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.

By

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Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic

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I, Kanwal Deep Sood, do declare that this dissertation is representative of my own work in both conception and execution.

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DEDICATION

I would like to dedicate this dissertation to my parents, Neena and Jimmy Sood, for their tremendous love and support throughout my life. They have worked extremely hard over the years and have always wanted the best for me, and I hope this humble dissertation fills them with pride.

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ABSTRACT

Objectives:

To compare trunk flexion and lateral flexion range of motion (ROM) pre-post intervention.

To compare the bowling speed of Action Cricket fast bowlers pre-post intervention.

To determine the correlation between change in bowling speed immediately post-intervention to change in trunk flexion and lateral flexion ROM immediately post-intervention.

To determine the association between change in bowling speed immediately post-intervention and the subjects' perception of change in bowling speed.

Methods:

Forty asymptomatic Action Cricket fast bowlers were divided into four groups of ten each. Group 1 received lumbar spine manipulation, Group 2 received thoracic spine manipulation, Group 3 received combined thoracic and lumbar spine manipulation and Group 4 received the sham laser intervention (placebo). Pre- and post-intervention trunk flexion and lateral flexion ROM and bowling speed were measured using a digital inclinometer and a SpeedTrac™ Speed Sport Radar. The subjects' perception of a change in bowling speed post-intervention was also recorded. SPSS version 15.0 was used to analyse the data. Two-tailed tests were used in all cases.

Results:

Trunk flexion and lateral flexion increased significantly ($p < 0.05$) post-spinal manipulation. There was a significant increase in bowling speed post-thoracic ($p = 0.042$) and post-combined manipulation ($p < 0.000$). A significant yet weak positive correlation ($p = 0.003$; $r = 0.451$) was seen in change in bowling speed and change in thoracic flexion and lateral flexion. There was no significant difference in the percentage subjective change by intervention group ($p = 0.217$).

Conclusions:

Spinal manipulation is a valid intervention for short-term increase in bowling speed.

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LIST OF ABBREVIATIONS

ADAS-cog:	Assessment Scale-cognitive subscale
AHR:	Antiseptic hand rub
AMA:	American Medical Association
ANOVA:	Analysis of variance
AP:	Anteroposterior
B:	Blacks
BMI:	Body mass index
BROM:	Back Range of Motion
C:	Coloureds
CG:	Control group
CI:	Confidence interval
cm:	Centimeters
df:	Degrees of freedom
Ed:	Editor
Extn:	Extension
Flxn:	Flexion
I:	Indians
IAPs:	Inferior articular processes
ICC:	International Cricket Council
kg:	Kilograms
L:	Left
L1-L5	Lumbar vertebra with corresponding number
LBP:	Low back pain
LCD:	Liquid crystal display
LflexA:	Lumbar flexion after intervention
LflexB:	Lumbar flexion before intervention
Lflx:	Lateral flexion
LLflxA:	Lumbar lateral flexion after intervention
LLflxB:	Lumbar lateral flexion before intervention
m:	Meters
MMSF:	Manitoba Medical Services Foundation

N.M:	Not Measured
N/A:	Not Available
***n*:**	Sample size
PC:	Pearson's correlation
R:	Right
ROM:	Range of Motion
Rotn:	Rotation
Rx:	Treatments or interventions
SAPs:	Superior articular processes
SD:	Standard deviation
SI:	Sacroiliac
SMT:	Spinal manipulation
SPs:	Spinous processes
T1-T12	Thoracic vertebra with corresponding number
TflexA:	Thoracic flexion before intervention
TflexB:	Thoracic flexion after intervention
TLflxA:	Thoracic lateral flexion after intervention
TLflxB:	Thoracic lateral flexion before intervention
TVP:	Transverse process
TVPs	Transverse processes
viz.:	Namely
vs.:	Versus
W:	Whites

LIST OF DEFINITIONS

Kinematic Chain: A link between rigid body segments (Zatsiorsky, 2002).

Trunk: The part of the body excluding the head and limbs (therefore, the bony anatomy of the trunk includes the thoracic and lumbar spine) Moore and Dalley (2005).

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

Traditionally, it was thought that the primary throwing force was generated by the shoulder complex. Recent literature, however, indicates that in the throwing athlete, the force generated primarily by the shoulder complex is not adequate for maximal ball propulsion. The current view is that the shoulder acts as a funnel and functions as a regulator of the throwing force that is generated in other areas of the body (Burkhart *et al.*, 2003). Many authors now believe that the trunk plays an instrumental role in generating this throwing force (Davis and Blanksby, 1976; Tyson, 1976; Elliott *et al.*, 1986; Elliott and Foster, 1989; Young *et al.*, 1996; Burkhart *et al.*, 2003). The mobility or lack thereof of the trunk contributes to the throwing/bowling force and thus the ball release speed. The trunk is composed of primarily the thoracic and lumbar spines and surrounding musculature (Moore and Dalley, 2005; Williams *et al.*, 2005). Currently, the contribution of each of the two spinal areas of the trunk to overall trunk mobility and its impact on ball release (bowling) speed is not yet fully understood. To address improving trunk mobility, this study focused on spinal manipulation as this has been shown to be a safe and effective way of increasing spinal joint mobility and thus improving trunk flexibility (Herzog *et al.*, 1988; Gal *et al.*, 1994; Herzog, 2000; Gatterman *et al.*, 2001; Gatterman, 2003).

1.2 AIMS AND OBJECTIVES OF THE STUDY

The primary aims of this study were:

- To determine the immediate effect of lumbar spine, thoracic spine, combined lumbar and thoracic spine manipulation, and sham laser intervention on flexion and lateral flexion range of motion (ROM) of the trunk and bowling speed of Action Cricket fast bowlers (n = 40).

- To determine the association between change in bowling speed pre- post-intervention and the subjects' perception of change in bowling speed.

Several specific objectives were identified and these included:

1.2.1 To determine and describe the physical characteristics and demographic profile of the subjects (*n* = 40) who participated in the study.

1.2.2 To compare trunk flexion ROM before the intervention to trunk flexion ROM immediately after the intervention.

1.2.3 To compare trunk lateral flexion ROM before the intervention to trunk lateral flexion ROM immediately after the intervention.

1.2.4 To compare the bowling speed before the intervention to bowling speed immediately after the intervention.

1.2.5 To determine the correlation between change in bowling speed immediately post-intervention and change in trunk flexion and lateral flexion ROM immediately post-intervention.

1.2.6 To determine the association between change in bowling speeds immediately post-intervention and the subjects' (*n* = 40) perception of change in bowling speed (post-intervention).

1.3 HYPOTHESES OF THE STUDY

For objectives **1.2.2** and **1.2.3**, with respect to spinal manipulation, Alternate Hypotheses (H_a) were set based on the work of Herzog *et al.* (1988), Gal *et al.* (1994), Jansen (1995), Kretzmann (1995), Myburgh (1998), Kruger (1999), Broughton (2000), Herzog (2000), Schiller (2001), Gatterman *et al.* (2001), Dimopoulos (2002), Gatterman (2003). These stated that there would be a significant difference in:

- Thoracic flexion and lateral flexion ROM immediately following thoracic spine manipulation.
- Lumbar flexion and lateral flexion ROM immediately following lumbar spine manipulation.
- Thoracic and lumbar flexion and lateral flexion ROM immediately following combined thoracic and lumbar spine manipulation.

With respect to the sham laser intervention, the Null Hypotheses (H_o) were, however, set viz. that there would be no significant difference in:

- Thoracic flexion and lateral flexion ROM immediately following the sham laser intervention.
- Lumbar flexion and lateral flexion ROM immediately following the sham laser intervention.

For objectives **1.2.4** and **1.2.5**, the Null Hypotheses (H_o) were set viz.:

- There would be no significant immediate increase in bowling speed post-intervention.
- There would be no significant correlation between change in bowling speed immediately post-intervention and change in trunk flexion and lateral flexion ROM.

For objective **1.2.6**, with respect to spinal manipulation, the Alternate Hypothesis (H_a) was set, based on the work of Maigne and Vautravers (2003), which stated that there would be a significant association between change in bowling speed immediately post-thoracic, post-lumbar and post-combined thoracic and lumbar spine manipulation, and the subjects' perception of change in bowling speed.

With respect to the sham laser intervention, the Null Hypothesis (H_o) was, however, set viz. that there would be no significant association between change in bowling speeds immediately post-intervention and the subjects' perception of change in bowling speed.

1.4 SCOPE OF THE STUDY

The results of 40 apparently healthy, asymptomatic Action Cricket fast bowlers, who met all the inclusion criteria of the study, are reported in this dissertation. The subjects were divided into four groups of ten each. Group 1 received the lumbar spine manipulation, Group 2 received the thoracic spine manipulation, Group 3 received the combined thoracic and lumbar spine manipulation and Group 4 received the sham laser intervention. Baseline testing included trunk flexion and lateral flexion ROM and bowling speed measurements. These measurements were repeated immediately post-intervention. The subjects' perception of a change in bowling speed post-intervention was also recorded.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In the kinematic chain of the throwing athlete, the ground, legs, and trunk function as the generators of the force, the shoulder functions as a funnel which regulates the force, and the actual force delivery mechanism is the arm. The throwing force generating capability of the shoulder in itself is not large. In other words, for the shoulder segment to function properly in these athletes, contributions are required from other body segments to generate the necessary forces for ball propulsion as well as to transfer the forces to more distal segments (Burkhart *et al.*, 2003).

2.2 AN OVERVIEW OF THE GAME OF CRICKET

2.2.1 Description

Cricket is a sport contested by two teams composed of 11 players each that is usually played on a large, flat, oval grass field **(Figure 2.1)**. At the centre of the field lies the pitch, which is a flat strip of ground approximately 20 meters in length **(Figure 2.2)**. At either end of the pitch are three wooden stakes which are impaled in the ground parallel to each other **(Figure 2.2)**. Two small cross pieces of wood called bails are placed across the top of the wooden stakes. The three wooden stakes and the bails are collectively called the wickets (Marylebone Cricket Club, 1990). At any given time in a cricket match there are two batsmen from one team (the batting team) on the pitch and 11 players from the opposing team (the fielding team) on the field. Designated players from the fielding side, called bowlers, are assigned the task of hurling (bowling) a hard leather-covered ball at a batsman. Each bowler has six consecutive attempts at bowling a cricket ball at the batsman. This constitutes one over in the game. The aim of the batsman is to:

- Prevent the ball from hitting the wickets that he is defending.
- Striking the ball in such a manner that it is not caught before bouncing on the field by any fielder including the bowler.

- Strike the ball away from the fielders and then run the length of the pitch. A single run across the length of the pitch by both batsmen constitutes one run. A batsman may be run-out if:
  - A fielder hits the wickets with ball in hand before the batsman reaches that end of the pitch (the crease).
  - A ball thrown by a fielder which hits the wickets before the batsman reaches that end of the pitch (the crease).
- Strike the ball in such a manner that it rolls over the boundary of the field (this constitutes four runs) or crosses the boundary without bouncing on the field (this constitutes six runs).

A new over commences when the bowler has had six consecutive legitimate attempts at the batsman and then the next bowler resumes bowling from the other end of the pitch. The aim of the bowler is to get the batsman out by:

- Bowling the ball in such a manner that the ball either strikes the wickets directly (i.e. the batsman misses the ball) or off the batsman's bat/body or the batsman hits the ball which is caught by a fielder before it strikes the ground.

The position of the fielders may vary considerably in any given game and can change during the game except once the bowler has commenced his run-up. When a batsman is out, he is then replaced by the next batsman in the team's line-up. Once ten batsmen are out, it brings to an end a single innings of the batting side. The total runs accrued by all batsmen in the team constitute the score for that innings. The fielding side now becomes the batting side and vice-versa and the team who has scored the most runs at the end wins the match (Marylebone Cricket Club, 1990).

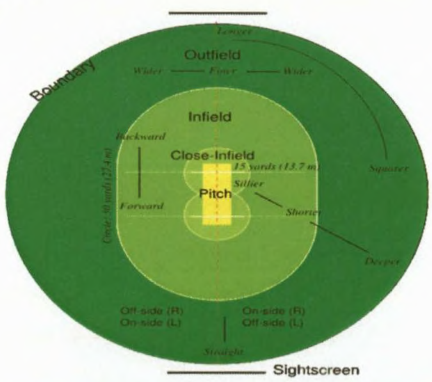

Figure 2.1 Schematic diagram of a cricket field
From www.dangermouse.net/cricket/field.html

Figure 2.2 A typical cricket pitch
From www.dangermouse.net/cricket/field.html

2.2.2 Forms of Cricket

Test Cricket

This is usually considered as the ultimate form of cricket and is played over a maximum of five days and consists of two innings per side. A test match may be drawn (i.e. the game is a draw) if the match is not completed within the five days (www.icc-cricket.com).

One-Day or Limited Overs Cricket

These are matches that take place over a single day. Each side has one innings only and a maximum of 50 overs per innings. Variations of this form of cricket include the "day-night" game (www.icc-cricket.com).

Twenty20 or Pro20 Cricket

This is the latest form of cricket and can be considered a variation of the limited overs format. Each side has one innings only and a maximum of 20 overs per innings. Matches typically last about three to four hours (www.icc-cricket.com).

Action or Indoor Cricket

This form of cricket is played between two teams of eight players each in an indoor arena and can be considered as a modified indoor limited overs match. The majority of individuals who play Action Cricket are between the ages of 18-26 (Thomas, 2007). Thick protective netting material comprises the "walls" of the arena. Each innings consists of 16 overs, with each player having to bowl two overs and bat in a partnership of four overs. The indoor playing area is completely enclosed by tight netting a few meters from each side of the indoor pitch (which is the same length as a conventional cricket pitch). Other differences from conventional cricket include 1) artificial grass matting is the preferred playing surface, 2) a modified cricket ball with a softer centre is used and 3) The scoring and other rules may differ e.g. a batsman may be given out if a fielder has caught the ball after it has bounced once off the wall (www.indoorcricketworld.com).

2.3 BOWLING IN CRICKET

2.3.1 Stages of the Bowling Action

The Run-Up:

The bowler's run up **(Figure 2.3)** commences when he walks or jogs over to his marker and continues as he approaches the wicket, gradually increasing his speed. The end of the run-up is marked by the beginning of the pre-delivery stride as the bowler jumps into the air in preparation for the back foot strike. Run-up length may vary considerably between bowlers as there is no consensus as to its ideal length (Bartlett *et al.,* 1996) even though Elliott and Foster (1989) had earlier suggested that it should be between 15 and 30 m.

The Pre-Delivery Stride:

This stage separates the run-up from the delivery stride. In a right-handed bowler, it commences as he jumps off the left foot and ends as he lands on the right or back foot (Marylebone Cricket Club, 1976). The bowler engages in this stride with the shoulders pointing down the wicket and with the right foot passing in front of the left foot and then turning to land parallel to the bowling crease. In a side-on bowler the pre-delivery stride **(Figure 2.3)** is long enough to allow sufficient time for the bowler's feet to cross in preparation for the right foot to land in a side-on position. A front-on bowler, however, does not need to achieve this side-on foot position and therefore, no major changes to his stride length are necessary.

Delivery Stride:

This stage follows the pre-delivery stride and consists of three sub-stages viz. back foot strike, front foot strike and ball release (Marylebone Cricket Club, 1976; Bartlett *et al.,* 1996).

Back foot strike signals the start of the delivery stride **(Figure 2.3)** and at this stage the bowler's weight is on the back (right) foot that he had just landed on, with his body leaning away from the batsman. The type of action used by each bowler determines the degree of trunk lean away from the batsman and since this results from lateral flexion of the spine, there is a greater degree of trunk lean in side-on bowlers. Bartlett and Best (1988) suggested that this probably served to increase the path of acceleration of the ball.

With the continuation of the delivery stride, front foot strike occurs when the front (left) foot strikes the ground **(Figure 2.3)**. The cricket ball is delivered (bowled) immediately thereafter. Law 26 (Marylebone Cricket Club, 1976) states that the ball is deemed to be thrown if either umpire considers that any part of the process of straightening the bowling arm took place during that portion of the delivery swing which directly precedes the ball leaving the hand. Therefore, the action of the bowling arm is limited to circumduction of the upper arm about the glenohumeral joint and flexion and extension of the wrist and finger joints (Marylebone Cricket Club, 1976; Bartlett *et al.,* 1996).

