



Faculty of Sciences
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Core Muscle Function in Young Adults Aged 18 to 30

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Abstract

Background: The core or the lumbopelvic region of the body is a complex that comprises many anatomical structures that act in concert to maintain core stability and function. Good core muscle function plays an important role in maintaining good spinal health by reducing occurrences of lower back pathologies and injuries. In addition, it plays a vital role in reducing lower limb injuries. However, gender differences, the effects of age, physical activity, and body composition on core muscle function of young adults have not been fully understood.

Aims: Using a cross-sectional study design, the project aimed to investigate the effects of physical activity and body composition on core muscle function. In addition, the project explored gender and age related differences in core muscle function in young adults. Moreover, the relationship between core muscle function and lower limb muscle function was examined.

Methods: 98 young adults (men = 48, women = 50) between the ages of 18 to 30 participated in this project. Body composition variables such as height, weight, body mass index (BMI), sum of skinfolds (subcutaneous fat mass) and waist circumference were measured. Lengths of time holding the front bridge and side bridge were recorded as measure of core muscle function. Standing long jump distance was recorded as measure of lower limb muscle function. Weekly exercise duration was used as measure of physical activity level and this information was collected using a questionnaire. IBM SPSS statistics software version 19 was used to run descriptive statistics, one-way analysis of variance (ANOVA), and correlation analysis among the variables.

Results: It was found that increased subcutaneous fat mass, weight and waist circumference were associated with poor core muscle function in men and women ($p <$

0.05). However, high BMI correlated negatively with men's core muscle function only ($p < 0.05$). ANOVA analysis revealed that men had significantly better core muscle function and lower limb muscle function than women ($p < 0.05$). Exercise duration had a moderate positive correlation with core muscle function in men only ($p < 0.05$). Significant positive correlation was present between core muscle function and lower limb muscle function in men only ($p < 0.05$). No significant association was observed between age and core muscle function and lower limb muscle function in young adults.

Conclusion: The results suggest that young men have better core and lower limb muscle function compared to young women. This may have been due to the higher muscle mass and lower fat mass in men. In addition, body composition is a good predictor of core and lower limb muscle function. Further, side bridge exercise may not be a good core muscle assessment tool for untrained women due to their intrinsically weak core muscle function and the exercise's demanding nature.

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Declaration

I, Hazheer Rasif, certify that the work reported in this thesis is entirely my own effort, except where otherwise acknowledged. This thesis is an original document created to fulfil the requirements of the Bachelor of Science Honours degree at University of Southern Queensland and I certify that it has not been submitted previously as part of requirement for courses at this or any other institution.

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Abbreviations

CNS Central Nervous System

PNS Peripheral Nervous System

EMG Electromyography

ANOVA Analysis of Variance

Chapter One: Introduction

1.1 Background

Movement in human body is governed by nervous and musculoskeletal systems which complement each other. Musculoskeletal activity is controlled by the central and peripheral nervous system (CNS & PNS) in response to internal or external stimuli. Mechanosensors, such as osseous and ligamentous tissues, connective tissue, and muscle spindles feedback information to the CNS via the PNS. CNS then responds to the input to initiate, or inhibit movement via muscle contractions and relaxation depending on the stimulus (Behm et al. 2010).

Muscles exert force on skeletal bones that act as levers which enable human movement (Turner 1998). In addition, muscles provide balance, stability, act as shock absorbers and protect vital internal organs. Muscles of the lumbopelvic region of the body i.e. core muscles particularly serve this function and facilitate trunk rotation, load transfer and stabilisation of the lumbopelvic region (McGill 2010). Core muscles provide the strength and endurance required to maintain dynamic stabilisation of the body and support to the lumbar spine and pelvic systems (Panjabi 1992a).

Core muscles work in a feed forward manner to protect the spine from excessive movement and compressive forces caused by external stimuli. Without well-developed core muscles, the body is no longer able to stabilise itself during activity (Panjabi 1992a, McGill 2010, Colsten 2012a, Warren et al. 2014, Leetun et al. 2004, Wilson et al. 2005, Ferreira et al. 2007). Poor core muscle function may lead to excessive stress being placed on the spine, which can result in lower back pain, lower back and lower extremity injuries (Colsten 2012a, Warren et al. 2014, Leetun et al. 2004, Wilson et al. 2005, Ferreira et al. 2007).

1.2 Statement of the Problem

Male and female individuals differ vastly when comparing muscle function and capacity. However, there are few studies that report gender related differences in core muscle function of young adults aged 18 to 30. There are studies on core muscle function in young people (Chon et al. 2010, Behm et al. 2005, Steffen et al. 2008, Arnold et al. 2015) but they did not report on differences between males and females. Although, it is widely accepted that muscle function is influenced by age, the changes that occur in core muscle function between ages of 18 to 30 years has yet to be documented.

Regular exercise improves and maintains good muscle function. Yu and Lee (2012) investigated the effects of eight week Pilates training on core stability in 40 healthy individuals aged 25 to 35. They found that the Pilates training program significantly improved core stability in the training group when compared to the control group. Stanton et al. (2004) demonstrated that six weeks of core stability training improved core muscle function in young male athletes. These studies demonstrate the efficacy of different exercise interventions on core muscle function. However, there are few cross-sectional studies about the effects of daily physical activity on core muscle function in healthy young adults.

Behm et al. (2005) investigated the efficacy of unstable and unilateral resistance exercises on core muscle activity of healthy individuals age 20 to 45. They found that performing resistance exercises for the limb improved core muscle function. Wilson et al. (2006) reported that knee strength and joint orientation were influenced by hip musculature, suggesting a relationship between lower limb muscle function and core muscle function. Few studies have presented cross-sectional data on this relationship in healthy young adults.

In a recent study, Ervin et al. (2014) assessed core, upper and lower body muscle strength in children and youth aged between 6 to 15 years. They found that as body weight increased, the length of time the bridge was held decreased. They concluded that increasing body weight is negatively correlated with core muscle strength. Further research is needed to determine whether body composition affects core muscle function in young adults.

1.3 Aims

This project aimed to gain a deeper understanding of core muscle function and the variables that affect it by presenting cross-sectional data on the variables that influence core muscle function in young adults aged 18 to 30 years. Firstly, this study investigated gender related differences and age related changes in the core muscle function of young adults. Secondly, this study provided evidence of how exercise duration affects core muscle function. Thirdly, influences of body composition factors such as body weight, BMI, sum of skinfolds, and waist circumference on core muscle function was investigated. Finally, the relationship between lower limb function and core muscle function was explored.

1.4 Hypotheses

In this project the following hypotheses were examined:

1. There is a difference between core muscle function of young men and women age 18 to 30 years.
2. Increased weight, BMI, sum of skinfolds, and waist circumference negatively affects core muscle function.
3. Exercise duration improves core muscle function.
4. Good core muscle function improves lower limb muscle function and vice versa.

5. Age related changes exist in core muscle function of young adults aged 18 to 30 years.

1.5 Significance

Poor core muscles function has been linked lower back pathologies (Colsten 2012a, Warren et al. 2014, Leetun et al. 2004, Wilson et al. 2005, Ferreira et al. 2007).

According to Australian Institute of Health and Wellbeing (AIHW) (2015) in 2011-12, 14% of Australians reported back problems. In addition, Global Burden of Disease reports that lower back pain is ranked first in Australasia (Australia, New Zealand, the island of New Guinea, and neighbouring islands in the Pacific Ocean) (AIHW 2015).

A research study that examines the above hypotheses (listed in section 1.4) and contributes to the existing body of knowledge will be beneficial in gaining a deeper understanding of core muscle function and the variables that affect it. The knowledge gained will enable better intervention design that will help young adults better assess and improve their core muscle function so that they can avoid pain and injury. This in turn will have a positive impact on their quality of life, reduce financial impact due to less visits to healthcare professionals.

So far, there has been a lack of studies that report gender related differences and age-related changes in core muscle function of young adults. As far as we know, this study is the first attempt to explore how factors such as body composition and training state influence core muscle function.

Chapter Two: Literature review

Following literature review will provide detailed overview of the core muscles and their function. In addition, it will explain disorders that arise from poor core muscle function. Moreover, an overview of future directions and the study questions that arise as the outcome of the review will be discussed.

2.1 Introduction

The core or the lumbopelvic region of the body is a complex that comprises many anatomical structures that act in concert to maintain core stability and function. The main purpose of the core is to provide a stable foundation for the movement of upper and lower extremities (Panjabi 1992a, McGill 2001, Willardson 2007a). In addition, the core maintains the spine within the physiological limits in order to protect the spinal cord and propagating nerves (Colsten 2012a, Warren et al. 2014, Willardson 2007a). In contrast to other muscles of the body, core musculature functions to inhibit motion rather than initiate it. This is key to the core musculature's ability to maintain spinal stiffness and stability (McGill 2010).

The anatomical structures that comprise the core have been a matter of debate. Kibler et al. (2006) argued that the core consists of the musculoskeletal structures of the spine, hips, pelvis, abdomen, and the proximal lower limb. In contrast to this, Akuthota & Nadler (2004) defined the core as comprising the diaphragm as the roof; the pelvic floor and hip girdle as the floor; and the abdominals, spinal, and gluteal muscles serving as the walls. Frank et al. (2013) proposed that the core consists of the deep cervical flexors, deep spinal extensors of cervical, thoracic and lumbar regions, the diaphragm, pelvic floor, and the abdominals. In summary, the muscles, osseous and ligamentous, and neural systems that are integrated to provide support and protect the spinal cord during

movement, maintain spinal stiffness and integrity, transfer force from lower body to the upper body and vice versa make up the core.

To this date, the most commonly accepted model for the core is one that was devised by Panjabi (1992a). Panjabi (1992a) categorised the core into three major components: the passive, active and neural subsystems. In this review, these subsystems will be discussed in detail to provide an insight into the core anatomy and physiology. In addition, this review will discuss some of the pathologies associated with poor core muscle function and how these pathologies are investigated, and treated.

2.2 The core

Panjabi (1992a) divided the core into three subsystems; passive, active and neural subsystems. The passive subsystem supports minimal load as it consists of ligaments and facet articulations (Panjabi 1992a). The active subsystem consists of muscles that support the body mass and other loads associated with body movements and activities (Panjabi 1992a, McGill 2001). The neural subsystem controls the active and passive subsystems via communication between CNS and mechanoreceptors (muscle spindles, spinal ligaments and Golgi tendon organs) present in the passive and active subsystems (Panjabi 1992a, McGill 2001). Using feedback from the mechanoreceptors, the neural subsystem activates the active subsystem to create tension, which generates compressive forces between lumbar vertebrae to stabilise in the lumbar spine (Panjabi 1992a, Panjabi 1992b, McGill 2001). These subsystems are integrated together to provide core stability during movement and maintain correct posture.

2.2.1 The passive subsystem

The passive subsystem consists of osseous and ligamentous structures of the vertebrae that protect the spinal cord and serve as attachment areas for the muscles of the local

subsystem (Figures 1 & 2). These structures provide passive stiffness to the lumbar spine and include zygapophyseal joints, pedicle, lamina, pars interarticularis and muscle attachment sites (Panjabi 1992a, Akuthota & Nadler 2004). This subsystem cannot handle external loads. Excessive lumbar flexion and extension will cause failure in the passive subsystem which leads to poor spinal stability and injury (Panjabi 1992a, Panjabi 1992b). The passive subsystem is supported by the active subsystem. According to Akuthota & Nadler (2004), weak muscular control leads to excessive loads on the spine causing damage to the intervertebral disks.

