A randomised clinical trial comparing the effectiveness of two exercise programmes on core strength and balance in healthy females

By

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I, Nicole Mavimbela, do declare that this dissertation is a representation of my own work in both concept and execution.

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DEDICATION

I dedicate this dissertation to:

My mother Welile Tshabalala for the unconditional love and support and for all the sacrifices made to get me to this point. For dreaming this dream for me before I had the wisdom to want if for myself.

Monte Mamba for carrying us through the darkest times.

To my siblings Ivan, Felix and Sphesihle; for being as constant as the sun and for loving me as much as I love you.

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ABSTRACT

Low back stability and low back strengthening exercises have emerged as popular techniques related to optimal athletic/occupational performance and the rehabilitation of painful backs (McGill 2001). The core provides local strength and balance as well as reduces the risk of low back injury (Kibler, Press and Sciascia 2006). Core strength is important in providing a solid base for the body to exert or resist forces. According to Anderson and Behm (2005), however, it is still uncertain as to which type of training is most effective in providing trunk and joint stability in its role in injury prevention and its contribution to balance.

AIM:

To determine if exercises performed on an unstable surface would result in greater balance improvements in healthy female participants when compared with exercises performed on a stable surface.

METHODS:

Forty asymptomatic females between the ages of 18 and 30 were recruited via self-selection. The study was a randomised clinical trial where all participants underwent a case history, a physical examination and a lumbar spine regional examination. Thereafter, participants were asked to stand on the Biosway Portable Balance System where baseline readings of the Clinical Test of Sensory Integration and Balance (CTSIB) and the Postural Stability Test were taken. The CTSIB has four test conditions – Condition 1: eyes open firm surface, Condition 2: eyes closed firm surface, Condition 3: eyes open foam surface, and Condition 4: eyes closed foam surface. The Postural Stability Test was presented in terms of overall postural stability, anterior/posterior stability and medial/lateral stability. Participants were then taught how to activate their core muscles by means of the prone coactivation exercise. A Pressure Biofeedback Unit was used to provide an objective measurement of the successful execution of the exercise.

Participants were then allocated to either Group A or B and were taught how to perform the various core strength exercises. Participants in Group A performed the side bridge and single leg extension hold on a stable surface; participants in Group B performed the prone bridge and the quadruped reach on a Swiss ball. Participants were instructed to perform their respective

exercises daily at home and they were also told the required number of sets repetitions they were to do. During the first week the participants were to perform three sets of 30 second holds daily, for the bridge exercises and three sets of 60 seconds for the extensor exercises. During the second week the participants were to perform four sets of 30 and 60 second holds, respectively. In the third and fourth weeks the participants were expected to perform five sets of 30 and 60 second holds respectively. The study participants reported to the Chiropractic Day Clinic once a week for four weeks and performed their exercises in the presence of the researcher. In the fourth week, however, the participants were asked to stand on the Biosway Portable Balance System and final readings of their CTSIB and Postural Stability Test were taken. All data was collected by the researcher. SPSS version 21 was used to analyse the data. A p value < 0.05 was considered as statistically significant. Intra-group analysis was done on each treatment group individually to assess the effect of the treatment over time using repeated measures ANOVA for each outcome separately. Inter-group analysis was achieved using repeated measures ANOVA with a between group effect of the intervention. A significant time x group intervention effect would signify a treatment effect. Inter-group correlations between changes in outcomes over time were achieved using Pearson's correlation coefficient.

RESULTS:

The mean (± SD) age of the participants was 22.1 years. In terms of the CTSIB test under condition 1 there was no statistically significant effect of the intervention ($p=0.431$), group B showed a decrease in their sway index after the intervention. Under condition 2 group A participants showed a decline in their sway index, however results were statistically insignificant ($p=0.129$). Both groups showed a decrease in sway index overtime under conditions 3 and 4 with group B showing a faster decline in sway index overtime under condition 3. Results remained statistically insignificant for both conditions ($p=0.171$) and ($p=0.766$) respectively. In terms of the Postural Stability Test the intervention was found to have no effect on the balance of study participants ($p=0.548$).

CONCLUSION:

The results of this study demonstrated a statistically insignificant improvement in the core strength and balance of the participants in both study groups. Taking into account the nature of the study population there is a possibility of a clinically significant effect were this study to be conducted on older individuals instead of younger individuals.

For some of the outcomes measured there was a non-statistically significant trend towards an effect of the intervention, however for others both groups displayed the same trend over time. The power of the study to show a significant effect where one might have existed was low and thus the study should be repeated with a larger sample size using the outcomes which showed differential results between the treatment groups.

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Chapter 1
Introduction

1.1 Introduction

The term 'core strengthening' is used to describe the muscular control required around the lumbar spine to maintain functional stability (Akuthota and Nadler 2004). The core can be defined as the 29 pairs of muscles that support the lumbo-pelvic-hip complex in order to stabilise the spine, pelvis and kinetic chain during functional movement (Faries and Greenwood 2007). When these muscles contract they provide direct support and increased intra-abdominal pressure to the inherently unstable spine (Faries and Greenwood 2007). Core strength is important in providing a solid base for the body to exert or resist forces, however according to Anderson and Behm (2005), it is still uncertain which type of training is most effective in providing trunk and joint stability in its role in injury prevention and its contribution to balance.

Balance is achieved by the interaction of various body systems, including the active and passive restraints of the muscular system (Anderson and Behm 2005). Musculoskeletal weakness, defined as decreased muscle endurance and muscle fatigability, has been associated with impaired balance (Hodges and Richardson 1996). According to Pollock, Durward and Rowe (2000) human stability is the inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall. The inherent ability refers to the motor and sensory systems and to the physical properties of the person, whereas postural control can be defined as the act of maintaining, achieving or restoring a state of balance during any posture or activity. The premise behind core strength training is that for one to achieve or maintain balance then one must have functional postural control. The postural control will come from appropriate activation and timing of the core musculature (Oliver and Di Brezzo 2009).

In the rehabilitation sector, core strength training includes using the traditional strength training methods such as stable benches and floors (Anderson and Behm 2005). The introduction of instability by using the Swiss ball, among other things, has been thought to result in increased proprioceptive demands and stress the core muscles for better athletic performance and balance (Cosio-Lima *et al*. 2003).

As people age there is a general deterioration in a number of musculoskeletal and sensory systems that affect postural control and balance (Isles *et al*. 2004). Petrofsky *et al*. (2005) stated that due to the muscular weakening that occurs naturally with aging, elderly subjects tend to have weakened core musculature. Therefore, strengthening these weak muscles increases functionality and balance in these subjects (Petrofsky *et al*. 2005). Low Choy *et al*. (2003) stated that the identification of balance norms may aid in the early identification of balance deficits in young people. It is for this reason that a sample population of 18 to 30 year- old healthy females was selected.

A number of studies have been conducted to determine what effect resistance training has on balance (Anderson and Behm 2005; Cosio-Lima *et al*. 2003; Kibele and Behm 2009), however consensus has not been reached as to which form of resistance training significantly affects balance. This study was designed as a randomised clinical trial comparing the effect of two different forms of core strength training programmes on balance in healthy females.

1.2 Aims and Objectives

1.2.1 The aim of the study was to determine if exercises performed on an unstable surface would result in greater core strength and balance improvements in healthy female subjects when compared with exercises performed on a stable surface.

1.2.2 The objectives of the study were:

Objective one

To compare the effectiveness of a stable versus unstable core muscle endurance training programme on healthy females in terms of core stability.

Objective two

To compare the effectiveness of a stable versus unstable core muscle endurance training programme on healthy females in terms of balance.

Objective three

To compare the effectiveness of a stable and unstable core stability training programme on healthy females in terms of core strength and balance.

1.3 The hypothesis

A hypothesis was set that there would be no statistically significant difference in the core strength and balance improvements of the study participants in the two different groups.

1.4 The scope of the study

Core strength and stability is seen as being pivotal for efficient biomechanical function to maximise force generation and minimise joint loads in various types of activities (Kibler, Press and Sciascia 2006). Research has demonstrated higher core muscle activity when resistance exercises were performed on a Swiss ball versus a stable surface (Willardson 2007). Behm *et al*. (2007), compared activation of the core musculature during six common trunk exercises performed on a Swiss ball, and on the floor or stable bench. The exercises performed on the Swiss ball resulted in greater lower abdominal muscle activation than those exercises performed on a stable surface. The purported advantage of instability is the increased muscular demand required to maintain postural stability (Imai *et al*. 2010).

Postural balance plays an important role in maintaining functional capacity (Era *et al*. 2006). Low-Choy *et al*. (2003) demonstrated an increase in postural sway with age in women. Good balance is possibly a precondition for certain types of occupations where demands on balance are high, as well as in sporting activities and hobbies (Era *et al*. 2006). Musculoskeletal weakness has been associated with impaired balance (Hodges and Richardson 1996). Woollacott and Shumway-Cook (1990) found delays in muscle response times to perturbations in older adults when compared with younger adults. Hodges *et al*. (1996) demonstrated that low back pain causes muscle fatigue.

Core strength training has been shown to have beneficial effects in relieving pain and disability in patients with chronic low back pain and lowering recurrence rates after an acute pain episode (Richardson *et al.* 2002). The socioeconomic burden resulting from the global prevalence of low back pain, affecting between 4 - 33% of the population at any given point can be greatly improved if chiropractors employ core stability exercise principles when treating their patients (Woolf and Pfelger 2003). In addition, a number of studies have found core stability training results in an improvement in the functions of extremity joints such as the ankle. Hertel and Mckeon (2008) found that core stability training could lead to prevention of future ankle sprains after acute episodes of injury. Since chiropractors treat musculoskeletal conditions, the use of core stability training may provide benefit in the rehabilitation phase of many joint injuries. The strength and proprioceptive gains that result from core stability training will assist in reducing recurrence of joint injuries or pain episodes.

1.5 Limitations of the study

The sample size (*n* = 40) was relatively small. This was principally owing to human resource and financial constraints. The participants were tasked with performing the exercises at home and they may not have been performing the exercises correctly. They may also have not been performing the exercises as often as they had been instructed to and, some participants may not have been completing their exercise diaries honestly. This would therefore speak to the need for supervised exercise sessions to ensure compliance and proper technique.

In the remaining chapters, the researcher will review the literature on core strength training and balance (Chapter 2); describe in detail the methodology of this study (Chapter 3); present the statistics and results of the study (Chapter 4); and present the conclusions and recommendations for future studies (Chapter 5).

Chapter 2
Literature Review

2.1 INTRODUCTION

This chapter reviews the literature relevant to this study and provides a description of the anatomy of the core musculature. It also discusses the relationship between core stability training and balance and how these two concepts are different between females and males.

2.2 Core strength and core stability

Faries and Greenwood (2007) describe core strength as a muscle's ability to exert or withstand a force, and describe core stability as the body's ability to control the range of motion of a joint so there is no neurological deficit, deformity or incapacitating pain. Therefore, core musculature serves to stabilise the spine during functional demands so that the body maximises stability.

Core stability and core strength training have transcended into the sports medicine world. Some of the benefits of core stability training have been listed as improving athletic performance, preventing or reducing injury risk, as well as alleviating low back pain (Akuthota *et al.* 2008). Akhutota and Nadler (2004) describe the core as a box with the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom. The core functions to stabilise the body and spine both with and without limb movement, and as such has been referred to as the powerhouse - the foundation of all limb movements (Akuthota and Nadler 2004).

Panjabi (2003) defines clinical instability as the loss of the spine's ability to maintain its patterns of displacement under physiologic loads so there is no initial or additional neurologic deficit, no major deformity, and no incapacitating pain. He also described a three-component system of spinal stabilisation – an active part which is muscular, a passive part which is osteoligamentous, and a controlling part which is the central nervous system (Panjabi 1992). These three systems are interdependent as an injury or dysfunction in anyone of them may lead to spinal instability. Liebenson (1997) describes core instability as an increase in the neutral zone around a joint or a decrease in joint stiffness. Once instability occurs excessive muscle activity is required to prevent injury (Cholewicki and McGill 1996).

The goal when rehabilitating the motor system is to improve spinal stability. With the demands of modern day sedentary living overworking the postural muscles they are prone to tightness; underworking the dynamic muscles making them prone to atrophy and inhibition; therefore neuromuscular control must be taught to prevent injury and repetitive strain (Liebenson 1997). Stability is a dynamic process that involves both static positions and controlled movement (Barr, Griggs and Cadby 2005), therefore it can be surmised that the gradual degeneration of joints and soft tissue due to repetitive microtrauma may lead to spinal instability.

When there is a relative increase in the range of the neutral zone, also known as functional instability, active stiffness or stability of the spine is then required. This stiffness can be achieved by co-contraction of the transverse abdominus muscle (Akuthota *et al*. 2004). The act of co-contraction also connects the stability of the lower and upper extremities by means of the abdominal fascial system (Akuthota *et al*. 2004). A programme that strengthens or teaches refacilitation of the neuromuscular system is thought to prevent and rehabilitate various lumbar spinal and musculoskeletal disorders as a way to improve stability of the spine.

2.2.1 Balance

Ragnarsdottir (1996) defines balance as a function demanding continuous adjustments of muscle activity and joint position to keep the body weight above its base of support, while Edwards and Patterson (2011) define balance as the ability to maintain the centre of gravity of a body within its base of support with minimal postural sway. Balance is seen as pivotal for functional competence, essential for the execution of activities of daily living as well as being necessary for performing exercises that require great speed or force (Era *et al.* 2006).