Follow-Through:

This is the final stage of the bowling action **(Figure 2.3)**. Little data is available on this stage as most analyses on the bowling action stop shortly after ball release (Bartlett *et al.,* 1996). Elliott and Foster (1989) suggested that the right-handed bowler should ideally make sure that his bowling arm follows-through down the outside of his left thigh, nearly brushing the ground and allowing a gradual reduction in his speed. The right-handed bowler moves towards the left and carries on jogging for a few paces down the pitch as he slows down, coming to a halt almost halfway down the pitch (Marshall, 1994). The bowling action of Action Cricketers is no different to that of conventional cricket bowlers.

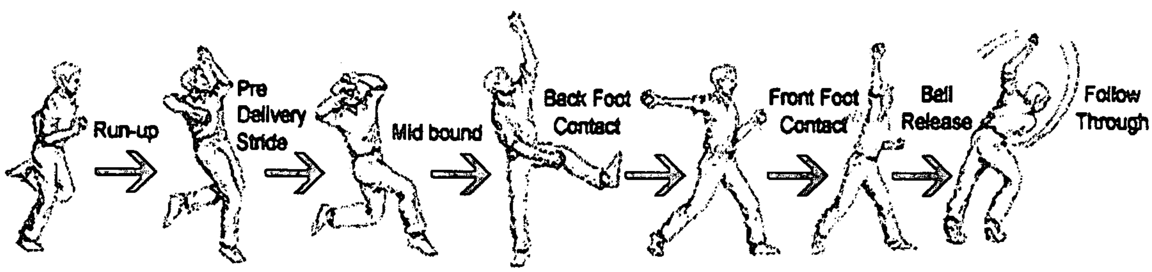

Figure 2.3 The typical fast bowling action
http://en.wikipedia.org/wiki/Bowling_action

2.3.2 Types of Bowling Action

Three basic bowling techniques have been identified by various authors (Elliott and Foster, 1989; Foster *et al.*, 1989; Elliott *et al.*, 1992; Stockill and Bartlett, 1992; Bartlett *et al.*, 1996) viz. the side-on, front-on and mixed techniques. It is almost impossible to isolate the boundaries between these techniques (Bartlett *et al.*, 1996).

The side-on technique has commonly been described as the most correct and effective bowling technique (Bartlett *et al.*, 1996). A bowler using this technique typically starts off with a relatively low run-up speed at the start of his delivery stride, assumes a rear foot position that is parallel to the popping crease and at rear foot strike points his shoulders straight down the wicket. Thus, the angle between the wickets and the line joining his shoulders is approximately 180°.

A fast bowler who adopts the front-on technique typically has a relatively higher run-up speed, assumes a rear foot position that points straight down the wicket towards the direction the ball travels and has a more open-chested position at rear foot strike with his shoulders at an angle comfortably greater than 180° (Bartlett *et al.*, 1996).

The mixed technique is a mixture of the two techniques described above. A bowler utilising this technique adopts a front-on foot and shoulder orientation at back foot strike, and then realigns his shoulders to a more side-on position during his delivery stride (Bartlett *et al.*, 1996).

2.3.3 Bowling Speed and Types of Bowling

Although outdoor cricket bowlers are usually classified as being slow, medium, medium-fast, fast-medium, and fast (www.stats.cricinfo.com), there are no definite speed boundaries that exist between these classifications. Despite this, it is generally accepted that a slow bowler bowls between 70-85 $km.h^{-1}$, a medium-pace bowler bowls between 86-113 $km.h^{-1}$, a medium-fast bowler bowls between 114-129 $km.h^{-1}$, a fast-medium bowler bowls between 130-145 $km.h^{-1}$, and a fast bowler bowls above 145 $km.h^{-1}$. These values may not apply to Action Cricket bowlers as there are differences in the run-up length, the playing surface and ball used (www.indoorcricketworld.com). Thus, a fast bowler in Action Cricket may bowl between 85-125 $km.h^{-1}$ or greater (Thomas, 2007).

There are a number of different types of balls that medium to fast bowlers bowl to try to get batsmen out (Chappell, 1975) e.g. inswingers and outswingers. An inswinger swings into the batsman after bouncing and an outswinger swings away from the batsman after bouncing. Bowlers often try to bowl a ball that pitches over a full length, the yorker, almost landing under the batsman's bat which makes it difficult for the batsman to negotiate the ball and often results in him being bowled. A bouncer is a ball that is bowled short so that it bounces steeply and is often aimed towards the batsman's head or midriff. The slower ball is also often used by fast bowlers. The ball bowled is slower than those normally bowled by the bowler and it is this disguised change in pace often fools the batsman. Lastly, bowlers can bowl a ball in such a way that it turns off the pitch, the so-called cutter (Chappell, 1975).

Spin bowlers, who use wrist or finger motion to impart rotation to the ball before release, fall under the category of slow bowlers (Chappell, 1975). The aim is for the ball to bounce and then deviate off the pitch before it reaches the batsman, thus making it difficult for the batsman to play the ball.

2.4 AN OVERVIEW OF THE BONY ANATOMY OF THE THORACIC AND LUMBAR SPINES AND THEIR ROM

2.4.1 Thoracic Spine

The kyphotic thoracic spine commences immediately after the cervical spine and ends at the thoracolumbar area just before L1 with a total composition of 12 thoracic vertebrae **(Figure 2.4)**. A typical thoracic vertebra has a body, two transverse costal (rib) facets, two inferior and two superior costal facets, a vertebral foramen, two transverse processes (TVPs), articular processes and a spinous process (SP) (Williams *et al.*, 2005). An atypical thoracic vertebra has a long, almost horizontal SP that is very prominent. It also has tubercles similar to the mamillary and accessory processes of a typical lumbar vertebra (Moore and Dalley, 2005).

Although the lateral/transverse costal facets are found on the TVPs, they are usually absent in the latter two or three TVPs. The costocapitular facets articulate with the heads of the ribs, while the costotubercular facets articulate with the tubercles of the ribs (Williams *et al.*, 2005). All thoracic vertebrae are classified as typical vertebrae with the exception of the first thoracic vertebra (T1) and T9-T12 which are known as atypical vertebrae (Moore and Dalley, 2005).

The typical body of a thoracic vertebra is heart-shaped and is almost in the form of a waisted cylinder except where the vertebral foramen commences. The anteroposterior (AP) and transverse dimensions of the body are almost equal. Two costal facets are located on either side of the body with one pair at the superior border and one pair at the inferior border. The superior pair lies anterior to the pedicles and is usually larger, while the inferior pair lies anterior to the vertebral notches and is usually smaller. The vertebral foramen of a typical thoracic vertebra is small and circular and the laminae are thick, short, broad and overlap superiorly to inferiorly. The spinous processes (SPs) are long, slender and are angled inferiorly from T5-T8 (Williams *et al.*, 2005). The TVPs, which project from the pediculolaminar junctions in a posterolateral direction, shorten as one moves down the thoracic spine. An anterior oval facet that articulates with the tubercle of the corresponding rib is found on the tip of each of these TVPs (Moore and Dalley, 2005).

Projecting from the pediculolaminar junctions are the thin and nearly flat superior articular processes (SAPs) which face posteriorly and slightly superolaterally. The inferior articular processes (IAPs) project anteriorly and slightly superomedially. The facet joints of the thoracic spine lie principally in the coronal plane allowing for a mainly rotational movement of the thoracic spine (Williams *et al.*, 2005). At T11 the articular processes change in orientation from the thoracic to the lumbar type (the so-called transitional vertebra), but this can also occur at T10 or T12. The SAPs in the transitional vertebra face posterolaterally, with the IAPs transversely convex and directed anterolaterally (Moore and Dalley, 2005).

The transitional vertebra is the area where mobility suddenly changes from a mainly rotational movement to predominantly flexion and extension.

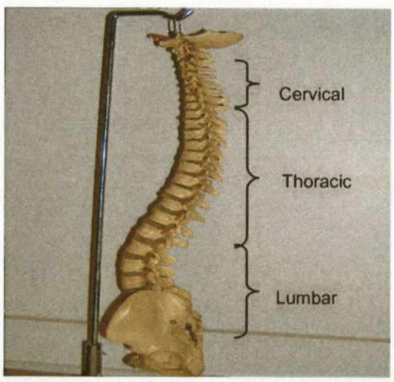

Figure 2.4 Model of the entire spine and pelvic bones

Table 2.1 Thoracic ROM values in asymptomatic individuals

Reference	Flexion (°)	Extension (°)	Lateral flexion (°)	Rotation (°)
Magee, 2002	20-45	25-45	20-40	35-50
Gerhardt *et al.*, 2002	50	N/A	N/A	30
Rothman and Thiel, 2005	45	N/A	N/A	40

N/A = Not available

The range of the normal values for thoracic ROM is provided by Magee (2002) **(Table 2.1)**. The major ROM in the thoracic region is rotation. The maximum thoracic flexion and rotation values reported by Rothman and Thiel (2005) lie within the range of Magee (2002) **(Table 2.1)**. The American Medical Association (AMA) norm (Gerhardt *et al.*, 2002) for maximum thoracic flexion is higher than those of Magee (2002) and Rothman Thiel (2005) **(Table 2.1)**. Therefore, these reports do indicate that there are slight differences in the norm reference values for thoracic ROM.

2.4.2 Lumbar Spine

This lordotic region of the spine commences immediately after the thoracic spine and ends just before the sacrum **(Figure 2.4)**. Typically, there are five lumbar vertebrae (L1-L5) which are all large in size and without any transverse foramina or costal facets (Moore and Dalley, 2005). The bodies are deeper in front and wider transversely than the thoracic bodies, while the vertebral foramens are triangular in shape and larger than those of the thoracic region. Variations occur in their coronal and sagittal dimensions, both between and within normal populations (Williams *et al.*, 2005). The SPs are short, quadrangular, thickened, and horizontally directed. Each superior articular process has a mamillary process on its posterior border and also has vertical concave articular facets that are posteromedially directed. Each inferior articular process has a vertical convex articular facet which is anterolaterally directed. In the superior three vertebrae, the SAPs are further apart than the inferior ones. The superior facets are concave and the inferior facets are convex, which allow for flexion, extension, lateral flexion, and little rotation motion in the lumbar spine. Pure lateral flexion of the lumbar spine does not occur; rather, joint coupling occurs with the result that some rotation of the vertebrae also occurs during lateral flexion (Williams *et al.*, 2005).

The TVPs are slender and long, projecting laterally and posterosuperiorly (except for L5 which incline superiorly and posterolaterally) (Moore and Dalley, 2005). Each TVP has a small accessory process on its posteroinferior aspect near its base. Each TVP increases in length from the first to the third vertebrae, and then shortens till the fifth. Short pedicles arise posterolaterally near the upper border of each body. The inferior vertebral notches are deep and the superior ones are shallow. The lumbar laminae, which are short and broad, do not overlap to the same degree as those of the thoracic spine (Williams *et al.*, 2005).

Table 2.2 Lumbar ROM values in asymptomatic individuals

Reference	Flexion (°)	Extension (°)	Lateral flexion (°)	Rotation (°)
Magee, 2002	40-60	20-35	15-20	3-18
Gerhardt *et al.*, 2002	60	25	25	N/A
Rothman and Thiel, 2005	60	30	30	N/A

N/A = Not available

The range of the normal values of lumbar ROM is provided by Magee (2002) **(Table 2.2)**. The major ROM in the lumbar spine is flexion, followed by extension and lateral flexion with little rotation occurring in this region. With respect to lumbar flexion ROM values, there is agreement by the three authors on the maximum value **(Table 2.2)**. The maximum value reported by Rothman and Thiel (2005) and AMA norms for lumbar extension (Gerhardt *et al.*, 2002) lies within the range of Magee (2002). With respect to lumbar lateral flexion, however, the maximum values of Rothman and Thiel (2005) and AMA norms (Gerhardt *et al.*, 2002) are higher than those of Magee (2002) **(Table 2.2)**. Therefore, as with the thoracic ROM values, these reports do indicate that there are slight differences amongst authors on the norm reference values for lumbar ROM.

2.5 BIOMECHANICS OF CRICKET BOWLING

2.5.1 The Baseball Pitching Action

Despite some differences between the bowling action of cricketers and baseball pitching, the basic biomechanical principles will apply with respect to the arm and trunk action. The typical baseball pitching motion for a right-handed individual has six distinct phases according to Dillman *et al.* (1993):

Wind-Up:

This phase refers to the initiation of the pitching motion. The right-handed pitcher's left knee is brought towards his chest, which raises his centre of gravity and this allows for maximising the potential to eventually impart speed to the ball. The throwing and non-throwing hands are together, with the non-throwing (left) shoulder and hip facing the pitcher's target or slightly turned towards the throwing arm side. The body weight is kept over the supporting (right) leg.

Stride-Phase:

During this phase lower extremity movement towards home plate is initiated, along with separation of the throwing and non-throwing hands (Glousman *et al.*, 1988). Chest rotation has not yet commenced, with the chest not facing home plate and the stride (left) leg moves towards home plate. The throwing arm is placed in a semi-cocked position when it moves upwards and then downwards as the shoulder begins to assume an externally rotated position. Thereafter, the stride foot makes contact with the ground, thus signalling the end of this phase.

Arm Cocking Phase:

This phase commences once stride foot contact occurs and the hips and trunk begin to rotate. The lordotic curvature of the lumbar spine is still maintained, with the shoulder achieving maximum external rotation in an abducted position allowing for impartation of maximal acceleration to the ball.

Arm Acceleration:

During this phase, the shoulder rapidly moves from external to internal rotation and trunk flexion begins with the upper torso now facing home plate. As the arm moves forward, elbow extension begins and the forearm begins to pronate. High valgus forces are placed upon the elbow at this time. This phase ends with the release of the ball.

Arm Deceleration:

During the final phase, eccentric contraction of the humeral external rotators and muscular stabilisers of the scapula occurs, and thus shoulder internal rotation continues with a decreased angular velocity. Trunk flexion occurs and the centre of gravity moves over the stride leg.

Follow Through:

This phase signals the completion of the pitching motion. The throwing arm is adducted and extension of the stride knee occurs.

2.5.2 The Role of the Thoracic and Lumbar Spines

Young *et al.* (1996) conducted a study to investigate the role of the spine during baseball pitching. They hypothesized that one cannot be restricted to evaluating the glenohumeral joint alone when analysing shoulder dysfunction in throwing athletes. The shoulder on its own is incapable of generating the force necessary to throw a baseball at speeds of 145-160km/h. The same principle could be applied to the bowling action of cricketers. The spine is an important component of the kinematic chain, transferring force from the lower to the upper limbs as well as functioning as a force generator capable of accelerating the arm. This idea was first mooted by Tyson (1976) and supported by Elliott and Foster (1989), who described how trunk flexion not only facilitates rotation of the bowling arm, but also contributes to the rhythm and fluidity of the bowling action. It has also been shown that trunk flexion contributes fairly significantly to the speed of the ball. Davis and Blanksby (1976) and Elliott *et al.* (1986) calculated that trunk flexion contributed 11% and 13% respectively to final ball release speed.

Once back foot and front foot strike occur in the fast bowling action, the ground reaction forces come into significance and these must be absorbed by the body and transferred to higher segments (Bartlett *et al.*, 1996). Several studies have documented the extent of these ground reaction forces (Elliott and Foster, 1984; Foster and Elliott, 1985; Elliott *et al.*, 1986; Foster *et al.*, 1989; Mason *et al.*, 1989; Saunders and Coleman, 1991; Elliott *et al.*, 1992; Elliott *et al.*, 1993). Despite the overall finding of peak vertical impact forces at front foot strike being 3.8-6.4 times the body weight, Mason *et al.* (1989) reported a mean peak vertical impact force approximately nine times the body weight. Anterior-posterior braking forces have been found to be around twice the body weight. Theoretically, upward transfer of the ground reaction force could be limited by reduced motion, abnormal curvature of the thoracic spine or thoracic facet injury (Young *et al.*, 1996).

