracic and lumbar spines do not have a single segmental level responsible for such a large contribution to movement of the entire spinal region (Moore, Dalley and Agur 2010; Bergmann and Peterson 2011). In future studies one would need to look at adjusting as many levels as possible within a region in order to affect multiple joints to determine if increased ROM is possible.

A factor that could have affected the ROM readings in this study is that the ROM does increase immediately post-SMT but the method used in the determining the ROM changes is not sensitive in capturing this effect (Millan *et al.* 2012).

To conclude ROM findings:

- Lumbar and Thoracic SMT was found to be statistically significant (*p-value = 0.047*) in increasing Thoracic RLAT ROM.
- Thoracic FF, Thoracic LLAT, Lumbar FF, Lumbar LLAT and Lumbar RLAT ROM were not statistically increased by SMT when compared to the control group..

5.5 Throwing Speed

The mean throwing speeds for each group are given in **Table 4.5, 4.8, 4.11** and **4.14** respectively. The mean of the average throwing speeds ranged from 91.7 km/h to 127.6 km/h.

The mean speed of Group A as shown in **Table 4.5** was 108.05 km/h and increased to a speed of 110.28 km/h post Thoracic SMT which was considered to be statistically significant (*p-value= 0.004).* The mean average speed of Group B as shown in **Table 4.8** was 113.68 km/h and increased to 115.78 km/h post Lumbar SMT which is statistically significant at (*p-value< 0.001).* The mean speed of Group C as shown in **Table 4.11** was 113.61 km/h and increased to a speed of 115.75 km/h post Thoracic and Lumbar SMT and is also statistically significant (*p–value= 0.019).* The mean speed of Group D as shown in **Table 4.14** was 108.55 km/h and increased to a speed of 109.08 km/h post Sham Laser which was not considered to be statistically significant at *p-value= 0.058.*

When comparing the change in average speed across the four intervention groups in **Table 4.17**, no statistical significance was found at $\alpha = 0.05$. Statistical significance was found at a level of α *= 0.10 with a p-value= 0.09*.This finding means that there is no statistical significance at 5% in change in average speeds between the placebo group and the SMT groups.

The pre- and post-average speeds recorded in this study are below those reported by Werner *et al.* (2008) 127.1 ±11 km/h, Oyama *et al.* (2013) 117 ±7.9 km/h and Escamilla *et al.* (2002) 136.8 km/h. The speeds recorded in this study can be compared to those of Solomito *et al.* (2015) who reported speeds of 115.2 ±6.8 km/h amongst lower level American college players. This can also be due to the similarities in the ages of this study and those reported by Solomito *et al.* (2015) of lower college levels. However, although the pitching velocities mean is similar, the wider standard deviation seen in this study compared to Solomito *et al.* (2015) indicates the inability to maintain a constant speed while pitching. This is due to the amateur status of the players in the KZN Baseball Premier League compared to those of American High School (Oyama *et al.* 2013), American College (Werner *et al.* 2008; Solomito *et al.* 2015) and professional baseball players (Escamilla *et al.* 2002). This wide range in deviation has an important effect of masking the small changes in performance that SMT might bring about. Factors that may affect this include the amateur nature players lacking the ability to maintain constant pitching biomechanics (Stodden *et al.* 2005) which can affect the average of speed between each individual pitch and the young age of the participants (Fleisig *et al.* 2009).

As there are no similar studies conducted on baseball throwing speed and SMT, the results of this study would need to be compared to the similar studies done by Sood (2008).

Sood (2008) found that Thoracic SMT ($p=0.042$) and combined Thoracic and Lumbar SMT ($p=0.001$) increased cricket players bowling speed performance. As cricket bowling and baseball pitching share similar biomechanics characteristics (Sood 2008) one would assume similarities in results. This study showed that an increase in pitching speed does occur in the SMT groups but it is not considered to be at a statistical significant at 5% confidence level.

Conclusion:

- The speeds recorded in this study are equivalent to low level American College baseball (Solomito *et al.* 2015).
- When comparing pre-average speeds with post-average speeds within the SMT groups there was an increase in speed noted, however it was not considered to be statistical significant at *5%* when compared to the placebo group.

5.6 Correlation between ROM and Speed

No correlation exists (**Table 4.21)** between the change in Thoracic and Lumbar ROM and the change in the participant's post-intervention speed. From the increased Thoracic RLAT it was found that there was no correlation between the increase ROM and the participant's speeds. From the above information one can accept the Null Hypothesis (H_o) stating that no statistically significant relationship between change in pitching speed immediately post-intervention and change in range of motion of the lumbar and thoracic spines exists.

As there was no significant increase in contralateral lateral flexion of the lumbar or thoracic spines, it would not be possible to compare the results against Oyama *et al.* (2013); Solomito *et al.* (2015) whereby pitching speeds increased due to contralateral trunk lean. Even thought there was increased Thoracic RLAT, 39 out of the 40 pitchers were right handed so only increased ipsilateral trunk lean occurred. As there was no increased significance of trunk forward flexion the studies by Escamilla *et al.* (2002); Stodden *et al.* (2005); Werner *et al.* (2008); Weber *et al.* (2014); Solomito *et al.* (2015) where forward flexion of the trunk was identified as one of the kinetic factors affecting ball speed, could explain why no statistical increase in pitching velocities were seen.

