The Relationship Between Core Stability and Bowling Speed in Asymptomatic Male Indoor Action Cricket Bowlers.

By

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

Durban University of Technology

I, Bruce Kevin Hilligan, 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, Ralph and Viki, for their unconditional love and support throughout my life. Thank you for giving me the opportunity to pursue my goals and passions in life as well as a solid upbringing that has enabled me to persevere in the past. I hope this dissertation symbolizes an achievement worthy of all the sacrifices you have made for me over the years.

ACKNOWLEDGEMENTS

It is with sincere gratitude and appreciation that I would like to thank the following individuals:

1. My supervisor, Dr. N. de Busser, of the Department of Chiropractic, Faculty of Health Sciences, Durban University of Technology, for her time, guidance and positive attitude. Dr de Busser's feedback was always swift and accurate and without her this study would not have been possible.

2. My parents and siblings for their valuable support throughout this study.

3. Drs. Gregg Audie and Grant Harper for their off-campus supervision of this study.

4. The Research Committee of the Department of Chiropractic, Durban University of Technology, for their advice and assistance throughout this project.

5. Mrs. Tonya Esterhuizen for her assistance with the statistical analyses used in this study.

6. Mrs Inez Ireland for her administrative assistance throughout the research process.

7. Miss Pat van den Bergh and Mrs Linda Twigg, administration and reception staff at Durban University of Technology Chiropractic Clinic, who gave me much needed assistance in my clinic and research years.

8. The staff/managers at the Durban North, Game City and Pinetown Action Sports Arena's for their co-operation during my study.

9. The subjects who participated in this study, for without them this would've not been possible.

I should further like to acknowledge that full financial support for this project was obtained from the Durban University of Technology's research fund.

ABSTRACT

Objectives:

To determine whether a relationship exists between core stability and bowling speed in Action Cricket bowlers.

Methods:

Thirty asymptomatic indoor Action Cricket fast and fast-medium bowlers were divided into two groups of 15 each, with Group A having well-developed core stability and group B having poorly-developed core stability. The concept of matched pairs was used for age and cricket experience in order to maintain homogeneity between the groups. The core stability and bowling speed of each participant was measured using a pressure biofeedback unit (PBU) and speed sports radar respectively. SPSS version 15.0 was used to analyse the data.

Results:

When comparing the core stability factors (initiation of contraction; timed contraction; core strength parameters; lumbar pelvic stability) between the two groups (inter-group analysis) it was expected that these factors would differ between the two groups since a combination of these factors were the determinants of the grouping system. There was no significant difference in the fluctuation (in mmHg) away from 70mmHg between the two groups (p = 0.308). However, the difference (in mmHg) and the time (in seconds) for which an individual could maintain the contraction were significantly different between the groups, the latter being highly significant (p = 0.047; p < 0.001). There were significant differences in the grades (1a, 1b, 2a and 2b) between the groups when testing lumbar pelvic stability in terms of both the saggital and rotation tests (p = 0.006; p = 0.004; p <0.001; p < 0.001). There was a highly significant difference in bowling speed between the two groups (p<0.001), with Group A (117.3 ± 7.14 $km.h^{-1}$) bowling significantly faster than group B (101.6 ± 3.76 $km.h^{-1}$).

Conclusion:

The group with well-developed core stability bowled significantly faster than the group with poorly-developed core stability. This suggests that well-developed core stability has a positive effect on bowling speed.

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LIST OF ABBREVIATIONS

C+I:	County and International
KE:	Kinetic Energy
LD:	Lattismus Dorsi
LM:	Lumbar Multifdus
L4:	Fourth lumbar vertebra
L5:	Fifth lumbar vertebra
MCC:	Marylbone Cricket Club
PE:	Potential Energy
PBU:	Pressure Biofeedback Unit
S2:	Second sacral segment
TA:	Transversus Abdominis
USA:	United States of America

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CHAPTER ONE
INTRODUCTION

1.1 INTRODUCTION TO THE PROBLEM

A legend former Australian fast bowler and international bowling coach, Dennis Lillee, stated that "fast bowling is the toughest job on the cricket field and that a pace bowler had to be stronger than the rest of the team". The key factors according to Lillee are fitness and strength that should be backed up by a fine technique. He also believed that trunk strength was vital for a paceman and recommended Swiss ball exercises for this purpose as he felt "a fast bowler should be perfectly balanced at the point of delivery" (Dinakar, 2001).

In the kinematic chain of the throwing athlete the force delivery mechanism is the arm while the shoulder functions as a funnel, which regulates the force. The generators of the force are the ground, legs, and trunk. The throwing force generating capability of the shoulder in itself is not large, *viz* 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).

According to Bartlett *et al.,* (1996), there are five stages in the bowling action. The run-up, the pre-delivery stride, the delivery stride, the ball release and the follow-through. It is during the pre-delivery and delivery stride that the lumbar spine and musculature is so beneficial to the biomechanics of the bowler. When bowling, maximum shoulder counter-rotation generally occurs after the hips have initiated rotation towards the batsman and hence the prime movers for subsequent rotation, flexion and lateral flexion are placed on stretch. The stored elastic energy resulting from such a pre-stretch is used in the subsequent movement towards the batsman as coordinated concentric activation of pre-stretched muscles 'diagonally related' to each other would lead to greater force generation and projectile velocity (Bartlett *et al.*, 1996 and Young, 1996). The trunk flexes from its extended position at back foot strike to enable the body to prepare for the rotation of the bowling arm. The role of trunk flexion is the facilitation of bowling arm rotation, contribution to rhythm and fluidity of the action and has a significant contribution to the speed of the ball (Bartlett *et al.*, 1996).

Trunk rotation aids in the arm reaching a fully cocked position while the internal and external oblique muscles serve as a trunk rotator, the rectus abdominis as an anterolateral flexor, the paraspinals as lateral flexor and rotators, the bowling side gluteus maximus as a push off force, and the non-bowling side gluteus as a pelvic stabilizer during hip flexion. This is significant because the activation patterns of these muscles, creates contralateral flexion and counterclockwise rotation of the trunk, which contributes to the forces producing abduction of the bowling arm (Young *et al.*, 1996).

The thoracolumbar fascia and its interdigitation with the transversus abdominis (TA) muscle also has an important role to play as it facilitates trunk rotation and maintains the semi-rigid cylinder necessary for bowling performance and via its attachment to the lattismus dorsi it has an indirect link to the humerus at the intertubercular groove. The transversus abdominis has been found to be the first trunk muscle active with voluntary upper and lower limb movement in each direction and with expected and unexpected loading of trunk producing trunk flexion (Hodges, 2001). Thus, the appropriately timed and coordinated activation of muscles influencing spine motion reduces the need for the shoulder muscles to act as primary movers of the arm. 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 (Young *et al.*, 1996).

Core stability is in essence a description of the muscular control required around the lumbar spine to maintain functional stability. The core muscles include abdominal (rectus abdominis, internal and external oblique and transverses abdominis), lumbar (multifidi, quadratus lumborum, superficial and deep erector spinae, intertransversarii and interspinales), hip girdle musculature (gluteus maximus and gluteus medius), the diaphragm and pelvic floor muscles and the thoracolumbar fascia (Hedrick, 2000 and Akuthota, 2004). A simultaneous co-contraction of the TA and lumbar multifidus muscles has been described by several researchers in relation to lumbar joint stabilisation as well as the stabilising role of the muscles (Jull *et al.*, 1995). The local muscle system has a primary responsibility for both segmental and lumbopelvic stabilisation and the global muscle system contributes to general core stabilisation and is the primary torque producer, their functions are integrally linked with one another (Jull *et al.*, 1995 and Jull, 2000).

Literature suggests, that all movements of the body either originates in or are coupled through the trunk, and this coupling action is created by a strong core. This becomes vital when the goal is high-level athletic performance since without adequate core strength and stability of the lumbar spine, the athlete will not be able to properly apply extremity strength (Akuthota, 2004 and Hedrick, 2000).

Stability of the lumbar spine requires both passive stiffness, through the osseous and ligamentous structures, and active stiffness, through muscles. Spinal instability occurs when either of these components is disturbed. The effect becomes particularly important in overhead athletes because that stability acts as a torque-countertorque of diagonally related muscles during throwing (Akuthota, 2004). A strong core is critical because force is transferred most efficiently through the body in a straight line. When the trunk is poorly developed, the result is poor posture, which can lead to less efficient movements. Such athletes will not be able to maximise their countertorque, often dissipating energy through jerky uncoordinated movement (Hedrick, 2000). The core muscles should be approached as a three-dimensional system, concerned with support, anticipation of unexpected loads, and to ensuring sufficient stiffness in any degree of freedom of the joint. Motor control activation and endurance is essential to achieveing core stability under all possible conditions for performance and injury avoidance. The importance of coordinated muscle activity in athletic function cannot be underestimated (McGill *et al*., 2003).

Literature suggests that core muscle strength and endurance is a key contributor to the stability of the lumbar spine (Panjabi, 1992, Jull and Richardson, 2000, Arakoski, 2001, McGill, 2003 Akuthota, 2004). Furthermore, literature suggests that lumbar stability has an effect on an individuals bowling speed (Young *et al*., 1996). In addition Bartlett *et al.*, (1996) suggested that studies were needed to establish a relationship between segmental dynamics, in particular between muscle strength of the lower back and core region and bowling speed. This study therefore seeks to establish whether a relationship exists between core stability and bowling speed.

1.2 AIMS AND OBJECTIVES OF THIS STUDY

The primary aim was to establish whether an observable difference exists between the bowling speeds of two groups of asymptomatic male indoor Action Cricket bowlers with respect to their core stability. One group of bowlers with well-developed core stability (n = 15) and another group with poorly developed core stability (n = 15).

The specific objectives of the study included the following:

1.2.1 To determine the core stability of each subject in terms of objective measurements.

1.2.2 To determine the bowling speed of each subject in terms of objective measurements.

1.2.3 To determine whether a relationship exists between core stability and bowling speed.

1.3 HYPOTHESIS

The following hypothesis was set to address the objectives identified in 1.2.1 to 1.2.3:

- *A relationship between core stability and bowling speed should be shown to exist in male indoor action cricket bowlers*

1.4 SCOPE OF THE STUDY

The study was a quantitative experimental trial conducted on 30 male fast and fast-medium indoor Action Cricket bowlers. The core stability and bowling speed of each participant was measured using a pressure biofeedback unit (PBU) and speed sports radar respectively.

Three venues were used namely the Game City, Durban North and Pinetown Indoor Action Sports Arena's. Participants were invited to an initial consultation at one of the three venues. Provided that participants fulfilled the inclusion and exclusion criteria they were self-selected and either placed into group A or B depending on their core stability assessment. The abdominal draw-in and lumbopelvic stability tests were used to measure participant's core stability. The concept of matched pairs was used for age and cricket experience in order to maintain homogeneity between the groups.

The participants were explained the procedures of these tests in detail and given an opportunity to practise the manoeuvre as well as being put through a set five minute warm-up which included jogging, stretching and practise bowling. The participants were then required to bowl three times as fast as possible and the bowling speeds were measured and an average of the three deliveries was recorded.

The data was analysed using the latest SPSS version 15.0 (SPSS Inc, Chicago, Illinois, USA). A p value of <0.05 was considered as statistically significant. Parametric testing was used to compare groups since the quantitative dependant variables were reasonably normally distributed. Independent t-tests were used to compare quantitative outcomes between the two independent groups (i.e.: good core stability, Group A vs. poor core stability, Group B). Pearson's chi square tests were used to compare categorical outcomes between the two groups. Pearson's correlation coefficients and p values have been reported to determine the relationships between these two quantitative variables.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the relevant available literature and includes a description of the anatomy of the core muscles, the biomechanics of the fast and fast-medium bowling action particularly related to ball velocity, the concept of core stability and the relationship between core stability and bowling speed. It must however be acknowledged that there is a paucity of literature regarding indoor Action Cricket with most published studies pertaining to the bowling action having been conducted on the conventional outdoor cricket pitch (Davis and Blanksby, 1976; Elliot *et al.*, 1986; Bartlett *et al.*, 1996). The action of indoor and outdoor cricket bowling however is one and the same, with the exception of the available length of the run-up. In the case of indoor cricket, the bowler is afforded a maximum run-up of five metres due to the constraints of the arena, compared to an unlimited and variable distance in outdoor cricket. Other differences from conventional outdoor cricket include: 1) artificial grass matting is the preferred playing surface and 2) a modified cricket ball with a softer centre is used (www.indoorcricketworld.com).