The thoracic spine contributes to 80% 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). Rotation of the thoracic spine plays a significant role during the arm cocking phase early in the throwing (bowling) motion (Pappas *et al.*, 1985; Gowan *et al.*, 1987) since the coronal orientation of the facet joints in the thoracic spine allow for more rotation of the spine ensuring that the AP forces from the lumbar spine are converted to the rotatory forces (torque) necessary to accelerate the shoulder resulting in an accelerated throwing (bowling) motion (Young *et al.*, 1996).

Counter-clockwise rotation of the right handed pitcher's trunk in the arm cocking phase has been found to be important in preparing for forward acceleration of the throwing arm (Pappas *et al.*, 1985). Trunk rotation towards the dominant shoulder ('pre-rotation' of the trunk), could in theory, also add to the force of contraction of the external oblique muscle (McGill and Hoodless, 1990). By limiting movement in the thoracic spine, the ribs and costovertebral joints create a stable site which accepts forces from below. In the arm cocking phase, extension of the thoracic spine maximises shoulder external rotation relative to the erect body axis (Young *et al.*, 1996).

The thoracic spine has a further influence on glenohumeral motion and scapulothoracic position. In the throwing action, there is an initial lateral and upward rotation of the scapula (Young *et al.*, 1996). Thereafter, the scapula migrates around the thorax in between the arm cocking and deceleration phases. Approximately 15 cm of retraction/protraction and 65° of rotation/abduction needs to occur.

During the fast bowling action, the trunk leans away from the batsman when the back foot hits the ground (Bartlett *et al.*, 1996). This may serve to increase the acceleration path of the ball since Bartlett and Best (1988) observed a similar response in javelin throwers who utilised this technique. At front foot strike, trunk rotation occurs which aids in the rapid adduction and extension of the non-bowling arm (Bartlett *et al.*, 1996). This action of the non-bowling arm which occurs before and during trunk rotation, aids in the summation of segmental velocities (Burden, 1990). At back foot strike trunk flexion occurs allowing for the rotation of the bowling arm (Tyson 1976; Elliott and Foster, 1989).

During the throwing (bowling) motion, the lumbar spine provides a level foundation that remains stable. 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). Lateral flexion of the lumbar spine has an influence on shoulder movement. 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 (Atwater, 1979; Feltner, 1989). 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. During the overhead throwing motion or even during bowling, lateral flexion of the spine away from the pitching arm and trunk rotation serve as the main source of abduction force upon the humerus.

2.5.3 Factors Affecting Bowling Speed

Run-Up Speed

In a study conducted on 17 fast bowlers, Davis and Blanksby (1976) reported that the six quickest bowlers used a run-up that was 2.14 m longer than the six slowest bowlers. No explanation, however, was offered as to how this affected the run-up speed. Elliott and Foster (1989) suggested that the ideal run-up length should be between 15 and 30 m with emphasis on balance and rhythm during the run-up. They also stated that the run-up speed should be built up gradually with the maximum speed to be attained about three to four strides from the end. Davis and Blanksby (1976) were of the opinion that the run-up contributed significantly to the speed of the ball.

In the study by Brees (1989), seven college standard bowlers were asked to bowl as fast and as accurately as possible with three different run-up speeds (slow, fast, and normal). The results indicated that generally the quickest ball release speeds were associated with the fast run-ups. Despite this finding, it was noted that a bowler with a run-up speed that is too fast will find it difficult to comfortably convert to a side-on delivery action, whereas a considerably slow run-up will reduce the contribution of the linear velocity of the hip to the ball (Elliott *et al.*, 1986). Burden (1990), however, reported a finding contrary to that of Brees (1989) in a two-dimensional cinematographic study of 10 college bowlers. He found no relationship between each bowler's run up speed and the speed at which the ball was released. The debate on the impact of the run-up speed on bowling speed is, therefore, yet to be resolved.

Pre-Delivery Stride

In the study by Davis and Blanksby (1976), the pre-delivery stride was 0.42 m (22%) longer than the last run-up stride for the six quickest bowlers. For the six slowest bowlers, however, this difference was only 0.05 m (5%). The apparent need to decelerate in the final stride along with the need to gather momentum for the final thrust were reported as the reasons for this increase in stride length. If the bowler continued to accelerate then there would not be enough time to change from a front-on delivery position in the approach to a more side-on position resulting in an ineffective delivery technique (Davis and Blanksby, 1976).

Arm Position

Upper arm circumduction is usually initiated between back foot and front foot strikes (Bartlett *et al.*, 1996) during fast bowling. The elbow, which is close to the hip joint, is either in full extension or at least at a constant angle. The degree of arm circumduction depends not only on the arm position at front foot strike, but also on its position at ball release. It has been suggested by Tyson (1976) that the arm position as the front foot lands is a good determinant of ball release speed. The author also stated that the fastest bowlers delayed the initiation of upper arm circumduction for as long as they could although there is no scientific evidence that suggests this plays a role in ball release speed.

Davis and Blanksby (1976) reported that five of the six fastest bowlers released the ball with the arm in front of the line of the trunk. They argued that if the arm was behind the line of the trunk at ball release, no summation of segmental velocities would occur resulting in negation of most of the effective swing of the arm. Later studies, however, do not support this observation (Elliott *et al.*, 1986; Burden and Bartlett, 1989; Foster *et al.*, 1989; Burden, 1990). Elliott and Foster (1989) suggested that at ball release the arm would almost be in a vertical position is at odds with the earlier findings of Davis and Blanksby (1976).

Body Segments (Besides the Trunk)

From front foot strike to final ball release the body segments rotate in order to produce a maximum hand velocity, which allow for maximum ball release speed (Bartlett *et al.,* 1996). Mason *et al.* (1989) concluded that hip rotation occurred just after back foot strike but before front foot strike when the ball was at its lowest point in line with the hip. Elliott *et al.* (1986) reported that the shoulders move through approximately 86.5° of rotation and that the hips move through about 30.4° of rotation and that these movements of the shoulder and hips contributed 15% and 13% respectively to final ball release speed. Earlier, Elliott and Foster (1984) conducted a study using four test match bowlers and found that the shoulders went through a range of approximately 100° of rotation, a finding dissimilar to that of Elliott *et al.* (1986). This implied that the elite fast bowlers put more emphasis into shoulder movement in the delivery action thus utilising the greater shoulder ROM to produce a greater hand velocity resulting in a quicker ball release speed.

In terms of body segments that have been analysed in the bowling action, the wrist and fingers are the most distal joints to have been included in the analyses. They are the final segments in the bowling action that contribute to the ball release speed. Davis and Blanksby (1976) suggested that extending the wrist maximally and then rapidly flexing the fingers and wrist as fast as possible just before ball release would maximise the release speed. According to these authors, the fingers contributed about 5% to final ball release speed. Later, Elliott *et al.* (1986) found that the wrist flexed 7.0° (± 19.8°) to reach almost complete extension of 177° (± 30°). They reported that the wrist and fingers contributed 50% and 22% respectively to final ball release speed, a much higher figure than that proposed by Davis and Blanksby (1976). Elliott and Foster (1989) were sceptical of the role of wrist and finger flexion in increasing ball release speed since they felt that wrist movement in the fast bowling action is usually less than is sometimes recommended in coaching manuals. The available data on segmental contributions to ball release speed is therefore inconclusive according to Bartlett *et al.* (1996).

Type of bowling action

Elliott and Foster (1984) felt that using the side-on technique allowed for more effective summation of segmental velocities than the front-on technique due to the greater degree of shoulder rotation displayed by side-on bowlers. Later, Stockill and Bartlett (1992) investigated the relationship between ball release speed and the orientations of the back foot, hips, and shoulders along with the degree of counter-rotation of the trunk. No significant relationships were found and this suggests that, by itself, the type of bowling action used by each bowler does not contribute to ball release speed and that one cannot predict if a bowler will bowl faster using a particular bowling action.

2.6 SPINAL MANIPULATION

2.6.1 Introduction

Manipulation of the spine has been practiced since ancient times (Triano, 2001). It is known that Hippocrates, the father of medicine, had also practiced spinal manipulation as a means of treating back pain (Wiese and Callender, 2005). Spinal manipulation gained popularity in Europe during the 18th century and was practiced predominantly by manual therapists called bonesetters (Wilson and Keating Jr, 2007). In 1895, the first chiropractic manipulation or adjustment was performed by D.D. Palmer (Wilson and Keating Jr, 2007).

Gatterman (2003) describes spinal manipulation as the use a short lever, high-velocity thrust of controlled amplitude on spinal articulations with the aim of restoring mobility to the individual articulations. This results in improved flexibility and increased joint mobility (Herzog *et al.*, 1988; Gal *et al.*, 1994; Herzog, 2000; Gatterman *et al.*, 2001; Gatterman, 2003). A more recent description of manipulation by Vernon and Mrozek (2005) states that manipulation entails moving the spinal facet joints beyond the physiological ROM (but not anatomical ROM) using a fast low-amplitude thrust, often resulting in an audible click or pop, the so-called joint cavitation (Shekelle, 1994; Vernon and Mrozek, 2005).

Spinal manipulation has been shown to be a safe and effective manual therapeutic intervention in the treatment of mechanical low back pain (Hurwitz *et al.*, 1996; Koes *et al.*, 1996; Gatterman *et al.*, 2001).

2.6.2 Spinal Manipulation and ROM

A summary of the studies that have investigated the effect of spinal manipulation on lumbar and thoracic spine ROM is presented in **Table 2.3**.

Table 2.3 A summary of the studies on the effect of spinal manipulation on thoracic and/or lumbar spine ROM *

Reference	Sample	Intervention and Instrumentation	ROM (°) Results: First set of mean measurements	ROM (°) Results: Second set of mean measurements**
Jansen, 1995	30 subjects with LBP diagnosed with lumbar facet syndrome divided equally into 2 groups; age 15-65	EXPG - spinous push technique CG -lumbar roll technique 9 Rx over 4 weeks *BROMII*	**CG** Flexion: 34.8 Lflx: 34.0 Extn: 15.1 Rotn: 24.4 **EXPG** Flexion: 40.7 Lflx: 33.4 Extn: 15.8 Rotn: 22.0	**CG** Flexion: 37.6 Lflx: 37.4 Extn: 15.9 Rotn: 24.7 **EXPG** Flexion: 42.4 Lflx: 34.2 Extn: 16.7 Rotn: 24.4
Kretzmann, 1995	30 subjects with mechanical LBP were randomly divided equally into 2 groups; age N/A	EXPG - Combination of SMT and McManus traction CG - SMT only 9 Rx with one-month follow-up *Autogon 2 Goniometer*	**CG** Flexion: 113.6 Lflx: 17.3 Extn: 34.9 Rotn: N.M	**CG** Flexion: 115.1 Lflx: 18.7 Extn: 30.1 Rotn: N.M
Myburgh, 1998	30 subjects with LBP diagnosed with lumbar facet syndrome or SI syndrome were divided equally into 2 groups; age 15-65.	Group 1 - Lumbar SMT Group 2 - Lumbar mobilization 6 Rx over 2 weeks *BROMII*	**Group 1** Flexion: 22.2 Lflx: 23.8 Extn: 8.6 Rotn: 9.1	**Group1** Flexion: 28.8 Lflx: 26.6 Extn: 10.9 Rotn: 11.4
Kruger, 1999	30 subjects with mechanical LBP were randomly divided equally into 2 groups; age 19-49	EXPG – Lumbar or SI SMT CG – Placebo (Vacotron Unit) 3 Rx over 2 weeks *BROMII*	**EXPG** Flexion: 29.2 Lflx: 30.7 Extn: 8.4 Rotn: 48.4 **CG** Flexion: 32.3 Lflx: 24.8 Extn: 10.5 Rotn: 49.3	**EXPG** Flexion: 30.6 Lflx: 31.9 Extn: 11.9 Rotn: 53.6 **CG** Flexion: 30.5 Lflx: 26.6 Extn: 9.3 Rotn: 49.8
Broughton, 2000	60 subjects with mechanical LBP divided equally into 2 groups; age 15-65.	Group 1 – Lumbar SMT Group 2 – Lumbar SMT with back strapping 6 Rx over a 2-week period *BROM II*	**Group 1** Flexion: 24.2 Lflx: 21.7 Extn: 9.5 Rotn: 14.7	**Group 1** Flexion: 26.67 Lflx: 22.9 Extn: 11.23 Rotn: 16.7
Schiller, 2001	30 subjects with mechanical thoracic back pain divided equally into 2 groups; age 16-55.	EXPG – thoracic SMT CG – Placebo (Detuned ultrasound) 6 Rx over a period of 2-3 weeks *BROMII*	**EXPG** Flexion: 17.6 Lflx: 42.2 Extn: 12.0 Rotn: 37.1 **CG** Flexion: 19.5 Lflx: 45.5 Extn: 12.5 Rotn: 38.3	**EXPG** Flexion: 18.0 Lflx: 48.1 Extn: 13.3 Rotn: 43.0 **CG** Flexion: 18.3 Lflx: 41.8 Extn: 11.5 Rotn: 36.8
Dimopoulos, 2002	40 subjects with chronic thoracic spine dysfunction divided equally into 2 groups; age 18-45	Group 1 – Thoracic SMT Group 2 - Passive thoracic oscillatory mobilization 4 Rx and 1 follow-up consultation over a 2-week period; *Digital Inclinometer*	**Group 1** Flexion: 30.3 Lflx: 29.9 Extn: 25.5 Rotn: 29.0	**Group 1** Flexion: 32.6 Lflx: 31.3 Extn: 28.3 Rotn: 31.8

ROM = Range of motion; N/A = Not available; LBP = Low back pain; EXPG = Experimental group; CG = Control group; Rx = Treatment or intervention; Lflx = Lateral flexion; Extn = Extension; Rotn = Rotation; SMT = Spinal manipulation; NM = Not measured; SI = Sacroiliac
* Only studies which reported actual ROM values were included; ** The measurement intervals depended on the study protocol

The majority of the pre-spinal manipulation (i.e. baseline values) ROM values for the lumbar and thoracic spines **(Table 2.3)** lie below the values reported by Magee (2002), Rothman and Thiel (2005) and the AMA norms (Gerhardt *et al.*, 2002) **(Table 2.1)**. A possible explanation for this finding was these values were measured on symptomatic individuals. Individuals with mechanical back pain are known to exhibit decreased ROM due to pain (Kirkaldy-Willis and Bernard, 1999). The exception to this were the baseline values reported by Dimopoulos (2002) **(Table 2.3)**. Variability in the baseline ROM values is seen in the four lumbar and two thoracic spine studies **(Table 2.3)**. Tanz (1953), Allbrook (1957) and Moll and Wright (1971) had earlier reported that considerable individual variability exists with respect to the lumbar spine ROM. With the exception of Kretzmann (1995) and Dimopoulos (2002), all the other studies measured ROM with a Back Range of Motion device viz. the BROM II. Breum *et al.* (1995) found that while the BROM II was a reliable instrument for measuring lumbar mobility in asymptomatic individuals, its reliability in symptomatic patients still needed further investigation. Other factors that could account for the differences in baseline values would be variability in examiners locating bony landmarks and the non-routine use of measuring instruments in clinical practice (Mayer *et al.* 1995). Dimopoulos (2002) utilised a digital inclinometer to measure thoracic ROM values. Although no studies prior to Dimopoulos (2002) reported the use of this device to determine thoracic ROM, Ng *et al.* (2001) reported that it was reliable for measuring lumbar ROM. Earlier, in 1997, Mayer *et al.* reported that the inclinometer error was minimal.

Despite the fact that none of the studies measured ROM immediately post-manipulation, nearly all the ROM values increased when the second set of measurements were taken **(Table 2.3)**, supporting the view of Herzog *et al.* (1988), Gal *et al.* (1994), Herzog (2000) and Gatterman (2003). It is thought that joint mobility may be limited by the presence of entrapped synovial folds (Shekelle, 1994) or intra-articular adhesions (Indahl *et al.*, 1997) although there is no conclusive evidence that these actually cause pain (Maigne and Vautravers, 2003). Bogduk and Jull (1985) demonstrated that paraspinal muscle spasm was inhibited by joint capsule stretching during intra-articular saline injections. The articular capsule is stretched during spinal manipulation resulting in a decrease in paraspinal muscle spasm and this could partly explain the increase in ROM post-manipulation. On the other hand, the study of Lehman and McGill (2001) on the effect of spinal manipulation on trunk kinematics and associated trunk myoelectric activity showed dissimilar results. Flexion, lateral flexion, and rotation of the lumbar spine were measured immediately before and after spinal manipulation.