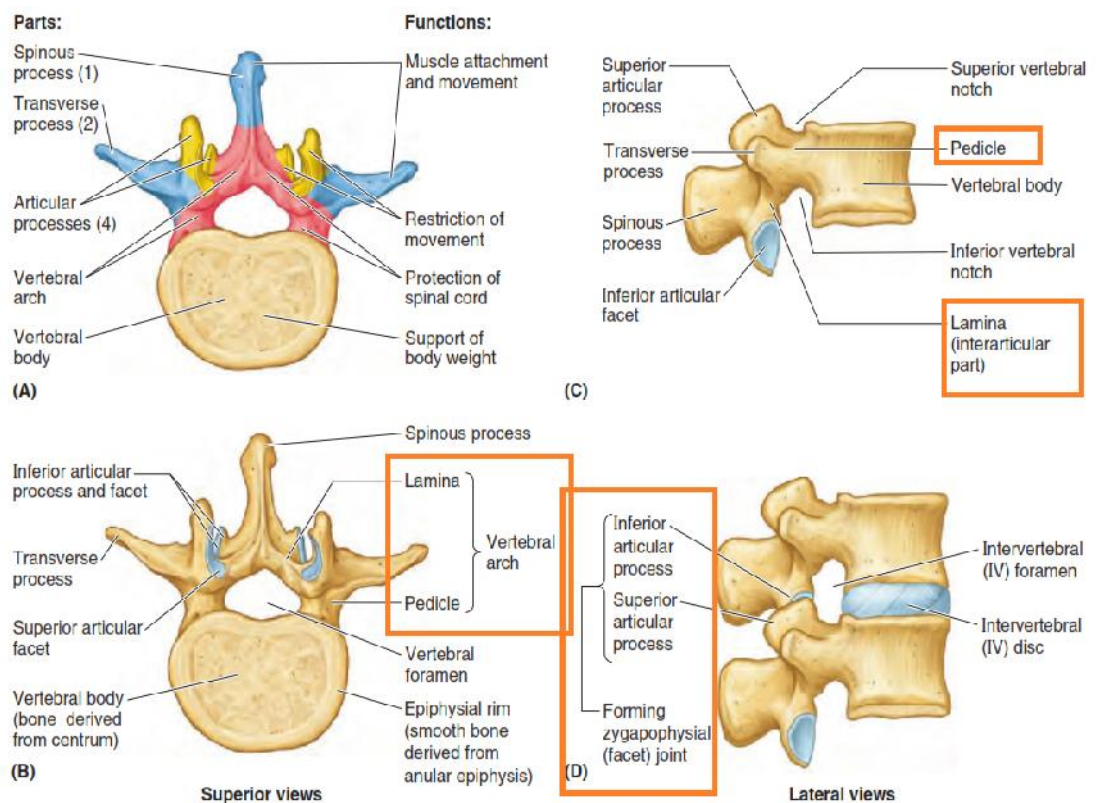


Figure 1 The passive subsystem (Source: Moore et al. 2014)

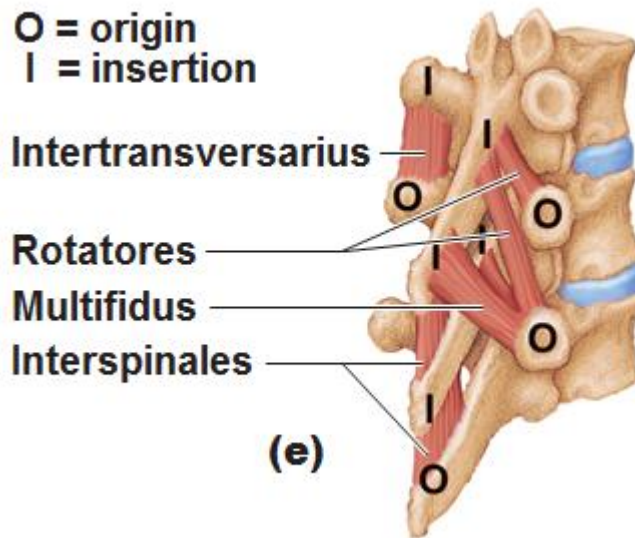


Figure 2 The passive subsystem and the deep core muscle origin and insertion points (Source: Marieb & Hoehn 2010)

2.2.2 The active subsystem

The active subsystem constitutes the muscles that provides support to the passive subsystem, controls movement and is responsible for core stability (Figures 3 & 4). Bergmark (1989) divided the core musculature into two groups according to their function; local and global muscles.

The local muscles consist of transversus abdominis, multifidi, interspinales, intertransversarii, local erector spinae muscle (Iliocostalis lumborum, longissimus lumborum), and the quadratus lumborum (medial fibres). They are made up of type I skeletal muscle fibres and are fatigue resistant. They are directly attached to the vertebrae and can only generate minimal torque due to their small momentum arm.

Their main function is to provide precise control of spinal vertebrae and posture control (Bergmark 1989, Warren et al. 2004).

Global muscles consist of the rectus abdominis, global erector spinae muscle group (longissimus thoracis and iliocostalis thoracis), quadratus lumborum (lateral fibres), internal oblique and external obliques (Bergmark 1989, Warren et al. 2004). They attach to the hip and thorax, and have a larger moment arm to generate torque to counteract the external forces placed on the spine during movement (Bergmark 1989, Warren et al. 2014). The function of the core muscles are discussed separately below.

Transverse Abdominis

The transverse abdominis (Figure 3) play an important role in creating intraabdominal pressure and support the spine during movement. The horizontally orientated fibres of the transverse abdominis when contracted create tension within the thoracolumbar fascia and co-contraction of the diaphragm and the pelvic floor muscles generate intraabdominal pressure (Cresswell et al. 1992). This creates stiffness within the core and protects the spine by decreasing the compression forces exerted on it. Transverse abdominis functions in a feed-forward manner and activates prior to movement to avoid spinal displacement (Colsten 2012). Absence of this protective mechanism may result in lower back pathologies (Colsten 2012).

Rectus Abdominis and the Obliques

Rectus abdominis and the obliques are global muscles. The rectus abdominis and the lateral fibres of the external oblique are the prime movers of trunk flexion bringing the ribcage and the pelvis closer (Norris 1995, Norris 1999). The bilateral action of the external oblique assists in trunk flexion in conjunction with rectus abdominis and the unilateral action of the external oblique facilitates flexion-rotation of the thoracic cage (Bergmark 1989). In addition, the internal obliques act as a stabiliser and assist the transverse abdominis in truck stabilisation (Norris 1995).

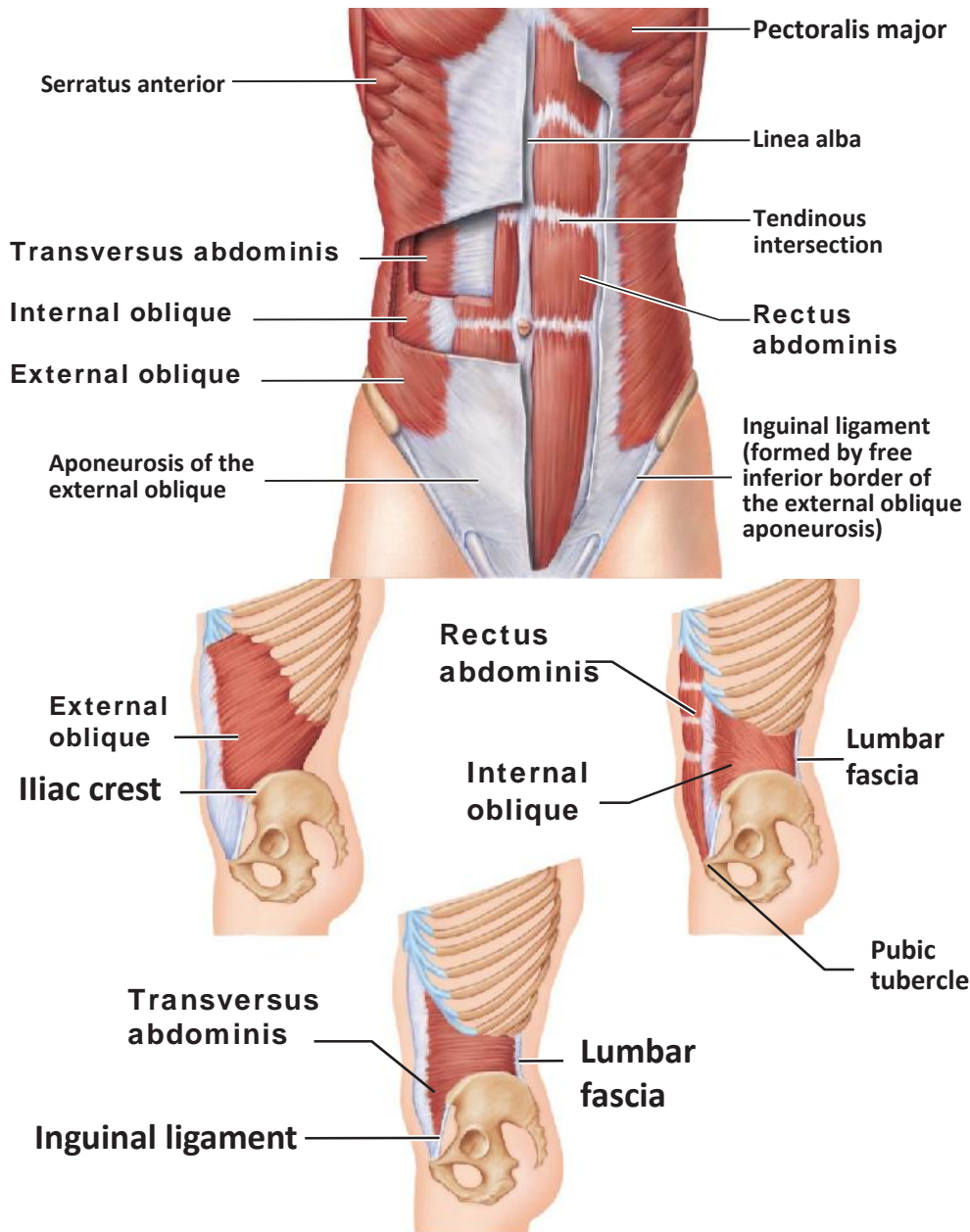


Figure 3 The main muscles of the active subsystem (Source: Marieb & Hoehn 2010)

Multifidi and Rotatores Lumborum

The multifidi and the rotatores lumborum provide segmental stability to the spine as they have direct attachments to the vertebrae (Figures 2 & 4). This allows for specific vertebral segment motion control when force is exerted on the spine (Bergmark 1989). Wilke et al. (1996) suggested that the multifidi and the rotatores lumborum act caudally

to generate intradiscal pressure. The rotatores lumborum cooperates with multifidi, interspinales and intertransversarii in protecting the articular structures of the vertebrae from excessive bending and strains (Ebenbichler et al. 2001). Due to the short arm of the multifidus muscle, it only contributes 20% to the total extensor movement of the lumbar spine (Colston 2012b). Similar to transverse abdominis, lower back pain or injury changes the activation pattern of the multifidus muscle and reduces its endurance. In addition to functional changes, morphologic changes such as type II skeletal muscle fibre atrophy and structural changes in type I skeletal muscle fibres of the multifidi muscles are observed after lower back injury (Colston 2012b).

Interspinales and Intertransversarii

The interspinales muscles connect to the spinous processes and the intertransversarii muscles connect to the transverse processes of the vertebrae (Bergmark 1989). These muscles cooperate to stabilise the spine during movement (Bergmark 1989).

Interspinales in conjunction with the multifidi muscles enable posterior sagittal rotation and the intertransversarii is associated with proprioception (Norris 1995)

Erector Spinae

There are four muscles in the erector spinae muscle group: longissimus lumborum, iliocostalis lumborum, longissimus thoracis, and iliocostalis thoracis. The longissimus lumborum and iliocostalis lumborum are part of the local muscles and facilitate and stabilise the spine during lumbar flexion and assist in posterior sagittal rotation. In addition, iliocostalis lumborum works together with the multifidi to counteract flexion caused by abdominal muscles during trunk rotation. The longissimus thoracis and the iliocostalis thoracis are part of the global muscles of the core. The longissimus thoracis functions indirectly maintaining the lumbar lordosis (normal curvature of the lumbar spine) by laterally flexing the thoracic spine which in turn laterally flexes the lumbar

spine. The iliocostalis thoracis facilitates the lumbar lordosis and control the extent to which the lumbar spine can be laterally flexed (Norris 1995).

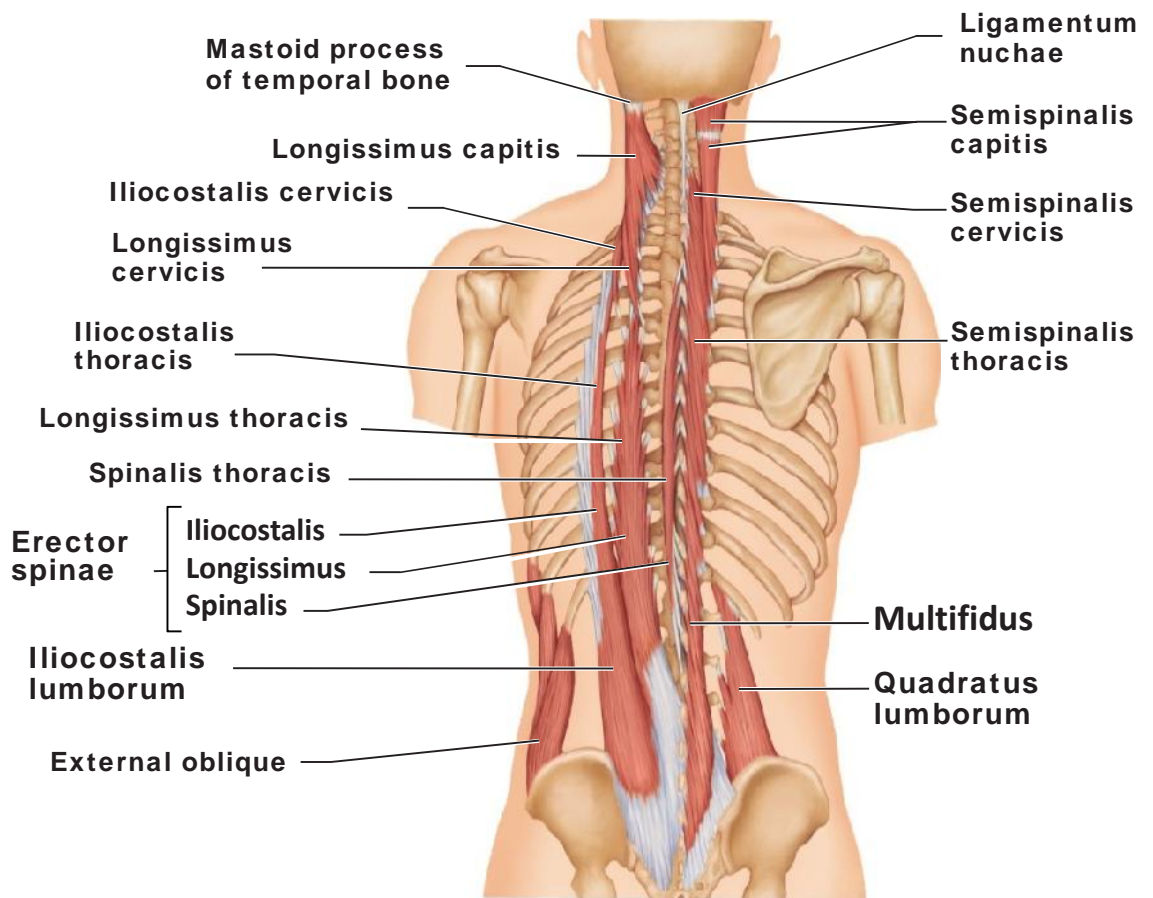


Figure 4 Deep core musculature

Quadratus Lumborum

The quadratus lumborum (Figure 4) is both a global muscle and a local muscle. The medial fibres of the quadratus lumborum are part of the local muscles of the core and its lateral fibres are global muscles (Bergmark 1989, Warren et al. 2004). The local quadratus lumborum facilitates lateral bending of the spine and stabilises the spine laterally and the global part acts as an antagonist to the diaphragm (Bergmark 1989).