2.2 ANATOMY OF THE CORE MUSCLES – LOCAL AND GLOBAL MUSCLE SYSTEMS

The muscles that make up the core region form a supportive "muscular corset", which serves to support and form the centre of the functional kinetic chain (Akuthota and Nadler, 2004).

For the purpose of this study, core muscles included the abdominal component:

i) rectus abdominis;
ii) external oblique;
iii) internal oblique; and

iv) transversus abdominis (TA)

As well as the lumbar component:

i) multifidus;
ii) quadratus lumborum;
iii) superficial and deep erector spinae;
iv) intertransversarii; and
v) interspinales
vi) rotatores (Hedrick, 2000)

The core muscles are categorized into local and global muscle systems based on their main mechanical roles in stabilization. The local system includes deep muscles and the deep portions of some muscles that have their origin or insertion on the lumbar vertebrae (Richardson *et al*., 1999). These muscles are capable of controlling the stiffness and intervertebral relationship of the spinal segments and the posture of the lumbar spine. The lumbar multifidus muscle, with its vertebrae to vertebrae attachments is a prime example of a muscle of the local system. The TAs, which is the deepest muscle, has direct attachments to the lumbar vertebrae through the thoraco-lumbar fascia and the decussations with its opposite in the midline and can also be considered a local muscle of the abdominal group (Richardson *et al*., 1999).

The global muscle system includes the large superficial muscles of the trunk. These include the:

i) internal oblique
ii) external oblique
iii) rectus abdominis
iv) lateral fibers of the quadratus lumborum; and
v) portions of the erector spinae muscles

These muscles are responsible for moving the spine as well as transferring load directly between the thoracic cage and the pelvis. The primary function of these global muscles is to balance the external loads applied to the trunk so that the residual forces transferred to the lumbar spine can be dealt with by the local muscles (Richardson *et al*., 1999).

2.2.1 Abdominal component

The table below (Table 2.1) discusses the origin, insertion, activation and innervation of each of the core muscles which form the abdominal component.

Table 2.1: Anatomy of the abdominal component of the core muscles (Moore, 1992 and Moore & Agur, 1995)

Name & description of muscle	Origin	Insertion	Action	Innervation
The **rectus abdominis** is a prominent, strap-like muscle, which is vertically orientated. These muscles are separated by the linea alba and lie close together inferiorly. The rectus abdominis is three times as wide superiorly.	The pubic symphysis and pubic crest	Inserts at the xiphoid process and the fifth to seventh costal cartilages.	The action of this muscle is to flex the trunk and compress the abdominal viscera. As well as this, the rectus abdominis stabilizes the pelvis during walking and during lower limb lifts from the supine position, it prevents tilting of the pelvis by the weight of the limbs.	The rectus abdominis is innervated by the ventral rami of the inferior six thoracic nerves.
The **external oblique** is a superficial flat muscle, which is located in the anterolateral aspect of the abdominal wall.	External surface of 5^{th} to 12^{th} ribs	The origin of this muscle inserts at the linea alba, pubic tubercle and the anterior half of the iliac crest.	The action is to compress and support the abdominal viscera as well as to flex and rotate the trunk.	The innervation is by the inferior six thoracic nerves and the subcostal nerve.
The **internal oblique** is the intermediate flat muscle, the fibers of which run at right angles to the external oblique.	The origin of this muscle is at the thoracolumbar fascia, the anterior two-thirds of the iliac crest and the lateral half of the inguinal ligament.	The insertion of the internal oblique is at the inferior borders of the tenth to twelfth ribs, the linea alba and the pubis via the conjoint tendon.	The action of the internal oblique is to compress and support the abdominal viscera as well as to flex and rotate the trunk.	The innervation is supplied by the ventral rami of the inferior six thoracic nerves and the first lumbar nerve.
The **transverses abdominis** is the innermost flat muscle of the anterolateral abdominal wall. Its fibers, except for the most inferior ones, run horizontally.	Its origin is the internal surfaces of the seventh to twelfth costal cartilages, thoracolumbar fascia, iliac crest and the lateral third of the inguinal ligament.	The insertion is at the linea alba with the aponeurosis of the internal oblique, pubic crest and pectin pubis via the conjoint tendon.	The function of this muscle is to compress and support the abdominal viscera.	It is innervated by the ventral rami of the inferior six thoracic nerves and the first lumbar nerve.

2.2.2 Lumbar component

The quadratus lumborum is located on the posterior abdominal wall. Superiorly, it attaches at the medial half of the twelfth rib and the tips of the lumbar spinous cesses. The inferior attachments are at the iliolumbar ligament and internal lip of the iliac crest (Moore and Agur, 1995). The actions of the quadratus lumborum are to control lateral flexion in the erect position. The stabilizing function of this muscle of the lumbar spine on the pelvis is so important that with bilateral paralysis of this muscle, walking is impossible (Travell and Simons, 1993). When acting unilaterally, with the pelvis fixed, the quadratus lumborum acts mainly as a flexor of the spine to the ipsilateral hip. When acting bilaterally, the quadratus lumborum extends the spine (Travell and Simons, 1993).

The lumbar multifidus is the most medial of the lumbar muscles and has unique vertebra to vertebra attachments between the lumbar and sacral vertebrae. This muscle has five separate bands, each consisting of a series of fascicles that stem from the spinous processes and laminae of the lumbar vertebrae. Each lumbar vertebra gives rise to one group of fascicles, which overlap those of the other levels. The fascicles from a given spinous process insert into mamillary processes of the lumbar or sacral vertebra three, four or five levels inferiorly. The longest fascicles, from L1, L2 and L3, have some attachments to the posterior superior iliac spine (Richardson *et al.*, 1999). The multifidus is innervated by the dorsal rami of spinal nerves and functions to stabilize vertebrae during local movements of the vertebral column (Moore and Agur, 1995).

The origin of the rotatores muscles is from the transverse processes. The fibres of the rotatores pass superomedially and attach to the junction of the lamina and transverse process of the vertebra of origin, spanning one to two segments. The function of these muscles is to stabilize vertebrae and assist with local extension and rotatory movements of the vertebral column. Innervation is supplied by the dorsal rami of the spinal nerves (Moore and Agur, 1993).

The erector spinae muscle consists of three components that span the cervical, thoracic and lumbar regions:

i) iliocostalis (lumborum, thoracis and cervicis);
ii) longissimus (thoracis, cervicis and capitis); and
iii) spinalis (thoracis, cervicis and capitis) muscles.

The segment of the erector spinae muscle that is described for the purposes of this study, is the iliocostalis lumborum. The erector spinae lies in a trough on either side of the spinous process, forming a prominent bulge on either side of the median plane. This muscle arises from a broad tendon from the posterior aspect of the iliac crest, the posterior aspect of the sacrum, the sacral and inferior lumbar spinous processes and the supraspinous ligament. The fibers of the iliocostalis lumborum run superiorly and attach at the angles of the lower ribs. Bilateral contraction of this muscle results in extension of the lumbar spine. Unilateral contraction of this muscle results in lateral flexion of the lumbar spine. Innervation is supplied by the dorsal rami of the spinal nerves (Moore and Agur, 1993).

The interspinales originate at the superior surfaces of spinous processes of cervical and lumbar vertebrae and inserts at the inferior surface of the spinous process of the superior vertebrae. Its main action is to aid in extension and rotation of the vertebral column and this muscles innervation is the dorsal rami of spinal nerves (Moore and Agur, 1993)

The intertransversarii originate at the transverse processes of the cervical and lumbar vertebrae, and insert at the transverse processes of adjacent vertebrae. The principal actions of these muscles are to assist in lateral flexion of the spine, and when they act bilaterally, they serve to stabilise the spine. The innervation of these muscles is supplied by the dorsal and ventral rami of the spinal nerves (Moore and Agur, 1993).

2.2.3 Thoracolumbar fascia

The thoracolumbar fascia is critical in the preservation of normal spinal mechanics. It is a tough fibrous sheath-like mass of connective tissue encasing the spinal extensors and extending downward from the posterior thoracic spine to the ilial and sacral attachments of the hip extensor musculature (Bogduk, 1984). It consists of three layers: the anterior, middle and posterior. The posterior layer has the most important role in supporting the lumbar spine and abdominal musculature. The posterior layer consists of two laminae: a superficial lamina with fibres passing downward and medially and a deep lamina with fibres passing downward and laterally. The TA has large attachments to the middle and posterior layers of the thoracolumbar fascia (Akuthota, 2004). It expands anteriorly in its mid portion form the lateral border of the erector spinae to interdigitate with the fibres of the muscles of the abdominal wall such as the internal oblique, TA and the serratus posterior inferior (Young, 1996). The aponeurosis of the thoracolumbar fascia with the lattismus dorsi muscle above and the gluteus maximus muscle below provides a link between the lower and upper limb. Its deeper layers directed caudi-laterally from the midline and encase the erector spinae and connect with the internal oblique muscle and TA (Young, 1996 and Akuthota, 2004). When the muscular contents contract, the thoracolumbar fascia acts as an activated proprioceptor (Akuthota, 2004).

2.3 BIOMECHANICS OF FAST AND FAST/MEDIUM BOWLING

Cricket has not been well served by biomechanical research. The majority of the coaching texts are based on texts of similar nature, observation of top players or anecdotal evidence. Most of the scientific research to date into the biomechanics of men’s cricket has however been carried out on the technique of fast or fast-medium bowling. This may be because of the importance, which this element of the game has acquired, when pairings, trios or even quartets of fast bowlers have been a major feature in success at International Test level. Success in fast bowling is determined by a combination of many factors, one extremely important variable being the speed at which the ball is released. A fast ball release speed reduces the time available for the batsmen to make correct decisions about the path of the ball, thus increasing the demands on the effector mechanism responsible for executing the correct shot (Bartlett *et al.*, 1996).

For the purposes of this review, the action of bowling is divided into the four distinct stages of the run-up, the pre-delivery stride, the delivery stride and the follow-through.

2.3.1 Run-up

This stage commences when the bowler walks or jogs over his approach marker, gradually increasing speed on his approach to the wicket, and ends as he leaps into the air at the start of the pre-delivery stride in preparation for the back foot to strike the ground, which marks the commencement of the delivery stride (Bartlett *et al.*, 1996). Elliot and Foster (1984) considered that the run-up speed should be sufficient to produce as high a linear velocity of the body as possible for ball release, but also must allow the correct delivery technique to be adopted. They also demonstrated that due to considerable differences in modes of delivery and run-up speeds, that the percentage contribution of the run-up to ball release speed will vary between bowlers (Elliot an Foster, 1984). In a study by Brees (1989) who investigated the effect of experimentally manipulating run-up speed on the ball release speed, the kinematics of the delivery stride and accuracy. The results revealed a positive correlation ($p < 0.05$) between run-up speed and ball release speed but a negative correlation ($p < 0.05$) between run-up speed and accuracy, suggesting that the bowlers 'normally' selected an approach speed that produced optimal ball speeds and optimal accuracy. Bartlett *et al.*, (1996) states that available data does not support the conclusion that the run-up speed makes a significant contribution to ball release speed under match conditions.