In order to maintain upright posture the body undergoes continuous adjustments to its position to keep the centre of gravity over its base of support. The differential effect of postural instability on upright posture is due to two mechanisms: the alteration of proprioceptive messages at the peripheral level, and anticipatory postural adjustments by the central nervous system (Anderson and Behm 2005).

The proprioceptive and peripheral control mechanisms of postural control are due to the numerous efferent and afferent control strategies within the sensory motor system which use feedback from the somatosensory, visual and vestibular systems (Borghuis, Hof and Lemmink

2008). Anderson and Behm (2005) stated that viscolestic forces within the ankle joint correct disturbances to upright posture and if the perturbation is large, greater contraction of muscle is required. The authors suggest that these contractions could emanate from stretch or vestibulospinal reflexes or be a voluntary response triggered by multimodal sensory input. Furthermore, proprioceptive input from the trunk and upper leg muscles establishes the timing of automatic triggered balance corrections; this information is then processed by the vestibuar system and modulated in muscles that prevent falling. The afferent information is then processed by the cerebellum following which motor commands are initiated allowing balance to be maintained.

The central nervous system then co-ordinates the focal movement by means of anticipatory postural adjustments. Gamma motor neuron activity during this process allows for co-contraction of the muscles involved in maintaining upright posture. Indeed, it is known that leg and trunk muscles are activated prior to limb movement; this occurs in order to minimise equilibrium disturbances that occur with limb movement (Borghuis, Hof and Lemmink 2008). Anderson *et al*. (2005) speculate that these anticipatory adjustments occur in order for the supporting structures to be stabilised for the efficient execution of limb movement. Lin and Woollacott (2002) studied muscle activity during supported and unsupported standing and found increased electromyography (EMG) activity of lower limb muscles during unsupported standing. The authors discovered that the soleus and tibialis anterior were active prior to limb movement when study participants were unstable, but found no anticipatory activation when study participants were stable. During movement complex neuromuscular processes maintain our upright posture. The mechanical problem of maintaining posture is challenging nonetheless. With central processing by the cerebellum coupled with anticipatory postural adjustments and proprioceptive feedback, we are able to meet the continuous demands for maintaining posture and balance (Anderson and Behm 2005).

2.2.2 Age and balance

Balance has been widely studied in older adults and those with neurological deficits, however a limited number of studies are available that examine balance in healthy young adults. Woollacott and Shumway-Cook (1990) showed evidence of changes across all levels of the postural control system as the motor control system ages. These changes are greater at the level of vestibular control, moderate at the level of autonomic responses, and minimal at the monosynaptic levels. Woollacott and Shumway-Cook (1990) found that with increased age there are small increases in muscle onset latencies and disruptions in the temporal organisation of postural muscle activity when balance is challenged. The authors also discovered that with deterioration of the motor control system elderly individuals use the antagonist muscle more often in co-activation with the agonist muscle when balancing.

Increased postural muscle activity has been found with increasing age. Laughton *et al*. (2003) demonstrated an increase in activity of the tibialis anterior, soleus and biceps femoris muscles in older subjects when compared with younger study participants. The authors further state that this result was not exclusive to elderly subjects who had reported a history of falls, it was inclusive of elderly subjects who had no history of falls. Laughton *et al*. (2003) theorises that this increased muscle activity may be due to the deterioration of the sensory and neuromuscular mechanisms which control posture. Increased levels of muscle activity are thought to assist in augmenting joint proprioception by increasing the firing rate and recruitment of primary afferents, in so doing improving the functional behavior of the associated closed-loop postural control mechanisms.

While studying the effect of age on postural stability Du Pasquier *et al*. (2003) demonstrated that postural stability improves gradually up to the age of 25, but then begins to deteriorate from age 25 onwards. Isles *et al*. (2004), however, found that the most significant decline in postural stability in females was between the fourth and sixth decade. Several authors (Pasquier *et al*. 2003; Isles *et al*. 2004; Era *et al*. 2006) report that increased postural sway has been linked with an increased risk of falls among elderly individuals; these falls are often debilitating for this population. Isles *et al*. (2004) stress the need to screen younger individuals for possible deficits in postural stability so that the necessary interventions can be employed to prevent debilitating falls later on in life. Interventions such as strength, flexibility and balance training have been found to have a significant effect in improving postural stability. Exercises that challenge the sensory and motor system have been found to have a positive effect on postural stability (Isles *et al*. 2004).

2.3 Anatomy

2.3.1 The lumbar spine

Figure 2.1

https://www.ceessentials.net/images/TSpineER/image007a.jpg

Figure 2.1 illustrates the lumbar vertebrae which are located between the thoracic vertebrae and the sacrum. The lumbar vertebrae are thicker towards the inferior end of the vertebral column because the weight they support increases closer to the lower end of the spine (Moore and Dalley 2006).

The lumbar spine consists of five large kidney-shaped bodies which increase in size from L1 to L5. The vertebral arch is horse-shaped and is made from laminae and pedicles. It consists of seven processes that project from it. These are the inferior and superior articular processes, one spinous process and two transverse processes. The inferior articular processes have a lateral orientation and the superior articular processes are oriented in a medial direction. The spinous processes are short and sturdy, being thick, broad and hatchet-shaped (Moore and Dalley 2006). The transverse processes extend from the junction of the laminae and pedicle; they are long and slender and consist of an accessory process on their posterior surface. These accessory processes provide a point of attachment for the medial intertransverse lumborum muscle. The spinous and transverse processes serve as a point for muscle and ligamentous attachment. The articulation between superior and inferior articular processes of adjacent vertebrae forms a locking mechanism which prevents locking and twisting of the vertebral bodies (Moore and Dalley 2006).

2.3.2 The sacrum

Figure 2.2

http://fotosearch.com

The sacrum, as illustrated in **Figure 2.2** above, is a fusion of the five sacral segments that results in a triangular wedge-shaped bone. The sacral base, which is formed by the S1 superior surface, has two superior facets that articulate with L5. Laterally, it articulates with the ilium. The sacral apex points downwards to articulate with the coccyx by means of a disc. The sacral tubercles, located in the midline, correlate with the spinous processes of the fused vertebrae, whereas the tubercles on the posterolateral aspect correlate with the transverse processes. The sacrum provides strength and stability to the pelvis and transmits the weight of the body to the pelvis. It supports the vertebral column and forms the posterior part of the pelvis (Moore and Dalley 2006).

2.3.3 Muscles of the Lumbar Corset

The core consists of 29 pairs of muscles which support the lumbopelvic hip complex in order to stabilise the spine, pelvis and kinetic chain during functional movement (Shankar and Chaurasia 2012). The transverse abdominus, multifidus, diaphragm and pelvic floor muscles are the main muscles, also known as the powerhouse muscles. They provide a solid base from which all other muscles can work to initiate movement (Shankar and Chaurasia 2012).

Akuthota *et al.* (2008) state that the core has muscles that have slow twitch and fast twitch fibers. The muscles containing slow twitch fibers are known as local muscles as they are found close to the spine. These muscles control inter-segmental motion and respond to changes in posture and extrinsic loads. The two primary local muscles are the transverse abdominus and the multifidii. The fast twitch muscles are known as the global muscles. These are the superficial muscle layer; they are long and possess large lever arms. This allows them to produce large torque and movement. Key global muscles include the erector spinea, rectus abdominus, quadratus lumborum as well as the internal and external obliques.

2.3.3.1 The local muscle system

<u>Transverse abdominus</u>

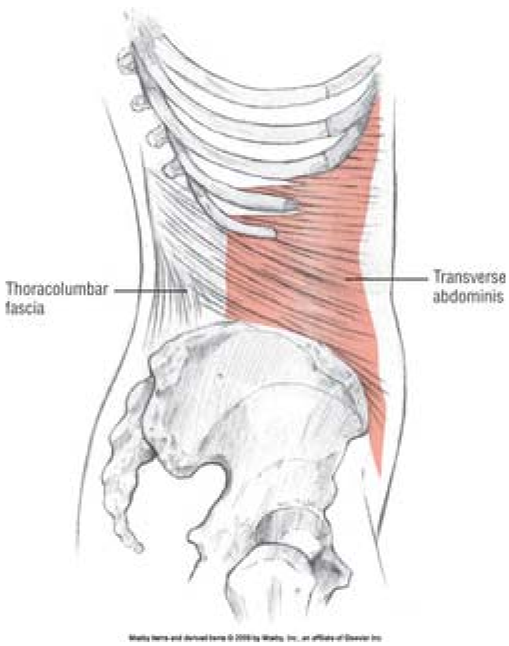


Figure 2.3

http://www.biotawellness.com/uploads/1/6/1/5/16159734/6978830.jpg

The transverse abdominus, in **Figure 2.3** begins at the lateral third of the inguinal ligament, iliac crest, thoracolumbar fascia and the internal surfaces of 7th – 12th costal cartilages. It inserts at the midline of the linea alba via the rectus sheath and to the pubis through the conjoined tendon. This muscle is innervated by branches from the 8th – 12th intercostal nerves and the first lumbar nerves (Moore and Dalley 2006).

Multifidus

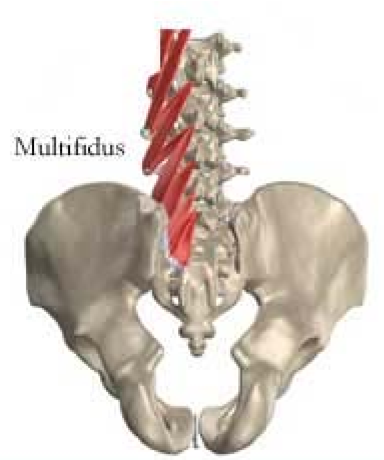


Figure 2.4

http://www.drummondeducation.com/wp/wp-content/uploads/2013/11/multifidus3.jpg

The multifidi, as shown in **Figure 2.4** arises from the posterior sacrum, the posterior iliac spine of the ilium and the bases of spinal processes. This muscle is broadest in the lumbar region; the fibers pass obliquely superomedially to entire length of spinous processes of vertebrae. This muscle is innervated by the posterior rami of spinal nerves (Moore and Dalley 2006).

Functions and actions of the local muscle system

As already stated the muscles of the local muscle system lie proximal to spinal segments and respond to external loads and changes in posture. The transverse abdominus is a key stabiliser of the lumbar spine and evidence suggests that a rehabilitation focus on its role in stabilisation of the spine helps reduce low back pain (Richardson *et al.* 2002). Contraction of the transverse abdominus increases intra-abdominal pressure and tensions the thoracolumbar lumbar fascia (Kibler, Press and Sciascia 2006). The multifidii also provides single-segment control upon their contraction, thus allowing the longer, multi-joint muscles to work more efficiently to provide lumbar spine control (Kibler, Press and Sciasa*.* 2006). These muscles fire independently of other muscles in response to visual stimulus and prior to limb movement (Barr, Griggs and Cadby 2005). Hodges and Richardson (1999) found that these two muscles contract 30ms before shoulder movement and 110ms before movement of the leg in healthy people. This function is thought to stabilise the spine.

The multifidus extends and stabilises the vertebral column (Moore and Dalley 2006). Richardson and Jull (1995) demonstrated that it contributes to the control of the neutral zone and provides more than two-thirds of the stiffness increase at the L4 and L5 segments. The mechanism through which these muscles provide stability to joints is known as co-contraction. This is a process whereby muscle stiffness is increased by contracting the agonist and antagonist muscles on either side of the joint (Richardson and Jull 1995). The muscles involved in co-contraction are shown to provide stability even at levels of 25% maximum voluntary contraction (Richardson *et al*. 2002).

Maintaining balance in the local muscles is the key, as their dysfunction will lead to compensation by the larger global muscles and result in spinal instability (Sharrock *et al.* 2011).

2.3.3.2 The global muscle system

Internal oblique

Figure 2.5
http://sr.photos3.fotosearch.com/bthumb/LIF/LIF126/3D610005.jpg

Figure 2.5 shows the internal oblique originates from the thoracolumbar fascia, anterior two-thirds of the iliac crest and the lateral half of the inguinal ligament. It then inserts at the inferior borders of the 10^{th} – 12^{th} ribs, linea alba and pecten pubis. It receives its nerve supply from the anterior rami of the inferior 6 thoracic nerves and the 1^{st} lumbar nerves (Moore and Dalley 2006).

External oblique

Figure 2.6
http://sr.photos2.fotosearch.com/bthumb/CSP/CSP100/k18009830.jpg

The external oblique, shown in **Figure 2.6** originates from the external surfaces of the 5th and 12th ribs. It then inserts at the linea alba, pubic tubercle and the anterior half of the iliac crest. This muscle receives its innervation from the thoracoabdominal nerves and the subcostal nerve (Moore and Dalley 2006).

Rectus abdominus

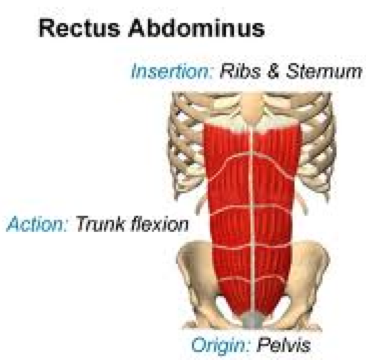


Figure 2.7
http://www.thansworld.com/ONLINEanatomy_1/images/section5/oi_rectus_ab.jpg

The rectus abdominus, as seen in **Figure 2.7** originates from the pubic symphysis and the pubic crest and inserts at the xyphoid process and 5th and 7th costal cartilages. It receives its nerve supply from the anterior rami of the inferior 6 thoracic nerves (Moore and Dalley 2006).