Pelvic girdle, Diaphragm and Hip musculature

Besides the major local and global muscles mentioned above, the diaphragm and the pelvic floor assist in the generation of intraabdominal pressure, which is vital for maintaining spinal stability during general movement and lifting activities (Akuthota & Nadler 2004). Pelvic floor plays a critical role in maintaining correct lumbo-pelvic stability. This is important when force is being transferred between lower extremity and the spine. Lumbo-pelvic stability is important in preventing lower back pain and low extremity imbalances, misalignments, and injuries (Colsten 2012b). O'Sullivan and Beales (2002) studied the mechanics of the diaphragm and the pelvic floor in people with sacroiliac joint pain. Using ultrasonography, they measured the diaphragmatic excursion and pelvic floor descent during active straight leg raise with and without manual compression through the ilia. They observed decreased diaphragmatic excursion and increased pelvic floor descent in individuals with sacroiliac joint pain when performing the active straight leg raise. However, these observations were not present when the pelvis was stabilised using manual compression through the ilia. They concluded that imbalance and poor motor control in the pelvic floor musculature causes pain in the sacroiliac joint which causes non-specific chronic lower back pain (O'Sullivan & Beales 2002). In addition, they argued that lack of neural control and reduced muscle capacity are the main factors causing dysfunction in the pelvic floor musculature. Furthermore, they pointed out that physical training aimed to increase muscle endurance and neural control has been successful in reducing pain and increasing sacroiliac joint stability.

Hip flexors, extensors, adductor and abductors are part of the global muscles of the core as they originate from the lumbar vertebrae and insert in the proximal portion of the femur, tibia, or fibula (Willardson 2007b). These muscles are important during walking as they play a role in stabilising the pelvis and the trunk (Lyons et al. 1983). In addition,

these muscles are involved in force transmission between the lower extremities, the pelvis and the spine (Akuthota & Nadler 2004). Hip flexors include rectus femoris, sartorius, iliacus, and psoas major and minor. Hip extensors are the gluteus maximus, semimembranosus, semitendinosus, and long head of the biceps femoris. Hip adductors consist of the adductor magnus, adductor brevis, adductor longus, gracilis, and pectineus. Hip abductors include tensor fascia latae, gluteus medius, and gluteus minimus (Willardson 2007a).

Thoracolumbar Fascia

Though, the thoracolumbar fascia is not a muscle, it plays an important role in core stability and function. The thoracolumbar fascia consists of anterior, medial and posterior layers with the posterior layer being more involved in spinal stability due to its large attachments with the transverse abdominis. In addition, it provides feedback to the neural subsystem during general movement or lifting activities (Akuthota and Nadler 2004). The thoracolumbar fascia is extensively attached to the local and global muscles of the core so that it can transfer tension between these muscles. It surrounds the quadratus lumborum and the erector spinae muscle groups; and it is connected to the latissimus dorsi in the upper extremity of the core and to the gluteus maximus in lower extremity of the core (Colston 2012a). Therefore, it acts as a natural back belt and provides support to the lower back and transfers force between the lower and upper body.

2.2.3 The neural subsystem

Good core muscle function requires an individual to control the activation of voluntary muscles of the active subsystem, thereby having good sensory-motor control.

Inadequate sensory-motor control introduces neuromuscular imbalances in the core musculature which causes instability in the spinal segments and imbalanced load

distribution (Macedo et al. 2009, Warren et al. 2014). This leads to poor stability and control in spinal segments during movement, which may cause injury and lower back pain. The CNS controls the core muscles via feedback and feed-forward motor control mechanisms (Behm et al. 2010). Ligaments, joint capsules, and muscles feedback sensory information to the CNS. CNS uses this information to adjust core muscle activity in anticipation of spinal movement or external load stresses in a feed-forward manner to maintain spinal stability (Behm et al. 2010). The feedback and feed-forward systems help keep the spinal segments in correct alignment and within physiological limits known as the neutral zone (Behm et al. 2010). An imbalance in the neural subsystem translates to poor core muscle function causing lower back pathologies and lower extremity dysfunction.

2.3 Pathologies

2.3.1 Lower back pain

Lower back pain is one of the chronic diseases affecting many people in Australia. AIHW (2015) reported that in 2011-12, 14% of Australians reported back problems. In addition, according to Global Burden of Disease, lower back pain is ranked first in Australasia (Australia, New Zealand, the island of New Guinea, and neighbouring islands in the Pacific Ocean) (AIHW 2015). Lower back pain is generally caused by the lack of neuromuscular response to sudden loading force on the spine. Poor core muscle endurance and suboptimal neuromuscular coordination are major risk factors of lower back pain (Colsten 2012a, Warren et al. 2014, Leetun et al. 2004, Wilson et al. 2005, Ferreira et al. 2007). To prevent pain and injury, core muscle endurance and strength must be sufficient to overcome external loads placed upon the spine and to maintain spinal alignment.

Lack of neuromuscular coordination and poor core muscle function compromises core stability by introducing incorrect motor patterns and compensatory movements which can compromise core stability (Colston 2012a). Good neuromuscular control means that CNS can anticipate and react to external forces which results in good spine stability reducing the risk of injury and mitigating lower back pain (Leetun et al. 2004, Wilson et al. 2005, Ferreira et al. 2007, Warren et al. 2014).

Training the neuromuscular recruitment patterns to pre-activate the core muscles to contract in anticipation to movement is vital for good core muscle function (Ferreira et al. 2007). This anticipatory mechanism provides a stable foundation prior to movement and protects the spine from injury (Ferreira et al. 2007). Co-contraction exercises, balance training, proprioceptive training and skill specific exercises assist in training or retraining neuromuscular recruitment patterns for better core muscle control and stability during movement (Caraffa et al. 1996).

2.3.2 Lower extremity injuries

Hip and pelvic muscles are associated with maintaining pelvic-femoral alignment. Fatigue, imbalances and weakness in hip and pelvic musculature may result in many lower extremity misalignments such as trunk flexion, anterior pelvic tilt, hip adduction, hip internal rotation, knee valgus, and foot pronation. Wilson et al. (2006) studied the association between trunk, hip and knee strength and the orientation of the knee joint. They determined peak isometric torque for trunk flexion, extension and lateral flexion, hip abduction and external rotation, and knee flexion and extension. In addition, the frontal plain projection angle of the knee during a 45-degree single leg squats was measured. They found that individuals with greater hip external rotation strength resist hip internal rotation and have a smaller frontal plain projection angle of the knee. This suggests that hip musculature influences knee strength and joint orientation.

Poor core muscle function leads to imbalanced loads on the knee joint during movement as the muscles that act on the knee joint originate at the lower lumbopelvic region (Willardson 2007a). This may increase the risks of anterior cruciate ligament (ACL) injuries. Exercises that introduce destabilisation improve muscle readiness and neuromuscular response to external and internal stimuli, which reduces the risk of lower extremity injuries such as ACL injury (Willardson 2007a). Preventing these types of injuries proves important not only to the general public but takes great precedence in sports.

2.4 Core muscle function in sports

Correct core stability is important in improving sports performance and reducing injury. From an athletic point of view, it is widely understood that good core muscle function improves performance as it enhances force transfer efficiency between lower and upper extremities of the body. Behm et al. (2005) studied the effect of unstable and unilateral resistance exercises on trunk muscle activation in healthy adults. They observed electromyographic (EMG) activity of the upper lumbar, lumbosacral erector spinae, and lower-abdominal muscles. They found that unilateral exercises and exercises performed in unstable surfaces showed higher core musculature activation. In addition, their results showed that the side bridge exercise activated core musculature to higher degree than the front bridge, pelvic tilt, alternate arm and leg extension, parallel hold, superman, chest press and shoulder press exercises.

Core stability exercises that are used to increase sports performance need to be designed for the specific sport. Studies have shown that when traditional exercise are modified such that the core musculature is activated whilst performing the exercise, core muscle function and sports performance are improved (Frank et al. 2013, Willardson 2007a, Willardson 2007b, McGill 2001). Stanton et al. (2004) investigated the

effects of a six-week Swiss ball training on core stability and running economy in 18 male athletes. The athletes were aged between 15.5 and 17.0 years. The authors found that core muscle function had been improved after the training intervention. However, due to the lack of specificity of the training, no improvements were observed in running economy. They argued that core muscle endurance, and strength training result in overall improved performance only if the design of the exercises simulates the movements involved in the sport.

Core musculature work in concert to stabilise the spine and support the body when external loads are exerted on the body. To improve core muscle function, training should focus on local, global and other core musculature simultaneously. Using a biomechanical model, Cholewicki and Van Vliet (2002) compared core muscle contribution during seated, standing and isometric tasks. They used EMG to measure muscle activity during these tasks and to estimate stability of the lumbar spine. They repeatedly ran trials on the model and removed one of the 10 major trunk muscles from the model at each simulation. It was reported that depending on the direction and magnitude of the movements, all core musculature were involved in maintaining core stability with erector spinae muscle group being the major contributor in maintaining stability.

In a comparative study of core musculature, Arokoski et al. (2001) observed similar activity pattern and simultaneous activation and function in the multifidus and longissimus thoracis muscles. This is interesting because the multifidus is a local muscle and the longissimus thoracis is a global muscle. This study shows that all core muscles are needed to function optimally to maintain stability and prevent lower back and lower limb injuries. Core muscle response to movement is relative to type and phase of the movement. According to McGill et al. (2003), as movement progresses, the contribution

of each core muscle changes, meaning that at different stages of movement, different core muscles are activated to varied intensity.

All sports involve a destabilising component, therefore training program needs to include exercises with an instability component in order to improve core muscle function (Behm et al. 2002, Andersen and Behm 2004). When traditional resistance exercises such as squats or a chest press are performed on an unstable surface, maximal force output is considerably reduced due to the unstable nature of the exercise but core muscle activity is increased (Behm et al. 2002, Andersen and Behm 2004). To improve core muscle function, increasing core muscle endurance is more important than strength and power (Arokoski et al. 2001, McGill 2001). Therefore, core exercises would be better if performed on an unstable surface and incorporate light loads and long tension times to increase core muscle endurance (McGill 2001).

2.5 Training and rehabilitation programs

Any training or rehabilitation program designed to improve core muscle function should consider the complexity of the structure and function of the core. Akuthota & Nadler (2004) suggested that prior to attempting core muscle exercises in functional positions, training to develop motor pattern awareness is necessary. Once this has been achieved, core stability exercises in functional positions need to be performed. This reduces the risk of further injury and eases individuals into core muscle training and strengthening. The authors further pointed out that exercises that cause full spine flexion and torsion such as sit ups and roman chair exercises are deemed unsafe for individuals with lower back pain or spinal injury.

McGill (2010) advocated three rehabilitative exercises that encourage motor pattern awareness and increase core stability. These exercises are the bird dog, the curl-up, and

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side-bridge exercises (Figures 5, 6, 8). These exercises are beginner level activities that train motor pattern awareness and muscle recruitment. However, to increase core muscle endurance and strength, more complex exercises are required that are goal or skill specific.



Figure 5 The Bird Dog



Figure 6 The Curl Up

Suitable exercises are to be designed such that the whole core is engaged to avoid introducing imbalances in the core structure and function as injury risks characteristically arise from such imbalances. Hibbs et al. (2008) pointed out that for a training program to be effective, it must include exercise that engage the core at a low and high level of muscle activation and be goal specific. Good core stability program needs to include low-load motor control training as this type of training enhances CNS ability to control muscle coordination (Hibbs et al. 2008).

Exercises such as bird dog (Figure 5), curl ups (Figure 6), front bridge (Figure 7), and side bridge (Figure 8) are low load exercises that are used for motor control training (McGill 2010, Akuthota & Nadler 2004). High load exercises incorporate external loads such as weights to increase the magnitude of stimulus (Hibbs et al. 2008). Hibbs et al. (2008) suggested that programs that include low and high-load exercise result in elimination of imbalance in the core musculature which reduces the risk of injury. Further, using low-load and high-load training in a training method improves core muscle function and performance in sports.