Crosbie *et al.* (2008) states that thoracic spines position can influence the glenohumeral joint and scapulothoracic position. A study by Kebaetse, McClure and Pratt (1999) showed that the position of the thoracic spine can have an effect on scapular kinematics and a resultant decreased muscle force. The increased thoracic RLAT of this study did not show any significant increase in speeds. A reason for this finding can be that during the stride phase of the throwing motion the chest of the pitcher remains closed away from the target (Calabrese 2013). This is so there can be an increased distance of trunk rotation and lateral flexion in the opposite direction (Young *et al.* 1996; Calabrese 2013). Now as there was only increased thoracic RLAT this may cause the front shoulder to remain closed even longer as more movement away from the target occurs causing the pitcher to have to throw across the body in order to reach their target (Calabrese 2013).

Calabrese (2013) states that the later phases of throwing emphasize spinal movement and loading. Keeley et al. (2008) indicated that younger and less experienced pitchers that can be related to this present study have early rotation in their pitching movements. The study stated that the early increased rotation of the spine can lead to shoulder hyperangulation which is not considered optimal in producing high velocities (Keeley *et al.* 2008).

As the movements of the thoracic spine are coupled (Moore, Dalley and Agur 2010) the increased thoracic movement may have an increased effect on this hyperangulation (Keeley *et al.* 2008) of the arm which is not optimal for increased speed. The change in the proximal kinetic chain, due to the SMT of the spine, may be further effecting the shoulder, elbow or wrist biomechanics (Putnam 1993; Weber *et al.* 2014) that are more distal in the chain which may now have an altered biomechanics (Chu *et al.* 2016). These segments could possibly have mobility changes the previous segments have now gained more mobility which would place increased stresses on the shoulder complex, elbow or wrist (Putnam 1993; Hirashima *et al.* 2008; Seroyer *et al.* 2010; Chu *et al.* 2016)

As noted from the literature on increased baseball pitching speed (Aguinaldo, Buttermore and Chanmbers 2003; Whiteley 2007 ; Werner *et al.* 2008; Calabrese 2013; Oyama *et al.* 2013; Solomito *et al.* 2015), a big component of the performance is related to timing of movement rather than range. From the literature the neurophysioloical (Pickar 2002) component of manipulation needs to be focused on when looking at increased sporting performance as the timing of kinetic chains movements is just as important as ROM of the movements (Hong, Cheung and Roberts 2001; Hirashima *et al.* 2008; Seroyer *et al.* 2010; Urbin *et al.* 2013; Chu *et al.* 2016). A factor may also be that because these individuals are already at their most capable ROM and thus at their peak velocities.

5.7 Perception of change in throwing speed

From the information in **Table 4.20** a Pearson's Chi Square test (χ^2 = 9.903) was performed to determine the association between change in throwing speeds pre- and post-intervention, and the participant's perception of change in throwing speed. No statistical significance (*p-value* = 0.129) was detected for a change in perception post-manipulation.

A trend noted in **Table 4.20** is that, overall five participants reported a decreased performance (12.5%), 17 reported an increased performance (42.5%) and 18 reported no change in performance (45%). In Group A 50% of participants perceived an increase performance, in Group B 60% of participants perceived an increase performance, in Group C 60% of participants perceived no change in performance and in Group D 60% percent of participants perceived no change in performance.

It is noted that Group A - where 50% of participants felt they improved - and Group B - where 60% of participants felt they improved - were the groups where there was a statistical significance in Thoracic RLAT ROM. The perceived increased performance the participants felt may be due the increased ROM they felt and reported on.

Many of the individuals who reported an increase in subjective change claimed that they felt a more “freedom” throughout their post-SMT throws. This could be due to the effect described by Pickar (2002); Triano *et al.* (2003); Gatterman (2005); Haldeman (2005); Lederman (2005); Bergmann and Peterson (2011); Henderson (2012).

From the above information one may accept the Null Hypothesis (H_o) as there was no statistical change in the subject’s perception of change in speed post-SMT.

5.8 Power of statistical analysis

The power of statistical analysis can be determined by numerous different factors (Heckard and Utts 2012). The most common aspects that determine power are, the statistical significance criterion used in the test, the standard deviations and the sample size used to detect the effect (Heckard and Utts 2012).

5.8.1 Statistical significance criterion

In order to increase the power of the statistical analysis one may perform a less conservative test by using a larger significance such as $\alpha = 0.1$ instead of the commonly used $\alpha = 0.05$ (Heckard and Utts 2012). Increasing the statistical significance criterion causes the chance of rejecting the Null Hypothesis (H_o) to increase (Heckard and Utts 2012).

5.8.2 Standard deviation

When the standard deviation is small the power is considered higher than when the standard deviation is larger (Heckard and Utts 2012). By reducing the standard deviation by sampling from a population of subjects that are close to each other as possible, by reducing random measurement errors, and by making sure the experimental methodological procedures are applied identically, a higher power of statistical analysis can be obtained (Heckard and Utts 2012). This study could have had a greater power of analysis if professional or more experienced baseball players were used. Individual standard deviations between throws tended to be greatest for younger pitchers and decrease as the level of competition increased to professional level, as variability is exhibited in their throwing motions (Fleisig *et al.* 2009).

5.8.3 Sample Size

The sample size used in this study was 40. As only 43 individuals actually pitch in the KwaZulu Natal baseball league it shows a good representation of the pitchers in the league (Heckard and Utts 2012). The sample size determines the amount of sampling error inherent in a test result. The small sample size makes effects harder to detect thus increasing sample size boosts the statistical power of a test (Heckard and Utts 2012). Future studies that examine a larger population of pitchers for example at a national level may yield results that are both statistically significant in both intra and intergroup analysis.