Quadratus lumborum

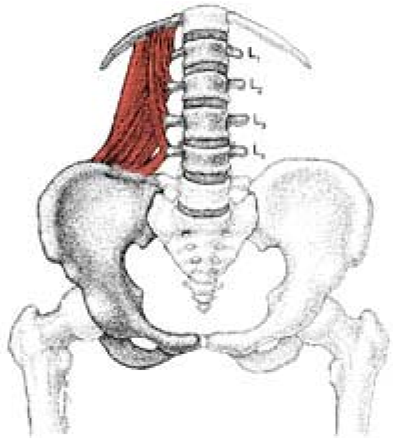


Figure 2.8
http://www.floota.com/images/QuadratusLumborumDiagram.jpg

Figure 2.8 shows the quadratus lumborum originates from the medial half of the inferior border of the 12th ribs and the tips of the lumbar transverse processes. It inserts at the iliolumbar ligament and internal lip of the iliac crest. The muscle receives its nerve supply from the anterior branches of T12 and L1-L4 nerves (Moore and Dalley 2006).

Erector spinae

Figure 2.9
http://o.quizlet.com/i/lyjJ_jhRYScsCoUr682oTA_m.jpg

Figure 2.9 shows the erector spinae lies in a trough on either side of the spinous processes, 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 (Clarke 2009). In the lumbar spine the erector spinae are composed of two major muscles, longissimus and illiocostalis. These are actually primary thoracic muscles that act on the lumbar spine via a long tendon that attaches to the pelvis. This long movement arm is ideal for lumbar spine extension and for creating posterior shear with lumbar flexion (Akuthota and Nadler 2004)

Functions and actions of the global muscle system

The muscles of the anterior abdominal wall serve as support for the anterolateral abdominal wall, protect abdominal viscera and assist in respiration. They also move the trunk and maintain posture (Moore and Dalley 2006). The internal and external oblique muscles form a muscular girdle to increase intra-abdominal pressure and to flex the trunk. When functioning unilaterally they bend the trunk towards the ipsilateral side and aid in trunk rotation (Travell and Simmons 1999). The rectus abdominus is a prime mover in trunk flexion; it stabilises the pelvis during walking and when performing lower limb lifts (Moore and Dalley 2006).

The quadratus lumborum controls lateral flexion to the contralateral side, it also fixes the last rib during respiration. Working unilaterally on a fixed pelvis, it acts as a lateral flexor to the ipsilateral side. When the muscle functions bilaterally it extends the lumbar spine (Travell and Simmons 1999).

2.3.3.3 The thoracolumbar fascia

Figure 2.10

http://o.quizlet.com/wDvyBCsGd06j2ju046wkNQ_m.png

The thoracolumbar fascia as shown in **Figure 2.10** dense network that extends from the sacrum to the upper back and neck. It is prominent in the lumbar region and consists of three layers of connective tissue – the anterior, middle and posterior layers. The three layers merge laterally and serve as points of attachment for the internal and internal obliques and the transverse abdominus muscles. The posterior layer is the thickest and strongest of the three and is the only layer to extend into the thoracic region.

The posterior layer attaches to the spinous processes of the lumbar vertebrae and lies posterior to the erector spinea and multifidus muscles. The middle layer is attached to the lumbar transverse processes and separates the deeper lumbar portion of the erector spinea muscle from the quadrates lumborum muscle. The thinner anterior layer covers the anterior surface of the quadratus lumborum muscle. This anterior layer forms an attachment with the diaphragm via the lateral lumbocostal arch (Vleeming, Mooney and Stoeckart 2007).The diaphragm working with the muscles of the pelvic floor as well as transverse abdominus increases the stiffness of the spine by increasing intra-abdominal pressure (Hodges and Richardson 1996).

The posterior layer is designed to transmit forces between the shoulder girdle, lumbar spine, pelvic girdle and lower extremity (Hodges and Richardson 1996). When muscles that are connected to the fascial network contract there is an increase in fascial tension, which results in stiffening of the spinal column (Vleeming, Mooney and Stoeckart. 2007). Linkages between the muscles involved in stabilising the lumbar spine and the thoracolumbar fascia are important as this connection augments spinal stability.

The thoracolumbar fascia may also play a proprioceptive role in lumbar stability. As it is attached to ligaments and muscles as well as mechanoreceptors, it is closely related to the three subsystems of Panjabi's model of spinal stability (Vleeming, Mooney and Stoeckart 2007). Panjabi (1992) states that the mechanoreceptor feedback from muscles and ligaments might be incorporated into the neural subsystem and the tension in the muscles may be modified to prevent excessive segmental motion. The thoracolumbar fascia provides a link between the lower and upper limbs; when the muscles attached to it contract it behaves as an activated proprioceptor providing feedback during various activities (Akuthota and Nadler 2004).

2.3.3.4 Ligaments of the Lumbar Spine

The main ligaments of the lumbar spine are the anterior longitudinal ligament, the posterior longitudinal ligament, the iliolumbar ligament and the sacroiliac ligaments. **Figure 2.11** shows the anterior longitudinal ligament as a long, broad fibrous structure that originates from the anterior basal aspect of the occipital bone and ending at the upper anterior aspect of the sacrum. Its fibres attach on the anterior aspect of the vertebral bodies (Kirkaldy-Willis and Bernard 2004). The anterior longitudinal ligament limits hyperextension of the vertebral column and maintains stability of the joints between vertebral bodies (Moore and Dalley 2006).

Figure 2.11
https://aclandanatomy.com/images/videoTnails/abstract_3-1-4.jpg

The posterior longitudinal ligament, as shown in **Figure 2.12,** is located on the posterior surface of the vertebral column; it arises from the basal aspect of the occipital bone at the foramen magnum. It is thinner than the anterior longitudinal ligament and attaches to the superior margin of the vertebral bodies and intervertebral discs. It is thinner in the thoracic and lumbar regions (Kirkaldy-Willis and Bernard 2004). It functions in preventing hyperflexion of the vertebral column and helps prevent or redirect posterior herniation of the nucleus pulposus (Moore and Dalley 2006).

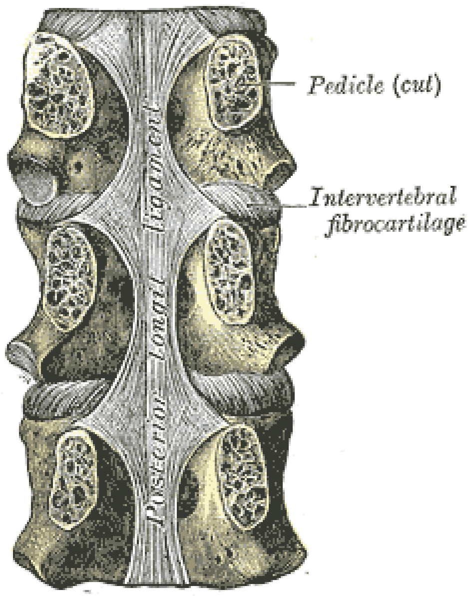


Figure 2.12
http://fotosearch.com

Figure 2.13 shows the iliolumbar ligament which is thick and broad. Proximally it attaches to the tip and anterior part of the fifth transverse process. It usually divides into two bands, the superior band attaches to the iliac crest in front of the sacroiliac joint and the inferior band blends into the anterior sacroiliac ligaments. This ligament is a major stabiliser of the L5 vertebral body on the sacrum (KIrkaldy-Willis and Bernard 2004).

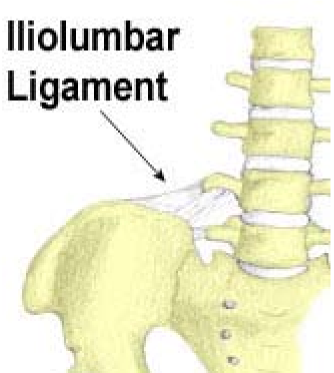


Figure 2.13

http://return2fitness.com/media/injuries/iliolumbar.jpg

The sacroiliac ligaments, as shown in **Figure 2.14**, are found on the anterior and posterior aspect of the sacrum; they are also known as the interosseous ligament. This ligament fills the space immediately above and behind the joint. It has deep and superficial fibres which blend and form a fibrous sheet covering the entire posterior part of the joint. Anteriorly the ligament is a weak thickening of the capsular ligaments (Kirkaldy-Willis and Bernard 2004).

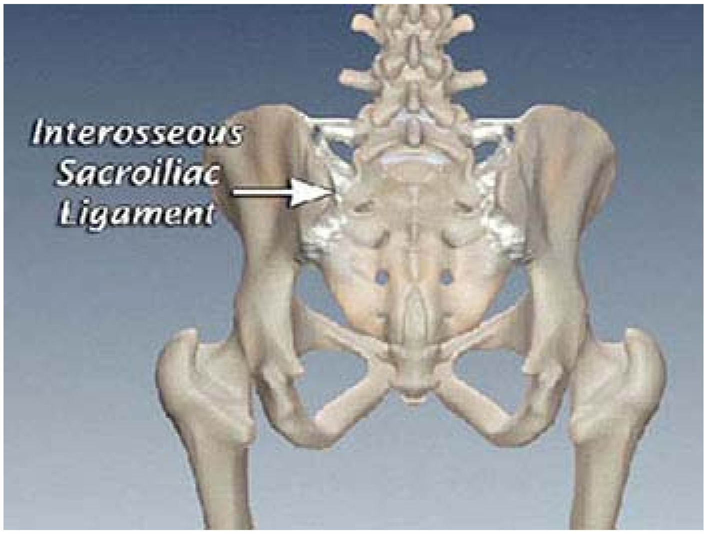


Figure 2.14

http://www.sijoint.com/images/interosseous-sacroiliac-ligament.jpg

2.4 Biomechanics of spinal instability

As previously stated, spinal stability is dependent on the coordinated efforts of the passive, active and neuromuscular systems (Panjabi 1992). The spinal column provides intrinsic stability, the muscles provide dynamic stability, and the neural system has a proprioceptive role and co-ordinates muscle response times to external forces. Instability occurs when there is an increase in the neutral zone of a joint or if there is a decrease in joint stiffness (Liebenson 1997). The neutral zone is the part of range of motion within which there is minimal resistance to vertebral motion. In a stable spine the neutral zone is small but in an unstable spine this zone is wider (Panjabi 2003). The area of the neutral zone may be increased due to injury, disc degeneration and weakness of the muscles (Clarke 2009). Therefore, an increase in the neutral zone translates to spinal instability.

The spinal column on its own can withstand forces up to 90 N, but *in vivo* it is able to withstand forces as large as 1 500 N and greater (McGill 2001). This increased ability to withstand external loads is enhanced by the function of the muscles which act as guy wires stiffening the spine, increasing its critical load and its stability (Panjabi 2003). While studying the effect of injury on the spinal column, Panjabi (2003) found an increase in the neutral zone and the range of motion of affected spinal segments. During the same experiment, however, it was established that when the forces applied to the vertebral segments were reduced, in this case from 90 N to 60 N, the neutral zone decreased to within normal limits. The authors hypothesised that the muscles function to stabilise the spine by reducing the neutral zone.

With instability there may be a deficit in the neuromuscular subsystem especially with proprioception (Demoulin *et al*. 2007). This deficit is evident under dynamic conditions when postural control is assessed by measuring the sway of the center of gravity of the body. Investigations revealed sensorimotor dysfunction such as modified postural control and delayed motor response (Demoulin *et al.* 2007). Hodges and Richardson (1999) found that in cases of spinal instability the transverse abdominus muscle had a delayed response time. In healthy individuals this muscle showed EMG activity 25 m/s prior to limb movement. The sensorimotor dysfunction in this muscle is thought to result in the decrease of spinal stability at the onset of limb movement.

Spinal stiffness improves with flexor-extensor muscle co-activation. Co-activation of all muscles of the lumbar corset increases intra-abdominal pressure. According to Hicks *et al.* (2005) all muscles are involved in ensuring stability of the spine and the motor patterns of co-contraction of these muscles are essential in ensuring spinal stability.

2.5 Gender differences in core strength and stability

Recent studies suggest that structural differences between males and females may contribute to differences in core strength and stability. One such structural difference was noted by Pool-Goudzwaard *et al*. (1998). The authors stated that the cartilage of the male sacro-iliac joint was more irregular than that of the female sacro-iiac joint. This structural difference was thought to be due to the requirements of pregnancy and childbirth and possibly different localisation of the centre of gravity of the sacro-iliac joint.

Females were also found to have greater hip adduction, knee abduction, hip internal rotation and tibial external rotation when compared with males in a study by Ferber, McClay Davis and Williams (2003). Leetun *et al*. (2004) compared gender differences in core strength between males and females and found that females demonstrated inferior strength in side bridge endurance and hip abduction and external rotation isometric strength. The authors suggested that hip and core muscle weakness reduces the ability of females to stabilise the hip and core, rendering these segments vulnerable to perturbations when large external forces are exerted upon them.

In an effort to compile a database of normative data for endurance times for core endurance exercises, McGill, Childs and Libenson (1999) found that females demonstrated reduced endurance when performing the side bridge exercise and torso flexion when compared with their male counterparts. Nadler *et al*. (2001) stated that females demonstrated a greater difference in side-to-side hip extension strength symmetry when compared with the males in their study. Bohannon (1997) identified greater isometric strength in hip abduction by 19% in males versus females after strength was normalised to body strength.