2.3.2 Pre-delivery stride

This stage separates the run-up from the delivery stride and begins, for a right-handed bowler, with a jump off the left foot and is completed as the bowler lands on the right or back foot. During this stride, with the shoulders pointing down the wicket, the right foot passes in front of the left with the right foot turning to land parallel to the bowling crease. No data is available with regards the pre-delivery stride and ball release speeds, however studies have shown that this stride is longer than a normal stride (Bartlett *et al.*, 1996). This is caused by the apparent necessity to decelerate in the final stride and was probably associated with the need to ‘gather’ for the final thrust (Davis and Blanksby, 1976).

Figure 2.1. The pre-delivery stride
From www.cricketnews.com.au; www.stuff.co.nz/.../2007/12/13/hell-for-leather/; www.answers.com/topic/bowling

2.3.3 Delivery Stride

As this is considered the most technical stage of the bowling action, the delivery stride will be outlined according to three key events: the back foot strike, front foot strike and ball release (Bartlett *et al.*, 1996).

Back foot strike:

At the start of the delivery stride, the bowlers weight is on the previously planted back foot with the body leaning away from the batsman. According to Bartlett *et al.*, 1996, this leaning back of the trunk may serve the purpose of increasing the acceleration path of the implement ball.

Figure 2.2. Back foot strike
From http://en.wikipedia.org/wiki/Fast_bowling

Front foot strike:

As the delivery stride proceeds, the front foot strikes the ground. The values for peak vertical impact force from previous force-platform studies has been found to be between 3.8 and 6.4 times body weight with anterior-posterior braking forces around two times body weight (Bartlett *et al.*, 1996). Implications of this have mostly been recorded in terms of injury potential, with few relationships to ball release speed or the bowling technique being reported. The Marylebone Cricket Club [MCC] (1976) and Elliot (1986) recognized that the length of the delivery stride is dependant on the speed of approach into the delivery stride and also the physique of the bowler. Elliot and Foster (1989) concurred with these previous findings and warned that bowlers who approach the crease with excessive speed will often have a reduced delivery stride and this ‘uncontrolled’ approach may inhibit the ability to master a side-on delivery. There is, however, too little current available data to substantiate any general conclusion at present (Bartlett *et al.*, 1996).

According to Bartlett *et al.*, (1996) the angle of the front knee during the delivery stride has received much scrutiny, not only with regards to its effect upon ball release speed but also to its role in the attenuation of impact forces. There are three main types. The first is ‘the straight leg technique’ where the bowler lands with a fully or almost fully extended front limb at front foot strike and remains at, or near, to this angle at ball release. This is thought to be advantageous in terms of maximizing ball release speed as it provides a stable lower body fulcrum that the bowler may use as an effective lever. Davis and Blanksby (1976), Elliot (1986), Burden and Bartlett (1990b) have suggested that an angle of greater than 150^o would be sufficient to provide these benefits. This, however, may be potentially injurious, as the joint does not then play a role in the attenuation of impact forces. The second type of front knee activity has been observed in a number of bowlers who land with a flexed knee (approximately 150^o) and either maintain this angle, or flex the knee still further following foot strike. Knee flexion on impact provides apparent benefits in terms of force attenuation, but the lack of subsequent knee extension fails to provide the beneficial aspects of bowling over a straight front leg. The third type of front knee action involves the knee flexing slightly on landing (thus attenuating the impact forces) and subsequently extending to a near straight or straight front leg, thus providing the benefits of bowling over a straight front leg. Although this technique is considered the optimal front knee activity, it is quite rare in fast bowling. In a review of the biomechanics of fast bowling in men’s cricket, Bartlett *et al.*, (1996) concluded that there was in fact no conclusive agreement on the importance of the front knee action for ball release speed.

The orientation of the shoulders, hip and angle of the back foot during the delivery stride is largely dependent on the type of action adopted by each bowler. Elliot (1992, 1993) suggested that this movement of the shoulders between back and front foot strikes to be of prime importance in predisposing the lumbar spine to injury, but made no mention of its relationship to ball release speed. Stockill and Bartlett (1992) used Pearsons' product-movement correlations to investigate the relationship between ball release speed and the orientation of the back foot, hips and shoulders along with the degree of counter-rotation. No significant relationships were found, suggesting that the type of action used was not, in itself, a valid predictor of the speed at which the ball will be released. Bartlett *et al.,* (1996) however, stated that maximum shoulder counter-rotation generally occurs after the hips have initiated rotation towards the batsman and hence the prime movers for subsequent rotation, flexion and lateral flexion are placed on a stretch. The stored elastic energy resulting from such a pre-stretch is used in the subsequent movement towards the batsman if the occurrence of the subsequent shoulder rotation occurs as soon as possible.

Elliot and Foster (1989) stated that the non-bowling arm should be almost vertical and placed such that the bowler can look over the outside of the arm at the batsman before front foot strike for a side-on technique and inside the front arm for a front-on technique. They also emphasised that both the arm and the front leg must be thrust down together, which in turn brings about the flexion and rotation of the trunk and rotation of the bowling arm. The limb then continues to rotate backwards as part of the follow-through. The rapid adduction and extension of the non-bowling arm, which occurs before and during trunk rotation, also aids in the summation of segmental velocities (Burden, 1990).

The trunk flexes from its extended position at back foot strike to enable the body to prepare for the rotation of the bowling arm. The role of trunk flexion is not limited to the facilitation of bowling arm rotation, as it also contributes to the rhythm and fluidity of the bowling action. Trunk flexion has also been found to provide a significant contribution to the speed of the ball (Bartlett *et al.*, 1996). Davis and Blanksby (1976) and Elliot (1986) calculated that trunk flexion contributed 11% and 13% respectively to final ball release speed. Burden and Bartlett (1990a) found differences in trunk kinematics for a group of nine college bowlers compared to a group of seven county and international (C+I) bowlers. Although the trunk angles were similar at back foot strike (C+I, 106° ± 7°; college, 104° ± 8° degree) and front foot strike (C+I, 86° ± 4°; college, 89° ± 5°), a difference occurred between front foot strike and ball release. The C+I bowlers exhibited higher maximum trunk angular velocities (529° ± 80° s^{-1}) than the college bowlers (355° ± 59° s^{-1}) and were in a more flexed position at ball release (C+I, 49° ± 4°; college, 60° ± 6°). This higher rate of trunk flexion was reflected in the slightly greater difference between maximum linear velocities of the hip joint centre and the seventh cervical vertebra in the elite fast bowlers. The C+I bowler's greater bowling speeds therefore might be related to their higher rate of trunk flexion.

Figure 2.3. Front foot strike: 'straight leg' technique vs 'flexed knee' technique
From www.cricketweb.net; www.abc.net.au/reslib/200704/r137554_468125.jpg

Ball release:

The laws of cricket limit the action of the bowling arm to circumduction of the upper arm about the gleno-humeral joint and the extension and flexion of the wrist and finger joints (though it is recognised that the wrist could also abduct and adduct, the radio-ulnar joints could supinate/pronate and the carpal joints can move) [Bartlett *et al.*, 1996]. The circumduction of the upper arm with the elbow either fully extended or at least a constant angle starts from a position close to the hip joint. Initiation of upper arm circumduction usually occurs between back foot and front foot strikes. The literature suggests that the degree of circumduction between front footstrike and ball release varies and that it is dependant not only on the position of the arm at release, but also on its position as the front foot lands (Bartlett *et al.*, 1996).

Elliot and Foster (1989) suggested that the arm should be almost vertical at release and the angle between the trunk and the arm approximately 200°. The wrist and fingers are the most distal joints of the body to add velocity to the ball however because each bowler seems to have their own unique way of flexing their wrist and fingers when releasing the ball, there are no studies suggesting the most correct method. There is a lack of data relating the degree of wrist and finger flexion to ball release speeds as the large standard deviations indicate a large degree of inter-subject variability. Literature, however, suggests that wrist and finger flexion may play a role, if only minor (at least 5%), in increasing ball release speed (Bartlett *et al.*, 1996).

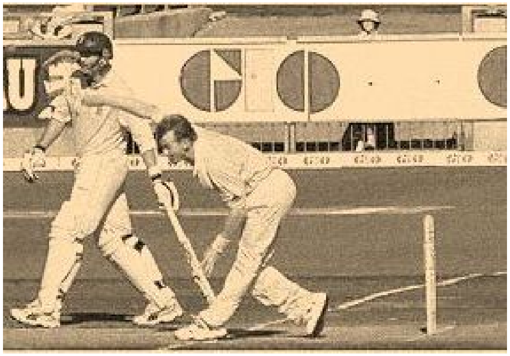


Figure 2.4. Ball release
From http://en.wikipedia.org/wiki/Fast_bowling

2.3.4 Follow-through

Limited data is available on the follow-through, as most analyses stop shortly after ball release. It was suggested by Bartlett *et al.*, (1996) that the bowler should ensure that the bowling arm follows through down the outside of the left thigh allowing a gradual reduction in the bowlers speed and that the first stride of the follow-through should be behind the line of the ball, before running off the wicket for a further 2-3 strides (Figure 2.5).

Figure 2.5. Follow-through

From http://en.wikipedia.org/wiki/Fast_bowling

2.4 IMPORTANCE OF CORE STABILITY

2.4.1 Concept of core stability

Core stability is in essence “a description of the muscular control required around the lumbar spine to maintain functional stability" (Akuthota, 2004). Wisbey-Roth (1996) defined core stability as the optimal alignment and control of the spine and pelvis region to ensure efficient transfer of momentum and summation of forces across the segment, resulting in greater precision and safety of dynamic activity. Core stability results from highly coordinated muscle activation patterns involving many muscles, which provide support and control of the joints, and that the recruitment patterns must continually change, depending on the task (Jull, 1993 and McGill, 2003).

According to the Lee (2001) model of integrated joint function, adequate approximation of the joint surfaces must be the result of all forces acting across the joint if stability is to be insured. Consequently, the ability to effectively transfer load through joints is dynamic and requires integrated functioning of the bodies neuromusculoskeletal system. The first component, form closure comprises intact bones, joints and ligaments. In a stable joint with closely fitting articular surfaces no extra forces are needed to maintain the state of the system, given the actual load situation (Lee, 2001). To analyze stiffness the zones of motion available to every joint must be considered including, the neutral and the elastic zone’s. The neutral zone is a small range of movement near the joint’s neutral position where minimal resistance is given by the osteoligamentous structures. The elastic zone is the part of the motion from the end of the neutral zone up to the physiological limit. The size of the neutral zone may increase with injury, articular degeneration and/or weakness of the stabilizing musculature (Panjabi, 1992).

The second component according to Lee (2001) is called force closure and relies on optimal function of the muscles which includes the ability to contract tonically in a sustained manner. Force closure reduces the size of the neutral zone and thus shear is controlled between the two joint surfaces. Several ligaments, muscles and fascial systems contribute to force closure of the pelvis. The inner unit consists of the muscles of the pelvic floor, TA, multifidus and the diaphragm also known as the local stabilizers. The outer unit consists of several slings or systems of muscles (global stabilizers and mobilizers) that are anatomically connected and functionally related. When muscles contract, they produce a force that spreads beyond the origin and insertion of the active muscle. This force is transmitted to the muscles, tendons, fascia, ligaments, capsules and bones that lie both in series and in parallel to the active muscle. In this manner, forces are produced quite distant from the origin of the initial muscle contraction.

The third component, motor control, is the ability of the muscles to perform in a co-ordinated manner such that the resultant force is adequate compression through the articular structures at an optimal point (tailored), in other words the timing of specific muscle action and release. Superb motor skills require co-ordination of muscle action such that stability is ensured and loads are transferred effortlessly. The last component is that of neural control (emotions and awareness), which ultimately orchestrates the pattern of motor control. This requires constant accurate afferent input from the mechanoreceptors in the joint and surrounding soft tissues, appropriate interpretation of the afferent input and a suitable motor response (Lee, 2001).