2.6 Future directions

Current literature discussed in this review mainly studied the effect of training on core muscle function. It has been found that core muscles work in concert to provide core stability and protect the spine from damage by keeping the spinal movement within physiological limits. The literature review revealed that poor core muscle function is mainly due to poor neural control of core musculature which leads to an array of lower back and lower extremity pathologies.

There are many studies on the effects of different exercises on core muscle function. However, fewer studies have been done to understand the nature of core muscle function in healthy young people and how it is influenced by age, exercise and body

composition. There is a lack of knowledge in the changes that occur in core muscle function between the ages of 18 to 30 years. Further to this, it is important to understand if exercise improves core muscle function in young healthy people. Investigating these variables can help in predicting how core muscle function changes over time in individuals whether they are active, sedentary or sports oriented. By understanding how core muscle function changes throughout these years, better rehabilitation and training programs can be devised to assist individuals in improving their core muscle function. This can assist in reducing spinal, lower back and lower extremity injuries, which can improve individuals' quality of life. In addition, better core muscle function improves sport performance and assist in maintaining good occupational health.

2.7 Conclusion

The core is a complex structure comprising of passive, active and neural subsystem that work together to provide spinal control, stiffness and stability. The neuromuscular control of the core musculature is the main reason for core dysfunction as it introduces musculature imbalances that fail protect the spine and maintain its movement within physiological limits. Core muscle endurance is another contributor that plays a vital role in core stability during different bodily movements because fatigued core muscles are not able to counteract external loading on the spine. Understanding core muscle function and how it changes within certain age groups makes it possible to design protective intervention that may improve core muscle function. Understanding how core muscle function is affected by body composition and training state is an important factor that can mean the difference between an effective and poor core muscle intervention to improve structure and function.

Chapter Three: Methodology

This section will explain in details participants' information, research design, measurements, equipment, and data analyses.

3.1 Ethics approval

This project was approved by the USQ ethics committee on the 30th April 2015. The approval number for the project is H15REA102. Additionally, the Dean of Faculty of Health, Engineering and Sciences has approved the recruitment of USQ students for this project.

3.2 Study design

This was a cross-sectional study. Healthy young men and women aged 18 to 30 years old were recruited. All participants were given a questionnaire to collect information about lifestyle, physical activities, and medical history. Body composition was measured by BMI, sum of skinfolds, and waist circumference. Core muscle function was assessed using length of time front bridge and side-bridge positions were held. Lower limb muscle function was measured using long jump distance. Data analyses were run to evaluate the effects of age, gender, physical activity and body composition variables on core muscle function. In addition, relationship between core muscle function and lower limb muscle function in young adults was investigated.

3.3 Participants

Young male and female individuals were recruited from USQ and the wider Toowoomba population. Potential participants were given information sheets and consent forms pertaining to the project. Participants were divided into four age groups; 18-20, 21-23, 24-26, and 27-30 as the number of participants at each age was too low.

3.3.1 Inclusion and exclusion criteria

Participants were required to be between the age of 18 and 30 years. Individuals who had medical conditions that inhibited them from performing the exercises were excluded from the study. Individuals with conditions such as recent lower back, spinal, abdominal and lower extremity injury were excluded from the study. In addition, individuals who had undergone recent surgical intervention were not included in the study due to safety concerns. Individuals who were advised by their general practitioner to avoid exercising were also excluded from participating in the study.

3.3.2 Participant recruitment methods

Various methods were used to recruit participants for this study. Cold canvassing was the main method to recruit participants. Researcher approached individuals during common hours at USQ social gathering areas and the project was explained and individuals were asked if they wanted to participate. Researcher approached other establishments such as soccer clubs, gyms, workplaces and general public gathering areas to recruit participants. In addition to this, noticeboards at various USQ sites were used to promote the project. Finally, social media such as Facebook was another modality that was used to successfully recruit participants for the study.

3.3.3 Information sheet

Potential participants were provided with an information sheet (Appendix 1) that had detailed overview of the project so that individuals can make a well informed decision on whether they want to take part in the project. Project description, risks involved, privacy and confidentiality, expected benefits and researcher contact details were the main points presented in the information sheet. Upon providing the information sheet, researcher explained the contents within the information sheet and answered any

questions that were asked by the potential participants. This helped individuals understanding the project and what would be required from them if they chose to participate.

3.3.4 Consent form

All individuals who decided to take part in the study were given a consent form (Appendix 2) to sign and return. By signing the consent form, participants acknowledged that they understood the purpose of the research project and were well informed about what was required from them. Additionally, the participants were required to acknowledge that they understand that their participation was voluntary and agree to participate in the study.

3.4 Measurements

3.4.1 Body composition

Body composition measurements included height, weight, BMI, sum of skinfolds and waist circumference. Height was measured using a STANLEY millimetre scaled tape measure. The measurement was done in centimetres (cm) then converted to metres in order to calculate BMI. A digital scale accurate to two decimal places was used to measure weight in kilograms (kg). Sum of skinfolds in millimetres (mm) from four sites was used to represent body fat mass. SLIM GUIDE skinfold callipers were used to measure skinfold thickness in millimetres. Four regions of the body were used for the sum of skinfolds which included the triceps brachia, subscapular, abdomen and thigh. Waist circumference at the navel level was measured in centimetres using a tailor's tape measure which was accurate to one decimal place.

3.4.2 Physical activity

All participants had to give specific details regarding their physical activity levels in the questionnaire (Appendix 3). Participants were required to report the type of activity and its duration. The time spent in hours per week was used to determine physical activity level.

3.4.3 Core muscle function

Two exercises (Figures 7 & 8) were used to determine the quality of core muscle function. The exercises included the front bridge and the side bridge. Participants were timed whilst holding a front bridge and a side bridge and these times were used as an indicator of poor or good core muscle function.

The front bridge

The front bridge is performed with the front of the body facing the ground and the body is held up by having elbows and forearm on the ground and legs supporting with balls of the feet on the ground in a plank position (Figure 7). This exercise activates the core musculature simultaneously and can be used as a good indicator of core muscle function (Tan et al. 2013). The participants were shown to correctly perform this exercise and were asked to hold the exercise for as long as they can. The length of time holding the front bridge was used as one of the indicators for core muscle function.



Figure 7 The Front Bridge Exercise

The side bridge

The side bridge has been proven to be an excellent exercise as this exercise activates core musculature to higher degree and can be used as an indicator of the functional capacity of core musculature. Tan et al. (2013) measured EMG signals of the different core muscles on healthy men and found that this simple exercise activates all the major core muscles and a at a higher degree than the front bridge. This exercise is performed by laying on the side and supporting the body using the elbow, the forearm and feet (Figure 8). The participants were shown how to correctly and safely perform this exercise and the length of time this position was held was used as an indicator of core muscle function.



Figure 8 The side bridge exercise

3.4.4 Lower limb muscle function

Standing long jump (Figure 9) was used to determine quality of lower limb muscle function. The length of the standing long jump in centimetres (cm) was used to determine the lower limb muscle function.



Figure 9 The Standing Long Jump Exercise

3.5 Data analyses

IBM SPSS statistics software version 19 and Microsoft Excel 2013 was used to collate and analyse the data. All variables were presented as Mean \pm SD. One-way ANOVA and Pearson's correlation analyses were used to investigate the relationship among the variables.

3.5.1 One-way ANOVA

One-way ANOVA was used to analyse any significant differences in the variables between different age groups and gender related differences in core muscle function of young men and women. Mean front bridge, side bridge times and long jump distance were analysed to see if there any variation in different age groups. In addition, the analysis would suggest whether gender related differences exist in core muscle function of young adults.

3.5.2 Pearson's Correlation test

Pearson's correlation analysis was done to investigate the relation between core muscle function, body composition, physical activity level, and lower limb muscle function.

Chapter Four: Results

4.1 Descriptive statistics & gender related differences

One-way ANOVA was conducted to explore gender related difference in core and lower limb muscle function. Participants were divided into two groups according to their gender.

Table 1 Descriptive statistics of body composition, exercise duration, and core muscle and lower limb muscle function in men and women

	Male (n=48)	Female (n=50)
Age (Years)	22±4	22±4
Height (cm)	179±8	166±6*
Weight (kg)	77.0±11.8	63.9±12.5*
BMI	24.0±3.3	23.1±4.0
Exercise Duration (hours)	6.1±4.4	5.1±3.0
Sum of Skinfolds (mm)	58±32	77±34*
Waist Circumference (cm)	84.9±9.6	75.2±9.6*
Front Bridge Time (Seconds)	139±61	103±54*
Side Bridge Time (Seconds)	86±36	63±31*
Long Jump Distance (cm)	212±39	165±31*

Note: All data are presented as mean ± SD. *p < 0.05 between male and female

48 young men and 50 young women, with mean age of approximately 22 years took part in the study. All variables except age, BMI, and exercise duration are significantly different between male and female (p < 0.05).

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Figure 10 shows the difference in the means front bridge times (red), side bridge times (green) and standing long jump (blue) for young men and women. Overall, men performed better than women in the three exercises ($p < 0.05$).

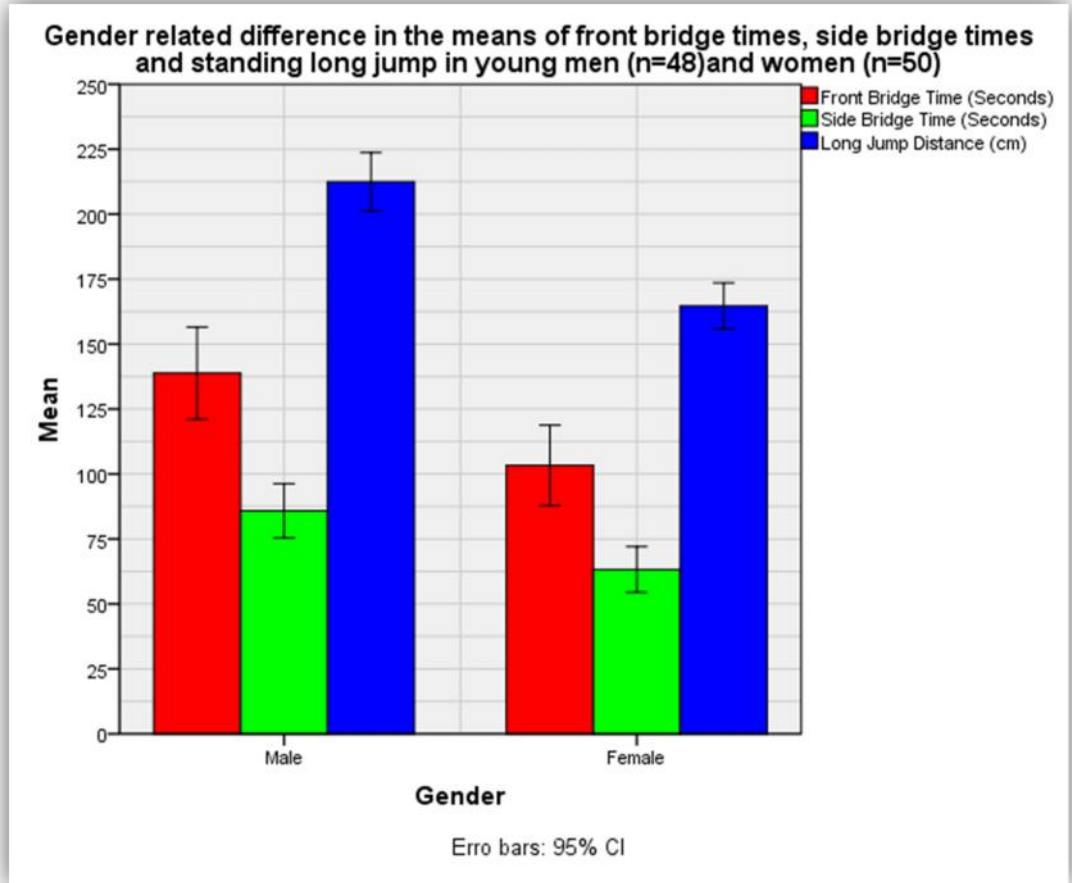


Figure 10 Bar chart showing gender specific difference in core muscle and lower limb muscle function

4.3 Body Composition and Core muscle function Correlation

Pearson correlation analyses were used to investigate the relationship of core muscle function with body composition, and exercise duration. In addition, relationship between core muscle function and lower limb function was explored.

4.3.1 Results for men

Table 2 shows results from Pearson correlation analyses of weight, BMI, exercise duration, sum of skinfolds, and waist circumference with front bridge times, side bridge times and long jump distance for young men.

Table 2 Correlation analysis of body composition and exercise duration with core and lower limb muscle function in young men (n = 48). * Correlation is significant at the 0.05 level (1-tailed). ** Correlation is significant at the 0.01 level (1-tailed).