Zazulak *et al*. (2007) theorised that this weakness in core strength is possibly related to bone structure and postural differences in the pelvis. Stability may be influenced by the anatomical alignment of the female pelvis which influences the angle of muscular attachments. Minor changes in the orientation of pull of the muscles of the trunk on the pelvis may result in a decreased ability to control the spinal unit. The gender differences in core strength and stability may speak to a need for the development of a core strengthening programme that takes into account the structural and biomechanical differences between the sexes in order for subjects to obtain the most benefit from any core training programme.

2.6 The use of instability to the train the core

Core muscle endurance and strength and upper body balance are essential for stabilising the trunk and maintaining appropriate posture and movement of the body. Cosio-Lima *et al.* (2003) state that the performance of core strengthening exercises (floor curl up and back extensions) on the floor to improve abdominal muscle endurance has been found to primarily strengthen the hip flexors and to have a minimal effect on the activation of core muscles. The authors further stated that the introduction of devices that provide an unstable environment could better strengthen the core musculature and improve whole body stability and balance. The use of devices such as the Swiss ball, wobble board, and the BOSU ball as compared to using the floor to perform trunk endurance exercises has been found to result in greater trunk and limb muscle activation (Kibele and Behm 2009).

The influence of surface stability on muscle activity appears to be muscle and exercise dependent. When comparing the activity of abdominal muscles on and off a Swiss ball Lehman, Hoda and Oliver (2005) discovered that during the prone bridge exercise the rectus abdominus was most activated when the Swiss ball was introduced, however during the supine bridge the erector spinae was not influenced. The rectus abdominus is the primary muscle resisting spinal extension and the erector spinae is the primary muscle resisting trunk flexion. Lehman Hoda and Oliver (2005) hypothesised that this difference in muscle activity is due to the decreased surface stability with the introduction of the Swiss ball. During the prone bridge more activity may have been needed for spinal stabilization.

Cosio-Lima *et al.* (2003) compared the results after a five week training programming of the effect of physioball training against conventional floor exercises. The result was improved static balance and increased erector spinae muscle EMG activity when compared with the control group. Behm *et al.* (2010) have stated that the increased instability elicited from the use of unstable devices may challenge the neuromuscular system to a greater degree than ground-based training methods. Therefore, the destabilising training environment may enhance the neuromuscular adaptations and lead to strength gains.

Despite the benefits of instability resistance training, Behm, Anderson and Curnew (2002) found that instability training results in decreased force production, reduced agonist muscle activation and increased antagonist muscle activity during knee extension. Force, power and performance can be restricted during instability training by increasing local joint stiffness. Behm *et al*. (2010) suggest that the joint stiffening strategy is employed when individuals face a threat to stability. This strategy negatively affects the magnitude of voluntary movements and reduces the velocity with which new movement patterns are learned.

Behm, Anderson and Curnew (2002) state that light to moderate degrees of instability are more suited to activities where force production needs to be maximised and greater instability is to be utilised when the focus of training is balance enhancement. The principle of training specificity states that in order to derive optimum improvement in balance, proprioception and core stability, training should be done under conditions that mimic the environment in which a muscle will be functioning (Behm *et al*. 2010); the use of instability to train the core is then justified. The unstable conditions provided by the instability devices may mimic the instability that individuals experience when performing sporting activities, occupational demands and activities of daily living.

2.7 Core strength training improves balance

The ability to maintain balance in an upright posture is crucial for undertaking daily activities, sports, and the subsequent prevention of injuries (Borghuis, Hof and Lemmink 2008). Trunk stability is essential for sustaining both static and dynamic balance especially in providing a solid base of support when one exerts force on external objects. Motor skill training, such as core strength training, is said to improve neuromuscular feedback at three levels of motor control within the central nervous system, namely: the spinal reflexes, brain stem reflexes and the motor cortex (Kollmitzer *et al*. 2000).

Kollmitzer *et al*. (2000) state that motor skill training enhances the sensitivity of the feedback pathways and reduces the muscle response time prior to movement by improving the proprioceptive ability of both antagonistic and agonistic muscles. The authors further state that the muscle is the final pathway of the sensorimotor system and significantly contributes to the maintenance of balance. The ability of the muscle to perform this function is dependent on the training status of that particular muscle, therefore the training of muscle groups that contribute to postural balance may improve muscle performance and postural stability.

Davidson, Madigan and Nassbaum (2004) state that muscle fatigue is a great contributor in the increase of postural sway (the measure of balance). Fatigue of the stabilising muscles of the spine has been cited in patients with low back pain and reduced spinal stability (Arokoski *et al.* 2001). In their investigation of the effect of lumbar extensor fatigability on postural sway, Davidson, Madigan and Nassbaum (2004) found that fatigue of the back extensor muscles increased the rate of postural sway, therefore implying impaired postural control. The authors further state that muscle fatigue reduces the force output rate of the fatigued muscle resulting in possible erratic control of the trunk and increased postural sway.

Filipa *et al.* (2010) state that training programmes should focus on core stability and strength training especially in females with impaired neuromuscular control and trunk proprioception. Inadequate core stability and decreased synergy of the muscles that contribute to maintaining posture has been thought to result in a decline in performance of power activities. This results in a higher incidence of injuries owing to a lack of control of ones centre of gravity, especially in females.

Borghuis, Hof and Lemmink (2008) suggest that postural instability results in impaired delivery of proprioceptive messages at the peripheral and central control systems of balance. The authors further state that this instability demands a change in how proprioceptive information is processed. They theorise that with instability the myopotentials of stabilising muscles, such as the erector spinea and rectus abdominus, are activated prior to any force being exerted by them or applied to them. These postural adjustments curtail postural destabilisation.

Resistance training has been shown to have a positive effect on balance. Moderate intensity strength exercise training was conducted by older adults and gait stability and balance was found to have improved (Arakoski *et al.* 2001). A study of younger individuals who performed resistance strength training and a balance skills test resulted in improved balance and strength after a one month follow-up (Kollmitzer *et al*. 2000). Resistance training that increases muscular strength also increases stability and co-ordination (Anderson and Behm 2005).The introduction of instability to core stability training programmes attempts to mimic activities of daily life where the balance has to be maintained under dynamic conditions.

Chapter 3
Materials and Methods

3.1 Introduction:

In this chapter the main methodological factors will be discussed in order to validate the basis for the data collection process. This chapter will be divided into the following subheadings:

- Study design
- Participant recruitment
- Sampling
- Inclusion criteria
- Exclusion criteria
- Research procedure
- Measurement tools
- Data analysis
- Ethical considerations

3.2 Study design

This study was a randomised clinical trial which was conducted at the Durban University of Technology's (DUT) Chiropractic Day Clinic (CDC). The aim of the study was to determine if exercises performed on an unstable surface would result in greater core strength and balance improvements in healthy female subjects when compared with exercises performed on a stable surface. The study was approved by the Institutional Research Ethics Committee and all ethical considerations were met (**Appendix C**).

3.3 Participant recruitment

Participants recruitment occurred via the self-selection method, utilising advertisements (**Appendix A**), and word of mouth. The advertisements were placed at DUT, local supermarkets and various locations in the greater Durban area. Permission was sought from the respective authorities before advertisements were put up. Potential participants were required to contact the researcher telephonically. The population from which the participants were recruited was that of females between the ages of 18 and 30 residing at the eThekwini Metropolitan area, in the city of Durban, KwaZulu-Natal.

3.4 Sampling

Methodology:

Self-selection sampling was utilised for this study.

Size: Forty participants were selected as per the inclusion and exclusion criteria consisting of two groups each containing twenty participants.

Group allocation: Group allocation was achieved by simple randomisation using the hat method.

3.5 Characteristics:

3.5.1 Inclusion criteria

1. Participants had to be females between the ages of 18 and 30.

2. Participants who were unable to hold the bridge exercise for 30 seconds and the extensor exercise for 60 seconds (McGill, Childs and Liebenson 1999). McGill *et al.* (1999) found 30 seconds and 60 seconds to be the mean endurance time participants were able to perform these exercises.

3. Participants who were able to perform the prone core-activation exercise and hold it for ten seconds (Biely, Smith and Silfies 2006). This was found to be an adequate amount of time to activate the transverse abdominus muscle.

4. Participants must have read and signed the Letter of Information and Informed Consent (**Appendix B**).

3.5.2 Exclusion criteria

1. Participants who had a history of low back surgery, ankle sprains, head or neck injuries or surgery to the lower limbs were excluded from the study.

2. Participants involved in sporting activity occurring more than three times a week, including going to the gym, were excluded from the study as it was thought that they engaged in some form of core strength training programme as part of their regular fitness routine.

3.6 Research procedure

3.6.1 Telephonic interview

Participants who had responded to the advertisement (**Appendix A**) were contacted telephonically by the researcher for a telephonic interview. The potential participants were informed that the purpose of the interview was to determine if they were eligible for the study. Participants had to provide verbal permission for the researcher to conduct the interview. Those participants who agreed to the interview were asked the questions in **Table 3.1.** If they provided the desired response to the questions, they were tentatively accepted into the study and an appointment was made at the CDC.

Table 3.1 Questions asked during the interview and desired responses

Questions asked of respondents	**Desired responses from respondents to ensure they qualified for the study**
Are you willing to answer a few simple questions related to the study in order to determine eligibility?	Yes
Are you female, between the ages of 18 and 30?	Yes
Are you involved in any sporting activity occurring more than three times per week, including going to the gym?	No
Are you currently suffering from any low back pain and/or pain in your lower limbs?	No
Do you have a history of low back surgery, ankle sprains, or head/neck injuries?	No

3.6.2 The First Consultation

At the first consultation at the CDC each participant was furnished with a Letter of Information and Informed Consent (**Appendix B**) which they were instructed to read. The researcher verbally explained the requirements and aims of the study to the participants and gave the participants an opportunity to ask any questions about the study. Those participants who voluntarily agreed to take part in the study were required to sign the Letter of Information and Informed Consent; those participants who did not agree to sign were excluded from the study. The participants were then randomly allocated into either Group A or Group B. A case history

(**Appendix D),** physical examination (**Appendix E**) and lumbar spine regional examination (**Appendix F**) were performed.

The participants were then requested to stand on the Biosway Portable Balance System where baseline readings of the Clinical Test of Sensory Integration (CTSIB) and Balance as well as the Postural Stability Test were taken. Participants were then taught how to activate their core muscles by means of the prone core-activation exercise (**Appendix G**). The Pressure Biofeedback Unit (PBU) provided an objective measure of successful performance of this exercise as the pressure on the cuff dropped by 6-10 mmHg from 70 mmHg.

Once the participants were able to perform the prone co-activation exercise and maintain the contraction for ten seconds they were then taught the various core strengthening exercises. The participants in Group A were taught how to perform the side bridge and the single leg extension hold on a stable surface (**Appendix H),** and the participants in Group B were taught how to perform the prone bridge and the quadruped reach exercises on a Swiss ball (**Appendix I**). The amount of time in seconds that each participant was able to hold their respective exercise position was recorded in the data collection sheet (**Appendix J**).

Participants were then told the required number of sets they were to perform daily for each exercise. During the first week the participants were to perform three sets of 30 second holds daily for the bridge exercises, and three sets of 60 seconds for the extensor exercises. During the second week the participants were to perform four sets of 30 and 60 second holds, respectively. In the third and fourth week the participants were expected to perform five sets of 30 and 60 second holds respectively (adapted from Cosio-Lima *et al.* 2003). Home exercise diaries (**Appendix K**) were provided to each participant and they were instructed to record the number of sets they did and the amount of time they held each exercise.

3.6.3 The Follow-Up Consultations

At the second and third follow-up consultations, which occurred at weekly intervals, the participants performed the relevant exercises in the presence of the researcher. This was conducted in order to monitor whether the participants were employing the correct technique while performing the exercises at home.

At the final visit (fourth follow-up), which occurred four weeks after the initial consultation, participants were again requested to stand on the Biosway Portable Balance System. Participants were asked to perform the CTSIB and the Postural Stability Test. The results from these tests were then taken and compared against the readings from the initial consultation.

3.7 Measurement Tools

3.7.1 The Pressure Biofeedback Unit

The Pressure Biofeedback Unit (PBU) is described by Cairns, Harrison and Wright (2000) as a tool designed to facilitate muscle re-education by detecting movement of the lumbar spine associated with a deep abdominal contraction in relation to an air filled reservoir. Cairns, Harrison and Wright (2000) further state that the PBU provides valuable visual biofeedback during treatment and provides an objective measure of the fatigue time of the deep abdominal muscles. The PBU consists of an inelastic, three section air-filled bag and a pressure cell. It is used to retrain the stabilising muscles of the lumbar spine as well as detecting movement in the lumbar spine (Jull *et al.* 1993).

Richardson and Jull (1995) described the prone position as one of the major positions for re-education and testing activity of the intrinsic core musculature. The prone position was selected as it inhibits the rectus abdominus muscle, a major global muscle of the core (Richardson and Jull 1995). In order to co-contract the transverse abdominus and the multifdus muscles in the prone position, the abdominal wall has to be drawn in (the abdominal draw). This position allows the PBU to detect changes in pressure as the abdominal muscles contract.

Testing in the prone position was performed as follows:

- The participants were instructed to lie prone with the pressure sensor beneath the lower abdomen, with the inferior border in line with the anterior superior iliac crest.
- The PBU was then inflated to 70 mmHg.
- The participant was then instructed to gently take breathe in so that their lower abdomen slightly lifts off the pressure sensor, and to maintain that position.
- When the desired contraction was achieved, a decrease in pressure of between 6 – 8 mmHg and a maximum of 10 mmHg was observed.