5.9 Final Discussion

According to Cerqueira *et al.* (2016) chiropractic SMT is widely used in sport to help improve performance with little to none evidence of SMT effecting sporting performance. More sport chiropractic research needs to be done in a clinical trial setting, which are much larger than pilot studies, as they do not undergo greater methodological rigor and increased number of participants than the clinical trials (Cerqueira *et al.* 2016).

It is suggested by Miners (2010) that future research is needed to be more accurate, scientific and evidence based when examining the impact of Chiropractic manipulation on sports performance rather than relying on terms such as “tend to suggest,” or “may indicate".

5.10 Conclusion

The aim of this study was:

- To determine via a controlled, prospective, investigative trial the effect of thoracic, lumbar and combined thoracic and lumbar manipulation on the pitching speed of asymptomatic baseball players registered in the Kwa-Zulu Natal Baseball Union.

With regards to the aim and objectives of the study:

- Group A (thoracic) and Group B (lumbar) showed statistical significance in increase in thoracic RLAT ROM post SMT.
- The SMT groups showed statistical significant increases, within each group, with regards to average pitching speed post SMT.
- The average pitching speed showed no statistical significance between the SMT groups and the placebo group.
- There was no significant association between change in pitching speed pre- and post- intervention and the participant’s perception of change in pitching speed.

One could accept the following Null Hypotheses (H_o) for the study:

- There would be no statistically significant relationship between change in pitching speed immediately post-intervention and change in range of motion of the lumbar and thoracic spines.

- There would be no statistically significant relationship between change in pitching speeds immediately post intervention and the participant’s perception of change in their pitching speed.

The outcomes of this study suggested that SMT increased pitching speed post manipulation in terms of intra-group analysis. The increase in pitching speed was however not considered statistically significant in terms of inter-group analysis. There was an increase in the right lateral flexion of the thoracic spine which was shown to have no effect on the throwing performance of the players.

5.11 Recommendations

- A similar study can include females in order to determine any possible gender differences in spine ROM and pitching speed post manipulation.

- As SMT seems to produce the most benefits in the cervical region (Millan et al. 2012) a future study can be done on the effect of cervical manipulation of baseball pitching speed.

- Due to the coupled movements of the spine (Herzog 2010; Moore, Dalley and Agur 2010), a study may need to look at rotation and extension movements when investigating the spine on increased throwing performance.

- Another study can focus more on the accuracy of the throws as part of the performance aspect rather than just considering the speed of the pitch. One may also look at how manipulation effect the fatigue of one's throwing as a more efficient kinetic chain requires less energy to perform (Pickar 2002).

- As amateur players there is a lot of variation between each individual throw. This study done on professionals may produce different results as they would be more adapt to the pitching mechanics which will allow for a small difference in means between individual throws (Fleisig et al. 2009). This study would not be possible in South Africa as there is no professional league at present.

- A study could be done on the lasting effects of manipulation over a longer period as this study only focused on the immediate effect. Studies can be done to determine the effect of SMT over time and upon regular SMT therapy.

- Studies that investigated the impact of SMT of the kinematic chain of the upper and lower limbs.

- Studies that investigate the impact of manipulation as part of wider protocol that included other modalities e.g. trigger point therapy, prop taping or therapeutic rehab.

- With more advanced equipment such as 3-dimensional motion analysis future studies can be done to measure the actual body kinematics and kinetic changes and determine if SMT was able to affect the movements.

- A study including an older age cohort, which can examine the effect of SMT on trunk flexion biomechanics.

References

Aguinaldo, A., Buttermore, J. and Chanmbers, H. 2003. Sequential body motion and shoulder joint torque between baseball pitchers of various levels. *Journal of Applied Biomechanics*,

Applied Concepts, I. Applied Concepts, I. 2016. S PRO II, Professional Sports Radar, Owner's Manual.

Barrett, D. D. and Burton, A. W. 2002. Throwing patterns used by collegiate baseball players in actual games. *Research Quarterly for Exercise and Sport*, 73 (1): 19-27.

Bergmann, T. F. and Peterson, D. H. 2011. *Chiropractic technique: principles and procedures*. 3rd ed. St. Louis, Mo: Elsevier/Mosby.

Bernier, D. 2014. *Types of pitches*. Available: http://probaseballinsider.com/baseball-instruction/fundamentals-of-hitting/types-of-baseball-pitches/ (Accessed 2017).

Bicalho, E., Palma Setti, J. A., Macagnan, J., Rivas Cano, J. L. and Manffra, E. F. 2010. Immediate effects of a high-velocity spine manipulation in paraspinal muscles activity of nonspecific chronic low-back pain subjects. *Manual Therapy*, 15 (5): 469-475.

Burkhart, S. S., Morgan, C. D. and Kibler, W. B. 2003. The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, 19 (4): 404-420.

Calabrese, G. J. 2013. Pitching Mechanics Revisited. . *International Journal of Sports Physical Therapy*, 8 (5): 652-660.

Cerqueira, M. S., Sales, R. M., Pinto, C. T. P., Mesquita, G., Moreno, B. G. D. and Filho, A. G. D. M. 2016. Effects of high-velocity low-amplitude manipulation (thrust) in athletic performance: A systematic review. *Physical Therapy in Sport*, 18

Chu, S. K., Jayabalan, P., Kibler, W. B. and Press, J. 2016. The Kinetic Chain Revisited: New Concepts on Throwing Mechanics and Injury. *PM&R*, 8 (3, Supplement): S69-S77.

Clark, B. C., Goss, J. D. A., Walkowski, S., Hoffman, R. L., Ross, A. and Thomas, J. S. 2011. Neurophysiologic effects of spinal manipulation in patients with chronic low back pain. *BMC Musculoskeletal Disorders*, 12 (1): 170-179.