Their results indicated that five subjects showed significant increases in forward flexion (2.70°-12.42°), while six showed no change, and three subjects showed decreases (1.00°-6.80°) immediately following spinal manipulation. For rotation two subjects showed decreases (3.26°-4.24°) in one direction each, nine showed no change, and one showed an increase (4.36°) in one direction. Six subjects showed overall increases in lateral flexion (1.63°-6.11°), two subjects showed no change, and four showed decreases (2.42°-9.37°). With respect to post-placebo intervention ROM measurements, mixed results were reported by Kruger (1999) while Schiller (2001) reported a decrease in all thoracic ROM values **(Table 2.3)**. These findings support those of Rasmussen (1979), Postacchini *et al.* (1988), Wreje *et al.* (1992) and Conway *et al.* (1993) who reported that spinal manipulation is more effective than placebo.

2.7 THE HAWTHORNE AND PLACEBO EFFECTS

2.7.1 The Hawthorne Effect

According to Mouton and Marais (1994), the mere fact that human beings are aware that they are being studied leads to atypical behaviour known as the Hawthorne effect. Despite relatively few studies on the Hawthorne effect, it may be an important factor affecting the generalisability of clinical research to routine practice (McCarney *et al.*, 2007). Many patients appear to respond better to treatment than those in normal practice by virtue of their participation in a clinical trial (McCarney *et al.*, 2007). The Hawthorne effect was first observed in the 1920s and 1930s when Chicago's Western Electrical Company's Hawthorne Works conducted an extensive research programme investigating methods of increasing productivity (Roethlisberger and Dickson, 1939; Mayo, 1993). It was observed that no matter what changes were made to working conditions e.g. reduced or improved lighting in the production areas being tested, the result was increased productivity. Franke and Kaul (1978) defined this phenomenon as "an increase in worker productivity produced by the psychological stimulus of being singled out and made to feel important". This definition has subsequently been expanded to include subjects in clinical trials by referring to their treatment response rather than their productivity (McCarney *et al.*, 2007).

Even though it was first reported in industrial research, the Hawthorne effect may well have implications for clinical research (McCarney *et al.*, 2007). If there is a demonstrable benefit from participating in clinical research, then this has implications for better care-giving and for improving clinical practice (Braunholtz *et al.,* 2001; Peppercorn *et al.,* 2004). The Hawthorne effect is not controlled for by usual controlled trial designs, but is a component of the non-specific effects of trial participation (McCarney *et al.*, 2007). Since the Hawthorne effect has some defining features such as increased levels of clinical surveillance and extra attention by researchers which apply equally to treatment and control groups, most clinical trials are unable to properly quantify the magnitude of the Hawthorne Effect (McCarney *et al.*, 2007).

2.7.2 The Placebo Effect

The term 'placebo' is derived from the term "I shall please" (Wall and Wheeler, 1996). McConnell and Philipchalk (1992) describe it is a "harmless, unmedicated treatment used for its psychological effect, often as a comparison with other treatments". Therefore, the term "placebo" is usually used to refer to pharmacological compounds which are normally given to "please" patients rather than to directly benefit them with therapeutic effects. It is, however, often argued that something which pleases patients is likely to benefit them in some way as well (Grahame-Smith and Aronson, 1990). The placebo effect can be used to create "blind" trials in which the participants don't know whether they are getting the active treatment or not (Draper, 2002). In this way the physical effects can be measured independently of the participants' expectations. As with all treatments, the placebo effect also occurs with spinal manipulation. A feeling that a misaligned vertebra returning to its normal position, the audible cavitation, the manual contact (Maigne and Vautravers, 2003) and the explanation of the manipulation provided by the practitioners (Wilder *et al.*, 1988) all contribute to this effect.

2.7.3 Similarities and Differences between the Hawthorne and Placebo Effects

They both cause an effect when the material intervention has none and this is attributed to the psychological effects of the participants. Both effects are created by the participants' reactions and perceptions. The Hawthorne effect, however, brings out the participants' response to being studied, whereas the placebo effect brings out their response to new methods, equipment, etc. The participants' false belief in the material efficacy of the intervention is the main cause of their responses in the placebo effect whereas the participants' response to being studied and getting attention while participating is the main cause of their responses in the Hawthorne effect. In both effects the researcher may be deceiving the participants with regards to the intervention. Generally, this deception by the researcher of making the participants believe in the efficacy of the intervention plays a more important role in the placebo effect than the Hawthorne effect (Draper, 2002).

2.7.4 Studies That Have Investigated the Role of the Hawthorne and Placebo Effects

The recent studies that have investigated the role of the Hawthorne and Placebo effects are summarised in **Table 2.4**.

Table 2.4 A summary of the recent studies that have investigated the role of the Hawthorne and Placebo effects

Reference	Sample/Population	Investigation	Effect	Results
Walker and Mac Hannaford, 1995	744 patients enrolled in 10 studies, conducted at 42 centres in 7 countries	Randomized, double-blind, placebo-controlled trials which compared the efficacy of buflomedil on intermittent claudication	Placebo	Buflomedil was shown to be statistically superior to placebo.
Rogers and Friedhoff, 1996	161 patients with Alzheimer's disease participated in the study with 20 drop-outs	Donepezil *vs.* placebo	Placebo	Donepezil was superior to placebo.
De Amici *et al.*, 2000	108 patients undergoing knee arthroscopy were divided into 2 groups. Each group received different information about the study from the anaesthetist during the preoperative interview	Comparison between the post-surgical psychological well-being in the 2 groups	Hawthorne	The subjects who were aware that they were part of a study scored significantly better on postoperative measures of psychological well-being and postoperative knee pain, compared to subjects who were unaware.
Feil *et al.*, 2002	40 patients with histories of poor oral hygiene were randomly assigned into 2 groups	Experimental subjects were presented with a situation that simulated participation in an experiment. Control subjects had no knowledge of study participation.	Hawthorne	The intentional use of the Hawthorne effect was found to improve oral hygiene compliance in orthodontic patients as measured by plaque scores.
Leung *et al.*, 2003	670 birth deliveries	A prospective study on all singleton deliveries in cephalic presentation with an attempt of instrumental delivery over a 12-month period (13 March 2000 to 12 March 2001)	Hawthorne	There was a significant reduction in the incidence of birth trauma and birth asphyxia related to instrumental deliveries during the study period (0.6%) when compared with that (2.8%) in the pre-study period (1998 and 1999).
Winemiller *et al.*, 2005	83 health-care employees who experienced non-specific foot pain for at least 30 days	To determine whether magnetic insoles are effective for relieving non-specific subjective foot pain in the workplace, resulting in improved job satisfaction	Placebo	No significant difference in pain response intensity was found between the group that used magnetic insoles *vs.* the group that used sham magnetic insoles.
Eckmanns *et al.*, 2006	5 intensive care units of a university hospital in Berlin, Germany	Medical personnel were monitored in 2 periods regarding compliance with antiseptic hand rub (AHR) use when there were indications for AHR use	Hawthorne	The Hawthorne effect has a marked influence on compliance with AHR use, with a 55% increase of compliance with overt observation.
McCarney *et al.*, 2007	176 subjects who were suffering from mild-moderate dementia	Minimal follow-up *vs.* intensive follow-up in a placebo-controlled trial of Ginkgo biloba	Hawthorne	Intensive follow-up resulted in a better outcome than minimal follow-up.
Yang *et al.*, 2007	200 peri-menopausal women with 45 drop-outs	To investigate the efficacy of pycnogenol in treating climacteric syndrome in peri-menopausal women	Placebo	Pycnogenol was superior to placebo in the treatment of climacteric syndrome.

vs. = versus

Generally, placebo studies are conducted to determine the efficacy of an intervention, usually a pharmacological drug (Draper, 2002). The basic premise is that if the outcomes of the active intervention are superior to that of the sham intervention (placebo), then such interventions may be used in clinical practice. Since there are several thousand drug trials which have compared the effects of the active drug to a placebo (inactive) drug, it is beyond the scope of this study to describe each one. The two examples shown in **Table 2.4** are sufficient to highlight the role of placebo in drug trials. Walker and Mac Hannaford (1995) reported that individuals with intermittent claudication who were on the drug buflomedil demonstrated greater walking distances compared to individuals who were on placebo medication **(Table 2.2)**. An improvement in Assessment Scale-cognitive subscale score (ADAS-cog) and Manitoba Medical Services Foundation (MMSF) scores, and a 50% reduction in the percentage of patients showing clinical decline were shown in Alzheimer's patients who were on the drug donepezil compared to those who were on placebo medication **(Table 2.2)**. In both these studies, it was almost impossible for the subjects to distinguish the active drug from the placebo one. On the other hand, the subjects' in the study by Winemiller *et al.* (2005) **(Table 2.2)** who were in the sham magnetic insole group could have tested the magnetic properties of the insoles thus eliminating subject blindness. Although the results of the two pharmacological studies differ from that of Winemiller *et al.* (2005) **(Table 2.2)**, they do highlight the significance of the placebo intervention being as close to the active intervention and the maintaining of subject blindness.

The instructions given to participants in a clinical trial and the nature of the follow-up demonstrate the clinical significance of the Hawthorne effect (De Amici *et al.*, 2000; McCarney *et al.*, 2007; **Table 2.4**) The significance of this effect is further highlighted in the studies of Fiel *et al.* (2002) and Eckmanns *et al.* (2006) **(Table 2.4)** where increased compliance by the subjects was noted in response to their awareness of being observed by the researchers. Birth trauma and birth asphyxiation related to instrumental deliveries incidence were significantly reduced when the delivery process was observed by the researchers (Leung *et al.*, 2003; **Table 2.4**). All these studies support the views of Braunholtz *et al.* (2001) and Peppercorn *et al.* (2004) who stated that the Hawthorne effect has implications for improving clinical practice.

2.8 CONCLUSION

Various factors such as run-up speed and arm position have been found to influence ball release speed in fast bowling (Davis and Blanksby, 1976; Tyson, 1976; Elliott and Foster, 1984; Elliott *et al.*, 1986; Brees, 1989; Burden and Bartlett, 1989; Elliott and Foster, 1989; Foster *et al.*, 1989; Mason *et al.*, 1989; Burden, 1990; Stockill and Bartlett, 1992; Bartlett *et al.*, 1996). The trunk, through its various movements such as flexion and lateral flexion, plays a key role in the bowling action, particularly in the summation of segmental velocities thus leading to a faster ball release speed. In both the pitching and fast bowling actions, lateral trunk flexion serves as the main abduction force on the humerus, thus increasing the path of acceleration of the ball (Atwater, 1979; Bartlett and Best, 1988; Feltner, 1989; Bartlett *et al.*, 1996; Young *et al.* 1996).

The spine has been found to be an important component of the kinematic chain, especially in overheard throwing/bowling as the shoulder is incapable of accelerating the arm all on its own (Young *et al.,* 1996; Burkhart *et al.*, 2003). High ground reaction forces have been documented in fast bowlers (Elliott and Foster, 1984; Foster and Elliott, 1985; Elliott *et al.,* 1986; Foster *et al.,* 1989; Mason *et al.,* 1989; Saunders and Coleman, 1991; Elliott *et al.,* 1992; Elliott *et al.,* 1993). The spine absorbs ground reaction forces from the lower limb and transfers them up the kinematic chain. In the case of the thoracic spine the oblique orientation of the facets helps to ensure that the AP forces from the lumbar spine are converted to the more appropriate rotatory forces necessary to accelerate the shoulder (Young *et al.* 1996).

By increasing the mobility and ROM of the thoracic and lumbar spine, increased overall mobility in the trunk would be seen, leading to a faster ball release speed. To address improving trunk mobility, this study focused on spinal manipulation as this has been shown to be a safe and effective way of increasing spinal joint mobility and thus improving trunk flexibility (Herzog *et al.*, 1988; Gal *et al.*, 1994; Herzog, 2000; Gatterman *et al.*, 2001; Gatterman, 2003). Despite several studies which have investigated the impact of the Hawthorne and Placebo effects **(Table 2.4)** in clinical trials, it is not known what the roles of these two effects are on spinal ROM and bowling speed. This study will, therefore, focus on the effect of spinal manipulation of the thoracic and lumbar spines and sham laser intervention on trunk flexion and lateral flexion ROM and bowling speed in the Action Cricket fast bowler.

CHAPTER THREE

METHODOLOGY

3.1 STUDY DESIGN

This was a randomised, controlled, prospective, investigative trial.

3.2 ADVERTISING

Advertisements **(Appendix A)** were placed at the local Action Cricket arenas. To maximise exposure to the study, advertisements were also placed at various First Level cricket clubs around Durban and at the Sahara Kingsmead cricket stadium. Prospective subjects were requested to contact the researcher telephonically for more information.

3.3 SAMPLE SIZE

A non-probability, convenience sampling technique was used. A sample size of 40 healthy Action Cricket fast bowlers was obtained. Budgetary constraint was the main factor for the relatively small sample size in this study. Prospective subjects who responded personally or telephonically to the advertisements were given more information regarding the nature of the study by the researcher. Thereafter, those who wished to participate in the study were invited for a consultation at the relevant Action Cricket arena.

3.4 THE CONSULTATION

At the consultation each prospective subject underwent a medical case history, physical examination and a full spine orthopaedic examination **(Appendices B, C,** and **D** respectively). If the subject met the inclusion criteria he/she was then given an opportunity to obtain more information on the study by being given the subject information sheet **(Appendix E)** to read. The entire research protocol or procedure was also explained in detail by the researcher to every prospective subject.

3.4.1 Inclusion Criteria

- Subjects had to be healthy Action Cricket fast bowlers i.e. bowling speed greater than or equal to 85 $km.h^{-1}$ (Thomas, 2007).
- Subjects had to be between the ages of 18 to 40 years. Subjects younger than 18 years would have required parental consent, while those older than 40 years would have had a greater chance of developing degenerative changes in the thoracic and lumbar spines (Kirkaldy-Willis and Bernard, 1999).
- The subjects had to have read and signed the subject informed consent form **(Appendix F)**.
- The subjects had to have been playing Action Cricket for at least six months.

3.4.2 Exclusion Criteria

- Any subject who had contraindications to spinal manipulation. These included stress fractures, cauda equina syndrome, hypermobility of vertebral segments, tumours and bone infections (Kirkaldy-Willis and Bernard, 1999; Gatterman, 2003).
- Pregnant females.
- Inaudible cavitation on manipulation of the relevant area of the spine. The cavitation is the "popping" sound heard on successful manipulation of a spinal joint (Shekelle, 1994; Vernon and Mrozek, 2005).
- Any subject in Group D (sham laser intervention) who did not consent to his/her data to be included in the data analysis (see procedure for more details).

3.4.3 Subject Informed Consent

If the subject agreed to take part in the study (after reading the subject information sheet and verbal explanation of the study by the researcher), he/she was then given an informed consent form **(Appendix F)** to sign.

3.4.4 Group Allocation

Once the informed consent was signed, the subject was allocated to one of four groups by a randomisation process. Each subject drew a piece of paper from an envelope containing four pieces of paper. Each piece of paper was marked either 'A', 'B', 'C' or 'D'. Those who drew out 'A' received lumbar spine manipulation, those who drew out 'B' received thoracic spine manipulation, those who drew out 'C' received both thoracic and lumbar spine manipulation, and those who drew out 'D' received the sham laser intervention.

3.4.5 Procedure

A summary of the procedure is outlined in **Table 3.1**.