The concurrent contraction of the multifidus can be palpated in the lower lumbar region, proximal to the lumbar spine. Once the participants had learned to co-contract the relevant musculature the PBU was used to monitor if participants could maintain the contraction for ten seconds (Biely, Smith and Silfies 2006). The PBU was available from the Department of Chiropractic and was calibrated prior to the commencement of the research study. The same PBU was utilised for the duration of the study to maintain reliability.

3.7.2 The Biosway Portable Balance System

The Biosway Portable Balance System is a balance assessment and training device. It provides valid, reliable and repeatable objective measures of a patient's neuromuscular control and ability to balance on a firm and/or unstable surface (www.Biodex.com).

1. The **Clinical Test of Sensory Integration and Balance** is an accepted test protocol for balance assessment on a static surface. It provides a generalised assessment of how well a patient can integrate various senses with respect to balance and compensate when one or more of those senses are compromised. There are four test conditions:

    - *Condition 1 – Eyes open firm surface: Baseline: incorporates visual, vestibular and somatosensory input.*
    - *Condition 2 – Eyes closed firm surface: Eliminates visual input to evaluate vestibular and somatosensory input.*
    - *Condition 3 – eyes open foam surface: used to evaluate somatosensory interaction with visual input.*
    - *Condition 4- eyes closed foam surface: used to evaluate somatosensory interaction with vestibular input.*

The CTSIB measures **Stability Index** and **Sway Index**. The Biosway tracks the subjects sway angle and direction from centre. The **Stability Index** is the average position from center, it does not indicate how much the subject swayed. To quantify how much the subject swayed the standard deviation of the stability index is used; this value is the **Sway Index.** The Sway Index is therefore the standard deviation of the stability index. The higher the sway index the more unsteady the person is during the test. The sway index is an objective quantification of what is commonly done with a time-based pass/fail for completing the CTSIB stage in 30 seconds without falling, or assigning a value of 1 to 4 to characterize the sway. 1= minimal sway, 4 = a fall.

CTSIB normative Sway Index ranges are:

Condition 1: eyes open firm surface: .21-.48

Condition 2: eyes closed firm surface: .48-.99

Condition 3: eyes open foam surface: .38-.71

Condition 4: eyes closed foam surface: 1.07-2.22

Before the participants could perform the test, their age and height were entered on the Biosway in order to obtain optimal foot placement for each individual. Once the foot placement was obtained the participants were then instructed to stand on the Biosway Unit. After a practice trial to familiarise themselves with the test, data was then collected. Each of the conditions was 30 seconds long.

2. **The Postural Stability Test**

This test emphasises a patient's ability to maintain centre of balance. The participant's score on this test assesses deviations from centre, thus a lower score is more desirable than a higher score.

Once participant age and height were entered and the optimal foot placement was obtained, participants were instructed to step on the Biosway unit. There were three trials performed, each 20 seconds long.

The stability index for the test was presented in the following format:

- Overall stability index – this takes account of displacement of the centre of gravity in the following directions:
    - Anterior/Posterior – represents displacement in a sagittal plane. A high score in this direction may indicate poor neuromuscular control of the quadriceps and hamstring muscles and the anterior/posterior compartment of the muscles of the lower leg.
    - Medial/Lateral – represents displacement in the frontal plane. A high score in this direction may be indicative of poor neuromuscular control of the adductor and abductor muscles of the thigh or poor neuromuscular control of the inversion or eversion muscles of the lower leg.

3.8 Data analysis:

SPSS version 21 was used to analyse the data. A p value < 0.05 was considered as statistically significant. Intra-group analysis was done on each treatment group individually to assess the effect of the treatment over time using repeated measures ANOVA for each outcome separately. Inter-group analysis was achieved using repeated measures ANOVA with a between-group effect of the intervention. A significant time x group intervention effect would signify a treatment effect. Inter-group correlations between changes in outcomes over time were achieved using Pearson's correlation coefficient.

3.9 Ethical considerations

1. Approval to conduct the study was obtained from the Faculty of Health Sciences Research Committee (FRC) and the Institutional Research Ethics Committee (IREC) **(Ethics Certificate Clearance Number IREC 096/13, Appendix B)**.

2. All participants were required to sign a Letter of Information and Informed Consent (**Appendix B**) at the initial consultation.

3. Participants were asymptomatic with regards to pain in the low back, lower limb and had no history of head or neck injuries. Participants also had a full case history and physical examination conducted at the initial consultation. Participants for this study were therefore considered healthy prior to any intervention.

4. The correct procedure when performing the core stability and core strength exercises was demonstrated by the researcher and the participants were only allowed to participate in the study once they were competent in performing those exercises. Participants were contacted telephonically on a weekly basis to monitor progress and address any issues. Contact details for both the researcher and supervisor were provided on the letter of information, should the participant need assistance.

Chapter 4

Statistical methodology and results

4.1 Introduction

The statistical findings and results found in the study will be explained in this chapter.

Demographic data consisting of age, height and weight were analysed. IBM SPSS version 21 was used to analyse the data. A p value <0.05 was used to indicate statistical significance. T-tests were used to compare continuous baseline variables between the two groups, and Pearson's chi square tests were used for categorical variables. Repeated measures ANOVA tests were used to compare the change over time from pre- to post-intervention between the groups. A significant time*group intervention was the indication of a significant treatment effect. The effect was shown visually using profile plots.

4.2 Results

4.2.1 Comparison of demographics between randomisation groups

There were forty female participants in the study, with group B participants being older than the participants in group A, however these differences were not significant. The age ranged between 18 and 30 years. The mean age of group A participants was 22.1 years compared to the 23.8 years mean age range of group B participants. Participants in group A were heavier in terms of weight when compared to the participants in group B. The mean weight being 60.7 kg and 58.7 kg respectively. **Table 4.1** depicts the various demographic data. There were more females from the Black race than any other race, as depicted in **Table 4.1.1**, the "other" race refers to one white participant, two Indian participants, one participant of Portuguese descent and one coloured participant.

Table 4.1 Comparison of demographic data

	GROUP				P value (t-test)
	A		B		
	Mean	Standard Deviation	Mean	Standard Deviation	
AGE	22.1	3.8	23.8	3.0	0.136
HEIGHT	1.6	.1	1.6	.1	0.451
WEIGHT	60.7	6.5	58.7	8.6	0.404

Table 4.1.1 Race distribution between the groups

Race	Group A	Group B	Percentage (%)
African	19	16	87.5
Other	1	4	12.5
Total	20	20	100

There was no difference between the two groups in terms of age, height and weight, indicating that the randomisation process was complete. It is evident from the above information that the groups were homogenous although the sample size was small.

4.2.2 Comparison of baseline variables between randomisation groups

Table 4.2 Pre-intervention CTSIB and Postural Stability Test

	GROUP				P value T-test
	A		B		
	Mean	Standard Deviation	Mean	Standard Deviation	
CTSIB eyes open firm surface	0.34	0.09	0.35	0.20	0.874
CTSIB eyes closed firm surface	0.75	0.41	0.57	0.20	0.087
CTSIB eyes open foam surface	0.67	0.14	0.65	0.14	0.678
CTSIB eyes closed foam surface	2.27	1.09	2.01	0.41	0.319
Overall Postural Stability	0.3	0.1	0.3	0.1	0.701
Anterior/Posterior Postural Stability	0.2	0.1	0.2	0.1	0.647
Medial/Lateral Postural Stability	0.2	0.1	0.2	0.1	0.565

Table 4.2 Demonstrates the baseline values of postural sway between the two groups. Group B participants demonstrated lower baseline variables in three of the CTSIB tests except for *Condition 1: eyes closed on a firm surface*. Group A had a mean value of 0.34 whereas Group B had a mean value of 0.35. With regards to the Postural Stability Test there was no difference in the baseline values amongst the two groups.

4.2.3 Effect of the intervention

Table 4.3 CTSIB – eyes open firm surface

Multivariate Tests[a]							
Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Time	Pillai's Trace	0.001	0.032[b]	1.000	38.000	0.859
	Wilks' Lambda	0.999	0.032[b]	1.000	38.000	0.859
	Hotelling's Trace	0.001	0.032[b]	1.000	38.000	0.859
	Roy's Largest Root	0.001	0.032[b]	1.000	38.000	0.859
time * GROUP	Pillai's Trace	0.016	0.634[b]	1.000	38.000	0.431
	Wilks' Lambda	0.984	0.634[b]	1.000	38.000	0.431
	Hotelling's Trace	0.017	0.634[b]	1.000	38.000	0.431
	Roy's Largest Root	0.017	0.634[b]	1.000	38.000	0.431
a. Design: Intercept + GROUP Within Subjects Design: time						
b. Exact statistic						

CTSIB – eyes open firm surface

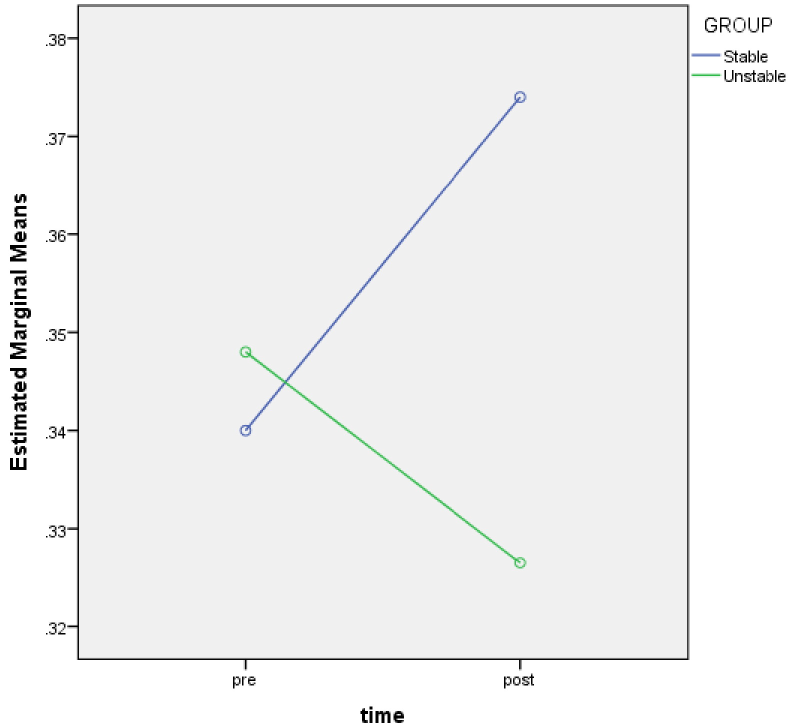


Figure 4.1

There was no statistically significant effect of the intervention over time (p=0.431). **Figure 4.1** shows a trend towards a differential effect in that group A (stable) increased in sway index over time while group B (unstable) decreased.

Table 4.4 CTSIB – eyes closed firm surface

Multivariate Tests[a]						
Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
time	Pillai's Trace	0.003	0.128[b]	1.000	38.000	0.723
	Wilks' Lambda	0.997	0.128[b]	1.000	38.000	0.723
	Hotelling's Trace	0.003	0.128[b]	1.000	38.000	0.723
	Roy's Largest Root	0.003	0.128[b]	1.000	38.000	0.723
time * GROUP	Pillai's Trace	0.060	2.409[b]	1.000	38.000	0.129
	Wilks' Lambda	0.940	2.409[b]	1.000	38.000	0.129
	Hotelling's Trace	0.063	2.409[b]	1.000	38.000	0.129
	Roy's Largest Root	0.063	2.409[b]	1.000	38.000	0.129

a. Design: Intercept + GROUP
Within Subjects Design: time

b. Exact statistic

CTSIB – eyes closed firm surface

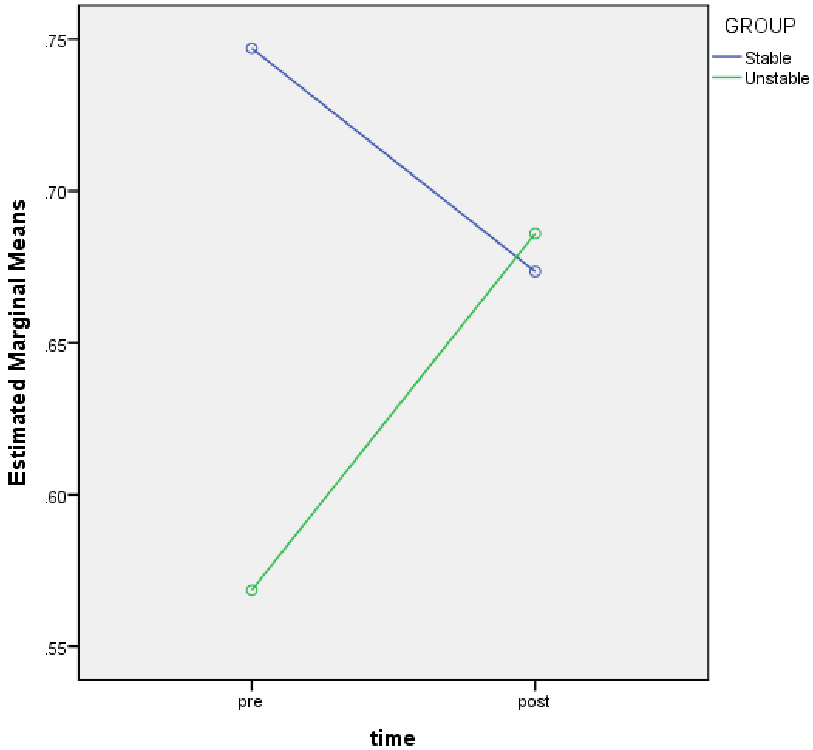


Figure 4.2

There was no statistically significant effect of the intervention (p=0.129). **Figure 4.2** shows a trend towards a differential effect in that group A (stable) decreased sway index over time while group B (unstable) increased.