Commons, W. *Files: Baseball diamond.svg*. Available: https://commons.wikimedia.org/w/index.php?title=File:Baseball_diamond.svg&oldid=118109196 (Accessed 6 May 2017)

Costa, S. M. V., Chibana, Y. E. T., Giavarotti, L., Compagnoni, D. S., Shiono, A. H., Satie, J. and Bracher, E. S. B. 2009. Effect of spinal manipulative therapy with stretching compared with stretching alone on full-swing performance of golf players: a randomized pilot trial. *Journal of Chiropractic Medicine*, 8 (4): 165-170.

Crosbie, J., Kilbreath, S. L., Hollmann, L. and York, S. 2008. Scapulohumeral rhythm and associated spinal motion. *Clinical Biomechanics*, 23 (2): 184-192.

Czaprowski, D., Pawłowska, P., Gębicka, A., Sitarski, D. and Kotwicki, T. 2012. Intra- and interobserver repeatability of the assessment of anteroposterior curvatures of the spine using Saunders digital inclinometer. *Ortopedia, Traumatologia, Rehabilitacja*, 14 (2): 145-153.

Deutschmann, K. C. 2015. A non-randomised experimental feasibility study into the immediate effect of three different spinal manipulative protocols on kicking speed performance in soccer players. *Chiropractic & Manual Therapies*, 23 (1): 1.

Draper, S. W. 2002 *The Hawthorne, Pygmalion, Placebo and other effects of expectation.* Available: http://www.psy.gla.ac.uk/~steve/XXXX.html (Accessed 14/03/2017)

Dun, S., Fleisig, G. S., Loftice, J., Kingsley, D. and Andrews, J. R. 2007. The relationship between age and baseball pitching kinematics in professional baseball pitchers. *Journal of Biomechanics*, 40 (2): 265-270.

Escamilla, R., Fleisig, G., Barrentine, S., Andrews, J. and Moorman, C. 2002. Kinematic and Kinetic Comparisons between American and Korean Professional Baseball Pitchers. *Sports Biomechanics*, 1 (2): 213-228.

Fleisig, G., Chu, Y. C., Weber, A. and Andrews, J. 2009. Variability in baseball pitching biomechanics among various levels of competition. *Sports Biomechanics*, 8 (1): 10-21.

Fleisig, G. S., Kingsley, D. S., Loftice, J. W., Dinnen, K. P., Ranganathan, R., Dun, S., Escamilla, R. F. and Andrews, J. R. 2006. Kinetic Comparison Among the Fastball, Curveball, Change-up, and Slider in Collegiate Baseball Pitchers. *The American Journal of Sports Medicine*, 34 (3): 423-430.

Gatterman, M. I. 1990. *Chiropractic management of spine related disorders*. Baltimore, Md: Williams & Wilkins.

Gatterman, M. I. 2005. *Foundations of chiropractic: subluxation*. 2nd ed. St. Louis, Mo: Elsevier/Mosby.

Gray, H. 1918. *Anatomy of the human body*. 20th ed. Philadelphia and New York: Lea and Febiger.

Haldeman, S. 2005. *Principles and practice of chiropractic*. 3rd ed. New York: McGraw-Hill Medical Publishing Division.

Heckard, R. F. and Utts, J. M. 2012. *Statistics*. 4th, international ed. Singapore: Brooks/Cole, Cengage Learning.

Henderson, C. N. R. 2012. The basis for spinal manipulation: Chiropractic perspective of indications and theory. *Journal of Electromyography and Kinesiology*, 22 (5): 632-642.

Herzog, W. 2000. The mechanical, neuromuscular, and physiologic effects produced by spinal manipulation. *Clinical Biomechanics of Spinal Manipulation*, 5: 191-207.

Herzog, W. 2010. The biomechanics of spinal manipulation. *Journal of Bodywork and Movement Therapies*, 14 (3): 280-286.

Hirashima, M., Yamane, K., Nakamura, Y. and Ohtsuki, T. 2008. Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. *Journal of Biomechanics*, 41 (13): 2874-2883.

Hong, D.-A., Cheung, T. K. and Roberts, E. M. 2001. A three-dimensional, six-segment chain analysis of forceful overarm throwing. *Journal of Electromyography and Kinesiology*, 11 (2): 95-112.

Kebaetse, M., McClure, P. and Pratt, N. A. 1999. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Archives of Physical Medicine and Rehabilitation*, 80 (8): 945-950.

Keeley, D. W., Hackett, T., Keirns, M., Sabick, M. B. and Torry, M. R. 2008. A Biomechanical Analysis of Youth Pitching Mechanics. *Journal of Pediatric Othopaedics*, 28 (4): 452-459.

Kibler, W., Sciascia, A. and Thomas, S. J. 2012. Glenohumeral Internal Rotation Deficit: Pathogenesis and Response to Acute Throwing. *Sports Medicine and Arthroscopy Review*, 20 (1): 34-38.

Kibler, W. B., Wilkes, T. and Sciascia, A. 2013. Mechanics and pathomechanics in the overhead athlete. *Clinical Sports Medicine*, 32 (4): 637-651.

Le Roux, S. 2008. The immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators. Durban University of Technology. Available: http://hdl.handle.net/10321/373 (Accessed 19/04/2017)

Leach, R. A. 2004. *The chiropractic theories: a textbook of scientific research*. 4th ed. Philadelphia, Pa: Lippincott Williams & Wilkins.

Lederman, E. 2005. *The science and practice of manual therapy*. 2nd ed. Edinburgh: Elsevier Churchill Livingstone.