Table 3.1 A summary of the procedure*

<table>
<tr><td colspan="4">Each subject was required to engage in a warm-up exercise for five minutes (Appendix G) so as to prevent injury while bowling and to stretch the appropriate muscles according to the techniques described by Travell and Simons (1993a and 1993b)</td></tr>
<tr><td colspan="4">Lumbar and thoracic spine flexion and lateral flexion was measured using a digital inclinometer (The Saunders Group, Chaska, MN) (as described in 3.6.1)</td></tr>
<tr><td colspan="4">Thereafter the bowling speed was measured using a SpeedTrac™ Speed Sport Radar (EMG Companies, Wisconsin, USA) (as described in 3.6.2)</td></tr>
<tr><td>Group A¥

Subjects received lumbar spine manipulation# according to the technique described by Szaraz (1990).</td><td>Group B¥

The subject received thoracic spine manipulation# according to the technique described by Szaraz (1990).</td><td>Group C¥

The subject received both lumbar and thoracic spine manipulation# using the same technique described before.</td><td>Group D¥

The subject received sham laser intervention for five minutes according to the technique described by Kriel (2005). The sham laser was applied over the entire thoracic and lumbar spine regions.</td></tr>
<tr><td colspan="4">Lumbar and thoracic spine flexion and lateral flexion was again measured using a digital inclinometer (The Saunders Group, Chaska, MN) (as described in 3.6.1). This was done within one minute of the respective intervention.</td></tr>
<tr><td colspan="4">Following the inclinometer assessment, the bowling speed was again measured using a SpeedTrac™ Speed Sport Radar (EMG Companies, Wisconsin, USA) (as described in 3.6.2). This was done within one minute of the ROM assessment.</td></tr>
<tr><td colspan="4">The final assessment included the subjects' perception of the change in their bowling speed (as described under 3.6.3)</td></tr>
</table>

*The entire procedure was supervised on-site by a qualified chiropractor.
¥All interventions on the subjects at the Action Cricket venues were done in an enclosed area to respect the privacy of the subjects.
#The manipulation was considered valid if there was an audible cavitation.

The Manipulative Techniques

The thoracic spine manipulations employed were either the cross bilateral **(Figure 3.1)** or the anterior supine fist techniques described by Szaraz (1990).

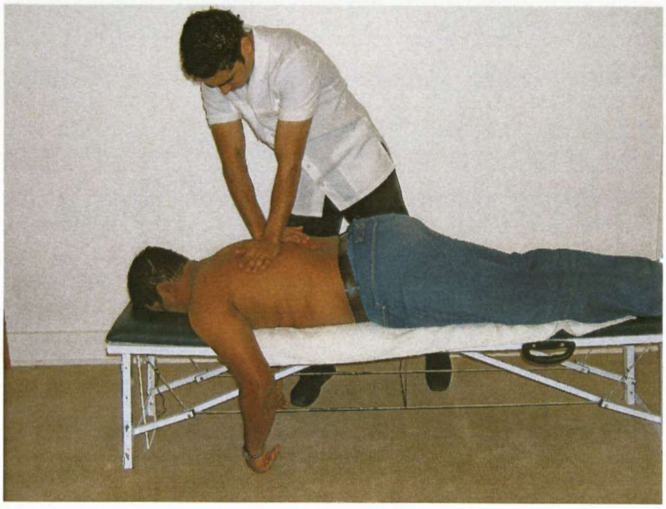

Figure 3.1 Manipulation of the thoracic spine: cross-bilateral technique

Lumbar spine manipulation was performed on each subject using the lumbar roll technique **(Figure 3.2)** described by Szaraz (1990).

Figure 3.2 Manipulation of the lumbar spine: lumbar roll technique

The need for the control group (Group D, sham laser intervention)

Subjects who received the lumbar spine manipulation and thoracic spine manipulation may have tried to impress the researcher during the post-manipulation bowling speed assessment (Hawthorne effect: Mouton and Marais, 1994 or Placebo effect: McConnell and Philipchalk, 1992). In order to minimise this effect, it was necessary for a control group to be included in this study. The reason for the inclusion of the sham laser intervention was to investigate whether it was the "mechanical effect" of the spinal manipulation or whether it was the subjects' perception that they were receiving some "intervention" which could have influenced the outcome of the study (Kriel, 2005).

The sham laser intervention was performed as follows:

The researcher demonstrated on the subject's hand the colour and nature of the laser beam i.e. it was red in colour and caused no alteration to his/her sense of touch and temperature. The subjects in Group D were then required to lie prone in a comfortable position with their thoracic and lumbar spine regions exposed. Thereafter the laser unit was set to zero. During this 'intervention', the subject was told to look at the floor so as to avoid any direct eye contact with the laser beam i.e. not to look at the laser beam as this would adversely affect his/her eyesight. To authenticate the procedure, the researcher also wore protective spectacles. During the actual procedure, the laser unit was, however, switched off. This sham laser intervention to the paraspinal regions of the thoracic and lumbar spines was done for five minutes and about a minute later the subject's bowing speed was measured again.

3.5 THE OUTCOME MEASURES

The outcome measures of this study included the following:

a) Thoracic lateral flexion (°) (Bartlett *et al.*,1996)
b) Thoracic flexion (°) (Davis and Blanksby, 1976; Elliott *et al.*, 1986)
c) Lumbar spine lateral flexion (°) (Young *et al.*, 1996)
d) Lumbar spine flexion (°) (Davis and Blanksby, 1976; Elliott *et al.*, 1986)
e) Bowling speed ($km.h^{-1}$)
f) Subjects perception of bowling speed pre- and post-intervention

3.6 MEASUREMENT TOOLS

3.6.1 Digital Inclinometer

The digital inclinometer (The Saunders Group, Chaska, MN) consists of a sensor with a digital display, an on/off button, an alternate zero button (to 'zero' the unit), a hold button and two Velcro straps. If the sensor is tilted e.g. 30° in any direction, then it will read 30°. If it is zeroed at 30° and then moves e.g. to 40° in any direction, then it will read 40°.

Assessment of flexion and lateral flexion of the thoracic spine

With the subject standing upright, a mark was made over the skin overlying the T6 spinous process. The sensor of the inclinometer was placed with its midpoint directly overlying the mark made on the skin at T6, and the Velcro straps were firmly secured around the subject's waist. The inclinometer was then switched on and zeroed. After this, with the reading on the liquid crystal display (LCD) display measuring 0°, the subject was asked to bend forward as far as possible, keeping the knees straight, whilst the inclinometer was held firm by the researcher so as to prevent any movement off the T6 point. At the limit of flexion, the reading was taken, thus indicating the degrees for forward flexion. The subject was then asked to straighten up again. The unit was zeroed once more, and the subject was asked to laterally bend to the left as far as possible without turning the shoulders. At the limit of lateral flexion, the reading was taken, thus indicating the degrees for left lateral flexion. The patient was asked to straighten up again and this procedure was then repeated for right lateral flexion and a reading taken, thus indicating the degrees for right lateral flexion.

Assessment of flexion and lateral flexion of the lumbar spine

With the subject standing upright, a mark was made over the skin overlying the midpoint between the L2 and L3 SPs. The sensor of the inclinometer was placed with its midpoint directly overlying the mark made on the skin between L2 and L3, and the Velcro straps were firmly secured around the subject's waist. The inclinometer was then switched on and zeroed. After this, with the reading on the LCD display measuring 0°, the subject was asked to bend forward as far as possible, keeping the knees straight, whilst the inclinometer was held firm by the researcher so as to prevent any movement off the L2-L3 point. At the limit of flexion, the reading was taken, thus indicating the degrees for forward flexion. The subject was then asked to straighten up again. The unit was zeroed once more, and the subject was asked to laterally bend to the left as far as possible without turning the shoulder. At the limit of lateral flexion, the reading was taken, thus indicating the degrees for left lateral flexion. The patient was asked to straighten up again and this procedure was then repeated for right lateral flexion and a reading taken, thus indicating the degrees for right lateral flexion.

3.6.2 SpeedTrac™ Speed Sport Radar

This device (EMG Companies, Wisconsin, USA) utilizes Doppler signal processing to measure speeds of small projectiles. When activated, an internal antenna sends out radio waves at a specific frequency. When a moving object such as a thrown ball enters this transmitted signal, then the frequency of this reflected signal off the ball is changed, and this change in frequency is proportional to the ball's speed. The radar then displays the speed in the units of choice, either kilometers per hour or miles per hour. The signal transmitted is able to pass through materials such as Plexiglas, netting, white mesh fencing, backdrops, or tarpaulins without being affected. Therefore a protective barrier can be placed between the moving object and the radar without affecting the accuracy of the measurements in any way. The speed range of the radar is 10-199 kilometers per hour, and the distance range is approximately nine meters. The accuracy of the radar is within 2-3 $km.h^{-1}$.The device was set-up as indicated in **Figure 3.3**.

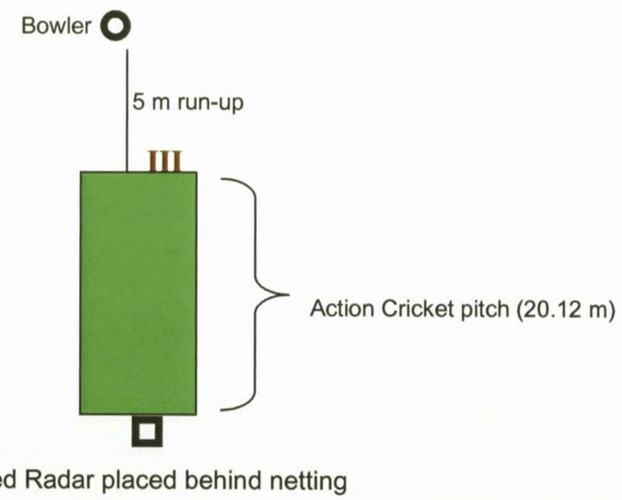

Figure 3.3 Set-up of the SpeedTrac™ Speed Sport Radar at the Action Cricket arena

3.6.3 Subjects' Perception of Bowling Speed

Subjects in all four groups were required to answer the following question post-intervention: "Did you feel that your bowling speed increased, decreased, or did not change after the intervention?"

The researcher recorded the responses in **Table 3.2 (Appendix H)**. Their response was compared to the objective measurements of bowling speed to furthermore determine the role of the Hawthorne effect (Mouton and Marais, 1994) or Placebo effect (McConnell and Philipchalk, 1992).

Table 3.2 Subjects' perception of bowling speed post-intervention

Increased	Decreased	No Change

3.7 ETHICAL CONSIDERATIONS IN THIS STUDY

Ethical clearance for this study was obtained from The Faculty of Health Sciences Research and Ethics Committee (Durban University of Technology; **Certificate Number: FHSEC 001/07**).

Only healthy individuals with no medical conditions were included in this study. All subjects were thoroughly screened for contraindications to spinal manipulation before inclusion in this study. An informed consent form was signed by all subjects in this study. The entire procedure was done in an enclosed area (screened-off) at the Action Cricket arena to respect the privacy of the subjects.

Some degree of deception was required in that subjects in Group D were told that they were receiving a genuine therapeutic laser intervention. Since all subjects were healthy, asymptomatic individuals, it was anticipated that there would be no adverse consequences for the subjects in the sham laser intervention group. After the sham laser intervention and the necessary outcome measures recorded by the researcher, the subjects were informed that the laser unit was not switched on and there was no actual laser intervention. The subjects were then asked if they would allow the researcher to include their data gathered for analysis. If the subject did not allow the researcher to use the data for analysis, the data sheet was shredded in front of the subject and was not utilised for analysis.

A qualified chiropractor was present on-site to supervise the entire procedure for all consultations.

3.8 STATISTICAL ANALYSIS

SPSS version 15.0 was used to analyse the data. An alpha (α) level of 0.05 was used to assess significance of statistical tests. Two-tailed tests were used in all cases. Therefore, a *p* value of <0.05 was considered as statistically significant.

Variables were checked for departure from normality using the skewness statistic and standard error. If the skewness statistic was more than twice the standard error, the variable was considered to be significantly skewed. Intra-group analysis involved paired *t*-tests to compare the change from pre- to post- intervention 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 bowling speed and mean bowling speed change was assessed using the Pearson chi square test.

CHAPTER FOUR

RESULTS

4.1 PHYSICAL CHARACTERISTICS AND DEMOGRAPHIC DATA

The mean (± SD) physical characteristics and age of the subjects who participated in this study are shown in **Table 4.1**. The age of the subjects ranged from 18 to 34 years. The mass of the subjects ranged from 55 to 102 kg, while the body mass index (BMI) ranged from 16.25 to 32.00 kg.m^{-2}. The majority of the subjects in this study were Indians (*n* = 34) followed by Whites (*n* = 4) and then Blacks (*n* = 2) as shown in **Figure 4.1**. There were no Coloured subjects in this study.

Table 4.1 Mean ± SD physical characteristics and age of the subjects (*n* = 40) who participated in this study

Variable	Mean ± SD
Stature (m)	1.77 ± 0.64
Mass (kg)	73.10 ± 10.90
Body Mass Index (BMI) (kg.m^{-2})	23.35 ± 3.82
Age (years)	22.38 ± 3.51

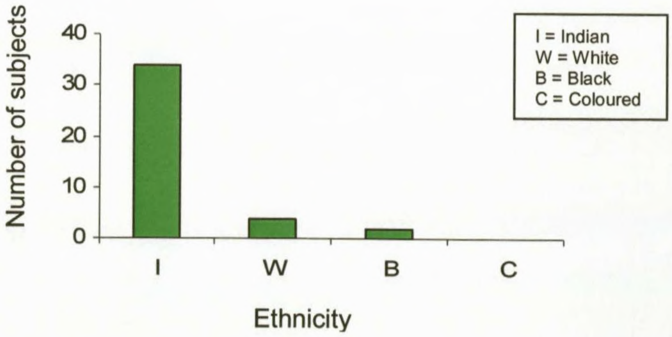

Figure 4.1 Ethnic profile of the subjects (*n* = 40) who participated in this study

4.2 TRUNK FLEXION AND LATERAL FLEXION ROM

4.2.1 Intra-Group Analysis

The mean (± SD) values of each outcome measured from pre- to post-intervention in each of the four intervention groups are shown in **Tables 4.2** to **4.5**. The lumbar spine manipulation group showed a statistically significant change from pre- to post-intervention with regards to lumbar flexion (p = 0.007) and lumbar lateral flexion (p = 0.010), but not for any of the other outcomes measured **(Table 4.2)**. The thoracic spine manipulation group showed a significant improvement in their thoracic flexion (p < 0.001), bowling speed (p = 0.042) and thoracic lateral flexion (p < 0.001) **(Table 4.3)**. The group which received both thoracic and lumbar manipulation showed highly significant improvements in all outcomes measured (p < 0.05; **Table 4.4**), while the sham laser intervention group only improved significantly with regard to lumbar flexion (p = 0.015; **Table 4.5**). Therefore, the intra-group analyses suggest that the combined manipulation group showed the largest improvement in all outcomes.