	Front Bridge Time	Side Bridge Time	Long Jump Distance
Weight	-.337**	-.323*	-.078
BMI	-.328*	-.396**	-.192
Sum of Skinfolds	-.568**	-.525**	-.400**
Waist Circumference	-.418**	-.443**	-.339**
Exercise Duration	.274*	.307*	.054

Sum of skinfolds, bridge times and long jump distance

Sum of skinfolds had significantly strong negative correlation with front bridge times ($r = -0.568$, $p < 0.001$) and side bridge times ($r = -0.525$, $p < 0.001$), and a moderate negative correlation with long jump distance ($r = -0.4$, $p = 0.002$) (Table 2). Figure 11 shows the relationship of sum of skinfolds with bridge times and long jump distance in young men. Larger sum of skinfolds measurement adversely affected bridge times and long jump distance. Note that figure 12 to 22 do not have y axes labels as variables shown in the figures have different units. The legend on the right if the figures provides the referencer required.

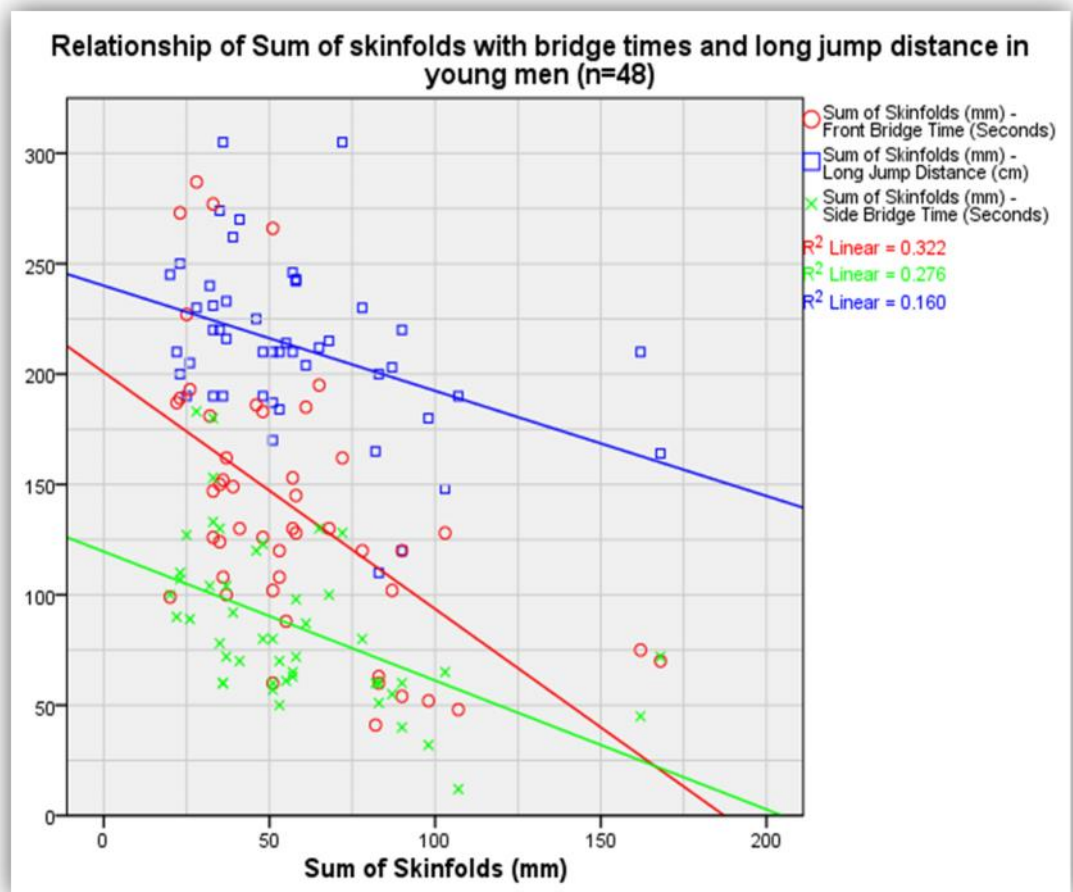


Figure 11 Scatter plot showing correlation of sum of skinfolds with front bridge times ($p < 0.01$) and side bridge times ($p < 0.01$), and long jump distance ($p < 0.01$) in young men

Waist circumference, bridge times and long jump distance

There was a statistically significant moderate negative correlation between waist circumference and front bridge times ($r = -0.418$, $p = 0.002$), side bridge times ($r = -0.443$, $p = 0.001$) and long jump distance ($r = -0.339$, $p = 0.009$) (Table 2). Figure 12 shows the relationship of waist circumference with bridge times and long jump distance in young men. Larger waist circumference adversely affected bridge times and long jump distance.

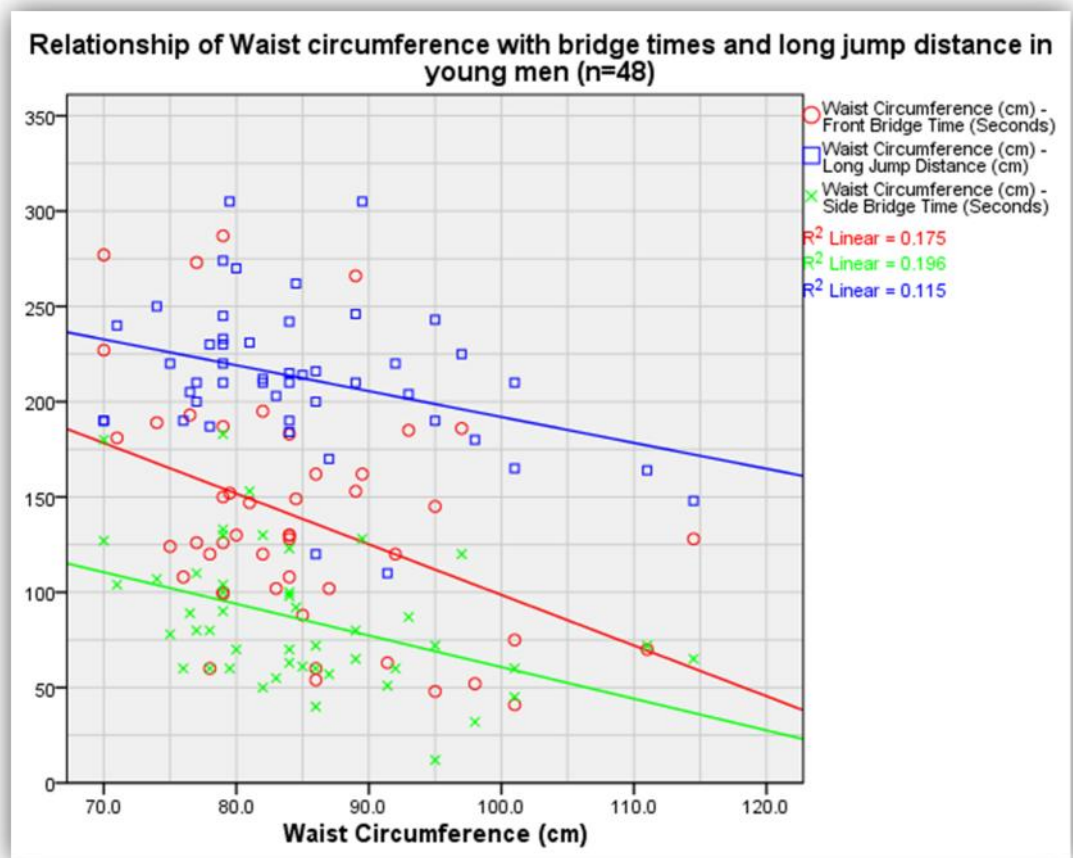


Figure 12 Scatter plot showing correlation of Waist Circumference with front bridge times ($p < 0.01$) and side bridge times ($p < 0.01$), and long jump distance ($p < 0.01$) in young men.

Weight, bridge times and long jump distance

There was a moderate but statistically significant negative correlation between weight and front bridge times ($r = -0.337$, $p = 0.01$), and weight and side bridge times ($r = -0.323$, $p = 0.013$). There was no significant correlation between weight and long jump distance ($r = -0.078$, $p = 0.3$) (Table 2). Figure 13 shows the relationship of weight with bridge times and long jump distance in young men. Increased weight reduced bridge time but had an insignificant impact on long jump distance.

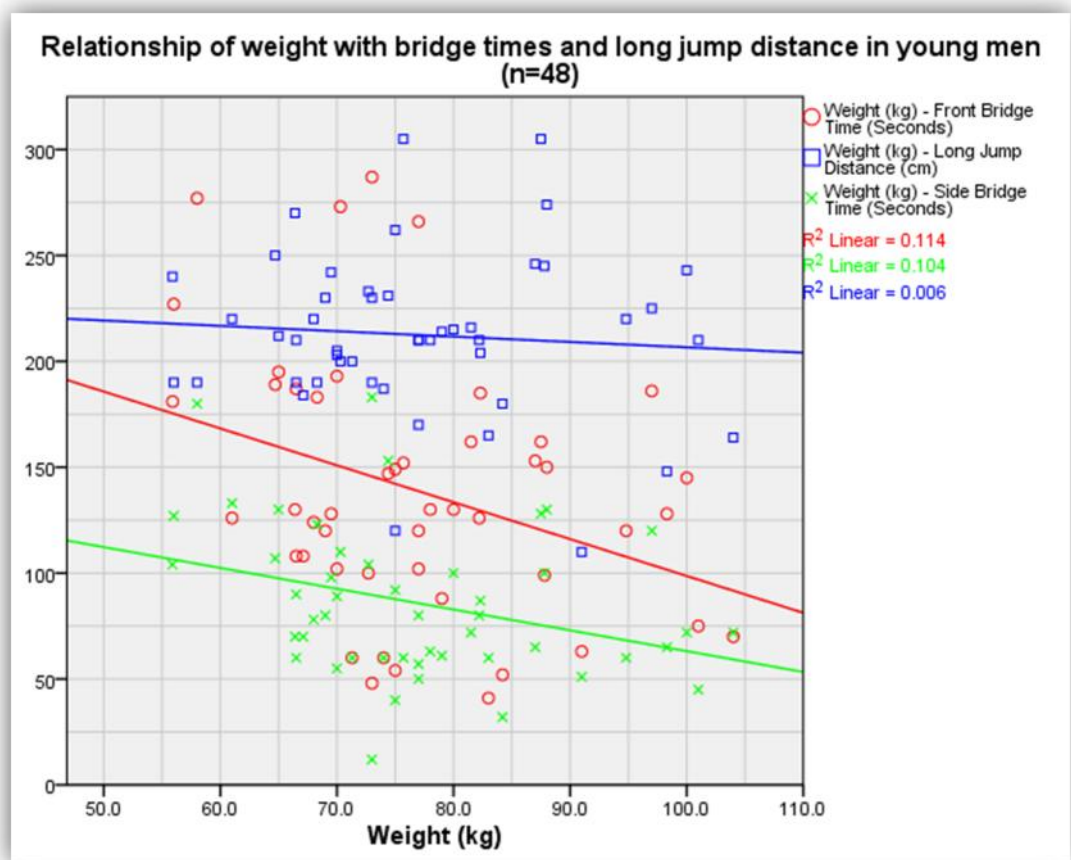


Figure 13 Scatter plot showing correlation of weight with front and side bridge times ($p < 0.05$), and long jump distance ($p > 0.05$) in young men.

BMI, bridge times and long jump distance

There was a statistically significant moderate negative correlation between BMI and front bridge times ($r = -0.328$, $p = 0.011$) and between BMI and side bridge times ($r = -0.396$, $p = 0.03$). BMI had a small non-significant negative correlation with long jump distance ($r = -0.095$, $p = 0.054$) (Table 2). Figure 14 shows the relationship of BMI with bridge times and long jump distance in young men. Increased BMI reduced bridge times but had an insignificant impact on long jump distance.

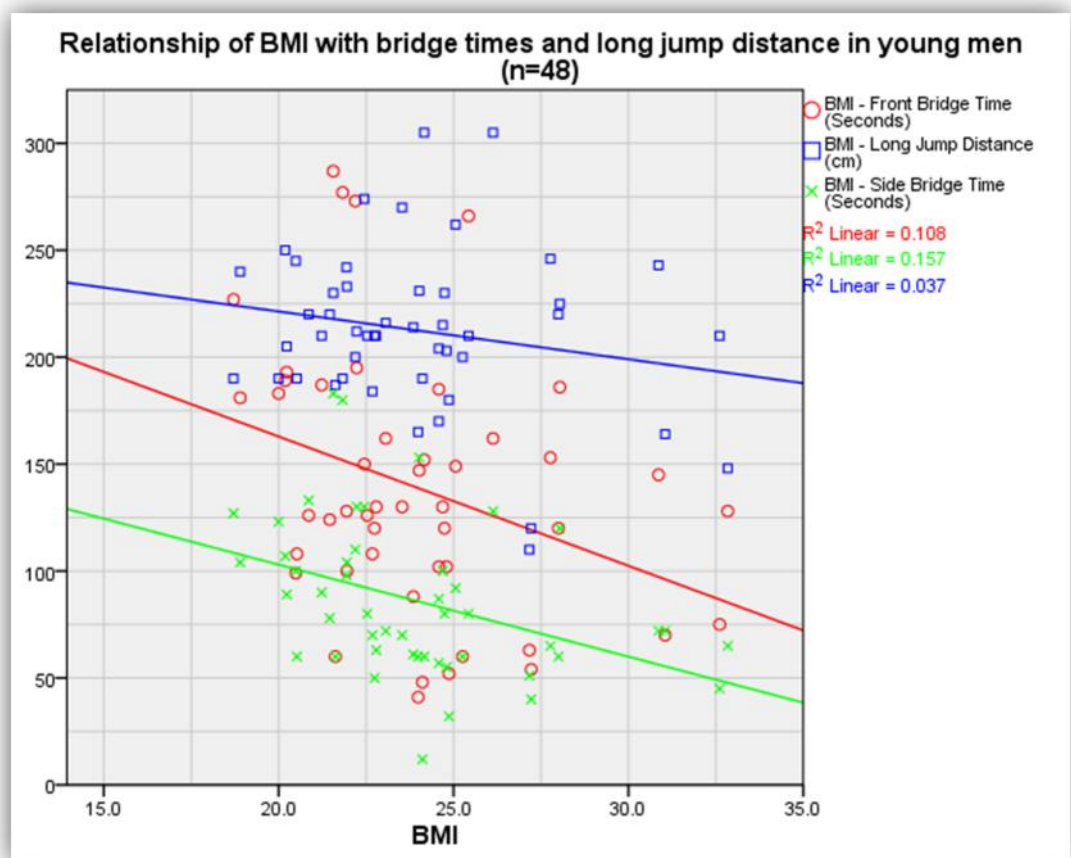


Figure 14 Scatter plot showing correlation of BMI with front bridge times ($p < 0.05$) and side bridge time ($p < 0.01$), and long jump distance ($p > 0.05$) in young men

4.3.2 Results for women

Table 3 shows Pearson correlation analyses of weight, BMI, exercise duration, sum of skinfolds, and waist circumference with front bridge times, side bridge times and long jump distance for young women.