Maigne, J.-Y. and Vautravers, P. 2003. Mechanism of action of spinal manipulative therapy. *Joint Bone Spine*, 70 (5): 336-341.

Matsuo, T., Escamilla, R. F., Fleisig, G. S., Barrentine, S. W. and Andrews, J. R. 2001. Comparison of kinematic and temporal parameters between different pitch velocity groups. *Journal of Applied Biomechanics*, 17 (1): 1-13.

McGill, S. M. and Hoodless, K. 1990. Measured and modeled static and dynamic axial trunk torsion dring twisting in males and females. *The Journal of Biomedical Engineering*, 12 (5): 403-409.

Millan, M., Leboeuf-Yde, C., Budgell, B., Descarreaux, M. and Amorim, M.-A. 2012. The effect of spinal manipulative therapy on spinal range of motion: a systematic literature review. *Chiropractic & Manual Therapies*, 20

Miller, F. G., Wendler, D. and Swartzman, L. C. 2005. Deception in research on the placebo effect. *PLoS Medicine*, 2 (9): e262.

Miners, A. 2010. Chiropractic treatment and the enhancement of sport performance: a narrative literature review. *The Journal of the Canadian Chiropractic Association*, 54 (4): 210-221.

MLB. 2017. *Offcial Baseball Rules*. Available: http://mlb.mlb.com/mlb/official_info/official_rules/official_rules.jsp (Accessed 13 May 2017).

Moore, K. L., Dalley, A. F. and Agur, A. M. R. 2010. *Clinically oriented anatomy*. 6th, international ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Mouton, J. 1996. *Understanding Social Research*. 3rd ed. Pretoria: Van Shaik Publishers.

Nagda, S. H., Cohen, S. B., Noonan, T. J., Raasch, W. G., Ciccotti, M. G. and Yocum, L. A. 2011. Management and Outcomes of Latissimus Dorsi and Teres Major Injuries in Professional Baseball Pitchers. *The American Journal of Sports Medicine*, 39 (10): 2181-2186.

Oyama, S., Yu, B., Blackburn, J. T., Padua, D. A., Li, L. and Myers, J. B. 2013. Effect of Excessive Contralateral Trunk Tilt on Pitching Biomechanics and Performance in High School Baseball Pitchers. *The American Journal of Sports Medicine*, 41 (10): 2430-2438.

Pickar, J. G. 2002. Neurophysiological effects of spinal manipulation. *The Spine Journal*, 2 (5): 357-371.

Pink, M. M. 2001. Understanding the linkage system of the upper extremity. *Sports Medicie And Arthroscopy Review*, 9 (1): 52-60.

Proske, U. and Morgan, D. 2001. Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications. *The Journal of physiology*, 537 (2): 333-345.

Putnam, C. A. 1993. Sequential motions of body segments in striking and throwing skills: Descriptions and explanations. *Journal of Biomechanics*, 26, Supplement 1: 125-135.

Redwood, D. 2003. Spinal adjustment for low back pain. *Seminars in Integrative Medicine*, 1 (1): 42-52.

Salkind, N. J. 2010. *Encyclopedia of research design*. 1 ed. Thousand Oaks, Calif: SAGE Publications.

Seroyer, S. T., Nho, S. J., Bach, B. R., Bush-Joseph, C. A., Nicholson, G. P. and Romeo, A. A. 2009. Shoulder Pain in the Overhead Throwing Athlete. *Sports Health*, 1 (2): 108-120.

Seroyer, S. T., Nho, S. J., Bach, B. R., Bush-Joseph, C. A., Nicholson, G. P. and Romeo, A. A. 2010. The Kinetic Chain in Overhand Pitching: Its Potential Role for Performance Enhancement and Injury Prevention. *Sports Health*, 2 (2): 135-146.

Solomito, M. J., Garibay, E. J., Woods, J. R., Õunpuu, S. and Nissen, C. W. 2015. Lateral Trunk Lean in Pitchers Affects Both Ball Velocity and Upper Extremity Joint Moments. *The American Journal of Sports Medicine*, 43 (5): 1235-1240.

Sood, K. D. 2008. The immediate effect of lumbar spine manipulation, thoracic spine manipulation, combination lumbar and thoracic spine manipulation and sham laser on bowling speed in action cricket fast bowlers*.* Durban University of Technology. Available: http://hdl.handle.net/10321/2186 (Accessed 19/04/2017)

Stodden, D. F., Fleisig, G. S., McLean, S. P. and Andrews, J. R. 2005. Relationship of biomechanical factors to baseball pitching velocity: Within pitcher variation. *Journal of Applied Biomechanics*, 21 (1): 44-56.

Triano, J. J., Rogers, C. M., Combs, S., Potts, D. and Sorrels, K. 2003. Quantitative feedback versus standard training for cervical and thoracic manipulation. *Journal of Manipulative and Physiological Therapeutics*, 26 (3): 131-138.

Urbin, M. A., Fleisig, G. S., Abebe, A. and Andrews, J. R. 2013. Associations Between Timing in the Baseball Pitch and Shoulder Kinetics, Elbow Kinetics, and Ball Speed. *The American Journal of Sports Medicine*, 41 (2): 336-342.

Van den Tillaar, R. and Ettema, G. 2004. Effect of body size and gender in overarm throwing performance. *European Journal of Applied Physiology*, 91 (4): 413-418.

Wall, M. and Wheeler, S. 1996. Benefits of the placebo effect in the therapeutic relationship. *Complementary Therapies in Nursing and Midwifery*, 2 (6): 160-163.