Table 4.2 Comparison of pre- and post-intervention mean ± SD thoracic and lumbar flexion and lateral flexion in the lumbar spine manipulation group (Group 1)

Pairs	Baseline mean ± SD	Post-lumbar manipulation mean ± SD	*p*-value
TflexB vs TflexA (°)	37.9 ± 4.8	37.9 ± 4.8	1.000
LflexB vs LflexA (°)	51.8 ± 3.8	53.2 ± 2.8	0.007*
TLflxB vs TLflxA (°)	35.6 ± 3.9	35.9 ± 3.8	0.052
LLflxB vs LLflxA (°)	17.8 ± 1.9	18.3± 1.6	0.010*

*** p < 0.05, paired *t*-test**

TflexB = Thoracic flexion before intervention
LflexB = Lumbar flexion before intervention
TLflxB = Thoracic lateral flexion before intervention
LLflxB = Lumbar lateral flexion before intervention

TflexA = Thoracic flexion after intervention
LflexA = Lumbar flexion after intervention
TLflxA = Thoracic lateral flexion after intervention
LLflxB = Lumbar lateral after before intervention

Table 4.3 Comparison of pre- and post-intervention mean ± SD thoracic and lumbar flexion and lateral flexion in the thoracic spine manipulation group (Group 2)

Pairs	Baseline mean ± SD	Post-thoracic manipulation mean ± SD	*p*-value
TflexB vs TflexA (°)	38.2 ± 5.0	40.1 ± 4.8	<0.001*
LflexB vs LflexA (°)	53.3 ± 3.7	53.7 ± 3.6	0.104
TLflxB vs TLflxA (°)	35.2 ± 2.6	36.3 ± 2.3	<0.001*
LLflxB vs LLflxA (°)	18.2 ± 1.5	18.5 ± 1.5	0.096

*** p < 0.05, paired *t*-test**

TflexB = Thoracic flexion before intervention
LflexB = Lumbar flexion before intervention
TLflxB = Thoracic lateral flexion before intervention
LLflxB = Lumbar lateral flexion before intervention

TflexA = Thoracic flexion after intervention
LflexA = Lumbar flexion after intervention
TLflxA = Thoracic lateral flexion after intervention
LLflxB = Lumbar lateral after before intervention

Table 4.4 Comparison of pre- and post-intervention mean ± SD thoracic and lumbar flexion and lateral flexion in the combined thoracic and lumbar manipulation group (Group 3)

Pairs	Baseline mean ± SD	Post-combined manipulation mean ± SD	*p*-value
TflexB vs TflexA (°)	38.3 ± 3.4	39.4 ± 2.9	0.012*
LflexB vs LflexA (°)	52.5 ± 2.8	54.3 ± 2.9	<0.001*
TLflxB vs TLflxA (°)	36.1 ± 1.9	37.1 ± 1.8	<0.001*
LLflxB vs LLflxA (°)	18.2 ± 1.1	18.9 ± 1.1	0.001*

* $p < 0.05$, paired *t*-test

TflexB = Thoracic flexion before intervention
LflexB = Lumbar flexion before intervention
TLflxB = Thoracic lateral flexion before intervention
LLflxB = Lumbar lateral flexion before intervention

TflexA = Thoracic flexion after intervention
LflexA = Lumbar flexion after intervention
TLflxA = Thoracic lateral flexion after intervention
LLflxB = Lumbar lateral after before intervention

Table 4.5 Comparison of pre- and post-intervention mean ± SD thoracic and lumbar flexion and lateral flexion in the sham laser intervention group (Group 4)

Pairs	Baseline mean ± SD	Post-sham laser mean ± SD	*p*-value
TflexB vs TflexA (°)	40.2 ± 3.3	40.5 ± 3.2	0.193
LflexB vs LflexA (°)	54.2 ± 3.1	54.7 ± 3.2	0.015*
TLflxB vs TLflxA (°)	36.7 ± 2.4	36.9 ± 2.3	0.104
LLflxB vs LLflxA (°)	18.3 ± 1.4	18.5 ± 1.4	0.081

* $p < 0.05$, paired *t*-test

TflexB = Thoracic flexion before intervention
LflexB = Lumbar flexion before intervention
TLflxB = Thoracic lateral flexion before intervention
LLflxB = Lumbar lateral flexion before intervention

TflexA = Thoracic flexion after intervention
LflexA = Lumbar flexion after intervention
TLflxA = Thoracic lateral flexion after intervention
LLflxB = Lumbar lateral after before intervention

4.2.2 Trunk Flexion

Inter-Group Analysis

This is the comparison between the absolute change and percentage change in trunk flexion ROM pre- post- intervention between the four intervention groups.

The values of the changes in each outcome by group are shown in **Table 4.6.** There was an increase in almost all outcomes after the intervention. The differences in ROM for thoracic flexion after the intervention were higher in the group that received the thoracic manipulation, while for lumbar flexion ROM it was the combined manipulation group which benefited the most. The total mean (± SD) baseline values for thoracic flexion and lumbar flexion were 38.7° (± 4.1°) and 53.0° (± 3.4°) respectively.

Table 4.6 Descriptive statistics for the change and percentage change in each outcome by group

Group		Tflex change (°)	Tflex % change	Lflex change (°)	Lflex % change
Lumbar spine	Mean ± SD	0.00 ± 0.67	0.02 ± 1.61	1.40 ± 1.27	2.85 ± 2.65
manipulation	*n*	10	10	10	10
Thoracic spine	Mean ± SD	1.90 ± 0.99	5.16 ± 2.74	0.40 ± 0.69	0.77 ± 1.30
manipulation	*n*	10	10	10	10
Combined T & L	Mean ± SD	1.10 ± 1.10	3.02 ± 3.01	1.80 ± 0.63	3.43 ± 1.21
spine Man	*n*	10	10	10	10
Sham laser	Mean ± SD	0.30 ± 0.68	0.78 ± 1.69	0.50 ± 0.53	0.92 ± 0.97
intervention	*n*	10	10	10	10

Tflex = Thoracic flexion; Tflex % = Thoracic flexion percentage
Lflex = Lumbar flexion; Lflex % = Lumbar flexion percentage
T & L spine Man = Thoracic and lumbar spine manipulation

There was a highly significant overall difference between the groups for all outcomes as indicated in **Table 4.7**. The individual groups which were significantly different for each outcome are shown in **Table 4.8**.

With respect to thoracic flexion and flexion percentage change, the thoracic spine manipulation group showed a significantly higher mean change than the lumbar manipulation group ($p < 0.001$; $p < 0.001$) and the sham laser group ($p = 0.002$; $p = 0.001$) as shown in **Table 4.8**. The combined manipulation group was significantly better than the lumbar manipulation group ($p = 0.050$; $p = 0.042$; **Table 4.8**). The lumbar and combined manipulation groups were not significantly better than the sham laser intervention group ($p > 0.05$). Therefore, for this outcome, the best intervention was the thoracic manipulation.

Lumbar flexion and flexion percentage change was significantly higher in the combined manipulation group than in thoracic manipulation ($p = 0.004$; $p = 0.006$, **Table 4.8**) and sham laser groups ($p = 0.008$; $p = 0.011$, **Table 4.8**). Thus, for a change in lumbar spine flexion ROM, the combined manipulation was the most effective.

Table 4.7 ANOVA tests for comparison of mean change between intervention groups

		Sum of squares	Mean square	F	*p*-value
Tflex change (°)	Between groups	21.88	7.29	9.409	<0.001*
	Within groups	27.90	0.76		
	Total	49.78			
Tflex % change	Between groups	161.97	53.98	9.806	<0.001*
	Within groups	198.21	5.51		
	Total	360.18			
Lflex change (°)	Between groups	14.08	4.69	6.783	0.001*
	Within groups	24.90	0.69		
	Total	38.98			
Lflex % change	Between groups	54.44	18.15	6.527	0.001*
	Within groups	100.07	2.78		
	Total	154.51			

***p* < 0.05, Repeated measures ANOVA**
df between groups = 3; df within groups = 36; df total = 39

Tflex = Thoracic flexion
Lflex = Lumbar flexion
Tflex % = Thoracic flexion percentage
Lflex % = Lumbar flexion percentage

Table 4.8 Bonferroni *post-hoc* tests for multiple comparisons between groups

Dependent variable	(I) Group	(J) Group	*p*-value	95% CI	
Tflex change	L spine Man	T spine Man	<0.001*	-3.00	-0.80
		Combined T & L spine Man	0.050 *	-2.20	0.00
		Sham laser intervention	1.000	-1.40	0.80
	T spine Man	L spine Man	<0.001*	0.80	3.00
		Combined T & L spine Man	0.297	-0.30	1.90
		Sham laser intervention	0.002*	0.50	2.70
	Combined T & L spine Man	L spine Man	0.050*	0.00	2.20
		T spine Man	0.297	-1.90	0.30
		Sham laser intervention	0.297	-0.30	1.90
	Sham laser intervention	L spine Man	1.000	-0.80	1.40
		T spine Man	0.002*	-2.70	-0.50
		Combined T & L spine Man	0.297	-1.90	0.30
Tflex % change	L spine Man	T spine Man	<0.001*	-8.07	-2.21
		Combined T & L spine Man	0.042*	-5.93	-0.07
		Sham laser intervention	1.00	-3.69	2.16
	T spine Man	L spine Man	<0.001*	2.21	8.07
		Combined T & L spine Man	0.294	-0.79	5.07
		Sham laser intervention	0.001*	1.45	7.31
	Combined T & L spine Man	L spine Man	0.042*	0.75	5.93
		T spine Man	0.294	-5.07	0.79
		Sham laser intervention	0.238	-0.69	5.17
	Sham laser intervention	L spine Man	1.000	-2.16	3.69
		T spine Man	0.001*	-7.31	-1.45
		Combined T & L spine Man	0.238	-5.17	0.69
Lflex change	L spine Man	T spine Man	0.065	-0.04	2.04
		Combined T & L spine Man	1.000	-1.44	0.64
		Sham laser intervention	0.124	-0.14	1.94
	T spine Man	L spine Man	0.065	-2.04	0.04
		Combined T & L spine Man	0.004*	-2.44	-0.36
		Sham laser intervention	1.000	-1.14	0.94
	Combined T & L spine Man	L spine Man	1.000	-0.64	1.44
		T spine Man	0.004*	0.36	2.44
		Sham laser intervention	0.008*	0.26	2.34
	Sham laser intervention	L spine Man	0.124	-1.94	0.14
		T spine Man	1.000	-0.94	1.14
		Combined T & L spine Man	0.008*	-2.34	-0.26
Lflex % change	L spine Man	T spine Man	0.051	-0.01	4.16
		Combined T & L spine Man	1.000	-2.67	1.50
		Sham laser intervention	0.084	-0.15	4.01
	T spine Man	L spine Man	0.051	-4.16	0.01

	Combined T & L spine Man	0.006*	-4.74	-0.58
	Sham laser intervention	1.000	-2.23	1.93
Combined T & L spine Man	L spine Man	1.000	-1.50	2.67
	T spine Man	0.006*	0.58	4.74
	Sham laser intervention	0.011*	0.43	4.59
Sham laser intervention	L spine Man	0.084	-4.01	0.15
	T spine Man	1.000	-1.93	2.23
	Combined T & L spine Man	0.011*	-4.59	-0.43

*** $p < 0.05$, Bonferroni *post-hoc* test**

Tflex = Thoracic flexion
Tflex % = Thoracic flexion percentage
Lflex = Lumbar flexion
Lflex % = Lumbar flexion percentage
L spine Man = Lumbar spine manipulation
T spine Man = Thoracic spine manipulation
Combined T & L spine Man = Combined thoracic and lumbar spine manipulation

4.2.3 Trunk Lateral Flexion

Inter-Group Analysis

The values of the changes in each outcome by group are shown in **Table 4.9**. All groups showed an increase in outcomes after the intervention. The differences in ROM for thoracic lateral flexion after the intervention were higher in the group that received the thoracic manipulation, while for lumbar lateral flexion it was the combined manipulation group which benefited the most. The total mean (± SD) baseline values for thoracic lateral flexion and lumbar lateral flexion were 35.9° (± 2.7°) and 18.1° (± 1.4°) respectively.

Table 4.9 Descriptive statistics for the change and percentage change in each outcome by group

Group		TLflex change (°)	TLflex % change	LLflex change (°)	LLflex % change
Lumbar spine	Mean ± SD	0.25 ± 0.35	0.74 ± 1.03	0.45 ± 0.44	2.68 ± 2.53
manipulation	*n*	10	10	10	10
Thoracic spine	Mean ± SD	1.15 ± 0.67	3.36 ± 2.12	0.25 ± 0.42	1.39 ± 2.41
manipulation	*n*	10	10	10	10
Combined T & L	Mean ± SD	1.00 ± 0.47	2.79 ± 1.36	0.70 ± 0.42	3.91 ± 2.48
spine Man	*n*	10	10	10	10
Sham laser	Mean ± SD	0.20 ± 0.35	0.57 ± 0.95	0.20 ± 0.35	1.08 ± 1.87
intervention	*n*	10	10	10	10
Total	Mean ± SD	0.65 ± 0.63	1.87 ± 1.86	0.40 ± 0.44	2.26 ± 2.52
	n	40	40	40	40

TLflex = Thoracic lateral flexion
TLflex % = Thoracic lateral flexion percentage
LLflex = Lumbar lateral flexion
LLflex % = Lumbar lateral flexion percentage
T & L spine Man = Thoracic and lumbar spine manipulation

There was a highly significant overall difference between the groups for all outcomes as indicated in **Table 4.10**. The individual groups which were significantly different for each outcome are shown in **Table 4.11**. With respect to the thoracic lateral flexion and lateral flexion percentage change, the thoracic spine manipulation group showed a significantly higher mean change than the lumbar manipulation group ($p = 0.001$; $p = 0.002$, **Table 4.11**) and the sham laser intervention group ($p < 0.001$; $p = 0.001$, **Table 4.11**). The combined manipulation group was significantly better than the lumbar manipulation group ($p = 0.007$; $p = 0.018$, **Table 4.11**) and the sham laser intervention group ($p = 0.004$; $p = 0.009$, **Table 4.11**). The lumbar group was not significantly better than the sham laser group. Looking at the magnitude of the difference, for this outcome the most effective intervention was the thoracic manipulation, followed closely by combined manipulation.

Despite a finding of an overall statistical difference ($p = 0.040$; $p = 0.039$, **Table 4.10**), lumbar lateral flexion change or lateral flexion percentage change was not significantly different ($p > 0.05$) between any of the intervention groups after the Bonferroni adjustment.

Table 4.10 ANOVA tests for comparison of mean change between intervention groups

		Sum of squares	Mean square	F	*p*-value
TLflex change (°)	Between groups	7.35	2.45	10.69	<0.001*
	Within groups	8.25	0.23		
	Total	15.60			
TLflex % change	Between groups	60.44	20.15	9.67	<0.001*
	Within groups	75.04	2.08		
	Total	135.48			
LLflex change (°)	Between groups	1.55	0.52	3.07	0.040*
	Within groups	6.05	0.17		
	Total	7.60			
LLflex % change	Between groups	50.54	16.85	3.09	0.039*
	Within groups	196.52	5.46		
	Total	247.06			

***$p < 0.05$, Repeated measures ANOVA**
df between groups = 3; df within groups = 36; df total = 39

TLflex = Thoracic lateral flexion
LLflex = Lumbar lateral flexion
TLflex % = Thoracic lateral flexion percentage
LLflex % = Lumbar lateral flexion percentage

Table 4.11 Bonferroni *post-hoc* tests for multiple comparisons between groups

Dependent variable	(I) Group	(J) Group	*p*-value	95% CI	
TLflex change	L spine Man	T spine Man	0.001*	-1.50	-0.30
		Combined T & L spine Man	0.007*	-1.35	-0.15
		Sham laser intervention	1.000	-0.55	0.65
	T spine Man	L spine Man	0.001*	0.30	1.50
		Combined T & L spine Man	1.000	-0.45	0.75
		Sham laser intervention	0.000*	0.35	1.55
	Combined T & L spine Man	L spine Man	0.007*	0.15	1.35
		T spine Man	1.000	-0.75	0.45
		Sham laser intervention	0.004*	0.20	1.40
	Sham laser intervention	L spine Man	1.000	-0.65	0.55
		T spine Man	0.000*	-1.55	-0.35
		Combined T & L spine Man	0.004*	-1.40	-0.20
TLflex % change	L spine Man	T spine Man	0.002*	-4.43	-0.82
		Combined T & L spine Man	0.018*	-3.86	-0.25
		Sham laser intervention	1.000	-1.64	1.97
	T spine Man	L spine Man	0.002*	0.82	4.43
		Combined T & L spine Man	1.000	-1.24	2.37
		Sham laser intervention	0.001*	0.99	4.59
	Combined T & L spine Man	L spine Man	0.018*	0.25	3.86

		T spine Man	1.000	-2.37	1.24
		Sham laser intervention	0.009*	0.42	4.02
	Sham laser intervention	L spine Man	1.000	-1.97	1.64
		T spine Man	0.001*	-4.59	-0.99
		Combined T & L spine Man	0.009*	-4.02	-0.42
LLflex change	L spine Man	T spine Man	1.000	-0.31	0.71
		Combined T & L spine Man	1.000	-0.76	0.26
		Sham laser intervention	1.000	-0.26	0.76
	T spine Man	L spine Man	1.000	-0.71	0.31
		Combined T & L spine Man	0.114	-0.96	0.62
		Sham laser intervention	1.000	-0.46	0.56
	Combined T & L spine Man	L spine Man	1.000	-0.26	0.76
		T spine Man	0.114	-0.06	0.96
		Sham laser intervention	0.059	-0.01	1.01
	Sham laser intervention	L spine Man	1.000	-0.76	0.26
		T spine Man	1.000	-0.56	0.46
		Combined T & L spine Man	0.059	-1.01	0.01
LLflex % change	L spine Man	T spine Man	1.000	-1.62	4.21
		Combined T & L spine Man	1.000	-4.15	1.69
		Sham laser intervention	0.810	-1.32	4.52
	T spine Man	L spine Man	1.000	-4.21	1.62
		Combined T & L spine Man	0.125	-5.44	0.39
		Sham laser intervention	1.000	-2.61	3.22
	Combined T & L spine Man	L spine Man	1.000	-1.69	4.15
		T spine Man	0.125	-0.39	5.44
		Sham laser intervention	0.062	-0.09	5.75
	Sham laser intervention	L spine Man	0.810	-4.52	1.32
		T spine Man	1.000	-3.22	2.61
		Combined T & L spine Man	0.062	-5.75	0.09

*** $p < 0.05$, Bonferroni *post-hoc* test**

TLflex = Thoracic lateral flexion
TLflex % = Thoracic lateral flexion percentage
LLflex = Lumbar lateral flexion
LLflex % = Lumbar lateral flexion percentage
L spine Man = Lumbar spine manipulation
T spine Man = Thoracic spine manipulation
Combined T & L spine Man = Combined thoracic and lumbar spine manipulation

4.3 BOWLING SPEED

4.3.1 Intra-Group Analysis

Bowling speed increased significantly ($p = 0.042$) after the thoracic spine manipulation, but the most significant increase was seen in the combined thoracic and lumbar spine manipulation ($p < 0.000$) as shown in **Table 4.12**. There were no significant changes in bowling speed post lumbar spine manipulation and sham laser intervention.