*Table 3 Correlation analysis of body composition and exercise duration with core and lower limb muscle function in young women (n = 50). * Correlation is significant at the 0.05 level (1-tailed). ** Correlation is significant at the 0.01 level (1-tailed).*

	Front Bridge Time	Side Bridge Time	Long Jump Distance
Weight	-.298*	-.076	-.070
BMI	-.170	-.063	-.167
Sum of Skinfolds	-.363**	-.170	-.288*
Waist Circumference	-.328**	-.119	-.189
Exercise Duration	.212	.194	.219

Sum of Skinfolds, bridge times and long jump distance

Sum of skinfolds had a statistically significant moderate negative correlation with front bridge times ($r = -0.363$, $p = 0.005$) but had weak negative correlation with side bridge times which was not statistically significant ($r = -0.170$, $p = 0.119$). Sum of skinfolds had a small but significant negative correlation with long jump distance ($r = -0.288$, $p = 0.021$) (Table 3). Figure 15 shows the relationship of sum of skinfolds with bridge times and long jump distance in young women. Larger sum of skinfolds measurement adversely affected front bridge times and long jump distance but its effect on side bridge times was not significant.

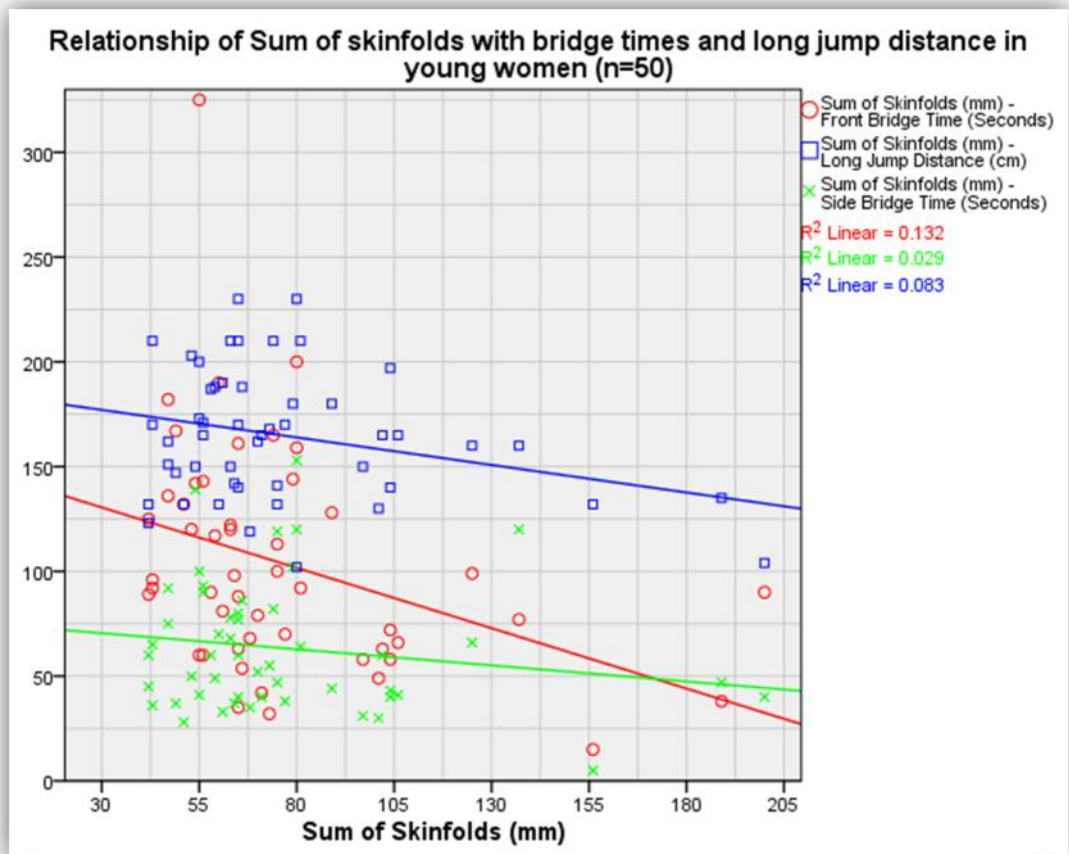


Figure 15 Scatter plot showing correlation of Sum of Skinfolds with front bridge times ($p < 0.01$) and side bridge times ($p > 0.05$), and long jump distance ($p < 0.05$) in young women.

Waist circumference, bridge times and long jump distance

Waist circumference had a statistically significant moderate negative correlation with front bridge times ($r = -0.328$, $p = 0.01$). However, it had small non-significant negative correlation with side bridge times ($r = -0.119$, $p = 0.205$), and long jump distance ($r = -0.189$, $p = 0.095$) (Table 3). Figure 16 shows the relationship of waist circumference with bridge times and long jump distance in young women. Larger waist circumference adversely affected front bridge times but its effects on side bridge times and long jump distance is not statistically non-significant.

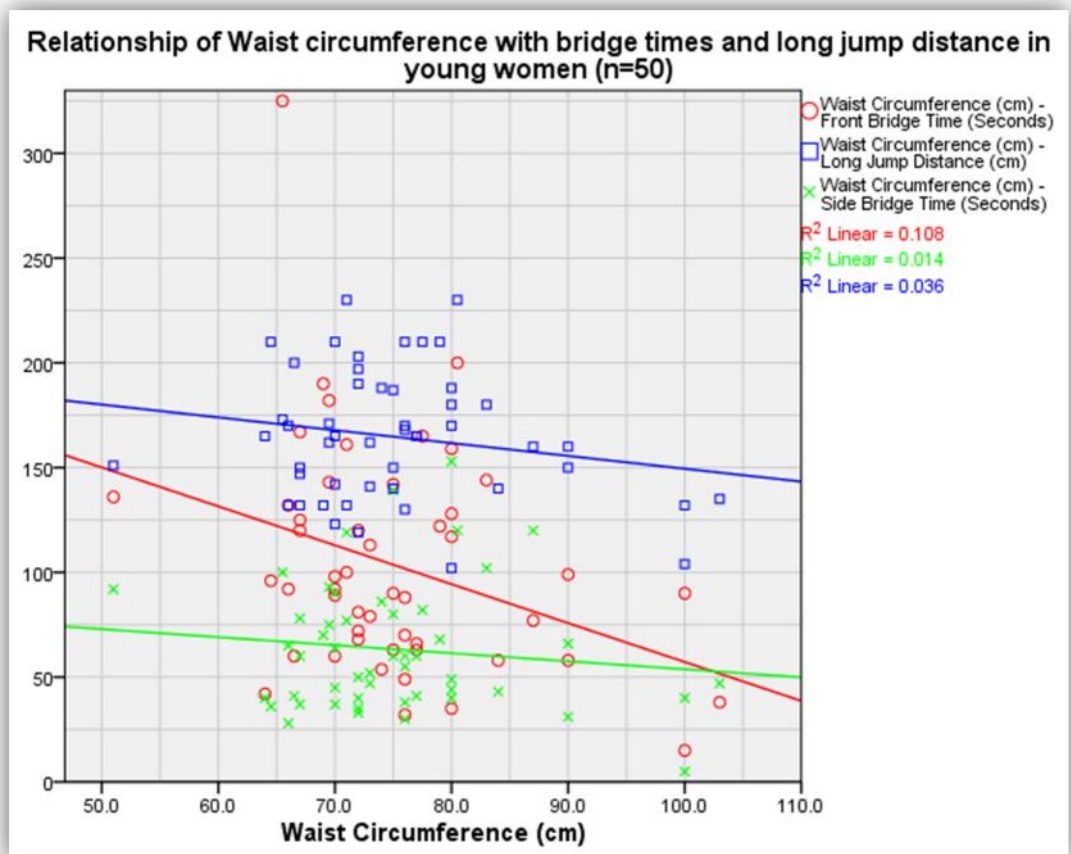


Figure 16 Scatter plot showing correlation of waist circumference with front bridge times ($p < 0.01$) and side bridge times ($p > 0.05$), and long jump distance ($p > 0.05$) in young women

Weight, bridge times and long jump distance

Weight had a moderate but statistically significant negative correlation with front bridge times ($r = -0.298$, $p = 0.018$). There was a very weak non-significant correlation between weight and side bridge times ($r = -0.076$, $p = 0.3$) and long jump distance ($r = -0.07$, $p = 0.314$) (Table 3). Figure 17 shows the relationship of weight with bridge times and long jump distance in young women. Increased weight reduced front bridge times but had an insignificant impact on side bridge times and long jump distance.

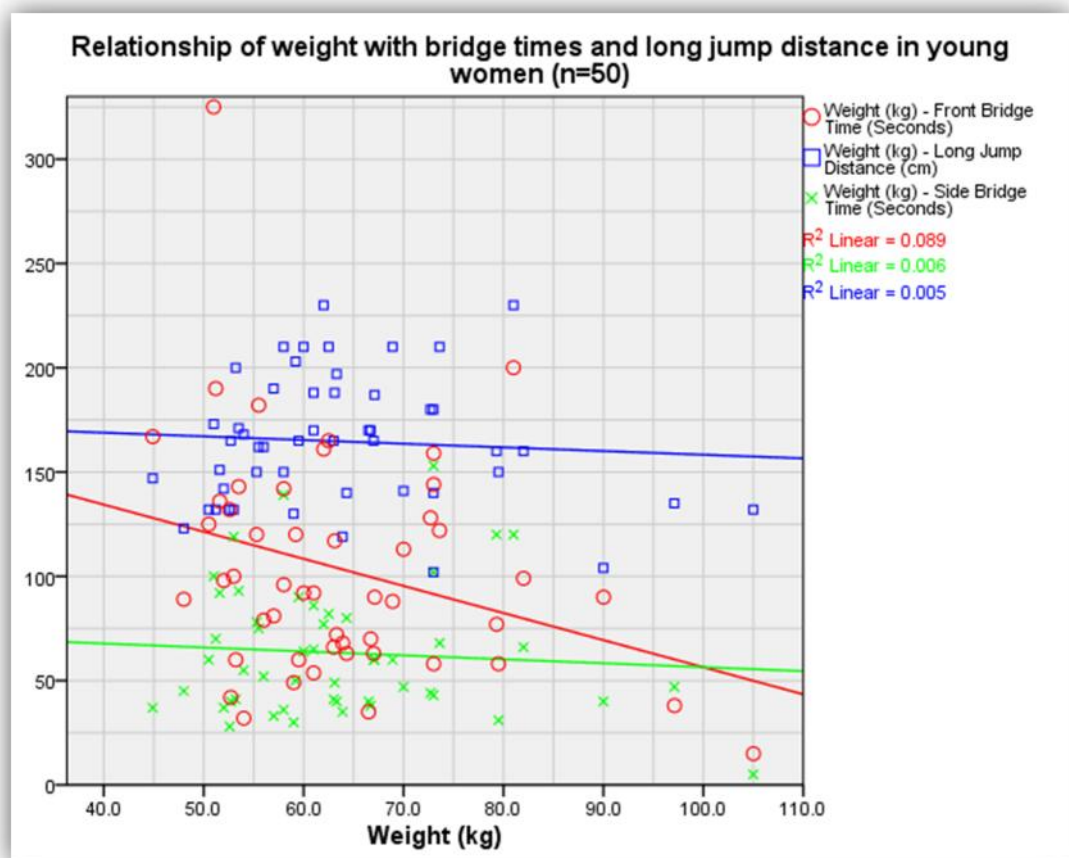


Figure 17 Scatter plot showing correlation of weight with front bridge times ($p < 0.05$) and side bridge times ($p > 0.05$), and long jump distance ($p > 0.05$) in young women.