Both groups showed better stability with eyes open as this incorporated visual, vestibular and somatosensory inputs. When eyes were closed the subjects relied on vestibular and somatosensory input alone to maintain stability, which resulted in greater sway between the two groups.

Table 4.5 CTSIB – eyes open foam surface

Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
Time	Pillai's Trace	0.245	12.360[b]	1.000	38.000	0.001
	Wilks' Lambda	0.755	12.360[b]	1.000	38.000	0.001
	Hotelling's Trace	0.325	12.360[b]	1.000	38.000	0.001
	Roy's Largest Root	0.325	12.360[b]	1.000	38.000	0.001
time * GROUP	Pillai's Trace	0.049	1.947[b]	1.000	38.000	0.171
	Wilks' Lambda	0.951	1.947[b]	1.000	38.000	0.171
	Hotelling's Trace	0.051	1.947[b]	1.000	38.000	0.171
	Roy's Largest Root	0.051	1.947[b]	1.000	38.000	0.171
a. Design: Intercept + GROUP Within Subjects Design: time						
b. Exact statistic						

CTSIB – eyes open foam surface

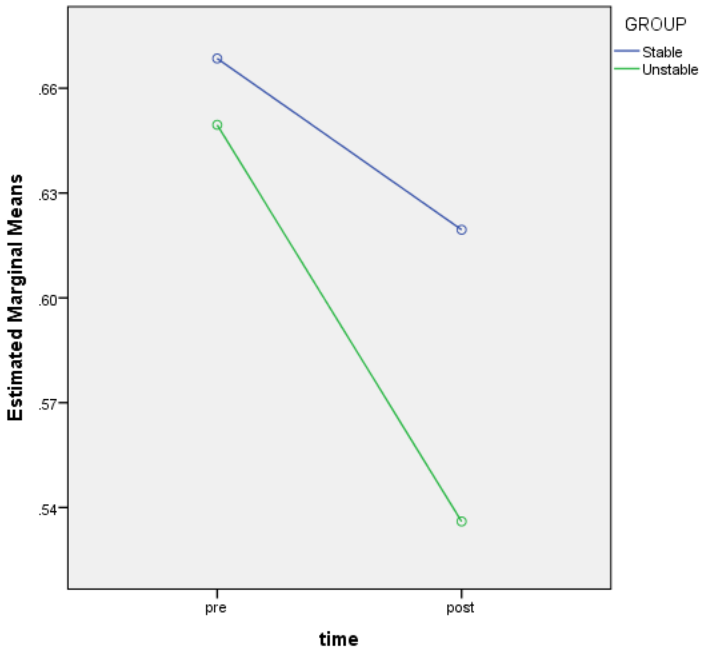


Figure 4.3

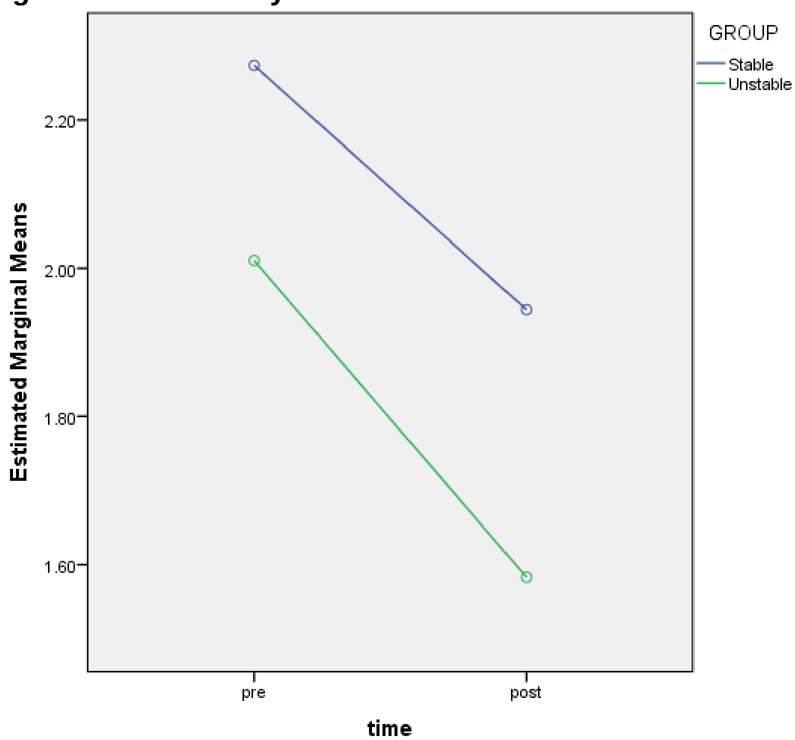
There was no significant effect of the intervention (p=0.171). **Figure 4.3** shows that both groups decreased sway index over time, but group B decreased at a slightly faster rate.

Table 4.6 CTSIB – eyes closed foam surface

Multivariate Tests[a]						
Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
time	Pillai's Trace	0.125	5.438[b]	1.000	38.000	0.025
	Wilks' Lambda	0.875	5.438[b]	1.000	38.000	0.025
	Hotelling's Trace	0.143	5.438[b]	1.000	38.000	0.025
	Roy's Largest Root	0.143	5.438[b]	1.000	38.000	0.025
time * GROUP	Pillai's Trace	0.002	.090[b]	1.000	38.000	0.766
	Wilks' Lambda	0.998	.090[b]	1.000	38.000	0.766
	Hotelling's Trace	0.002	.090[b]	1.000	38.000	0.766
	Roy's Largest	0.002	.090[b]	1.000	38.00	0.766

	Root				0	
a. Design: Intercept + GROUP Within Subjects Design: time						
b. Exact statistic						

Figure 4.4 CTSIB – eyes closed foam surface



There was no effect of the intervention (p=0.766). **Figure 4.4** confirms that both groups decreased sway index at the same rate over time.

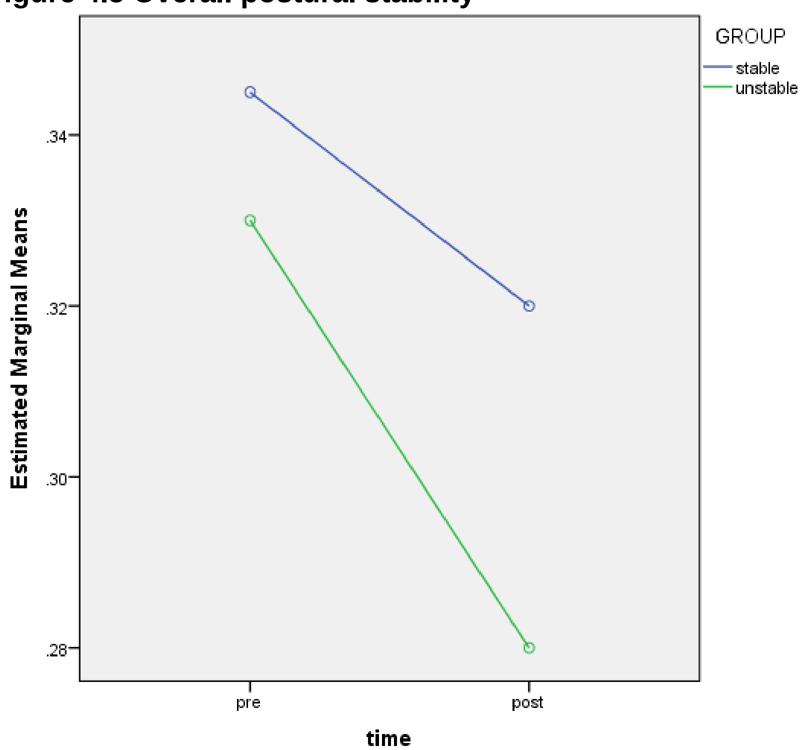
With the introduction of instability by means of the foam surface both groups demonstrated increased instability at the beginning of the study. With the elimination of visual input the instability increased. Participants in group B showed a faster decrease in instability over time than the participants in group A.

Table 4.7 Overall postural stability test

Multivariate Tests[a]						
Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
time	Pillai's Trace	0.080	3.301[b]	1.000	38.000	0.077
	Wilks' Lambda	0.920	3.301[b]	1.000	38.000	0.077
	Hotelling's Trace	0.087	3.301[b]	1.000	38.000	0.077
	Roy's Largest Root	0.087	3.301[b]	1.000	38.000	0.077
time * GROUP	Pillai's Trace	0.010	0.367[b]	1.000	38.000	0.548
	Wilks' Lambda	0.990	0.367[b]	1.000	38.000	0.548
	Hotelling's Trace	0.010	0.367[b]	1.000	38.000	0.548
	Roy's Largest Root	0.010	0.367[b]	1.000	38.000	0.548
a. Design: Intercept + GROUP						

Within Subjects Design: time
b. Exact statistic

Figure 4.5 Overall postural stability



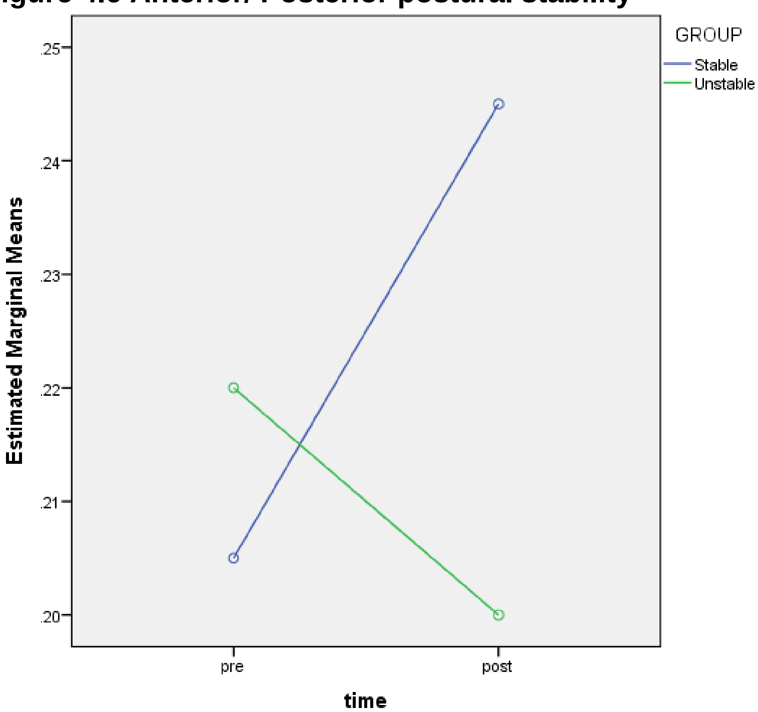
There was no effect of the intervention (p=0.548). **Figure 4.5** demonstrates that there was no significant increase in the overall postural stability after the intervention.

Table 4.8 Anterior/Posterior Postural Stability

Multivariate Tests[a]						
Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
time	Pillai's Trace	0.008	0.317[b]	1.000	38.000	0.577
	Wilks' Lambda	0.992	0.317[b]	1.000	38.000	0.577
	Hotelling's Trace	0.008	0.317[b]	1.000	38.000	0.577
	Roy's Largest Root	0.008	0.317[b]	1.000	38.000	0.577
time * GROUP	Pillai's Trace	0.070	2.850[b]	1.000	38.000	0.100
	Wilks' Lambda	0.930	2.850[b]	1.000	38.000	0.100
	Hotelling's Trace	0.075	2.850[b]	1.000	38.000	0.100
	Roy's Largest Root	0.075	2.850[b]	1.000	38.000	0.100

a. Design: Intercept + GROUP Within Subjects Design: time
b. Exact statistic

Figure 4.6 Anterior/ Posterior postural stability



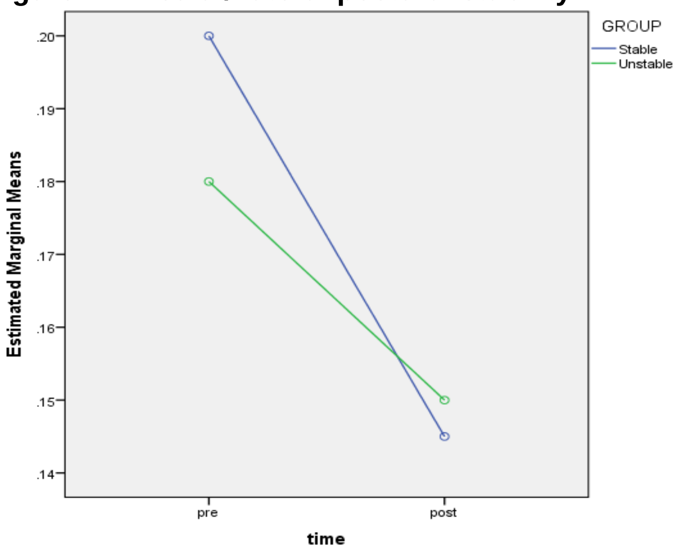
There was no significant effect of the intervention (p=0.100). **Figure 4.6** does show, however, that group A increased in postural sway and group B decreased over time following the intervention.