The lumbar multifidus (LM) and TA muscles in particular have been shown to have the greatest contribution to the control of the neutral zone (Panjabi, 1992 and Richardson, 1995). Wilke (1995) in a biomechanical study demonstrated that the LM provided more than two thirds of the stiffness increase at the L4-L5 segment. Results of a study by Hodges (2003) indicate that elevated intra-abdominal pressure and contraction of the diaphragm and TA provide a mechanical contribution to the control of spinal intervertebral stiffness or stabilization particularly with regards to the drawing in of the abdominal wall.

2.4.2 Stability versus movement

According to McGill (1993), only a modest amount of stability is required to stabilize a joint, if there is too little stiffness, the joint will buckle under load. Too much stiffness will cause massive loads and limit joint motion. Too much compression over a long period of time will wear out the joints and lead to osteoarthritis. Too little compression creates episodes of giving way and collapse (Lee, 2001). Interestingly the literature shows that in most situations only a modest amount of stability is required to stabilize a joint (McGill, 2003). Cholewicki and McGill (1996) and Cholewicki (1997) have demonstrated that sufficient stability of the lumbar spine (neutral spine) is achieved with modest levels of co-activation of agonist and antagonist muscles that lie each side of the joint. Motor control endurance is essential to achieving the stability target under all possible conditions of performance (McGill 2003).

The muscles of the local system are deep and, anatomically, are closely related to the individual vertebrae. They are capable of increasing spinal segmental stiffness. Muscles of the global system are primarily the larger torque-producing muscles and are more remote from the joint but important for controlling spinal orientation and balancing external loads. Both local and global muscle systems and the normal synergistic function between the two systems is required for spinal stabilization and support (Jull, 2000).

Akuthota (2004) proposes that the core musculature serves as the centre of the functional kinetic chain and a comprehensive strengthening or facilitation of these core muscles has been advocated as a way to prevent and rehabilitate various lumbar spine and musculoskeletal disorders and as a way to enhance athletic performance.

2.5 CORE STABILITY AND FAST/MEDIUM BOWLING

2.5.1 Transfer of energy and role of musculature

In the kinematic chain of the throwing athlete the force delivery mechanism is the arm while the shoulder functions as a funnel, which regulates the force. The generators of the force are the ground, legs, and trunk. The throwing force generating capability of the shoulder in itself is not large, *viz* 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). The lumbar spine is instrumental in providing a level foundation. If the spine and its associated musculature are not adequately mobile and strong, there is the potential for loss of control, dissipation of energy and altered shoulder biomechanics throughout the motion. In this phase there is a ‘controlled falling’ during which there is a change from potential energy (PE) to kinetic energy

(KE). If there is not excessive dissipation of this energy in the ensuing motions, then the arm accepts the forces from the larger legs and trunk, by the formula:

1. KE = PE
2. KE = ½ mv^2 and
3. $\frac{1}{2}(m_{body})(v_{body})^2 = \frac{1}{2}(m_{arm})(v_{arm})^2$

m= mass
v= velocity

The reduction in kinematic chain segment mass results in acquisition of greater rotational velocity in the upper extremity. This is accomplished via the successive acquisition of KE form the contiguous caudal segment with development of rapid acceleration as that caudal segment decelerates or stops. This is referred to as 'sequencing' of motions, with the final ball velocity being the summation of previous sequentially developed velocities in all the more proximal moving joints. There is a general consensus that the back, trunk, and hips serve as both centre of rotation and the transfer link from the legs to the shoulder. During the pre-delivery stride, the major forces at work are in the lower half of the body. Increased tensile forces are developed in the abdomen, hip extensors and spine with medial rotation of the lead hip occurring prior to contact with the ground. The subsequent counterclockwise rotation of the pelvis and trunk abruptly place the arm behind the body in an externally rotated position (Young, 1996). Lateral trunk flexion is the determining factor in arm abduction with trunk rotation aiding in the abducting motion (Young, 1996). Davis and Blanksby (1976) compared two groups of fast/medium bowlers (Group one being the six fastest and Group two being the six slowest bowlers from their original sample) and indicated that it was important to observe the combination of arm and trunk angle. The greater the lateral lean of the trunk, the greater the tendency for the arm to move towards the vertical. The fact that Group one had less trunk lean than Group two, yet maintained practically the same degree of arm angle, indicated that there was less lateral movement of the body segments. Therefore, the forces generated within the body were more likely to be in the direction of movement of the ball. Trunk rotation aids in the arm reaching a fully cocked position while the obliques serve as a trunk rotator, the rectus abdominus as an anterolateral flexor, the paraspinals as lateral flexor and rotators, the bowling side gluteus maximus as a push off force, and the non-bowling side gluteus maximus as a pelvic stabilizer during hip flexion. This is significant because the activation patterns of these muscles, creates contralateral flexion and counterclockwise rotation of the trunk, which contributes to the forces producing abduction of the bowling arm. All of these muscles either directly or indirectly attach to the thoracolumbar fascia (Young, 1996).

2.5.2 Role of thoracolumbar fascia

The thoracolumbar fascia and its interdigitation with the transverses abdominis is the critical structure in the preservation of normal spinal mechanics and has multiple roles in the bowling action. It acts as an attachment, or anchorage for numerous muscles, facilitates trunk rotation and to maintain the semi-rigid cylinder necessary for bowling performance. Secondly, it plays a major role in the dissipation of shear forces normally imparted to the 'three joint complex' which is extremely important in rotational activities such as bowling. Thirdly and not to be underestimated, is its role at the level of the humerus. It applies forces via the lattismus dorsi (LD) muscle, which attaches directly to the humerus at the level of the intertubercular groove. Its function as the axial attachment site for the LD muscle is critical, as the LD muscle must be able to generate over 150% of its maximal manual muscle activity during the late arm cocking phase, and 133% during acceleration when it concentrically contracts to forcefully internally rotate the humerus (Young, 1996). The pectoralis major and LD muscles are integral in the rapid circumduction of the humerus during the bowling delivery (Portus, 2000). The transversus abdominis has been found to be the first trunk muscle active with voluntary upper and lower limb movement in each direction and with expected and unexpected loading of trunk producing trunk flexion. Furthermore it has been proposed that the TA muscle may contribute to trunk extension via its role in the production of increased intra-abdominal pressure (Hodges, 2001).

The presence of a lumbar lordosis and the extent to which it should occur has also been of concern (Young, 1996). If the supportive musculature of the lumbosacral spine fatigue, a more 'passive' lordotic posture ensues. This creates hip extension with greater reliance on the iliofemoral ligament and posterior elements of the spine for passive restraint as well as being harmful to the bowlers shoulder from the standpoint of being unable to fully externally rotate (fully load the tank) and hence the release point. On the other hand, a lordosis that is actively controlled through the eccentrically contracting spinal stabilizing musculature serves as part of the ‘pre-loading’ of these muscles in anticipation of subsequent force generation in the direction of the delivery. Furthermore, the appropriately timed reversal of lordosis is critical in the transition from late cocking to acceleration. With passive extension however, less pre-loading of the abdominal occurs. Under this condition, in order to deliver the ball at a high velocity, one of two things must happen, either more energy has to be expended by the trunk flexors and rotators to bring the spine and torso forward again, with reacquisition of proper setting up of the shoulder (unlikely if the muscles are already fatigued), or more force has to be generated at the level of the scapular and shoulder musculature to compensate for the biomechanically disadvantageous positions of the scapulothoracic and glenohumeral joints (young, 1996).

Coordinated concentric activation of pre-stretched muscles ‘diagonally related’ to each other leads to greater force generation and projectile velocity (Young, 1996). The effect becomes particularly important in overhead athletes because the stability acts as a torque-countertorque of diagonally related muscles during bowling (Akuthota, 2004). Furthermore, back and abdominal stabilisation exercises can improve extension strength, mobility and endurance (Arakoski, 2000). Thus, the appropriately timed and coordinated activation of muscles influencing spine motion reduces the need for the shoulder muscles to act as primary movers of the arm. 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 (Young *et al.*, 1996).

2.5.3 Core stability and performance

A well-developed core is vital when the goal is high-level athletic performance as all movements either originate or are coupled through the trunk (Hedrick, 2000). A well-developed core allows for improved force output, increased neuromuscular efficiency and decreased incidence of overuse injuries. It also enhances an athletes ability to utilise the musculature of the upper and lower body, which allows for more efficient, accurate and powerful movements. This is because force is transferred most efficiently through the body in a straight line. An athlete with a poorly developed core as well as poor posture will not be able to fully utilise their bodies potential power, often wasting energy through jerky, uncoordinated and extraneous movements. If the lumbar muscular component has not been trained to function optimally, this can lead to weakness and reduced movement capabilities. Over time, this can lead to impaired athletic performance, injury and pain (Hedrick, 2000). Motion is not an isolated event that occurs in one direction. Body movement is a complex event involving agonist and antagonist structures that work together to create motion and to stabilize the body in all three directional planes. Hence an athletes core must be strong, flexible and unimpeded in its movement in order to achieve maximum performance (Abelson, 2004).

Literature suggests that optimal core muscle strength, control and endurance working synergistically with the rest of the neuromusculoskeletal system is necessary for lumbar spine stability (Panjabi, 1992, Jull and Richardson, 2000, Arakoski, 2001, Lee, 2001, McGill, 2003, Akuthota, 2004). Further literature suggests that lumbar stability has an effect on bowling speed (Young *et al*., 1996). In addition Bartlett *et al.,* (1996) suggests that studies are needed to establish a relationship between segmental dynamics and bowling speed. This study therefore seeks to establish whether a relationship exists between core stability and bowling speed.

CHAPTER THREE

METHODOLOGY

3.1 THE STUDY DESIGN

The design of this study was that of a quantitative experimental trial conducted on 30 male indoor Action Cricket fast and fast-medium bowlers. The core stability and bowling speed of each participant was measured.

3.1.1 Ethical clearance and subjects

Clearance for this study was obtained from the Durban University of Technology on 15 October 2007 (Clearance no: FHSEC 029/07). The sample for this study consisted of 30 male indoor cricket fast and fast-medium bowlers who were divided into two groups of 15. Group A represented those with well-developed core stability and Group B represented those with poorly-developed core stability.

The research was conducted at three venues namely: Game City, Durban North and Pinetown Action Cricket arenas. An action cricket team consists of eight players and there were 100, 57 and 60 league teams respectively at the afore-mentioned venues, therefore there were approximately 1736 Action Cricket league players in the Greater Durban Area at the time of this research.

3.2 INCLUSION AND EXCLUSION CRITERIA

3.2.1 Inclusion criteria

Subjects were included in this study if:

1. They had no current episode of lower back pain and had to have been asymptomatic with regards lower back pain for three months or longer (Guerrerio, 1999).
2. They were between the ages of 18 to 35 years. Since those younger than 18 required parental consent, while those older than 35 have a greater chance of degeneration in the thoracic and lumbar spine area (Kirkaldy-Willis, 1999).

3. They had been playing Action Cricket in one of the intermediate leagues for at least six months. Subjects were matched to subjects of similar experience and league standing.
4. They were male. Differences between male and female anatomy and physiology were taken into account, and it was therefore found to be favourable to focus exclusively on a specific gender to further maintain homogeneity.

3.2.2 Exclusion criteria

Subjects were excluded from this study if they:

1. Had any relative contra-indications to abdominal muscle strengthening: i) Glaucoma ii) Hypertension iii) Osteoporosis iv) Spinal tumours v) Impaired circulation (Harms-Ringhdal, 1993).
2. Had extreme discomfort on contracting the abdominal muscles.
3. Were spin bowlers.
4. Bowled slower than 97 km/h (refer to discussion on page 33)
5. Had any current injury to the kinematic chain that impaired their ability to bowl.