BMI, bridge times and long jump distance

There was a weak negative correlation between BMI and front bridge times ($r = -0.170$, $p = 0.119$), side bridge times ($r = -0.063$, $p = 0.333$) and long jump distance ($r = -0.167$, $p = 0.123$) (Table 3), these relationships did not reach statistical significance. Figure 18 shows the relationship of BMI with bridge times and long jump distance in young women. Increased BMI had no significant impact on bridge times and long jump distance.

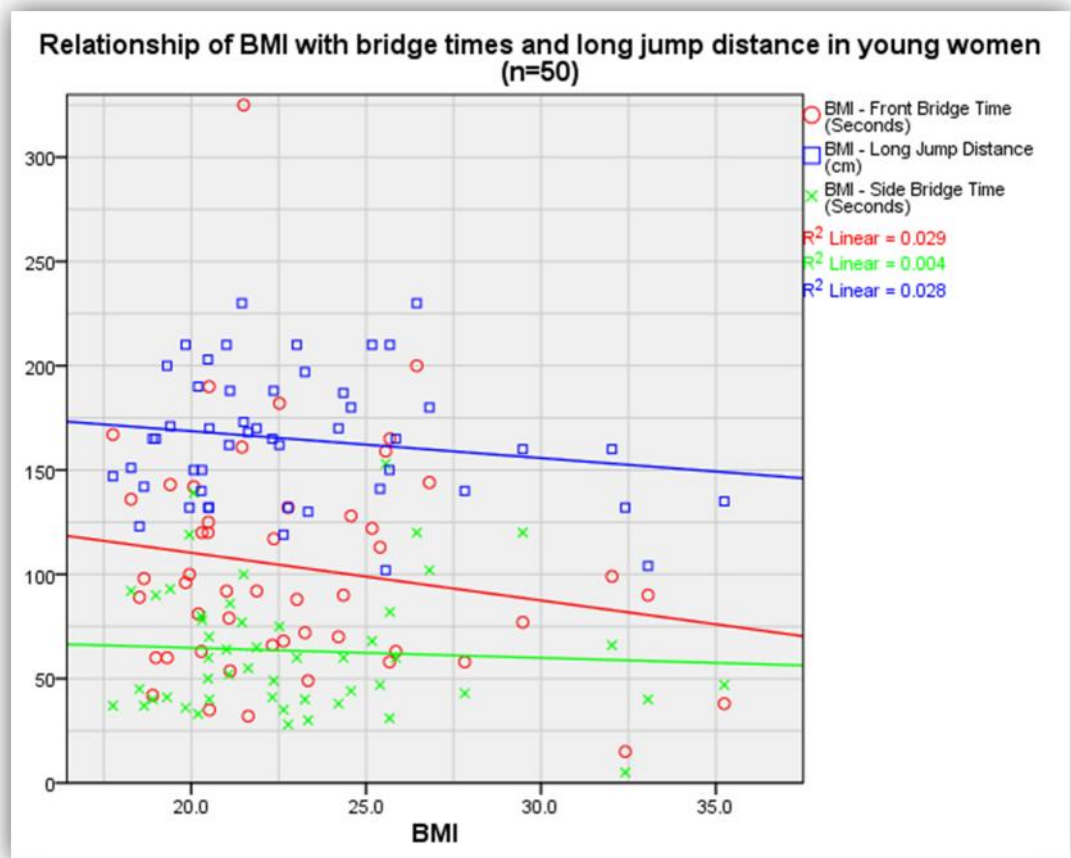


Figure 18 Scatter plot showing correlation of BMI with front bridge times ($p > 0.05$) and side bridge times ($p > 0.05$), and long jump distance ($p > 0.05$) in young women

4.4 Exercise duration, bridge times and long jump distance

4.4.1 Results for men

Exercise duration had a weak but statistically significant positive correlation with front bridge times ($r = 0.274$, $p = 0.03$) (Table 2) and a moderate positive correlation with side bridge times ($r = 0.307$, $p = 0.017$) (Table 2). However, long jump distance was not affected by exercise duration ($r = 0.054$, $p = 0.358$) (Table 2). Figure 19 shows the relationship of exercise duration with bridge times and long jump distance in young men. Longer exercise duration was associated with an improvement bridge times but had an insignificant impact on long jump distance.

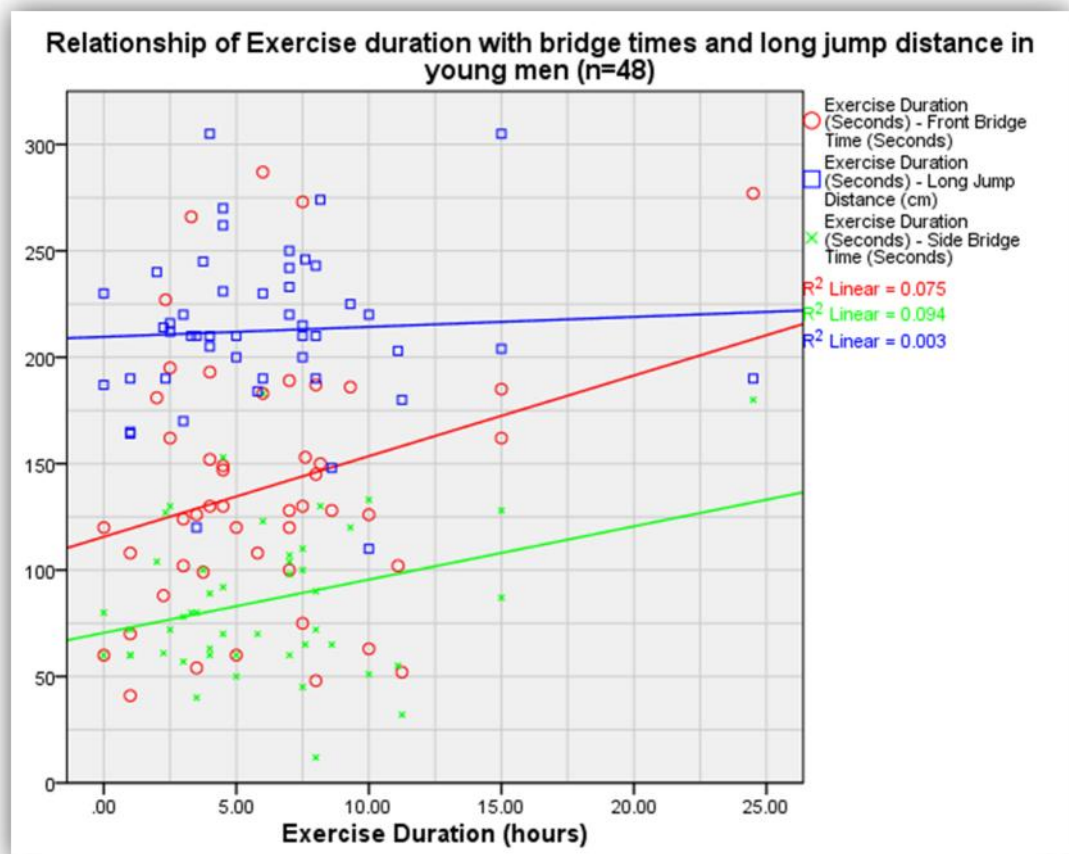


Figure 19 Scatter plot showing correlation of exercise duration with front bridge times ($p < 0.05$) and side bridge times ($p < 0.05$), and long jump distance ($p > 0.05$) in young men

4.4.2 Results for women

Exercise duration had a weak positive correlation with front bridge times ($r = 0.212$, $p = 0.07$), side bridge times ($r = 0.194$, $p = 0.088$) and long jump distance ($r = 0.219$, $p = 0.063$) (Table 3). These correlations were not statistically significant. Figure 20 shows the relationship of exercise duration with bridge times and long jump distance in young women. The improvement observed in bridge times and long jump distance was not statistically significant.

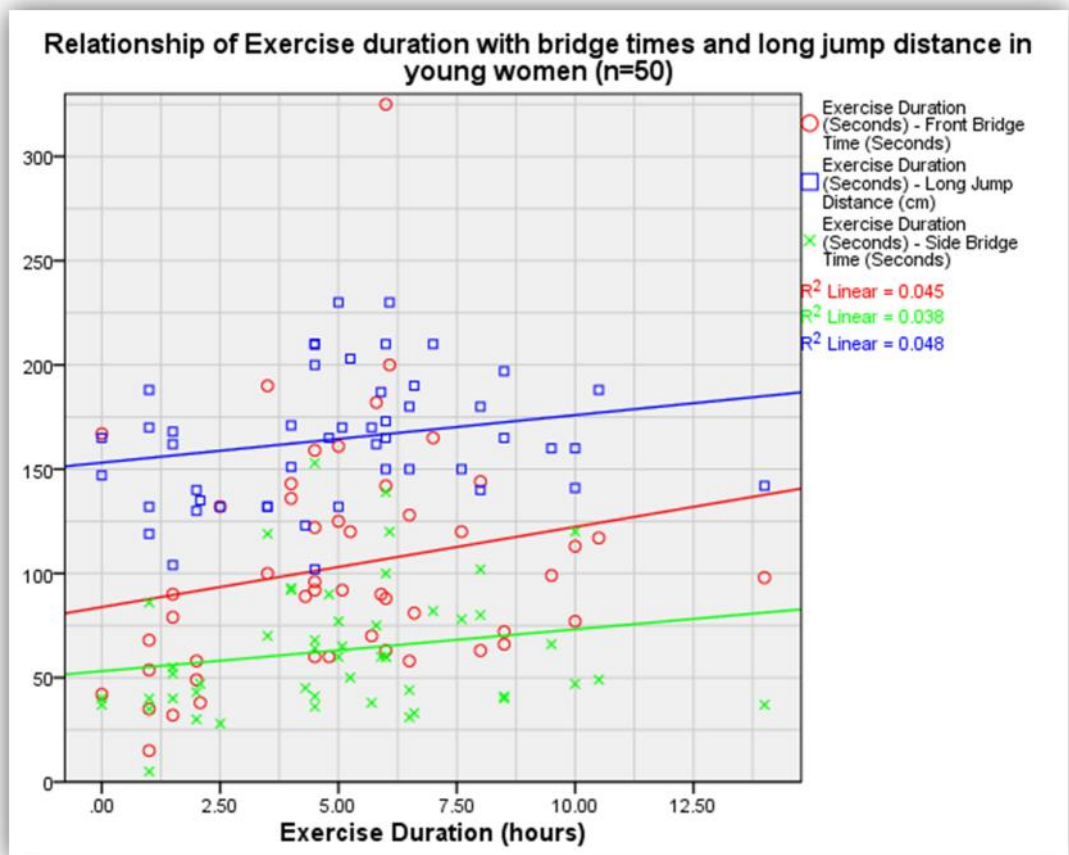


Figure 20 Scatter plot showing correlation of Exercise duration with front bridge times ($p > 0.05$) and side bridge times ($p > 0.05$), and long jump distance ($p > 0.05$) in young women.

4.5 Bridge times and long jump distance

4.5.1 Results for men

Standing long jump had moderate positive correlation with front bridge times ($r = 0.315$, $p = 0.015$) and side bridge times ($r = 0.342$, $p = 0.009$) (Table 2). Figure 21 illustrates these relationships. A high front bridge time was accompanied with a high side bridge time and greater long jump distance.



Figure 21 Relationship between long jump distance and front bridge times ($p < 0.05$) and side bridge times ($p < 0.01$) in young men.

4.5.3 Results for women

Standing long jump had a small non-significant positive correlation with front bridge times ($r = 0.155$, $p = 0.141$) and very weak positive correlation with side bridge times ($r = 0.058$, $p = 0.345$) which was not statistically significant (Table 3). Figure 22 illustrates these relationships. A high front bridge time was accompanied with a high side bridge time but there was no relationship present between bridge times and standing long jump.



Figure 22 Relationship between front and side bridge in young women ($p < 0.01$). Right: Relationship between long jump distance and bridge times in young women ($p > 0.05$).

4.6 Age related difference in core muscle function

One-way ANOVA analysis was performed to investigate age related differences in core and lower limb muscle function in young men and women. Each gender group was then subdivided into four age groups; 18 to 20, 21 to 23, 24 to 26 and 27 to 30 years.

4.6.1 Results for men

Table 4 shows mean and standard deviation of men’s front bridge, side bridge times and long jump distance for the four age groups.

Table 4 Age related descriptive analysis of core and lower limb muscle function in young men (n = 48).

	18-20 group (n=20)	21-23 group (n=11)	24-26 group (n=7)	27-30 group (n=10)	Total (n=48)
Front Bridge Time (Seconds)	145±62	150±69	129±51	120±60	139±61
Side Bridge Time (Seconds)	94±36	93±46	71±31	71±21	86±36
Long Jump Distance (cm)	216±24	216±37	224±65	195±42	212±39

Note: All data are shown as mean ± SD. No significant difference between age groups

Mean front bridge and side bridge times in men plateaued at the 21 to 23 age group and gradually reduced as age progressed. Reduction was observed in side bridge times.

However, these trends did not achieve statistical significance. No significant differences in these variables between the age groups were observed in young men (Table 4).

Figure 23 shows age related difference in the means for front bridge times, side bridge times and standing long jump distance in young men. Front and side bridge plateaued in the 21 to 23 age group then decreases as age increases. However, this trend was not significant ($p > 0.05$). There were no observable differences in the standing long jump distances.