Table 4.12 Mean ± SD bowling speed values and change in bowling speed by group

Group		Baseline bowling speed ($km.h^{-1}$)	Bowling speed ($km.h^{-1}$) post-intervention	Bowling speed change ($km.h^{-1}$)	*p*-value
Lumbar spine manipulation	Mean ± SD	99.20 ± 7.41	100.30 ± 7.08	1.10 ± 1.70	0.070
	n	10	10	10	
Thoracic spine manipulation	Mean ± SD	105.90 ± 7.95	108.70 ± 7.09	2.80 ± 3.74	0.042*
	n	10	10	10	
Combined T & L spine Man	Mean ± SD	98.50 ± 4.32	100.50 ± 4.86	2.00 ± 0.75	<0.000*
	n	10	10	10	
Sham laser intervention	Mean ± SD	99.50 ± 9.10	99.90 ± 9.16	0.40 ± 1.47	0.411
	n	10	10	10	
Total	Mean ± SD	100.78 ± 7.73	102.35 ± 7.86	1.58 ± 2.32	0.000*
	n	40	40	40	40

*** $p < 0.05$, paired *t*-test**

Combined T & L spine Man = Combined thoracic and lumbar spine manipulation

4.3.2 The Correlation between the Change in Bowling Speed Pre- Post-Intervention and Change in Trunk Flexion and Lateral Flexion ROM Pre- Post-Intervention

There was a significant though weak positive correlation between change in speed and change in thoracic flexion (r = 0.451; p = 0.003, **Table 4.13**). Similarly, thoracic lateral flexion change was also correlated positively with speed change (r = 0.469, p = 0.002; **Table 4.14**). Lumbar flexion and lateral flexion changes were not correlated with bowling speed changes.

Table 4.13 Pearson's correlation between bowling speed absolute change and absolute changes in other outcomes

		Bowling speed change	TLflex change	Lflex change	TLflex change	LLflex change
Bowling speed change	PC	1	0.451	0.138	0.469	0.076
	***p*-value**		0.003*	0.397	0.002*	0.639
	n	40	40	40	40	40
TLflex change	PC	0.451	1	0.095	0.720	0.221
	***p*-value**	0.003*		0.561	<0.001*	0.170
	n	40	40	40	40	40
Lflex change	PC	0.138	0.095	1	0.176	0.500
	***p*-value**	0.397	0.561		0.276	0.001*
	n	40	40	40	40	40
TLflex change	PC	0.469	0.720	0.176	1	0.400
	***p*-value**	0.002*	<0.001*	0.276		0.011*
	n	40	40	40	40	40
LLflex change	PC	0.076	0.221	0.500	0.400	1
	***p*-value**	0.639	0.170	0.001*	0.011*	
	n	40	40	40	40	40

*** Correlation is significant at the α = 0.05 level (2-tailed)**

Tflex = Thoracic flexion Lflex = Lumbar flexion TLflex = Thoracic lateral flexion LLflex = Lumbar lateral flexion
PC = Pearson's Correlation

There was a significant moderate positive correlation between percentage change in bowling speed and percentage change in thoracic flexion (r = 0.506; p = 0.001, **Table 4.14**). Similarly, thoracic lateral flexion percentage change was also correlated positively with bowling speed percentage change (r = 0.490; p = 0.001, **Table 4.14**). Lumbar percentage changes were not correlated with bowling speed percentage changes.

Table 4.14 Pearson's correlation between bowling speed percentage change and percentage changes in other outcomes

		Bowling speed % change	Tflex % change	Lflex % change	TLflex % change	LLflex % change
Bowling speed % change	PC	1	0.506	0.163	0.490	0.076
	p-value		0.001*	0.315	0.001*	0.640
	n	40	40	40	40	40
Tflex % change	PC	0.506	1	0.079	0.713	0.175
	p-value	0.001*		0.628	<0.001*	0.281
	n	40	40	40	40	40
Lflex % change	PC	0.163	0.079	1	0.154	0.517
	p-value	0.315	0.628		0.342	0.001*
	n	40	40	40	40	40
TLflex % change	PC	0.490	0.713	0.154	1	0.398
	p-value	0.001*	<0.001*	0.342		0.011*
	n	40	40	40	40	40
LLflex % change	PC	0.076	0.175	0.517	0.398	1
	p-value	0.640	0.281	0.001*	0.011*	
	n	40	40	40	40	40

*** Correlation is significant at the α = 0.05 level (2-tailed)**

Tflex % = Thoracic flexion percentage
Lflex % = Lumbar flexion percentage
Lflex % = Lumbar flexion percentage
PC = Pearson's Correlation
Tflex % = Thoracic flexion percentage

4.3.3 The Association between Change in Bowling Speeds Pre- Post-Intervention and the Subjects' Perception of Change in Bowling Speed

There was no significant difference in the percentage subjective change by intervention group (p = 0.217). However, the trend shown in **Table 4.15** suggests that the sham laser intervention group showed the lowest percentage of subjective change (20%) while the combined thoracic and lumbar spine manipulation group and the thoracic spine manipulation group showed the highest percentage of subjective change (60%).

Table 4.15 Subjects' Perception of Change in Bowling Speed by Group

Group		**Subjective change**		**Total**
		↑	**No change**	↑
Lumbar manipulation	Count	4	6	10
	% within group	40.0%	60.0%	100.0%
Thoracic manipulation	Count	6	4	10
	% within group	60.0%	40.0%	100.0%
Combine thoracic and lumbar manipulation	Count	6	4	10
	% within group	60.0%	40.0%	100.0%
Sham laser intervention	Count	2	8	10
	% within group	20.0%	80.0%	100.0%
Total	Count	18	22	40
	% within group	45.0%	55.0%	100.0%

↑ = Increase in bowling speed

CHAPTER FIVE

DISCUSSION

5.1 DEMOGRAPHIC DATA AND PHYSICAL CHARACTERISTICS

The mean (± SD) age of the subjects in this study **(Table 4.1)** indicated that the majority of Action Cricket players are young adults as reported by Thomas (2007). Despite the mixed nature of Action Cricket games (Routley and Valuri, 1993), no females participated in this study. All the subjects who participated in this study were asymptomatic individuals, which is in contrast to the studies of Jansen (1995), Kretzmann (1995), Myburgh (1998), Kruger (1999), Broughton (2000), Schiller (2001) and Dimopoulos (2002) **(Table 2.3)**. The ethnic profile of the subjects shown in **Figure 4.1** likely reflects the ethnic demographics of the city of Durban (www.durban.co.za) and, furthermore, the low number of Black subjects probably indicates that cricket's popularity in the Black population is still lagging behind other sports especially soccer (Welsh, 2007).

In terms of the key anthropometric measurement **(Table 4.1)**, the mean (± SD) BMI of the subjects in this study fell in the "normal" to "overweight" range for adults (World Health Organisation Classification, utilised by Hanlon *et al.*, 2006). Many of the subjects play Action Cricket on a part-time/social basis with little or none of the rigorous training involved in competitive professional cricket games. Therefore, while the subjects were asymptomatic and healthy, they could not be considered elite athletes in terms of their BMI's.

5.2 THORACIC AND LUMBAR ROM

The baseline means (± SD) indicated in **Tables 4.2-4.5** indicate the variability in the measurements for thoracic flexion, thoracic lateral flexion, lumbar flexion and lumbar lateral flexion ROM. Earlier, Tanz (1953), Allbrook (1957) and Moll and Wright (1971) reported that considerable individual variability exists with respect to the lumbar spine ROM. Based on the results of this study, this could also apply to the thoracic spine ROM. Despite this, the baseline mean (± SD) for thoracic and lumbar flexion and thoracic lateral flexion and lumbar lateral flexion indicated in **4.2.2** and **4.2.3** respectively, are in keeping with the normal range for asymptomatic individuals (Magee, 2002) **(Tables 2.1 and 2.2)**.

The baseline mean (± SD) thoracic and lumbar flexion and thoracic and lumbar lateral flexion ROM of this study are dissimilar with those of Jansen (1995), Kretzmann (1995), Myburgh (1998), Kruger (1999), Broughton (2000), Schiller (2001) and Dimopoulos (2002) **(Table 2.3)**. The subjects in these studies were all symptomatic individuals with considerable age ranges. Other factors that could explain the differences in the results are:

- The previous studies also utilised the BROM II to measure ROM with the exception of Kretzmann (1995) and Dimopoulos (2002), who utilised an Autogon 2 Goniometer and digital inclinometer respectively. The possible lack of reliability of the BROM II in measuring ROM in symptomatic individuals, therefore, cannot be ruled out (Breum *et al.*, 1995).
- The accurate location of bony landmarks by the examiner is important when utilising devices such as the BROM II and the inclinometer. Variability in examiners locating bony landmarks has been known to affect the outcome of the results (Mayer *et al.*, 1995).
- One needs to be familiar with the use of measuring devices, as non-routine use (i.e. seldom use of these measuring instruments) of measuring instruments in clinical practice has also been known to affect the outcome of the results (Mayer *et al.*, 1995).

5.3 SPINAL MANIPULATION AND THORACIC AND LUMBAR FLEXION AND LATERAL FLEXION ROM

The results shown in **Tables 4.2**, **4.3** and **4.4** are in keeping with the reports of Herzog *et al.* (1988), Gal *et al.* (1994), Herzog (2000), Gatterman *et al.* (2001) and Gatterman (2003), who stated that manipulation of the spine resulted in increased joint mobility. The overall post-manipulation results (not the actual ROM values) of this study were also similar to the studies of Jansen (1995), Kretzmann (1995), Myburgh (1998), Kruger (1999), Broughton (2000), Schiller (2001) and Dimopoulos (2002) **(Table 2.3)** despite the fact that none of these studies measured ROM immediately post-manipulation. The results of this study were dissimilar to those of Lehman and McGill (2001) **(in 2.5.2)**. The differences could be accounted for by the inclusion of symptomatic individuals and the use of the 3Space IsoTrak (Polhemus Navigation Sciences, McDonell Douglas Electronics, USA) to measure ROM in Lehman and McGill's (2001) study.

Manipulation of the lumbar spine had no significant effect on thoracic flexion and lateral flexion ROM **(Table 4.2)**, while thoracic spine manipulation had no significant effect on lumbar spine flexion and lateral flexion ROM **(Table 4.3)**. This indicated that regional manipulation of the spine resulted in no significant "spill-over" kinematic changes from one region of the spine to an adjacent region. The possible explanations for the increased ROM following spinal manipulation would include the release of entrapped synovial folds (Shekelle, 1994), breakdown of intra-articular adhesions (Indahl *et al.*, 1997), and articular capsule stretch resulting in a decreased muscle spasm (Bogduk and Jull, 1985). Another possible explanation would be the placebo effect following spinal manipulation proposed by Maigne and Vautravers (2003) and Wilder *et al.* (1988) **(in 2.6.2)**.

No adverse reactions to spinal manipulation were reported by any subject who participated in this study. This indicates that it is a safe procedure, provided it is performed by a qualified practitioner who has completed the necessary diagnostic and clinical examinations prior to the intervention.

5.4 SHAM LASER INTERVENTION AND TRUNK FLEXION AND LATERAL FLEXION ROM, AND BOWLING SPEED

Sham laser intervention resulted in no significant changes to trunk flexion and lateral flexion ROM, with the exception of lumbar flexion which increased significantly (p = 0.015; **Table 4.5**). Mixed ROM results following placebo intervention were also reported by Kruger (1999; **Table 2.3**). The findings of this study also support those of Rasmussen (1979), Postacchini *et al.* (1988), Wreje *et al.* (1992) and Conway *et al.* (1993) who reported that spinal manipulation is more effective than placebo. The notion that spinal manipulation directly affects the mobility of the facet joints is further strengthened by these results.

All subjects in the sham laser intervention group were unaware that they were not receiving an active intervention and this allowed the researcher to "measure" the physical effects independently of the subjects' expectations (Draper, 2002). Therefore, the responses of the subjects *in this group* were not related to their belief in the material efficacy of the intervention (Draper, 2002). It must be noted that the sham laser intervention is not similar to the spinal manipulation intervention in any way; it is therefore, possible that different results might have been obtained if the placebo intervention was similar to that of spinal manipulation. Nevertheless, since the sham laser intervention had no significant effect on bowling speed, the role of the spine in the bowling action is, therefore, further highlighted.

5.5 BOWLING SPEED AND THORACIC AND LUMBAR FLEXION AND LATERAL FLEXION ROM

The baseline mean (± SD) pre- and post-intervention bowling speeds recorded in this study **(Table 4.12)** are within the normal range (85-125km.h^{-1}) for Action Cricket fast bowlers (Thomas, 2007). This is due to the inclusion criteria of this study.

The results shown in **Table 4.12** suggest that although the thoracic spine plays a more significant role than the lumbar spine in the determination of the bowling speed, the combination manipulation (of the trunk) is the most effective intervention for increasing bowling speed. This supports the reports of Tyson (1976) and Elliott and Foster (1989), who described the contribution of trunk flexion to the facilitation of bowling arm rotation and the rhythm and fluidity of the bowling action. Davis and Blanksby (1976) and Elliott *et al.* (1986) also stated that trunk flexion contributed significantly to final ball release speed. The facet joints of the thoracic spine contribute significantly to the motion of the entire spine as load-bearing structures and also in the distribution of ground reaction forces up the kinematic chain in the bowling (throwing) athlete (Young *et al.*, 1996). Manipulation of the thoracic spine would also allow its coronal-plane-oriented facet joints to rotate more, ensuring that the AP forces from the lumbar spine are converted to the torque necessary to accelerate the shoulder which would, therefore, result in an increase in bowling speed (Young *et al.*, 1996). The influence of the thoracic spine on glenohumeral motion and scapulothoracic position (Young *et al.*, 1996) (by allowing for the appropriate scapula protraction/retraction and rotation during the arm cocking and deceleration phases) could also contribute to an increase in bowling speed post-thoracic spine manipulation.