3.3 PROTOCOL

3.3.1 Participant selection

Participants were recruited through advertising posters and flyers at Game City, Durban North and Pinetown Action Cricket arenas. Advertisements were also placed at various First level cricket clubs around Durban, and at the Kingsmead cricket stadium.

The participant evaluation and selection process began with all possible participants undergoing a cursory interview with the researcher in order to exclude subjects that did not fit the criteria for the study. Participants successfully complying with this interview were evaluated at a single consultation, during which each of them received: a Letter of Information (Appendix A); signed an Informed Consent Form (Appendix B) that explained the study and allowed them to withdraw at any time from the study with no repercussions. To determine whether subjects could participate in the study: a brief medical history; a history of lower back pain; a physical examination (Appendix C) and finally a lower back regional orthopaedic examination (Appendix D) was performed. Core muscle strength and endurance measurements as well as bowling speed measurements were then taken, and were recorded on a data collection sheet (Appendix E).

3.3.2 Sampling Procedure

Provided the particpants fulfilled the inclusion and exclusion criteria they were self-selected and placed into either Group A or B depending on the results of their core stability assessment (discussed further in section 3.4.2.1). The participants remained uninformed as to which group they had been placed into, in order to reduce a possible Hawthorne effect. The concept of matched pairs was used for age and cricket experience in order to maintain homogeneity between the groups.

3.4 THE DATA

3.4.1 Primary data

The raw data was obtained from the core stability assessment and bowling speed measurements. The pressure biofeedback unit measuring the former and the speed sports radar measuring the latter.

3.4.2 Variables

3.4.2.1 Core stability assessment

3.4.2.1.1 The pressure biofeedback unit

The first data collection tool was the pressure biofeedback unit (PBU). The PBU provided numerical readings, which were used for the purposes of statistical analysis. The PBU provided objective readings, which represented core stability muscle activation.

The PBU consists of an inelastic, three section air-filled bag which is inflated in order to fill the space between the target body area and a firm surface, as well as a pressure dial for monitoring the pressure in the bag for feedback on position (Richardson *et al*., 1999). The bag was inflated to an appropriate level for this purpose and the pressure was recorded. The movement of the body part off the bag resulted in a decrease in pressure (Richardson *et al*., 1999).

The device has come into general use for all parts of the body. Its use in assessing the abdominal drawing in action however, has become its most important use in relation to the treatment of problems of the local muscle system in lower back pain patients. The PBU was found to meet the need for quantification of the abdominal draw in action (Richardson *et al*., 1999).

Mills (2005) states that lumbopelvic instability is defined as a deviation of the lumbar spine and pelvis from an arbitrarily defined neutral position, and is demonstrated by a change in cuff pressure, which is indicated on the PBU. As the transversus abdominis (TA) produces narrowing of the abdominal wall, measurement of the amount of movement of the abdomen that is produced provides a method of identifying a patient's ability to perform the contraction (Richardson *et al*., 1999). The principle for using the PBU is that when the unit is placed under the abdomen, initially it conformed to the patients shape. As the patient draws in the stomach off the pad, the pressure in the pad is indicated as reduced on the pressure dial (Richardson *et al*., 1999). The pressure reduction is proportional to the degree to which the subjects could elevate the abdominal wall.

The specific construction of this device has considerable advantages:
First, since the material is inelastic it can accurately reflect abdominal wall motion without distortion. This is assisted by the partitioning of the device into three sections, which assists with the distribution of the air within the pad. When the device is positioned appropriately, the shape of the pad permits an evaluation to be made of the movement of the abdomen (Richardson *et al*., 1999). The same PBU was utililized throughout the testing process in order to prevent any intra-rater reliability issues as a result of using two different units.

According to Storheim *et al.*, (2002) the PBU may play a role in providing biofeedback to assist in the instruction of correct TA muscle contraction. They further demonstrated intra-tester reproducibility (co-efficient of variance = 21%) when using the PBU during abdominal draw-in. However, Storheim *et al.*, (2002) suggest that the use of the PBU needs to be improved for scientific purposes. Results of a study by Hodges (1996) when using both electromyography and PBU, revealed that on abdominal draw-in test both devices were suitable in measuring a reduction in TA co-ordination. A measurement model, which tests the lateral abdominal muscles' supporting capacity to control lumbo-pelvic rotatory movement under an applied low, unilateral leg load has been developed. Initial results indicate that the PBU can detect a loss of supporting trunk muscle function and further development of the model is warranted (Jull *et al.*, 1993).

3.4.2.1.2 Procedure

As a relatively full bladder hinders the ability to perform a core muscle contraction, subjects were first given the option to empty their bladder. Subjects were then shown how to perform the required core muscle contraction, before commencing the abdominal draw in test and the test for lumbopelvic posture. The four point kneeling position was used for the purpose of demonstrating to subjects how to recruit the TA and elicit a core muscle contraction. The four point kneeling position allowed subjects to be shown how to activate and isolate the TA muscle, such that assessment could be performed accurately. The position the subject assumed in the four point kneeling position was such that they were relaxed with hips over the knees and the shoulders over the elbows. Subjects were instructed to breathe in and out, then without breathing in, slowly draw the lower part of the abdomen up and in towards the spine without movement of the trunk or pelvis, Normal breathing was resumed once the contraction had been performed and was to be sustained for a period of 10 seconds (Richardson *et al*., 1999).

Subjects were also instructed to maintain a steady position of the spine, and to avoid deep inspiration in order to prevent abdominal wall movement (Richardson *et al*., 1999). By issuing these instructions, it allowed for subjects to perform an isolated TA muscle contraction while performing the abdominal draw in test, and the test for lumbopelvic posture.

The abdominal draw in test was performed with the subject in a prone lying position, and the PBU was utilized at this point in order to evaluate the ability of the subject to perform this abdominal isolation test (Richardson *et al.*, 1999). The prone position made the isolated abdominal contraction more challenging and therefore eliminated some of the stimuli present in the four point kneeling position.

The PBU was placed under the abdomen with the navel in the centre and the distal edge of the pad in line with the right and left anterior superior iliac spines. The PBU was then inflated to 70 mmHg and was allowed to stabilize, allowing for detection of fluctuations in pressure due to normal breathing, which may be approximately 2 mmHg for each inhalation and exhalation. Subjects were instructed to perform an abdominal contraction identical to that of the four point kneeling position (Richardson *et al.*, 1999). A normal reading was a reduction of 6-10mmHg as the subject performed a core contraction, this indicated that subjects were able to contract the TA successfully. A sudden rise in pressure indicated fatigue (Richardson *et al.*, 1999). Although more recent studies by Robertson (2005), Martin (2006) and Ferguson (2007) have recorded higher mean pressure readings of 13.00 – 13.08mmHg, 10.96 – 13.15mmHg and 10.9mmHg respectively.

Once the subject performed this test successfully, there was a two-minute rest period. Following the two minute rest period an endurance test was performed, whereby the above procedure was repeated, but the subject was required to maintain the core contraction for as long as possible. This was measured with a stopwatch and was measured in seconds. During this test, the researcher closely monitored the pressure gauge of the PBU and monitored the subject to detect whether any compensatory mechanisms were being employed, this included movements of the pelvis and spine, breath holding and rib elevation.

The test for lumbopelvic posture was also performed. This test examined the ability of the trunk muscles to hold the lumbopelvic region in a steady position during progressive levels of leg loading (Richardson *et al.*, 1999). Subjects were in "the supine crook lying position, as this permits monitoring of a stable or unstable lumbopelvic position with the applied leg load, without extraneous movement variables arising from the body sway and balance" (Richardson *et al.*, 1999). The

PBU was placed under the lumbar spine in order to identify movement of the lumbopelvic region. The PBU provided a measure of movement away from the neutral position. Measurements were taken bilaterally for assessment in the saggital, plane as well as bilaterally for assessment of rotary bias. If leg loading was directed in the saggital plane, the PBU was placed across the lumbar spine with its base at the S2 level. If the leg load emphasized a rotary bias, the PBU was placed longitudinally along the lateral aspect lumbar spine on the side that was to be evaluated. The PBU was inflated to 40 mmHg. A core muscle contraction and posterior pelvic tilt was performed and maintained before any leg loading occurred. The abdominal draw in contraction was maintained throughout the test. Subjects were required to maintain 40 mmHg on the pressure gauge while performing a series of leg loading movements. As the core muscle contraction was performed, the pressure increased slightly and the subject was instructed to maintain this pressure throughout the testing procedure. The leg loading movements were graded according to the point at which the patient could no longer maintain the posterior pelvic tilt.

The test was demonstrated to the subjects. Thereafter, subjects were required to perform a "practice test" to ensure that subjects understood the requirements of the test. Following a two-minute rest period after the practice test, the actual test commenced. The legs were placed in the adducted position to measure saggital control and with the legs abducted when assessing for rotary control.

Leg slide procedure for the purpose of this study:

The subjects were required to slide the "test leg" into extension along the examination surface either with heel in contact with the examination surface or 5 centimetres above it, depending on which stage of the testing was being conducted. The subject was then required to bring the leg back along the examination surface to the starting position.

Grade 1:

a) Single leg slide was performed with contralateral leg support; the test leg slides the heel down the surface of the examination surface.

b) Unsupported leg slide was performed with heel of the test leg held approximately 5 cm from the examination surface.

Grade 2:

a) Single leg slide with the contralateral leg unsupported. The test leg slides the heel down the surface of the examination surface.
b) Unsupported leg slide with the contralateral leg unsupported, and the test leg was held approximately 5 cm from the examination surface.

At the point when the leg load exceeded the muscle capacity, there were changes in the reading on the pressure gauge, either up or down, depending on whether the leg load was emphasizing saggital or rotary bias (Richardson *et al*., 1999).

Subjects were allocated a grading at the point at which they could not maintain the core muscle contraction. Subjects with poor control showed significant pressure changes on leg loading at grade 1 a (poor control) and 1 b (below average control) and were not able to complete grade 1 procedure. Subjects with good control showed minimal pressure changes with leg loading and were able to complete the procedure up to grade 2 a (good control) and 2 b (excellent control).

3.4.2.2 Bowling speed measurement

3.4.2.2.1 The speed sports radar

The SpeedTrac X speed sports radar (Part no. 52000) (EMG Companies, Wisconsin, USA) was used for this study. This device utilizes Doppler signal processing to measure speed. 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, the frequency of the reflected signal off the ball is changed, and the change in frequency is proportional to the ball's speed. The radar then displays the speed in the units of choice, either kilometres per hour or miles per hour. The signal transmitted is able to pass through materials such as Plexiglass, 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 device was set-up as indicated in Figure 3.1.

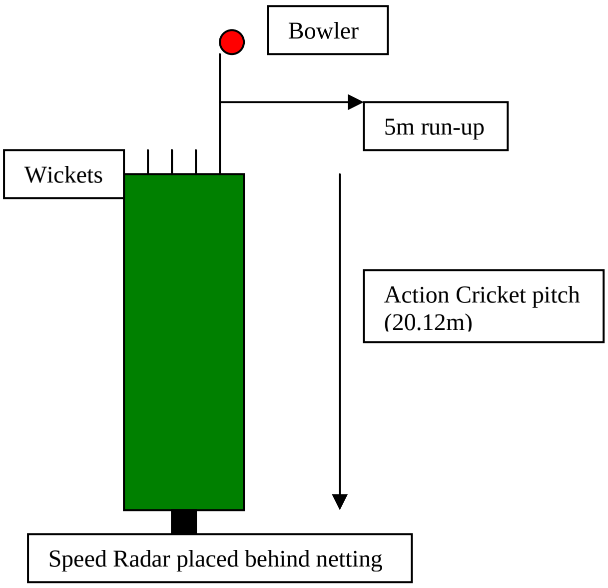


Figure 3.1. Set-up of the Speedtrac X speed sports radar at the Action Cricket arena

3.4.2.2.2 Procedure

After completion of core stability measurements the participant was then put through a set five minute warm-up. This brief warm-up comprised of one and a half minutes jogging, two minutes of stretching of the kinematic chain which included generalised stretches of the lower and upper limbs and lower back region and one and half minutes of bowling practise. This was done in order to prevent injury to the kinematic chain. The participants were then asked to bowl in the action cricket nets as fast as possible. The participants were required to bowl three times and the bowling speeds were measured using the sports radar. An average of the three measurements was recorded and this constituted one set of measurements.