Table 4.9 Medial/Lateral Postural Stability

Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
Time	Pillai's Trace	0.112	4.804[b]	1.000	38.000	0.035
	Wilks' Lambda	0.888	4.804[b]	1.000	38.000	0.035
	Hotelling's Trace	0.126	4.804[b]	1.000	38.000	0.035
	Roy's Largest Root	0.126	4.804[b]	1.000	38.000	0.035
time * GROUP	Pillai's Trace	0.011	0.416[b]	1.000	38.000	0.523
	Wilks' Lambda	0.989	0.416[b]	1.000	38.000	0.523
	Hotelling's	0.011	0.416[b]	1.000	38.00	0.523

	Trace				0	
	Roy's Largest Root	0.011	0.416[b]	1.000	38.000	0.523
a. Design: Intercept + GROUP Within Subjects Design: time						
b. Exact statistic						

Figure 4.7 Medial/Lateral postural stability



As seen in **Figure 4.7**, both groups decreased significantly (P=0.523) over time but the intervention did not have a differential effect in the two groups.

Both groups demonstrated better stability control in the anterior/posterior direction. This could be due to the fact that this direction is that of their heads and their gaze, therefore this is the direction that the visual stimulus comes from. The participants were standing facing the Biosway unit and this may have influenced their efforts to control their stability.

4.3 Summary of results

4.3.1 CTSIB – eyes open and closed firm surface

Under condition 1, group B showed a decline in postural sway whereas group A showed an increase, however the result was statistically insignificant. Under condition 2, group A showed a decline in postural sway whereas group B showed an increase. Although group A improved under condition 1, the improvement was not statistically significant. Training under stable conditions improves sensitivity of feedback pathways and reduces the activation time of the pertinent muscles by enhancing the proprioceptive ability of antagonist and antagonistic muscles (Kollmitzer *et al.* 2000). Improvements in task performance may have been due to changes in the recruitment patterns of the muscles that were targeted for the resistance training programme. The trained muscles were recruited in a more specific pattern after the training programme.

The principle of training specificity may explain the difference in the outcome variables. The principle of training specificity states that in order to reap maximum benefit from a training programme a muscle must be trained under conditions in which it will be function (Behm, Anderson and Curnew 2002). This may explain the increase in postural sway under condition 2 in group B participants.

Group B participants were training under unstable conditions for the duration of the study, so it can therefore be assumed that conditions 1 and 2 are not an environment under which the muscles of participants in group B would be functioning resulting in the unexpected decline in their performance outcomes. In addition, with increasing age postural muscle activity increases in order to improve joint proprioception (Laughton *et al.* 2003). The participants in group B were slightly older than their group A counterparts. Coupling the principle of training specificity and the neurological changes that occur in the postural muscles with increased age, it could be postulated that these two factors contributed to the poor performance of group B participants under condition 2.

4.3.2 CTSIB – eyes open and closed foam surface

At baseline readings both groups showed poor postural stability. Under conditions 3 and 4 both groups demonstrated a decrease in sway over time with group B showing a faster decline under condition 3 and both groups decreasing at the same rate under condition 4. According to Cosio-Lima *et al.* (2003) these faster changes could be due to the core musculature being stressed, therefore leading to an activation of the neuroadaptive mechanisms resulting in improvements in stability and proprioceptive activity. These neural adaptations include more efficient neural recruitment patterns, increased nervous system activation, improved synchronisation of motor units, and a lowering of neural inhibitory reflexes. Behm, Anderson and Curnew (2002) stated that the chief purpose of training with a Swiss ball is to improve balance and proprioception. Therefore the faster improvement in group B participants could be due to the faster improvements by means of an enhanced ability to activate trunk musculature, resulting in improved trunk stability and balance.

The research findings support other studies which report that balance performance is reduced when vision is eliminated. Edwards and Patterson (2011) found that females showed a 23.93% decline in performance of the CTSIB test with eyes closed when compared with their male counterparts, on both firm and foam surfaces. The degradation in postural balance can be attributed to the fact that subjects relied more on visual input to maintain equilibrium. Participants seemed to perform better under conditions 3 and 4, the more challenging part of the test. According to Tarantola *et al.* (1997) this could be because "in the adaptive process, the central nervous system took better advantage of the afference from the proprioceptors", this occurring when the stable condition was removed as in condition 1 and 2.

4.3.3 The Postural Stability Test

Results from the postural stability test show that the intervention had no statistically significant effect on the overall postural stability of study participants (P=0.548). Neither group showed a significant improvement over time after the intervention. Both groups showed equal competency when baseline variables were taken. It could be that this test provided minimal challenge to both groups, especially since the sample population was comprised of healthy subjects.

4.3.4 Anterior/Posterior and Medial/Lateral Stability

The results of the anterior/posterior (A/P) stability demonstrate that group B improved in stability over time, while group A did not. Balance in the A/P plane is controlled by the ankle, namely by the plantar and dorsiflexors. In the medial/lateral (M/L) plane both groups improved at the same rate over time. Balance in this plane is controlled by the hip, namely the adductors and abductors (Tarantola *et al.* 1997).

Bauby and Kuo (2000) stated that in the 45 degree stance position, the position used by all study participants, both ankle and hip balance strategies contribute to overall balance. In the M/L direction the two control strategies reinforce each other, however in the A/P direction the ankle plantar and dorsiflexors must work to overcome and correct inappropriate input from the hip. This finding could serve to explain why the M/L direction results seem to be consistent with the baseline variable data, as both groups showed equal competency and this trend was also seen with the post intervention data. The ankle balance strategy may have been overloaded in the A/P direction amongst group A participants resulting in a decline in postural stability in that direction.

4.3.5 Factors influencing results

Some factors may have influenced the performance and outcomes of this study. These factors include balance perception/efficacy, the choice of participant footwear, and the weight distribution of some of the participants as well as foot pronation or supination.

- Balance perception/efficacy – Larmache *et al.* (2007) defined balance efficacy as an individual's confidence in his/her ability to maintain balance and avoid falling when performing certain tasks. Poor balance efficacy has been associated with poor balance (Larmache *et al*. 2007). Balance perception can be manipulated using visual, verbal and physical means. At the initial consultation participants were unfamiliar with the Biosway Portable Balance System and a majority were fearful of falling off the foam cushion. The nervousness resulted in cautious quiet standing where participants appeared tense and demonstrated a lot of sway. Also, verbal persuasion has been shown to improve self-efficacy in a physical activity setting (McAuley, Talbot and Martinez 1999). With regards to this present study, participants who were told they had performed better in earlier tests may have been more confident and compliant with their exercise regimen. They may therefore have been less nervous at the final consultation, resulting in a more favorable outcome post intervention.

- Footwear – Participants may have been wearing inappropriate footwear prior to the tests being done. De Oliviera Pezzan *et al.* (2011) found that wearing high heels causes the gravity lines to shift 6mm towards the lateral malleoli, resulting in compensations such as increased plantarflexion and posterior displacement of the trunk and pelvis. There is conflicting literature regarding the effect of high heeled shoes on lumbar lordosis, however De Oliviera Pezzan *et al*. (2011) postulate that an increased lordotic curve may be found in individuals who wear high heeled shoes on a regular basis. Chronic usage of this footwear may have caused the body to adapt the lumbar spine to hyperlordotic curve. De Oliviera Pezzan *et al*. (2011) further state that increased lordosis of the lumbar spine is seen in conjunction with anterior tilt of the pelvis. The increased lordotic curve of the spine may cause a shift in the center of gravity affecting the outcome of the results from this study.

- Weight distribution – body weight may influence an individual's postural stability. Hue *et al.* (2007) found that increased weight contributed up to 50% of the variance balance control in a study of the effect of increased weight on postural stability. These findings imply that with a larger weight the balance control system is less attuned to regulating body sway oscillations (Hue *et al*. 2007). Increased weight may influence postural stability by reducing the mechanoreceptor sensitivity of the foot. Hills *et al.* (2001) discovered that overweight individuals may have larger plantar contact surface areas as well as increased pressure under the heel, midfoot and metatarsal heads. This increased pressure may inhibit the quantity and quality of sensory information arising from the plantar mechanoreceptors. Participants in group A were slightly heavier than their group B participants, although they were not above average Body Mass Index. The slight difference in weight between the two groups may explain the variation in results from both groups.

- Foot pronation or supination – Hertel, Gay and Denegar (2002) state that different foot types may react differently with ground reaction forces resulting in altered postural control strategies, therefore influencing ones postural stability. Excessively pronated or supinated feet may impact on somatosensory input either through changes in joint mobility or via changes in muscle recruitment strategies in order to maintain upright posture (Cote *et al.* 2005). Cote *et al*. (2005) found that altered foot posture altered postural stability. This alteration in postural stability, however, was thought to be due to structural differences and not due to differences in the processing of peripheral input from the foot surface. Given that foot type was not assessed in this study there is no conclusive way of determining what effect the different foot types of study participants had on the results of this study.

4.4 Conclusion

The results of this study mimic those of Cosio-Lima *et al*. (2003) and Lehman *et al.* (2005), in that improvements in postural stability were evident in the unstable core training group. Both stable and unstable core strength training programmes seemed to have a beneficial impact on balance in the study population, although these improvements were statistically insignificant. Taking into account that the study population was comprised of healthy, young adults these findings do not preclude the possibility of a clinical significance where this study would be conducted on older individuals with existing conditions affecting their balance.

Future study needs to explore each of the various outcome measures in depth, especially those with results that showed a discrepancy with the hypothesis. For some of the outcomes measured there was a non-statistically significant trend towards an effect of the intervention, but for others both groups displayed the same trend over time. The power of the study to show a significant effect where one might have existed was low and thus the study should be repeated with a larger sample size using the outcomes which showed differential results between the treatment groups.

Chapter 5

Conclusions and recommendations

5.1 Introduction

This chapter will discuss the outcomes of the study and make recommendations for future research.

5.2 Conclusions

The aim of this study was to determine if core strengthening exercises performed on an unstable surface would result in greater balance improvements when compared with exercises performed on a stable surface.

It was found that there was no statistically significant difference between the two groups. The group that performed exercises on an unstable surface, however, showed a faster decline in sway index when compared with the group performing exercises on a stable surface. A decline in sway index translates to reduced postural sway and therefore an improvement in one's balance. The group performing exercises on a stable surface showed a slower decline in their sway index.

In conclusion, the results demonstrated that both stable and unstable exercise programmes lead to improvements in the balance of study participants. However, the improvements were statistically insignificant but may be of clinical significance.Therefore, it can be said that combining both stable and unstable core strengthening exercises might yield better results. When the stable surface exercises are introduced first, this allows the individual to gradually become proficient in the simpler exercises. Once proficiency has been attained, instability can be introduced to provide more of a challenge to the neuromuscular system, thereby improving muscle, strength and proprioception.

5.3 Limitations of the study

1. The sample size was relatively small (n=40), due to human resource and financial constraints.

2. The participants were instructed to perform the core strength exercises at home, however they may not have been performing the exercises correctly or for the required number of times.

3. Effective co-activation of the deep core muscles was difficult to achieve and maintain. Therefore, the use of the correct posture when performing the exercises was not guaranteed.

4. There was no objective measure of muscle strength improvements. All the study participants performed their given exercises for the same amount of time with the same amount of sets and repetitions.

5.4 Recommendations for future research

1. The study should be repeated with a larger, more representative sample of a cross-section of the population. This may improve the validity of the study and make the results more statistically significant.

2. The study should be done over a longer time period. Cosio-Lima *et al*. (2003) state that it takes five weeks for neural adaptations to start occurring, therefore a study that is longer than four weeks may better demonstrate the effect of the exercise programme.

3. A fully supervised trial may be of benefit in order to ensure participants adhere to the stipulated research protocol and to ensure participants perform the exercises correctly.

4. In terms of the test for rotary bias, it is the researcher's opinion that for the purpose of future studies it may be beneficial to focus more on explaining the exercises and test procedure to the participants.

5. A similar study may be conducted comparing male and female subjects, and it may be beneficial to assess muscle recruitment patterns using electromyography or diagnostic ultrasound.

6. Lack of blinding may have resulted in researcher bias. Readings may have been more accurate with a research assistant taking subjective and objective readings.

7. A similar study could be conducted comparing two balance measurement tools, to enhance the reliability and validity of the measurement unit.

8. There use of electromyography (EMG) to measure muscle strength improvements would be useful to compare which type of exercise results in greater muscle improvements and if the greater muscle strength improvements lead to greater balance improvements.

9. The study population consisted of young, healthy subjects. For a future study a wider age range may be of benefit and would allow for a greater comparison of balance deficits or improvements over time with core strength training.

10. A similar study may be conducted comparing the effect of different foot types on postural stability. Hertel *et al.* (2002) and Cote *et al.* (2005) found a structural relationship between foot type and postural stability, however they did not determine the sensory effect foot type had on postural control.

11. The test conditions under which visual input was eliminated need to be explored in further detail, in order to determine the extent to which visual input controls influence postural control.

12. A similar study may be conducted including a certain range of Body Mass Index in the inclusion and exclusion criteria.

13. In future studies participants could be screened for hyper- or hypolordosis of the lumbar curve in order to determine what effect an increased or decreased curve will have on the center of gravity.

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Appendix A

Figure 1:http://teachmelife.wordpress.com

Are you female between the ages 18 – 30?

Are you interested improving your core stability?

Do you want to find out how core affects your balance?