With respect to lateral flexion of the lumbar spine, the findings of this study do not support those of Atwater (1979), Feltner (1989) and Young *et al.* (1996), who reported that lateral flexion of the lumbar spine had an influence on shoulder movement by serving as the main source of abduction force upon the humerus. During the fast bowling action, the overall trunk lateral flexion away from the batsman when the back foot strikes the ground may result in increased ball release speed as proposed by Bartlett and Best (1988), which is supported by the findings of this study. The findings of this study also suggest that facilitation of the transferring forces from the lower limbs and the lumbar spine to the accelerating arm occurs (Young *et al.*, 1996) through a "mobile" thoracic spine and that this has a significant impact on bowling speed. This supports the theory of Young *et al.* (1996) who stated that upward transfer of the ground reaction forces could be limited by reduced motion of the thoracic spine.

Cricket fast bowlers, especially those with a front-on bowling action, are prone to shoulder injuries (Aginsky *et al.*, 2004). A possible contributing factor to this finding is the emphasis some fast bowlers put into shoulder movement during the delivery action in order to attain quicker bowling speeds (Elliott *et al.*, 1986). Repeated bowling action of this type could lead to soft tissue injury and early degenerative changes in the shoulder complex. Therefore, the results of this study may have both practical and clinical significance for these athletes. The balance between utilisation of the shoulder complex and a mobile spine during fast bowling would not only allow for a smoother bowling action and faster bowling speeds, but could lessen the possibility of injuries to the shoulder and spinal areas.

5.6 PERCEPTION OF CHANGE IN BOWLING SPEED

The trend shown in **Table 4.15** suggests that the "feeling" of "a misplaced vertebra returning to its proper place", the audible cavitation and the manual contact associated with spinal manipulation (Maigne and Vautravers, 2003) (the so called "mechanical effects" (Kriel, 2005)) were possible factors in influencing perceptive change in bowling speed. The physical effect of the manipulation i.e. the subjects who received this intervention feeling "looser" post-manipulation could also possibly account for this finding. No subject reported a perceptible subjective decrease in bowling speed post-intervention irrespective of the intervention. This may indicate the applicability of the Hawthorne effect (Mouton and Marais, 1994) to all subjects who participated in this study. Since the increased clinical surveillance and extra attention which are characteristics of the Hawthorne effect (McCarney *et al.*, 2007) were applicable equally to all four groups, the researcher was unable to quantify magnitude of the Hawthorne effect in this study.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The primary aims of this study were:

- To determine the immediate effect of lumbar spine, thoracic spine, combined lumbar and thoracic spine manipulation, and sham laser intervention on flexion and lateral flexion ROM of the trunk and bowling speed of Action Cricket fast bowlers (*n* = 40).

- To determine the association between change in bowling speed pre- post-intervention and the subjects' perception of change in bowling speed.

With regards to the primary aims of the study:

- Lumbar spine flexion and lateral flexion ROM increased significantly but there were no significant changes to bowling speed post-lumbar spine manipulation.
- Thoracic spine flexion and lateral flexion ROM and bowling speed increased significantly post-thoracic spine manipulation.
- Thoracic and lumbar spine flexion and lateral flexion ROM and bowling speed increased significantly post-combined thoracic and lumbar spine manipulation.
- Lumbar spine flexion ROM increased significantly but there were no significant changes to bowling speed post-sham laser intervention.
- There was no significant association between change in bowling speed pre- post-intervention and the subjects' perception of change in bowling speed.

In terms of the specific objectives and associated hypotheses that were set at the onset of the study:

The Alternate Hypotheses (H_a) which stated that there would be a significant difference in:

- Thoracic flexion and lateral flexion ROM immediately following thoracic spine manipulation.
- Lumbar flexion and lateral flexion ROM immediately following lumbar spine manipulation.

- Thoracic and lumbar flexion and lateral flexion ROM immediately following combined thoracic and lumbar spine manipulation.

was accepted.

The Null Hypotheses (H_o) which stated that there would be no significant difference in:

- Thoracic flexion and lateral flexion ROM immediately following sham laser intervention.
- Lumbar flexion and lateral flexion ROM immediately following sham laser intervention.

was partially accepted.

The Null Hypotheses (H_o) which stated that there would be no significant immediate increase in bowling speed post-intervention was partially accepted.

The Null Hypotheses (H_o) which stated that there there would be no significant correlation between change in bowling speed immediately post-intervention and change in trunk flexion and lateral flexion ROM immediately post-intervention, was partially accepted.

The Alternate Hypotheses (H_a), with respect to spinal manipulation, which stated that there would be a significant association between change in bowling speed immediately post-thoracic, post-lumbar and post-combined thoracic and lumbar spine manipulation, and the subjects' perception of change in bowling speed, was rejected.

The Null Hypotheses (H_o), with respect to sham laser intervention, which stated that there would be no significant association between change in bowling speed immediately post-intervention and the subjects' perception of change in bowling speed, was accepted.

6.2 RECOMMENDATIONS

Recommendations for future studies include the following investigations:

- A similar study conducted in females in order to determine possible gender differences in trunk ROM and bowling speed in response to spinal manipulation.
- A study to determine the impact of myofascial trigger points of the paraspinal and shoulder musculature on bowling speed.
- A study to determine the impact of core stabilising muscles on trunk ROM and bowling speed.

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APPENDIX A

Attention all Action Cricket Fast Bowlers

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

Research* is being conducted at the Local Action Cricket Arenas on 4 interventions which may affect bowling speeds.

If you are interested in participating in this study, please contact Kanwal – (cell) 0835567949

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

APPENDIX B

DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ______________________________ Date: __________

File # : __________ Age: __________

Sex : __________ Occupation: ______________________

Intern : ______________________ Signature ______________________

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature :

Case History:

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL: Reason for Conditional:	
Signature:	Date:

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

Intern's Case History:

1. **Source of History:**

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

3. **Present Illness:**

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

4. **Other Complaints:**

5. **Past Medical History:**

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

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

- Allergies
- Immunizations
- Screening Tests incl. x-rays
- Environmental Hazards (Home, School, Work)
- Exercise and Leisure
- Sleep Patterns
- Diet
- Current Medication
  Analgesics/week:
- Tobacco
- Alcohol
- Social Drugs

7. **Immediate Family Medical History:**

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

8. **Psychosocial history:**

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

9. Review of Systems:

- General
- Skin
- Head
- Eyes
- Ears
- Nose/Sinuses
- Mouth/Throat
- Neck
- Breasts
- Respiratory
- Cardiac
- Gastro-intestinal
- Urinary
- Genital
- Vascular
- Musculoskeletal
- Neurologic
- Haematologic
- Endocrine
- Psychiatric

APPENDIX C

Durban University of Technology

PHYSICAL EXAMINATION

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 :**

DURBAN
UNIVERSITY *of*
TECHNOLOGY

APPENDIX D

THORACIC SPINE EXAMINATION

Patient:______________________________File:________ Date:______

Intern:______________________________Signature:____________________

Clinician: ______________________________Signature:________________

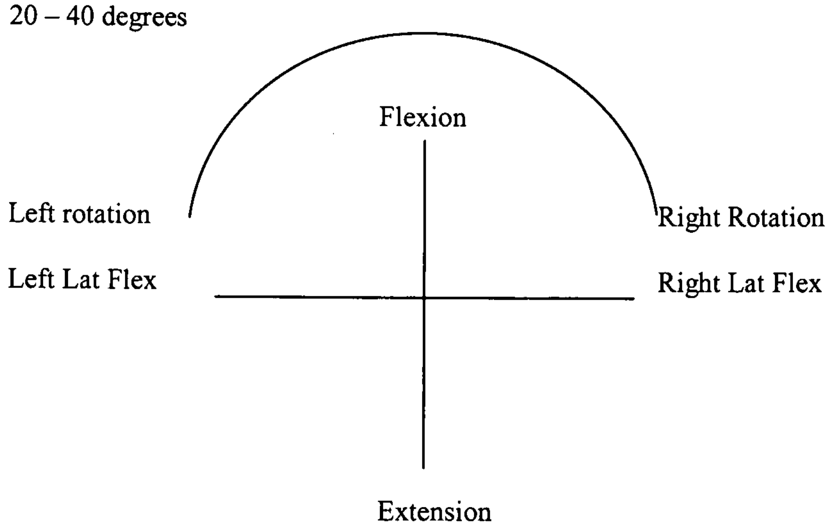
STANDING:

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 4th intercostal space)
Slump Test (Dural Stretch Test)

SUPINE:

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

SLR
Palpate abdomen

PRONE:

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

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

COMMENTS:____

NEUROLOGICAL EXAMINATION:

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

Basic LOWER LIMB neuro:

Myotomes	
Dermatomes	
Reflexes	

KEMP'S TEST:

MOTION PALPATION:

			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			

LUMBAR SPINE AND PELVIS EXAMINATION

STANDING:

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

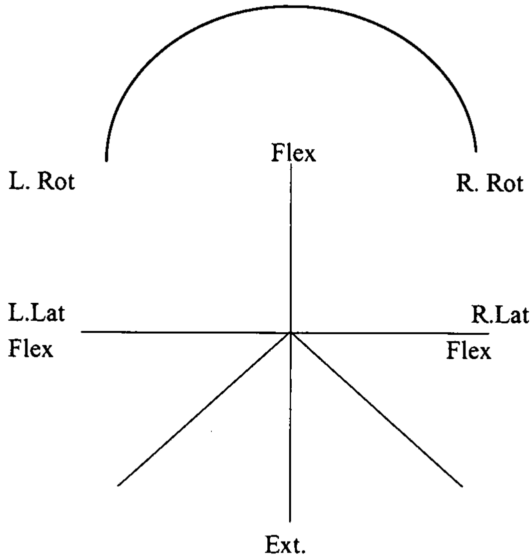
Minor's Sign
Muscle tone
Spinous Percussion
Scober's Test (6cm)
Bony and Soft Tissue Contours

GAIT:

Normal walking
Toe walking
Heel Walking
Half squat

ROM:

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



Which movt. reproduces the pain or is the worst?

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

SUPINE:

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

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

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

SITTING:

Spinous Percussion
Valsalva
Lhermitte

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

Slump 7 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 TRIGGER POINTS	Latent	Active	Radiation
QL			
Paraspinal			
Glut Max			
Glut Med			
Glut Min			
Piriformis			
Hamstring			
TFL			
Iliopsoas			
Rectus Abdominis			
Ext/Int Oblique muscles			

NON ORGANIC SIGNS:

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

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

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

MYOTOMES

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

BASIC THORACIC EXAM

History

Passive ROM

Upper Thoracics		
Lumbar Spine		
Sacroiliac Joint		

Orthopedic

BASIC HIP EXAM

History

ROM: Active

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

B) Supine (hip flexed): - Trochanteric bursa

MOTION PALPATION AND JOINT PLAY

L R

Appendix E

Subject Information Letter

Dear Subject

Welcome to my study which is titled: The immediate effect of lumbar spine manipulation, thoracic spine manipulation, combination lumbar and thoracic spine manipulation and laser on bowling speed in Action Cricket fast bowlers.

Name of Research Student: Kanwal Sood (2042512)

Name of Supervisor: Dr. J. Shaik (M. Tech. Chiro.; M. Med. Sci. (SM)) (204 2588)

Purpose of this study: To determine if spinal manipulation or laser application has any effect on bowling speeds in fast bowlers and To determine if a perceived change in bowling speed correlates with the actual readings

Procedure:

The consultation: 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 (lumbar spine manipulation), Group 2 (thoracic 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 5-minute warm exercise to stretch your muscles. Your back's range of motion (or amount of movement) will be measured using a digital inclinometer (a simple non-invasive device). You will then be asked to bowl as fast you can twice and the speeds will be measured by a bowling speed device (radar). Depending on which group you were allocated to, 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 bowl as fast as you can twice and again the bowling speed will be measured. Thereafter, you will be asked to answer one question on your indication of the change in bowling speed before and after the intervention. The consultation is expected to last about one and a half hours.

Risks/Discomforts: 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.

Remuneration and Costs: There are no financial or other rewards offered in this study. All subjects will qualify for one free consultation pertaining to a musculoskeletal complaint (e.g. back pain, shoulder pain, knee pain, etc.) within 1 month after participation in this study at the Chiropractic Day Clinic. There are no costs to you for taking part in this study

Confidentiality: Your name will not be revealed in the data sheets. All names will be coded and this will be used during data analysis. Only the researcher and his supervisor will have access to the data. If you have any queries about this study, which have not been satisfactorily explained by the researcher, please do not hesitate to contact the supervisor. You are not forced to take part in this study. Participation is purely on a voluntary basis. You may withdraw at any stage of this study with no negative repercussions whatsoever.

If you agree to participate in this study, please sign the attached informed consent form.

DURBAN UNIVERSITY of TECHNOLOGY

APPENDIX F

SUBJECT INFORMED CONSENT FORM

Date	:
Title of research project	: The immediate effect of lumbar spine manipulation, thoracic spine manipulation, combination lumbar and thoracic spine manipulation and laser on bowling speed in Action Cricket fast bowlers
Name of supervisor	: **Dr. J. Shaik (M. Tech. Chiro., M. Med. Sci. (SM))**
Tel ☎	: **(031) 373 2588**
Name of research student	: **Kanwal Sood**
Tel ☎	: **0835567949**

Please circle the appropriate answer YES /NO

1. Have you read the research information sheet? Yes No
2. Have you had an opportunity to ask questions regarding this study? Yes No
3. Have you received satisfactory answers to your questions? Yes No
4. Have you had an opportunity to discuss this study? Yes No
5. Have you received enough information about this study? Yes No
6. Do you understand the implications of your involvement in this study? Yes No
7. Do you understand that you are free to withdraw from this study? Yes No
   at any time
   without having to give any a reason for withdrawing, and
   without affecting your future health care.
8. Do you agree to voluntarily participate in this study Yes No
9. Who have you spoken to? ____________________

Please ensure that the researcher completes each section with you
If you have answered NO to any of the above, please obtain the necessary information before signing

Please Print in block letters:

Patient /Subject Name:____________________ Signature: ____________________

Witness Name:____________________ Signature:____________________

Research Student Name:____________________ Signature:____________________

APPENDIX G

WARM-UP STRETCHES FOR THE SUBJECTS

Each subject was put through a set of stretches for five minutes prior to bowling. The subjects were shown how to perform theses stretches by the researcher, according to the methods described by Travell and Simons (1993a and 1993b).

1 A supine self-stretch for the quadratus lumborum (30 seconds each side). The starting position for this stretch was supine, with the hips and knees bent. The hands were placed behind the head to elevate the rib cage. The controlling left leg was crossed over the right thigh (the side to be stretched). After the right thigh had been adducted as far as possible without resistance, during slow deep inhalation, the left leg was used to resist a gentle isometric abductive effort of the right thigh. The subject then slowly exhaled and relaxed the right side.

2 A seated self-stretch for the hamstrings (1 minute). The initial stretch was performed by slowly and gently sliding the fingers down the shins, keeping the knees straight. Post-isometric relaxation combined with deep breathing enhanced relaxation in the hamstrings.

3 A prone self-stretch for the quadriceps (30 seconds each side). The subject lay on the opposite side to the side being stretched, and used his/her hand to hold the ankle and slowly bring the heel against the buttock to flex the knee fully while maintaining and then increasing extension of the thigh at the hip by also pulling the knee and thigh posteriorly.

4 A seated self stretch for the latissimus dorsi (30 seconds each side).The Mouth Wrap-around test was performed. This required full abduction and external rotation of the arm at the shoulder. The subject performed this test by bringing the hand and forearm behind (not above) the head and sliding the hand as far forward as possible trying to cover the mouth.

5 A standing self stretch for the pectoralis major (1 minute). The In-doorway stretch was performed by the subject. He/she stood in a narrow doorway with the forearms against the doorjambs. One foot iwas placed in front of the other, and the forward knee was bent. The subject held the head erect looking straight ahead, neither craning the neck forward, nor looking down at the floor. As the forward knee bent and the patient leant through the doorway, a slow, gentle, passive stretch was exerted bilaterally on the pectoralis major. The hand position against the doorjamb was adjusted to vary the stretch on different sections of the muscle.

APPENDIX H

Subjects' Perception of Change in Bowling Speed

Group A	No.	Increased	Decreased	No Change
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			

Group B	No.	Increased	Decreased	No Change
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			

Group C	No.	Increased	Decreased	No Change
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			

Group D	No.	Increased	Decreased	No Change
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			