Wassinger, C. A. and Myers, J. B. 2011. Reported mechanisms of shoulder injury during the baseball throw. *Physical Therapy Reviews*, 16 (5): 305-309 305p.

Weber, A. E., Kontaxis, A., O'Brien, S. J. and Bedi, A. 2014. The Biomechanics of Throwing: Simplified and Cogent. *Sports Medicine And Athroscopy Review*, 22 (2): 72-79.

Werner, S. L., Suri, M., Guido Jr, J. A., Meister, K. and Jones, D. G. 2008. Relationships between ball velocity and throwing mechanics in collegiate baseball pitchers. *Journal of Shoulder and Elbow Surgery*, 17 (6): 905-908.

Whiteley, R. 2007 Baseball Throwing Mechanics as They Relate to Pathology and Performance - A Review. *Journal of Sports Science & Medicine*, 6 (1): 1–20.

Wiggett, M. 2015. The immediate effect of spinal manipulative therapy on drag flicking performance of field hockey players. Durban University of Technology. Avalible at http://hdl.handle.net/10321/1628. (Accessed 19/04/2017)

Young, J. L., Herring, S. A., Press, J. M. and Casazza, B. A. 1996. The influence of the spine on the shoulder in the throwing athlete. *J Back Musculoskeletal Rehabilitation*, 7 (1): 5-17.

Zhang, Y. and Jordan, J. M. 2010. Epidemiology of osteoarthritis. *Clinical Geriatric Medicine*, 26 (3): 355-369.

Appendix A

Letter of Information

Title of the Research Study:
The immediate effect of sham laser and three different spinal manipulative protocols on the throwing speed of baseball players in the KwaZulu Natal Baseball Union.

Principal investigator/s/researcher:
Michael Robson B.Tech Chiropractic

Co-Investigators/s/supervisor/s:
Dr. G. Haswell M.Tech Chiropractic

Brief Introduction and Purpose of the Study:
This study will investigate the effects of spinal manipulation on baseball players throwing velocity.

Outline of Procedure:
A full case history, physical examination and orthopaedic examination of the spine will be done behind a screened-off area. After this you will be assigned to one of four intervention groups depending on which piece of numbered paper you pick from an envelope i.e. Group 1 (thoracic spine manipulation), Group 2 (lumbar spine manipulation), Group 3 (combination lumbar and thoracic spine manipulation) and Group 4 (laser application to the trunk region). You will then need to do a five minute warm up to stretch your muscles. Your back's range of motion will be measured using a digital inclinometer. You will then be asked to throw as fast you can three times and the speeds will be measured by a radar gun. Depending on the group you were allocated, the appropriate intervention will be applied. Your back's range of motion will be measured again as before and you will then be asked to throw as fast as you can three times again and the pitching speed will be measured. Thereafter, you will be asked to answer one question on your indication of the change in throwing speed before and after the intervention. The consultation is expected to last about one and a half hours. You will be required to attend a one hour consultation at the D.U.T Chiropractic Clinic followed by a 30 minute consultation at the Queensmead Sports Centre. You will be required to perform the instructed warm up and throwing procedures and to comply with the range of motion tests.

Risks or Discomforts to the Participant:
All consultations are supervised by a registered, qualified chiropractor. Spinal manipulation may cause transient (short interval) discomfort to the back. There are no other discomforts expected with this intervention. Laser therapy is completely safe and no side-effects are expected.

Benefits:
The results of the study will be forwarded to the club coaches to allow for improvements in training to be made.

Reason/s why the participant may be withdrawn from the study:
Reasons for withdrawal include moving from the eThekwini municipality, no longer participating in baseball or no longer filling the inclusion criteria. However, there will be no adverse reactions should you withdraw from the study.

Remuneration:
You are to note that there is a 25% chance of the individual being placed in a placebo group during this trial. Those that are placed in the placebo group will receive a coupon for one free treatment at the DUT Chiropractic Clinic.

Cost of the Study:
No financial costs are required by you in this study.

Confidentiality:
All your information is confidential and the results of the study will be used for research purposes only. The researcher will be the only person who has access to the letters of consent and after the data collection process the data will be coded. You are entitled to be informed of any findings that are made from the study, and you are free to ask questions of an independent source. If you feel unsatisfied with any area of the study please feel free to contact the Durban University of Technology Research Ethics Committee.

Research Related Injury:
Indemnity cover relating to research activities is covered by the Durban University of Technology.

Persons to contact in the event of any problems or queries:

Michael Robson ([redacted]), Dr. G. Haswell ([redacted]) or the Institutional Research Ethics Administrator (0313732375).

Complaints can be reported to the Director: Research and Postgraduate Support, Prof S Moyoon 0313732577 or moyos@dut.ac.za

Appendix B

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Michael Robson, about the nature, conduct, benefits and risks of this study- Research Ethics Clearance Number**: IREC 92/17**
- 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 gender, 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	Signature

I, Michael Robson herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

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

APPENDIX C

Attention all Competitive baseball players

Are you healthy, between 18 and 40 years of age, and interested in having your throwing speed measured?

Research* is being conducted at the Local Baseball field on 4 interventions which may affect throwing speeds.