Bowlers were excluded from this study if their mean speed reading was less than 97 $km.h^{-1}$. The rationale for this was that although Peterson (2004) suggested the mean bowling speed of a fast medium bowler to be 108 (±5) $km.h^{-1}$, unofficial media classification, regarding a bowlers average ball speed, regard the range between 97 km.h^{-1} and 113 km.h^{-1} to be the middle range between several speed classifications (www.wikipedia.org/wiki/types_of_bowlers_in_cricket).

3.5 STATISTICAL ANALYSIS

The data was analysed using the latest SPSS version 15.0 (SPSS Inc, Chicago, Illinois, USA). A p value of <0.05 was considered as statistically significant.

Parametric testing was used to compare groups since the quantitative dependant variables were reasonably normally distributed. Independent t-tests were used to compare quantitative outcomes between the two independent groups (i.e.: good core stability, Group A vs. poor core stability, Group B). Pearson's chi square tests were used to compare categorical outcomes between the two groups. Pearson's correlation coefficients and p values have been reported to determine the relationships between these two quantitative variables.

CHAPTER FOUR

RESULTS

4.1 DEMOGRAPHIC FACTORS

There were 15 participants per group (*n* = 30). As shown in Table 4.1 the mean age, weight and height of the participants from the two groups were not statistically significantly different (p =0.762; p=0.910; p=0.165). This implies that the groups were comparable in terms of these demographic factors, which may also have influenced bowling speed. The majority of the subjects in this study were Whites (*n* = 22) followed by Indians (*n* = 7) and then Blacks (*n* = 1) as shown in Figure 4.1. There were no coloured subjects in this study.

Table 4.1: Comparison of mean age, weight and height between the two groups (*n* = 30)

	Group Allocation	*n*	Mean	Std. Deviation	Std. Error Mean	*p* value
Age	A	15	24.73	4.15	1.07	0.762
	B	15	25.20	4.20	1.08	
Weight (kg)	A	15	80.73	9.82	2.53	0.910
	B	15	81.20	12.41	3.20	
Height (m)	A	15	1.82	0.10	0.03	0.165
	B	15	1.77	0.07	0.02	

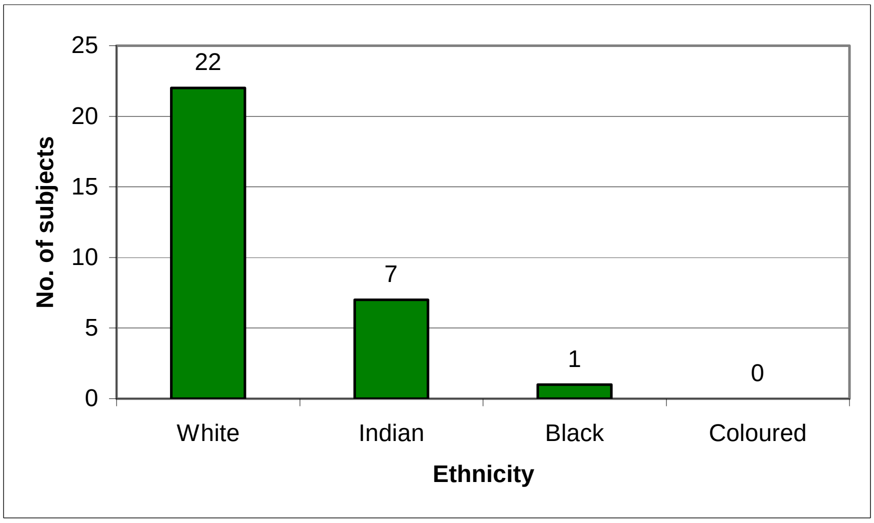


Figure 4.1. Ethnic profile of the subjects (*n* = 30)

The comparison of demographics shows two homogenous groups (well-developed and poorly-developed core stability), which adds strength to the findings of this study, although the sample size is small.

4.2 CORE STABILITY

When comparing the core stability factors (initiation of contraction; timed contraction; core strength parameters; lumbar pelvic stability) between the two groups (inter-group analysis) it was expected that these factors would differ between the two groups since a combination of these factors were the determinants of the grouping system. There was no significant difference in core initiation between the two groups (p = 0.143; χ^2 = 2.143) since the vast majority of all participants could initiate core contraction (n = 28). Only two could not, and these were both subjects from group B (Figure 4.2).

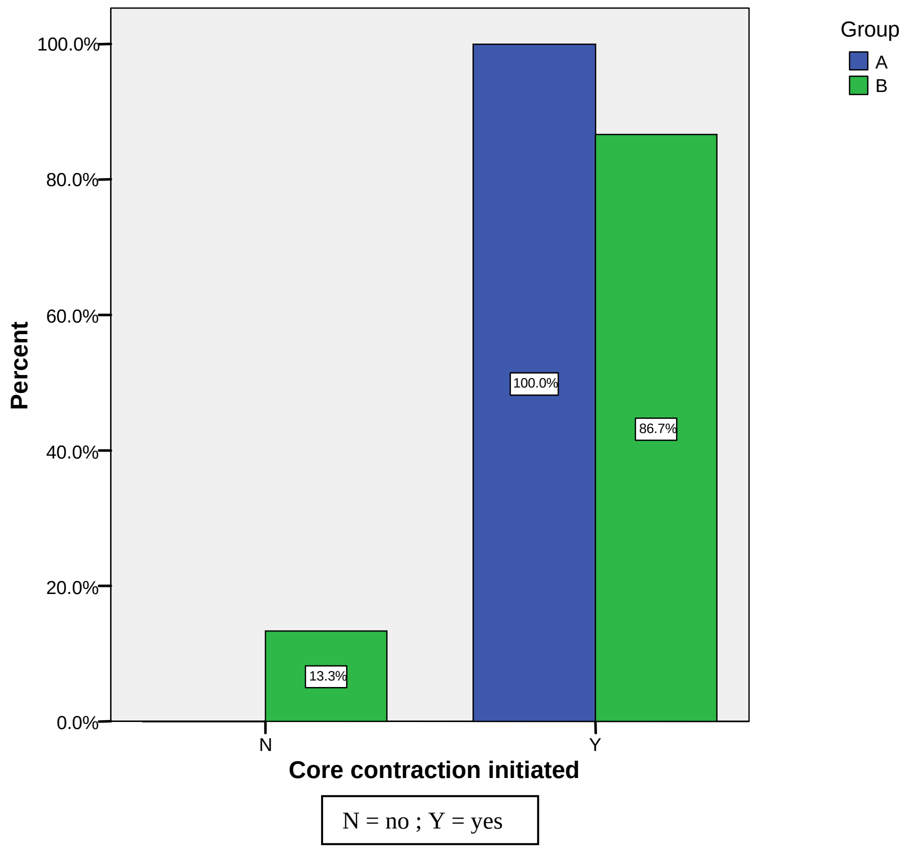


Figure 4.2: Percentage of core initiation (abdominal draw-in test) by group

Figure 4.3 shows that there was a significant difference between the two groups in terms of being able to maintain a contraction for 30 seconds (*p*=0.006; χ^2 = 7.50). All subjects (n = 15) in group A could maintain this contraction while only 60% (*n* = 9) of group B were able.

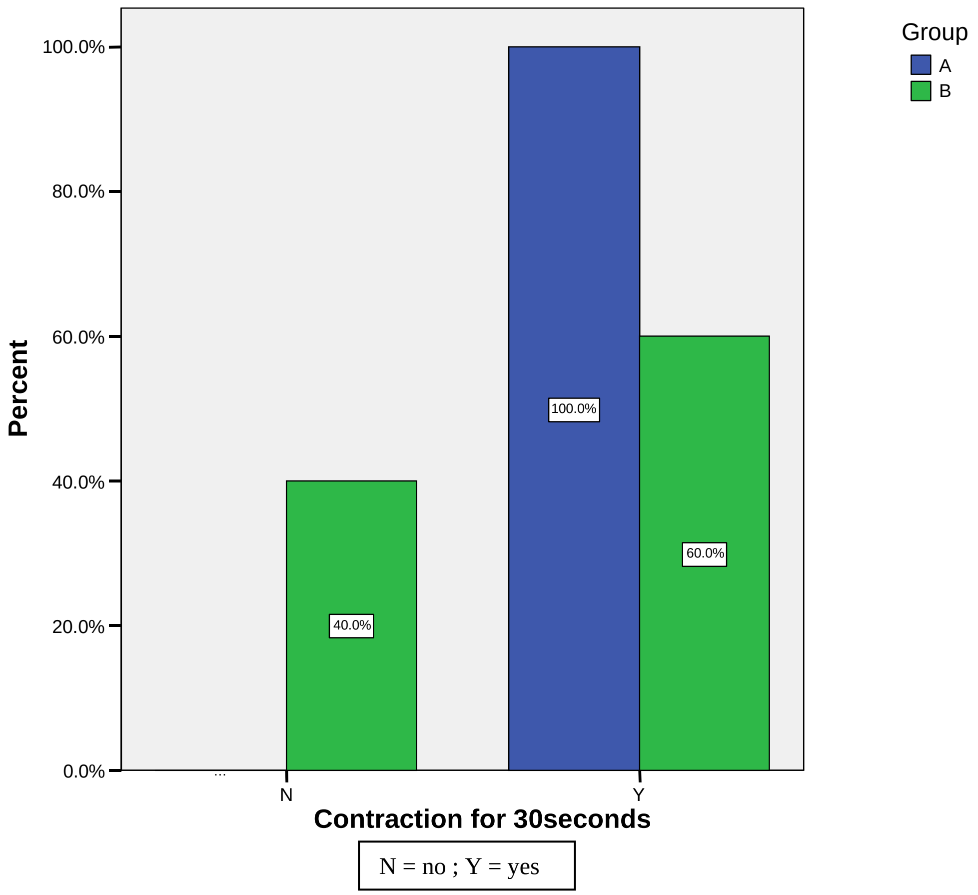


Figure 4.3: Percentage of subjects per group able to maintain core contraction for 30 seconds (abdominal draw-in test)

There was no significant difference in the fluctuation (in mmHg) away from 70mmHg between the two groups (*p* = 0.308), however, the difference (in mmHg) and the time (in seconds) that an individual could maintain the contraction for were significantly different between the groups, the latter being highly significant (*p* < 0.001). This is shown in Table 4.2 and Figure 4.4.