If yes, a study is currently being done at the Chiropractic Day Clinic

If interested please call Nicole 031 373 2511

Appendix B

LETTER OF INFORMATION

Dear participant thank you for having an interest in this study

Title of the Research Study: A randomised clinical trial comparing the effectiveness of two exercise programmes on core strength and balance in healthy females

Principal Investigator/s/researcher: Nicole Mavimbela, BT:Chiropractic

Co-Investigator/s/supervisor: Dr P.Z. Ndlovu, MT:Chiropractic

Brief Introduction and Purpose of the Study: This study intends to explore the relationship between the stability of your spine and your balance. The results gathered will help us understand a number of things. Firstly, how training your abdominal muscles to stabilize your spine on either a stable or unstable surface will affect your core stability. Secondly, how training your abdominal muscles on either a stable or unstable surface will affect your balance. Lastly, the two different training methods will be compared to each other.

Outline of the Procedures: You will be considered eligible for this study if you meet the following criteria:

<u>Inclusion criteria</u>

5. Participants must be female who are between the ages of 18 and 30
6. Participants must reside in the greater Durban area
7. Participants who are unable to hold the bridge exercise for 30 seconds and the extensor exercise for 60 seconds (McGill, Childs and Liebenson 1999). This relates to participants who will be unable to maintain a muscle contraction for the given time.
8. Participants must be able to perform the prone core-activation exercise and hold it for 10 seconds (Biely, Smith and Silfies2006).

If you meet the above criteria, you will be required to report to the Chiropractic Day Clinic for four visits inclusive of an initial visit and 3 follow ups. Upon arrival at the Chiropractic Day Clinic, you will be randomly allocated into one of two groups i.e. Group A or Group B. At the initial visit a case history, physical examination and lumbar regional examination will be conducted. Initial recordings of your balance, core stability and muscle endurance times will be taken – all of which will be demonstrated and explained to you by the researcher. Due to nature of the above examinations the initial visit will be 1hour long. You will then be expected to perform the exercises at home and when you report to the day clinic for each of your weekly visits. The duration of each follow up visit is expected to be 15 minutes long.

Risks or Discomforts to the Participant: There is very little risk associated with participating in this study. However, you may experience some muscle stiffness in the beginning of the research process. You will be shown a few simple stretches in order to remedy the muscle stiffness.

Benefits: According to the study hypothesis you will gain improved muscle endurance, core stability and balance. The results of this study will be published in the form of a dissertation and kept at the DUT Library.

Reason/s why the Participant May Be Withdrawn from the Study: You may be withdrawn from the study should you be unable to perform any of the exercises or experience severe pain while performing the exercises. Furthermore, participants who miss two of the four consultations will be withdrawn from the study. However, you are not obligated to continue your participation in the study should you wish to withdraw for any reason and you will not experience any adverse reaction should you withdraw from the study before the end of the four weeks. Participants in group B who withdraw or are withdrawn from the study will be required to return the Swiss balls issued to them at the beginning of research process.

Remuneration: There will be no remuneration for participating in this study

Costs of the Study: Your participation in this study will not cost you anything and all expenses will be incurred by the researcher

Confidentiality: Participant information will be kept confidential. Information will be stored in the Chiropractic Day Clinic for 15 years, after which it will be shredded.

Research-related Injury: The research will be non-invasive and there is minimal to no risk of injury to participants

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

Please contact: Dr. P.Z Ndlovu 031 202 3632(Research supervisor) Nicole Mavimbela: 072 747 5192(Researcher) Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F.Otieno on 031 373 2382 or dvctip@dut.ac.za.

CONSENT

Statement of Agreement to Participate in the Research Study:

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

____________________ __________ ______ _______________

Full Name of Participant Date Time Signature / Right Thumbprint

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

_________________ __________ ___________________

Full Name of Researcher Date Signature

_________________ __________ ___________________

Full Name of Witness (If applicable) Date Signature

_________________ __________ ___________________

Full Name of Legal Guardian (If applicable) Date Signature

Appendix C

DUT
DURBAN UNIVERSITY OF TECHNOLOGY

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

P O Box 1334, Durban, South Africa, 4001

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

www.dut.ac.za

29 November 2013

IREC Reference Number: **REC 71/13**

Ms N Mavimbela
Unit 266 Carr Gardens
1 High Road
Fordsburg
Johannesburg

Dear Ms Mavimbela

A randomised clinical trial comparing the effectiveness of two exercise programmes on core strength and balance in healthy females

I am pleased to inform you that Full Approval has been granted to your proposal REC 71/13. You are requested to ensure the following:

- All telephonic interviews are to be recorded and stored as part of the documentation.

The Proposal has been allocated the following Ethical Clearance number IREC 096/13. Please use this number in all communication with this office.

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

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

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

Yours Sincerely

[redacted]

Prof J K Adam
Chairperson: IREC

CHIROPRACTIC PROGRAMME Appendix D

CHIROPRACTIC DAY CLINIC CASE HISTORY

Patient:____Date: __________

File #: ________________ Age: __________

Sex: __________ Occupation: ______________________________

Student: ______________________________ Signature ______________________

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature:

Case History:

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL: Reason for Conditional:
Signature: Date:

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

Case Summary signed off: Date:

Student's Case History:

1. **Source of History:**

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

3. **Present Illness:**

	Complaint 1(principle complaint)	Complaint 2 (additional or secondary complaint)

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

4. Other Complaints:

5. Past Medical History:

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

6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

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

Tobacco Alcohol Social Drugs

7. Immediate Family Medical History:

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

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

8. Psychosocial history:

Home Situation and daily life Important experiences Religious Beliefs

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

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

CHIROPRACTIC PROGRAMME Appendix E

PHYSICAL EXAMINATION: SENIOR

Patient Name:			**File no:**		**Date:**
Student:		**Signature:**			
VITALS:					
Pulse rate:			Respiratory rate:		
Blood pressure:	R	L	Medication if hypertensive:		
Temperature:			Height:		
Weight:	Any recent change?	Y / N	If Yes: How much gain/loss	Over what period	
GENERAL EXAMINATION:					
General Impression					
Skin					
Jaundice					
Pallor					
Clubbing					
Cyanosis (Central/Peripheral)					
Oedema					
Lymph nodes	Head and neck				
	Axillary				
	Epitrochlear				
	Inguinal				
Pulses					
Urinalysis					
SYSTEM SPECIFIC EXAMINATION:					
CARDIOVASCULAR EXAMINATION					

RESPIRATORY EXAMINATION
ABDOMINAL EXAMINATION
NEUROLOGICAL EXAMINATION
COMMENTS
Clinician: **Signature:**

CHIROPRACTIC PROGRAMME Appendix F

REGIONAL EXAMINATION
LUMBAR SPINE AND PELVIS

Patient: ______________________________ File#: ______________ Date: _________

Student: ______________________________ Clinician: ____________________________

STANDING:

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

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

GAIT:

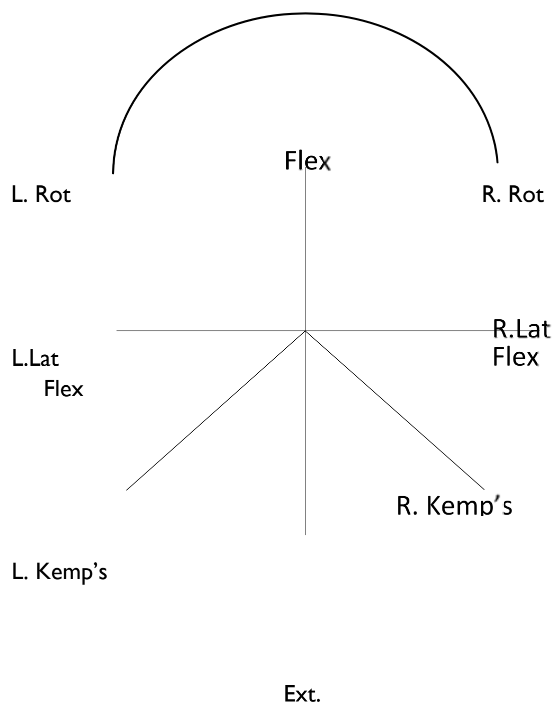
Normal walking
Toe walking
Heel Walking
Half squat

ROM:

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

-
- **Which movement reproduces the pain or is the worst?**
- Location of pain

Supported Adams: Relief? (SI)
Aggravates? (disc, muscle strain)



SUPINE:

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

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

	R										

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

SITTING:

Spinous Percussion

Valsalva

Lhermitte

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

SLUMP 7 TEST	**L**										
	R										

LATERAL RECUMBENT:

	L	R
Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

	L	R
Gluteal skyline		
Skin rolling		
Iliac crest compression		
Facet joint challenge		
SI tenderness		
SI compression		

Erichson's		
Pheasant's		

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

NON ORGANIC SIGNS:

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

NEUROLOGICAL EXAMINATION

Fasciculations						
Plantar reflex						
level	**Tender?**	**Dermatomes**		**DTR**		
		L	**R**		**L**	**R**
T12				Patellar		
L1				Achilles		
L2						
L3				Proprioception		
L4						
L5						
S1						

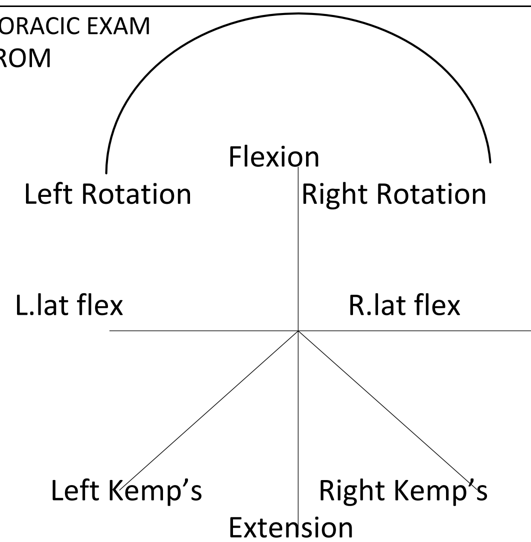
S2						
S3						

MYOTOMES

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

BASIC THORACIC EXAM

Passive ROM



History :

Orthopedic assessment:

BASIC HIP EXAM

History

ROM: Active

Passive: Medial rotation:

- hard \ soft end feel

- Trochanteric bursa

A) Supine (neutral) If reduced

B) Supine (hip flexed):

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

Appendix G

Prone Testing – abdominals

- Place the Pressure Bio-feedback Unit under the participants abdomen, aligning the inferior boarder with the ASIS
- Inflate the chambers to 70mmHg allow to stabilise
- The participant must take a relaxed breath in and out , then without inhaling draw the lower abdomen up and in
- The participant must keep this position and avoid any movement of the spine, pelvis or deep respiration
- The cuff should deflate by 6-10mmHg

Appendix H

1. Side bridge
    - Begin on your side, supported by the elbow and hip; co-contract. Knees are bent at 90 degrees.
    - Place your free hand over your shoulder to provide stability to the shoulder joint.
    - Lift your torso until the entire body is supported on the elbow and knee
    - You can place the free arm along the side of the torso - effectively placing more load on the bridge – advancing the effect of the exercise.

Figure 2: www.topendsports.com

2. The single leg extension hold
    - Begin on the hands and knees with hands under the shoulders and knees directly under the hips.
    - Co-contract your abdominals and stabilise your scapulae
    - Slowly lift one leg – either one – about 10cm off the ground or until your leg is parallel to the floor

Figure 3: www.examiner.com

Appendix I

1. Quadruped reach on a Swiss ball
    - Balance your abdomen on a Swiss ball using your toes for support
    - While co-contracting, stabilise your scapulae
    - Slowly raise your right arm until it is parallel to the floor then slowly raise your left leg until it is also parallel to the floor

Figure 4:http://exercise.about.com

2. Prone bridge on a Swiss ball
    - Balance your forearms on a Swiss ball with your legs shoulder width apart
    - Co-contract, stabilise your scapulae
    - Slowly raise your torso until your body is parallel to the floor
    - Do not use your forearms or toes for support – your balance comes from the abdomen

Figure 5: www.thera-bandacademy.com

Appendix J

Data collection sheet

Visit	Side bridge Time(s)	Single leg extension hold Time(s)	Quadruped reach on a Swiss ball Time(s)	Prone bridge on a Swiss ball Time(s)	Portable Biosway Balance System
Initial					
2					
3					
4					

Appendix K

Home exercise diary

Week I

	Side bridge(s)	Single leg extension hold(s)	Quadruped reach on a Swiss ball(s)	Prone bridge on a Swiss ball(s)
Day 1				
Day 2				
Day 3				
Day 4				
Day 5				
Day 6				
Day 7				

Week 2

	Side bridge(s)	Single leg extension hold(s)	Quadruped reach on a Swiss ball(s)	Prone bridge on a Swiss ball(s)
Day 1				
Day 2				
Day 3				
Day 4				
Day 5				
Day 6				
Day 7				

Week 3

	Side bridge(s)	Single leg extension hold(s)	Quadruped reach on a Swiss ball(s)	Prone bridge on a Swiss ball(s)

Day 1				
Day 2				
Day 3				
Day 4				
Day 5				
Day 6				
Day 7				

Week 4

	Side bridge(s)	**Single leg extension hold(s)**	**Quadruped reach on a Swiss ball(s)**	**Prone bridge on a Swiss ball(s)**
Day 1				
Day 2				
Day 3				
Day 4				
Day 5				
Day 6				
Day 7				