If you are interested in participating in this study, please contact Michael on [redacted]

*This research is being conducted under the auspices of the Durban University of Technology

APPENDIX D

Subjects' Perception of Change in throwing Speed

Group 1	Increased	Decreased	No change	Group 2	Increased	Decreased	No change
1				**1**			
2				**2**			
3				**3**			
4				**4**			
5				**5**			
6				**6**			
7				**7**			
8				**8**			
9				**9**			
10				**10**			
Group 3	**Increased**	**Decreased**	**No change**	**Group 4**	**Increased**	**Decreased**	**No change**
1				**1**			
2				**2**			
3				**3**			
4				**4**			
5				**5**			
6				**6**			
7				**7**			
8				**8**			
9				**9**			
10				**10**			

Appendix E

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ______________________________ Date: __________

File #: __________ Age: __________

Sex: __________ Occupation: ______________________

Student: ______________________ Signature ______________________

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature:

Case History:

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

CASE STATUS:

PTT: Signature: Date:

CONDITIONAL:

Reason for Conditional:

Signature: Date:

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

Case Summary signed off: Date:

<u>Student's Case History:</u>

1. Source of History:

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

3. Present Illness:

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

4. Other Complaints:

5. Past Medical History:

General Health Status

Childhood Illnesses

Adult Illnesses

Psychiatric Illnesses

Accidents/Injuries

Surgery
Hospitalizations

6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication
Analgesics/week:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

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

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

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 F

CHIROPRACTIC PROGRAMME

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

PHYSICAL EXAMINATION: SENIOR

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

Student: **Signature:**

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

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

SYSTEM SPECIFIC EXAMINATION:

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

Clinician: **Signature:**

Appendix G

THORACIC SPINE REGIONAL EXAMINATION

Patient: ______________________ File: __________ Date: ______________

Student: ______________________ Signature: ______________________

Clinician: ______________________ Signature: ______________________

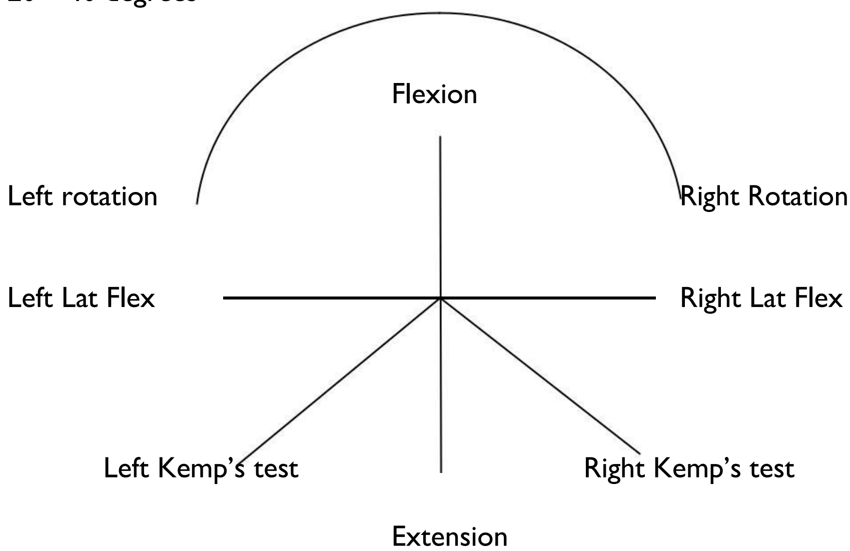
STANDING:

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

Scars
Chest deformity
(pigeon, funnel, barrel)

RANGE OF MOTION:

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



RESISTED ISOMETRIC MOVEMENTS: (in neutral)

Forward Flexion
L/R Rotation

Extension
L/R Lateral Flexion

SEATED:

Palpate Auxillary Lymph Nodes
Palpate Ant/Post Chest Wall
Costo vertebral Expansion (3 – 7cm diff. at 4_{th} intercostal space)
Slump Test (Dural Stretch Test): LOCAL PAIN (T/S) DISTAL PAIN (L/S) DISTAL PAIN (LEG)

SUPINE:

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

SLR
Palpate abdomen

PRONE:

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

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

COMMENTS:____

NEUROLOGICAL EXAMINATION:

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

Basic LOWER LIMB neuro:

Myotomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Dermatomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Reflexes	Patella – Left					Achilles – Left				
	Patella - Right					Achilles – Right				

MOTION PALPATION:

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

BASIC EXAM	History	ROM	Neuro/Ortho
LUMBAR			
CERVICAL			

Appendix H

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

REGIONAL EXAMINATION
LUMBAR SPINE AND PELVIS

Patient: ______________________ File#: ____________ Date: __________

Student: ______________________ Clinician: ______________________

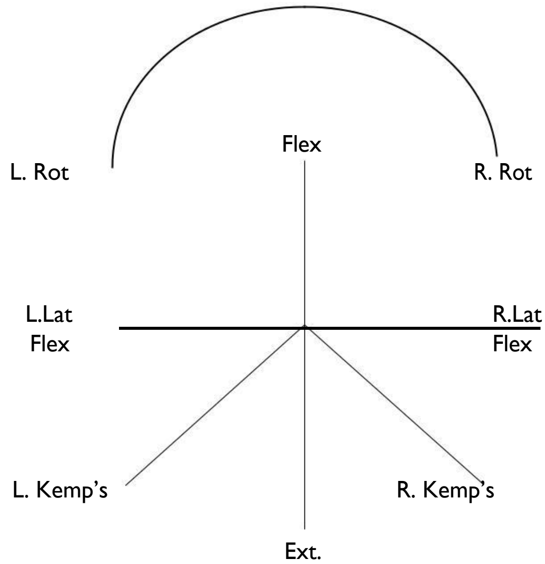
STANDING:

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

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

GAIT:

Normal walking
Toe walking
Heel Walking
Half squat



ROM:

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

Which movement reproduces the pain or is the worst?