Table 4.2: Comparison of core strength parameters (fluctuation, difference & time) between the two groups (n = 30)

	Group Allocation	*n*	Mean	Std. Deviation	Std. Error Mean	*p* value
Fluctuation in mmHg	A	15	55.33	4.499	1.162	0.308
	B	15	49.73	20.398	5.267	
Difference in mmHg	A	15	14.67	4.499	1.162	0.047
	B	15	10.93	5.298	1.368	
Time (sec)	A	15	61.55	25.464	6.575	<0.001
	B	15	29.85	17.554	4.533	

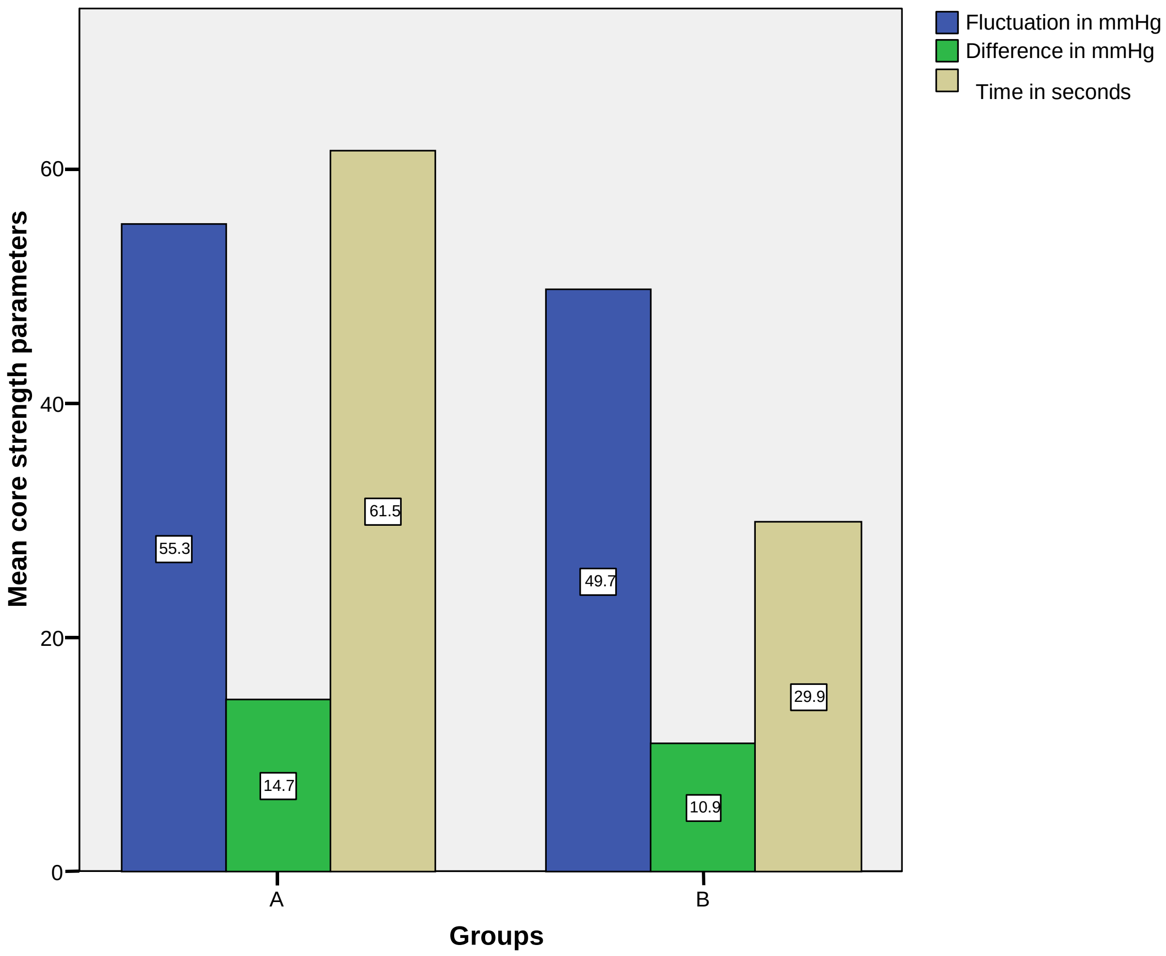


Figure 4.4: Mean core strength parameters (fluctuation, difference & time) by group

There were significant differences in the grades (1a, 1b, 2a and 2b) between the groups when testing lumbar pelvic stability in terms of both the saggital and rotation tests ($p = 0.006$; $p = 0.004$; $p < 0.001$; $p < 0.001$) as shown in Table 4.3.

Table 4.3: Comparison of grade of lumbar pelvic stability (saggital and rotation tests) between the two groups (n = 30)

Lumbar pelvic stability		Group A		Group B		*p* value
		n	%	n	%	
Grade - saggital test: left	1b	0	0%	6	40.0%	0.006
	2a	11	73.3%	9	60.0%	
	2b	4	26.7%	0	0%	
Grade - saggital test: right	1b	0	.0%	8	53.3%	0.004
	2a	11	73.3%	6	40.0%	
	2b	4	26.7%	1	6.7%	
Grade for rotation test left	1a	0	0%	4	26.7%	<0.001
	1b	0	0%	10	66.7%	
	2a	14	93.3%	1	6.7%	
	2b	1	6.7%	0	0%	
Grade of rotation test right	1a	0	0%	4	26.7%	<0.001
	1b	0	0%	11	73.3%	
	2a	14	93.3%	0	0%	
	2b	1	6.7%	0	0%	

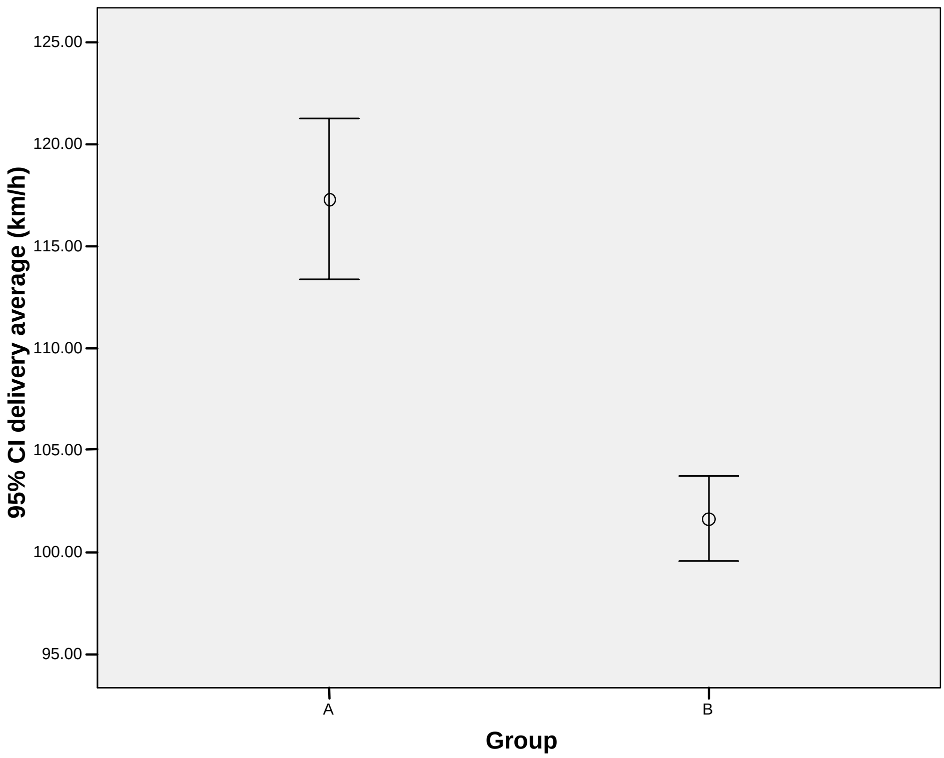
Table 4.4 shows that the groups were not statistically different in terms of the differences in mmHg on saggital and rotation tests of lumbar pelvic stability. The differences were, however, marginally higher in group B when compared to group A.

Table 4.4: Comparison of mean difference in mmHg on lumbar pelvic stability (saggital and rotation tests) between the two groups (n = 30)

	Group Allocation	n	Mean	Std. Deviation	Std. Error Mean	*p* value
Difference in mm/Hg saggital test left	A	15	7.47	4.853	1.253	0.093
	B	15	9.93	2.576	0.665	
Difference in mm/Hg saggital test right	A	15	6.67	4.320	1.116	0.076
	B	15	9.40	3.776	0.975	
Difference of mm/Hg rotation test left	A	15	9.93	3.900	1.007	0.257
	B	15	11.53	3.662	0.945	
Difference in mm/Hg rotation test right	A	15	10.47	4.155	1.073	0.781
	B	15	10.87	3.623	0.935	

4.3 BOWLING SPEED

There was a highly significant difference in bowling speed between the two groups (p<0.001), with Group A (117.3 ± 7.14 km.h^{-1}) bowling significantly faster than group B (101.6 ± 3.76 km.h^{-1}). Figure 4.4 shows that the 95% confidence intervals of the two groups' means did not overlap, therefore the difference was statistically significant.



<u>Figure 4.5: Mean and 95% confidence interval (CI) for bowling speed between the two groups</u>

4.4 CORE STABILITY AND BOWLING SPEED

The group with well-developed core stability bowled significantly faster than the group with poorly-developed core stability. This suggests that well-developed core stability has a positive effect on bowling speed.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

The aim of this study was to determine whether core stability had an effect on bowling speed. It was therefore important to sample two groups that were as homogenous as possible, with the main difference between the groups being the level of core stability.

Table 4.1. shows that there was no significant statistical difference between the two groups in terms of age, weight and height (p =0.762; p=0.910; p=0.165). The concept of matched pairs was also used in this study in order to further maintain homogeneity between the groups. All participants were asymptomatic with regards lower back pain as well as the kinematic chain required for bowling. All subjects had greater than six months cricket experience in an intermediate indoor/outdoor cricket league and only male fast and fast-medium bowlers were included. The ethnic profile of the subjects shown in Figure 4.1. is in contrast to that of a very similar study (n = 40) on the effectiveness of manipulative therapy in improving the bowling speed of Action Cricket players, where 34 were Indian, 4 were White and 2 were Black (Sood, 2008). Furthermore, it indicates that the popularity of cricket amongst Blacks is still trailing behind other sports especially the globally popular sport of soccer.

5.2 CORE STABILITY

Jull and Richardson (1993) suggest that there is evidence emerging to show that the oblique abdominals and TA muscles may not always be optimally recruited or may fatigue in their normal stabilising role even in normal, currently asymptomatic individuals. This is in keeping with the findings of this study with respect to initiation of core contraction and endurance as shown in Figures 4.2. and 4.3.

The mean values of the pressure readings taken during the abdominal draw-in test (Table 4.2. and Fig 4.4.) are in contrast to the findings of Richardson *et al*. (1999). They reported that successful performance of the abdominal draw-in test is indicated by a pressure reduction of 6-10 mmHg, which conflicts with the mean pressure readings noted during this study of 10.93 – 14.67 mmHg. However more recent studies by Robertson (2005), Martin (2006) and Ferguson (2007) have also recorded similar mean pressure readings of 13.00 – 13.08mmHg, 10.96 – 13.15mmHg and 10.9mmHg respectively.

In terms of the abdominal draw-in test mentioned above, Group A had a statistically greater ($p = 0.047$) pressure reduction (in mmHg) when compared to Group B. It has been suggested that a well-developed core allows for improved force output, increased neuromuscular efficiency and decreased incidence of overuse injuries (Hedrick, 2000).

Motor control endurance according to McGill (2003) is essential to achieving the stability target under all possible conditions of performance. Further to this Hodges (2003) indicated that elevated intra-abdominal pressure and contraction of the diaphragm and TA provided a mechanical contribution to the control of spinal intervertebral stiffness or stabilization particularly with regards to the drawing in of the abdominal wall. In the current study there was a statistically significant difference ($p < 0.001$) between the groups in terms of core muscle endurance (time in seconds) for the abdominal draw-in test this may suggest that Group A aside from having greater endurance of the core may also have greater lumbar stabilisation than Group B.

Richardson *et al.* (1999) acknowledged that the measurement of motor control (*viz* lumbar pelvic stability) will always present difficulties in both clinical and in research settings, in comparison to only measuring endurance of these muscle groups, this was also found to be problematic in a study on runners core stability (Martin, 2006). This may account for the apparent lack of clinically significant findings when assessing rotary bias. It is the opinion of the researcher that the test for rotary bias may be more difficult to perform when compared to the test for saggital bias and this may have had an effect on the readings obtained for the purpose of statistical analysis. Furthermore with regards the lumbopelvic stability test (Table 4.3. and 4.4.) it has been stated by previous researchers (Richardson and Jull, 1995) that participants sometimes recruit other musculature in the torso to substitute for poor stabilising muscle recruitment and that the global and local muscle patterns are difficult to differentiate and isolate from one another.