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

SUPINE:

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

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

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

SITTING:

Spinous Percussion
Lhermitte

Valsalva

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

SLUMP 7 TEST	**L**										
	R										

LATERAL RECUMBENT:	**L**	**R**
Ober's		
Femoral n. stretch		
SI Compression		

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

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

NON ORGANIC SIGNS:

Pin point pain
Trunk rotation
Flip Test
Ankle dorsiflexion test

Axial compression
Burn's Bench test
Hoover's test
Repeat Pin point test

NEUROLOGICAL EXAMINATION

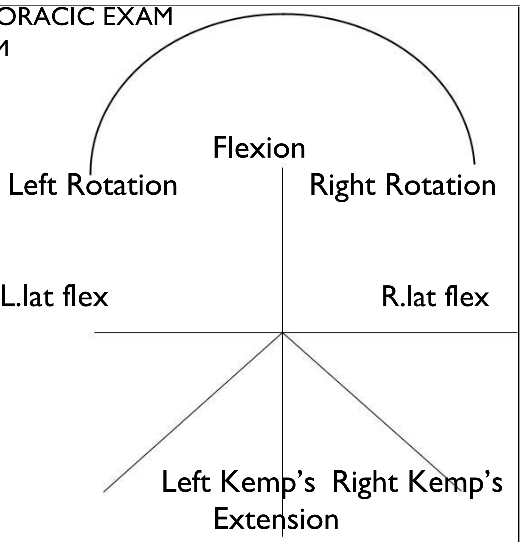
Fasciculations
Plantar reflex

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

MYOTOMES

Action	Muscles	Levels	L	R	
Lateral Flexion spine	Muscle QL				
Hip flexion	Psoas, Rectus femoris				5+ Full strength
Hip extension	Hamstring, glutes				4+ Weakness
Hip internal rotation	Glutmed, min, TFL, adductors				3+ Weak against grav
Hip external rotation	Gluteus max, Piriformis				2+ Weak w\o gravity
Hip abduction	TFL, Glut med and minimus				1+ Fascic w\o gross movt
Hip adduction	Adductors				0 No movement
Knee flexion	Hamstring,				
Knee extension	Quad				W - wasting
Ankle plantarflexion	Gastrocnemius, soleus				
Ankle dorsiflexion	Tibialis anterior				
Inversion	Tibialis anterior				
Eversion	Peroneus longus				
Great toe extensor	EHL				

BASIC THORACIC EXAM
Passive ROM



History :

Orthopedic assessment:

BASIC HIP EXAM

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

B) Supine (hip flexed):
- Trochanteric bursa

MOTION PALPATION AND JOINT PLAY	L	R
Thoracic Spine		
Lumbar Spine		
Sacroiliac Joint		

Appendix I:

To Whom It May Concern

I, Dr Michael Wiggett, am willing to assist Michael Robson with his research in terms of offsite supervision for his data collection.

Please contact me if you need anything else.

--

Yours in Health,

Michael Wiggett

Appendix J:

KWA-ZULU NATAL BASEBALL ASSOCIATION

E-mail: kznsealsbaseball@saol.com

3 July 2017

TO WHOM IT MAY CONCERN:

This serves to confirm that Michael Robson has approached the Association to perform and conduct research on Baseball Players for his Master's Thesis. We hereby grant permission to approach, interact and conduct the research with our Members accordingly.

Yours faithfully

[redacted]

Fritz Ackermann
President
082 775 0506

Appendix K

MEMORANDUM

To : Prof Ross
Chair : RHDC

Prof Adam
Chair : IREC

From : Dr Charmaine Korporaal
Clinic Director : Chiropractic Day Clinic

Date : 03.08.2017

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

---

Permission is hereby granted to :

Mr Michael Robson (Student Number: 21202901)

Research title : "The immediate effect of sham laser and three different spinal manipulative protocols on the throwing speed of baseball players in the Kwa-Zulu Natal Baseball Union".

Mr Robson, 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.

Thank you for your time.

Kind regards

Dr Charmaine Korporaal

Clinic Director : Chiropractic Day Clinic : Chiropractic and Somatology

Cc: Mrs Pat van den Berg : Chiropractic Day Clinic

Dr L O'Connor : Research co-ordinator

Dr. G. Haswell: Research supervisor

Appendix L

Throwing speed pre and post manipulation

GA	1	2	3	4	5	6	Δ	GB	1	2	3	4	5	6	Δ
1								**1**							
2								**2**							
3								**3**							
4								**4**							
5								**5**							
6								**6**							
7								**7**							
8								**8**							
9								**9**							
10								**10**							
GC	1	2	3	4	5	6	Δ	GD	1	2	3	4	5	6	Δ
1								**1**							
2								**2**							
3								**3**							
4								**4**							
5								**5**							
6								**6**							
7								**7**							
8								**8**							
9								**9**							
10								**10**							

APPENDIX M

Range of Motion Table

Participant	Thoracic FF	POST	Thoracic LLAT	POST	Thoracic RLAT	POST	Lumbar FF	POST	Lumbar LLAT	POST	Lumbar RLAT	POST
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
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40												

Appendix N:

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

8 November 2017

IREC Reference Number: **REC 92/17**

Mr M Robson
[redacted]

Dear Mr Robson

The immediate effect of sham laser and three different spinal manipulative protocols on the throwing speed of baseball players in the Kwa-Zulu Natal Baseball Union

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

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 Standard Operating Procedures (SOP's).

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

Yours Sincerely,

[redacted]

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY
2017 -11- 08
INSITUTUTIONAL RESEARCH ETHICS COMMITTEE
P O BOX 1334 DURBAN 4000 SOUTH AFRICA