5.3 BOWLING SPEED

Bowlers were excluded from this study if their mean speed reading was less than 97 $km.h^{-1}$. Although Peterson (2004) suggested the mean bowling speed of a fast-medium bowler to be 108 (±5) $km.h^{-1}$, unofficial media classification, regarding a bowlers average ball speed, believe the range between 97 km/h and 113 km/h to be the middle range between several speed classifications (www.wikipedia.org/wiki/types_of_bowlers_in_cricket). The mean speed reading and standard deviation of Group A was 117.31 (±7.14) $km.h^{-1}$ which is above the suggested mean stated by Peterson, whilst that of Group B was 101.64 (±3.76) $km.h^{-1}$.

Other factors that have been reported to influence bowling speed that were not measured in this study largely due to lack of specific equipment (i.e. high speed cameras and motion analysers) are run-up speed, knee angle at front foot impact and ball release, trunk and bowling arm angles to the horizontal and wrist and finger contributions (Bartlett *et al.,* 1996). Davis and Blanksby (1976) stated that a crucial period for velocity development occurred in the last fraction of a second before the release of the ball. The period of most rapid hand flexion coincided precisely with the sudden change in velocity differences between their two groups (one fast bowling group and one slower bowling group) exhibited in this phase. Elliot and Foster (1986) reported percentage contributions for the wrist and fingers to be 50% and 22% respectively.

5.4 CORE STABILITY AND BOWLING SPEED

Figure 4.4. shows a highly significant difference ($p < 0.001$) between the mean bowling speeds of Group A and B with the slowest bowler from Group A being 4.8 $km.h^{-1}$ faster than the fastest bowler from Group B. It has been suggested that leaning back of the trunk, which takes place at back foot strike, may serve the purpose of increasing ball acceleration (Bartlett *et al.*, 1996), it has further been proposed that the TA muscle contributes to this action (Hodges, 2001) and that the LM muscle provides two-thirds of the stiffness at L4/L5 (Wilke, 1995).

Trunk flexion, during the delivery, has also been found to provide a significant contribution to the speed of the ball (Bartlett *et al.,* 1996; Burden and Bartlett 1990a; Elliot *et al.,* 1986; Davis and Blanksby (1976)). The TA muscle according to Hodges (2001) is vital in terms of trunk flexion therefore this study supports the above-mentioned research regarding the contribution of trunk flexion to bowling speeds.

Research has shown that the core musculature serves as the centre of the functional kinetic chain and motor control strength and endurance has been advocated as being essential to achieving the stability target under all possible conditions and as a way to enhance athletic performance (Akuthota, 2004 and McGill, 2003). In support of the above, in the current study Group A had greater mean endurance readings when compared to Group B (Group A: 61.55sec and Group B: 29.85sec) for the abdominal draw-in test and performed significantly better than Group B in terms of bowling speed as seen in Figure and Table 4.2. and Figure 4.4 respectively.

Results of this study seem to be consistent with that of Davis and Blanksby (1976), although in the current study trunk angles during delivery were not measured, as those subjects with well-developed core stability were able to bowl significantly faster than those with below average core stability ($p < 0.001$). This may be because well-developed core stability has been suggested to provide greater control of the lumbar spine in the neutral zone therefore allowing less lateral movement so that forces are transferred through the body in a straight line (Hedrick, 2000 and Panjabi 1992).

Young (1996) stated that activation patterns of the core muscle stabilising system are significant because they create contralateral flexion and counterclockwise rotation of the trunk, which contributes to the forces producing abduction of the bowling arm. Furthermore, the local and global core stabilising muscles are hypothesised as synergists therefore with weakness and fatigue of the deeper group of muscles one could expect a decrease in performance and eventually dysfunction/ injury to the more superficial prime mover muscles (Jull, 2000). This was suggested in the current study as Group A performed significantly better than group B with regards to bowling speed (Fig. 4.4.).

The thoracolumbar fascia and its interdigitation with the TA muscle is the critical structure in the preservation of normal spinal mechanics and have multiple roles in the bowling action (Young, 1996). The TA muscle has been found to be the first trunk muscle active with voluntary upper and lower limb movement in each direction and with expected and unexpected loading of the trunk producing trunk flexion (Hodges, 2001). The thoracolumbar fascia's relationship to the lattismus dorsi (LD) muscle is important as the LD muscle directly attaches to the humerus and is highly active in producing forces that increase acceleration about the shoulder during the bowling delivery (Young, 1996).

The throwing force generating capability of the shoulder in itself is not large, *viz* 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).

Appropriately timed and coordinated activation of muscles influencing spine motion reduces the need for the shoulder muscles to act as primary movers of the arm. It also enhances ones ability to utilise the musculature of the upper and lower body, which allows for more efficient, accurate and powerful movements (Young, 1996). It is well documented that fast bowlers are subjected to large ground reaction forces (3.8 to 6.4 times body weight) and that these forces may be dissipated through having an unstable lumbar spine (Bartlett *et al.*, 1996 and Young, 1996). This study supports the possibility, as purported by Portus (2000) that players with well-developed core stability have adapted by using their core trunk musculature to facilitate their trunk being used as a rigid lever to summate forces, hence increasing ball release speed, instead of using their front lower limb. Hence the findings of this study support the views held by Abelson (2004) that "ones core must be strong, flexible and unimpeded in its movement in order to achieve maximum performance".

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The primary aim was to establish whether an observable difference exists in the bowling speed of two groups of asymptomatic male indoor Action Cricket bowlers with respect to core stability. One group of bowlers with well-developed core stability and one group with poorly developed core stability.

With regards to the primary aim of the study:

- An observable difference between the bowling speeds of the two groups was observed ($p < 0.001$).
- The group with well-developed core stability bowled at greater speeds than the group with poorly developed core stability.

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

The Alternate Hypothesis (H_a), which stated that a relationship between core stability and bowling speed in male indoor Action Cricket bowlers should be shown to exist, was accepted.

6.2 RECOMMENDATIONS AND LIMITATIONS

- Although the idea of matched pairs was used in the current study further factors that may increase homogeneity in future studies include: quantifiably measuring intrinsic factors such as body composition and body movement velocities and angles, specific details regarding training habits or mode of training of the participants.
- A similar study conducted on females in order to determine possible gender differences in the relationship of core stability and bowling speed.

- This study should be repeated in a larger more representative sample of a cross-section of the cricketing population. This may improve the study's validity.
- Only one reading for each core stability test at one particular time was taken in this study. It is advised to take multiple readings over a period of time so as to ensure consistency as well as negate factors like fatigue, dehydration and low muscle glycogen stores.
- In terms of the test for rotary bias, for the purpose of future studies, it may be more beneficial to focus on explaining the test procedure to the subjects. It may also be of use to evaluate subjects by taking readings from two pressure biofeedback units during the testing process in order to attain more accurate readings.
- It was not possible to distinguish between the activity patterns of the local and global core stabilising muscles during the clinical tests for core stability. In future studies the compensatory action of global muscles needs to be identified and minimized as much as possible. Perhaps ultrasound scans could ensure accuracy of contraction as well as provide visual data of the TA muscle. Surface electromyography could be used to track global muscle activity and input during core contractions.

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APPENDIX A

Letter of information

Dear Participant

Welcome to my study. Thank you for your interest.

The title of my study is: **The relationship between core stability and bowling speed in asymptomatic male indoor action cricket bowlers.**

Name of supervisors: Dr N. de Busser (031) 373 2533
(Master's degree in.Tech: Chiropractic)
Name of student: Bruce Hilligan (082) 785 9649
Name of institution: Durban University of Technology

Introduction
This study will involve research on 30 male action cricket bowlers between the ages of 18-35, who have been playing for longer than six months, who play in divisions B through G of their respective leagues. Participants will be divided into two groups of 15 each, one group with well-developed core stability and the other group will be those participants who have poorly developed core stability.

Procedure
On initial consultation you will be required to undergo a thorough case history, a physical and lower back orthapaedic exam will be carried out by the researcher, in a vacant room at the Game City Indoor Action Cricket Arena. Following this, you will be instructed on how to perform an abdominal contraction to isolate the transversus abdominis muscle specifically. The strength and endurance of this muscle will be tested using a pressure biofeedback unit, which will give the researcher an indication of your core muscle strength and endurance. Lumbo-pelvic stability will also be tested using the pressure biofeedback unit. You will then be required to undergo a set five minute warm up after which you will be given the chance to bowl three deliveries as fast as possible where the speed will be measured.

Purpose
It is hoped that the above process will show some form of relationship between core stability and bowling speed.

This study will be conducted at the Game City Action Cricket Arena. You may be removed from the study without your consent if any of the exclusion criteria are met. The consultation and assessment should take approximately 60 minutes. This information will be gathered for the purpose of establishing correlations between core stability and bowling speed.
All patient information is confidential and the results will be used for research purposes only, although supervisors and senior clinic staff may be required to inspect records. You have the right to be informed of any new findings that are made. You may ask questions of an independent source if you wish to

(my supervisor is available on the above numbers). If you are not satisfied with any area of the study please feel free to forward any concerns to the Durban University of Technology Research Ethics Committee.

Thank you for your interest and participation.

Yours faithfully,

Bruce Hilligan — Dr. N. de Busser (M.Tech: Chiropractic)

(Chiropractic intern) — (Supervisor)

APPENDIX B
INFORMED CONSENT FORM

(To be completed by patient / subject)

Date: **Time:**

Title of research project:
The relationship between core stability and bowling speed in asymptomatic male indoor action cricket bowlers.

Name of supervisor:
Dr. N. de Busser (M.Tech:Chiropractic) [031 – 373 2533]

Name of research student:
Bruce Hilligan (082 785 9649)

<u>Please circle the appropriate answer</u>

	YES /NO	
‣Have you read the research information sheet?	Yes	No
‣Have you had an opportunity to ask questions regarding this study?	Yes	No
‣Have you received satisfactory answers to your questions?	Yes	No
‣Have you had an opportunity to discuss this study?	Yes	No
‣Have you received enough information about this study?	Yes	No
‣Do you understand the implications of your involvement in this study?	Yes	No
‣Do you understand that you are free to withdraw from this study?		
at any time	Yes	No
without having to give any a reason for withdrawing, and	Yes	No
without affecting your future health care.	Yes	No
‣Do you agree to voluntarily participate in this study	Yes	No
‣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

Prof. Ngwele (Faculty of Health Sciences Research) [031 – 373 2703]

<u>Please Print in block letters:</u>

Patient /Subject Name:______________________________ Signature: ____________

Parent/ Guardian:__________________________________ Signature:_____________

Witness Name:____________________________________ Signature:_____________

Research Student Name:_____________________________ Signature:_____________

APPENDIX E

Data Capture sheet

Patient Name: ……………………………………… Date:……………….

Weight:……………………… Age: ……………….

Height:………………………

League:

Core Contraction:
Abdominal Draw In Test

Can the core contraction be initiated: YES / NO

Was the contraction maintained for 30 seconds: YES / NO

	Fluctuation of stabilizer From the set value of 70mm/Hg during core contraction (mmHg)	Difference between the set Value of 70mmHg and Fluctuation from this value During core contraction	Time of Sustained core Contraction (seconds)
Actual Endurance Test			

Lumbo-pelvic Stability Test:

	Grading		Fluctuation from set Value of 40 mmHg at the Point at which the subject Cannot maintain core Contraction (mmHg)		Difference between the set Value of 40 mmHg and Fluctuation from this value At the point at which the Subject cannot maintain Core contraction (mmHg)	
	Right	Left	Right	Left	Right	Left
Test						
Saggital Bias						
Test Rotary Bias						

Grade 1a / Grade 1b / Grade 2a / Grade 2b

Group Allocation:

A / B

Bowling Speed:

Delivery 1	
Delivery 2	
Delivery 3	

Mean speed: ……………. Km/h