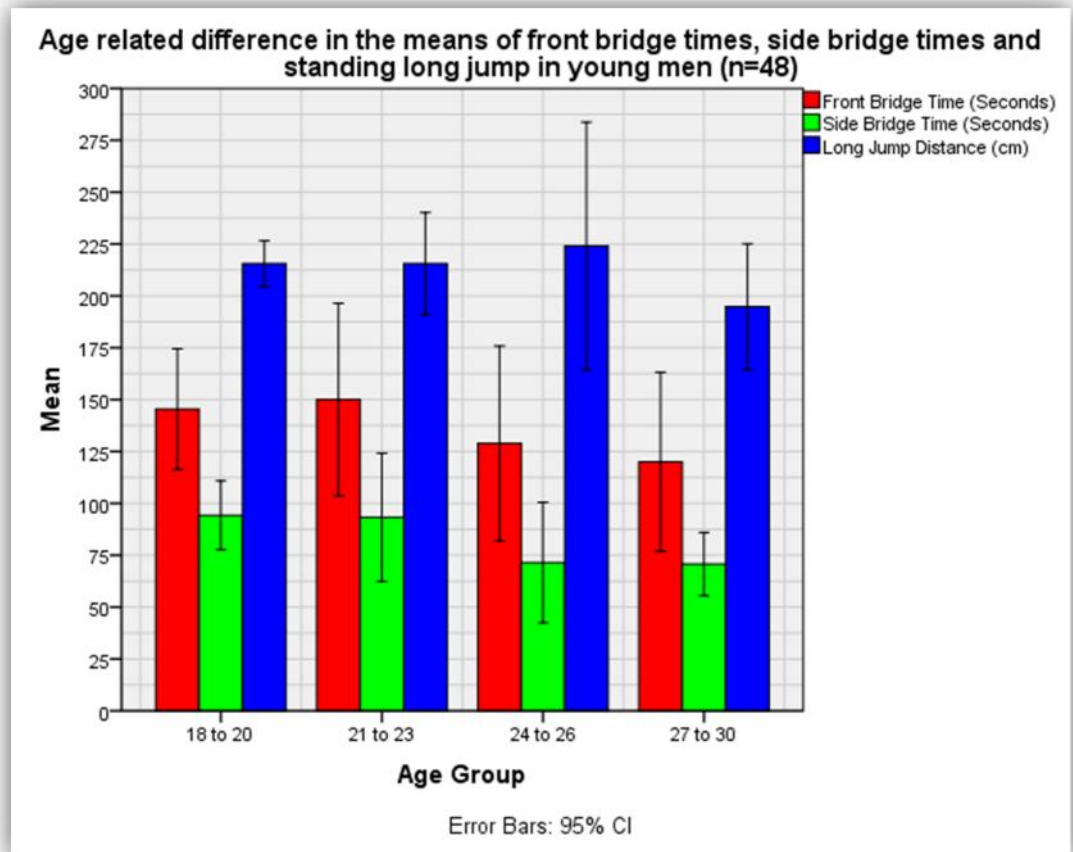


Figure 23 Bar chart shoes the age related difference in core and lower limb muscle function in young men

4.6.3 Results for women

Table 5 shows mean and standard deviation of women’s front bridge, side bridge and long jump distance for the four age groups.

Table 5 Age related descriptive analysis of core and lower limb muscle function in young women (n =50)

	18-20 group (n=21)	21-23 group (n=12)	24-26 group (n=10)	27-30 group (n=7)	Total (n=50)
Front Bridge Time (Seconds)	99±66	103±55	97±25	124±51	103±54
Side Bridge Time (Seconds)	66±35	57±26	63±34	65±25	63±31
Long Jump Distance (cm)	168±31	175±37	153±30	156±20	165±31

Note: All data are shown as mean ± SD. No significant difference between age groups

There is no observable age related differences in the bridge times and standing long jump distance in young women (Table 5).

Core Muscle Function in Young Adults Aged 18 to 30

The graph in figure 24 shows age related difference in the means for front bridge times, side bridge times and standing long jump in young women. There were no observable differences in core muscle and lower limb function in young women of different ages.

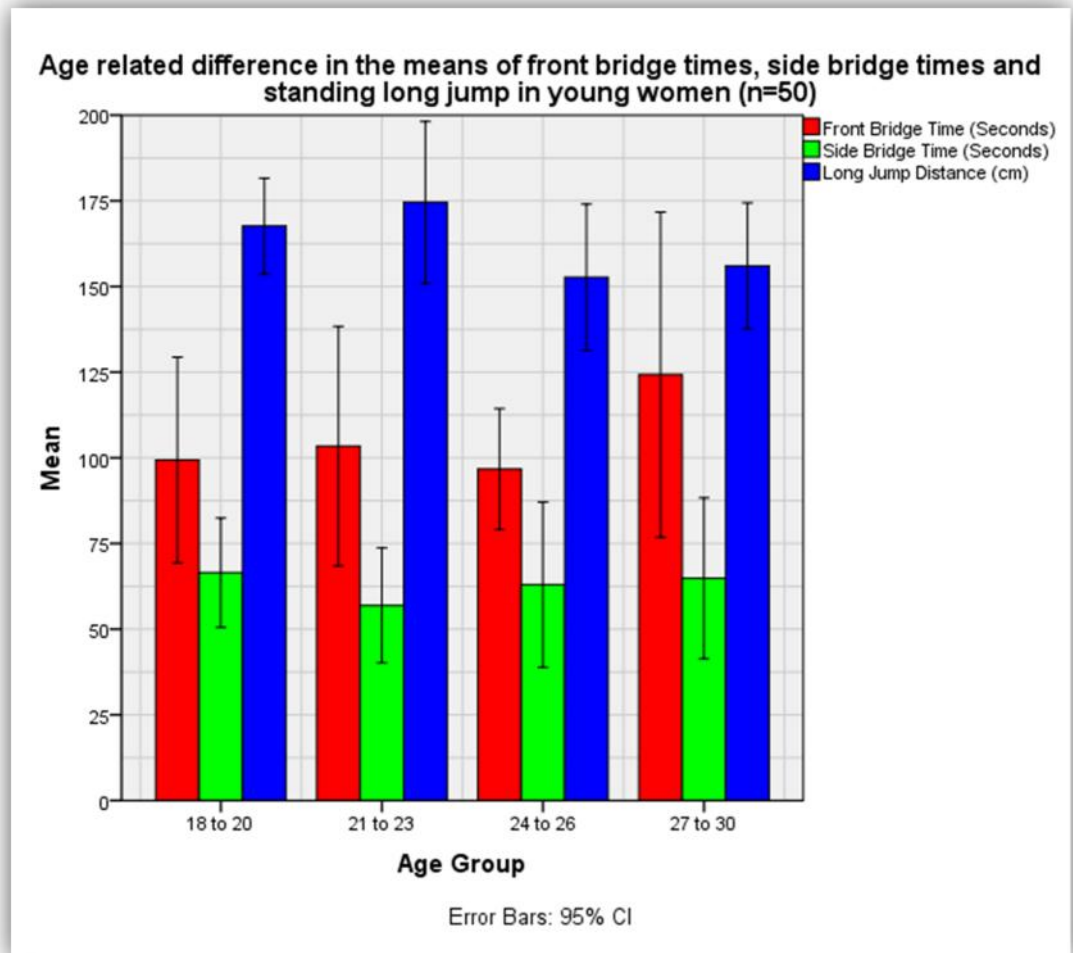


Figure 24 Bar chart shows age related difference in bridge times and long jump distance for young women

Chapter Five: Discussion

5.1 Gender related difference in core muscle function

In humans, male and female physiology differ greatly. So, there was no surprise that the results from this study would be representational of this fact. It was hypothesised that core muscle function between men and women are different. One-way ANOVA showed that core muscle function and lower limb muscle function differed greatly between men and women. Mean bridge times and long jump distance were better in men than that of women (Table 1). Young women had more fat mass and less muscle mass than young men. The results of this project showed that men and women had similar BMI ($p > 0.05$) but women had higher sum of skinfolds than men ($p < 0.05$) (Table 1). This shows that men had a higher lean body mass than women, i.e. men have more skeletal muscle. This could have been one of the factors causing the gender difference in core muscle function and lower limb muscle function.

To date, the present project is the only study that reports gender related differences in core muscle function between young people. However, studies have been done that report on skeletal muscle differences (Ervin et al. 2013, Marras et al. 2001, Häkkinen 1991, Nadler et al. 2000, Nadler et al, 2001, Hicks et al. 2001, Glenmark et al. 2004, Leetun et al. 2015) and fat mass differences (Blaak, E 2001) between men and women that support the existence of gender related differences in core muscle of men and women. In a cross-sectional study, Ervin et al. (2013) studied core muscle strength in children aged 6 to 11 and adolescents aged 12 to 15. They reported that adolescent males aged 12 to 15 performed better in the front bridge exercise than their female counterparts. The adolescent participants in their study were at pubertal age when the male and female sex characteristics develop and differentiate. The found significant

difference in bridge times between male and female adolescents in their study. Their results are similar to the results of my project.

Marras et al. (2001) used MRI to study geometrical differences in skeletal muscles of men and women. They found that men generally had larger trunk and lower limb muscle cross-sectional area than women, which could explain the results achieved in this study. Häkkinen (1991) studied muscle force production in male and female basketball players and found the men performed better in vertical jumping height and squat jump due to greater force generation. This study provides further evidence of gender related core muscle difference young adults.

Nadler et al. (2000) studied the effect of previous lower extremity injury and lower back pain on hip musculature in men and women. Their study found that hip musculature in women respond differently to these injuries when compared to men, suggesting a difference in core muscle function between the two. In another study, Nadler et al. (2001) studied the association between strength imbalance in hip musculature and lower back pain treatment. Their results showed that muscular strength differences in the left and right hip extensors predicted a need for treatment for lower back pain in young women but not in young men. The results of the above studies are indicative of existence of differences in the core muscle function of young men and women.

My study showed that core and lower limb muscle function differed greatly between men and women, supporting the hypothesis that gender related difference exist in core muscle function and lower limb muscle function in young adults. Generally, men performed better in the bridge times and long jump exercises.

5.2 Body Composition and Core Muscle Function

Skeletal muscles support the body and initiate or inhibit movement in accordance to external and internal stimuli. This study explored the effects of body composition parameters on core muscle function. Pearson correlation analyses were used to determine whether an association existed between body composition and core muscle function. This is the first study that explores effects of body composition on core muscle function in young adults.

5.2.1 Sum of Skinfolds and Core Muscle Function

In this project, sum of skinfolds from four sites was used as an indicator of fat mass. It is not as accurate as using methods such as dual X-ray Absorptiometry (DEXA) (Hussain et al. 2014). However, it is a non-invasive, low risk, low cost method to analyse body fat mass in individuals (Martins et al. 2011). Equations was not used to estimate the body fat percentage as this would introduce error in the measurement. Body fat percentage calculation using equation are prone to introducing error in body fat mass measurement (Davidson et al. 2011).

Correlation analysis showed a strong negative relationship between sum of skinfolds and bridge times in men ($p < 0.01$) (Table 2). In women, there was moderate negative correlation between sum of skinfolds and front bridge times ($p < 0.05$) but there was no significant correlation between sum of skinfolds and side bridge times ($p > 0.05$) (Table 3). It was hypothesised that an increase in sum of skinfolds would negatively affect core muscle function. The result of Pearson correlation supports this hypothesis showing a significant decrease in bridge times as sum of skinfolds increased in young men and women.

Though there is a lack of studies that report cross-sectional evidence for the relationship between core muscle function and sum of skinfolds or fat mass, other studies have demonstrated the negative impact of increased fat mass on postural stability (King et al. 2012) and muscle function (Hilton et al. 2008, Bittel et al. 2015). King et al. (2012) studied the relationship of body composition and postural balance in adolescent boys and girls. They found that increased body fat mass negatively affected postural balance. In my study, it was found that core muscle function decreased as body fat mass increased. Core muscles play a vital role in postural stability. Results from King et al. (2012) and my study point towards an interplay between the two factors, meaning that increased fat mass increases the load stress on core muscles affecting their ability to provide postural balance.

Hilton et al. (2008) studied the effects of intramuscular adipose tissue on calf muscle function. They reported that intramuscular adipose tissue was associated with poor muscle function. Their result indirectly supports my findings which showed that increased fat mass in young individuals caused poor core muscle function. In a more recent study, Bittel et al. (2015) investigated the effects of intermuscular and subcutaneous adipose tissue on calf muscle function. They found that intermuscular and subcutaneous adipose tissue had a negative impact on muscle function. Results of this project provides further evidence of the negative impact of fat mass on core muscle function

The results of my study showed that high sum of skinfolds decreased bridge times in young men and women. To the best of my knowledge, this is the first study that investigates the effects of body fat on core muscle function in young individuals. The results showed that increased fat mass may be detrimental to core muscle function.

5.2.2 Waist Circumference and Core Muscle Function

Waist circumference is a good measure of body composition as it is cost effective and non-invasive method. Waist circumference can be used as a simple and accurate test if other methods of measuring body composition are not suitable or available. Large waist circumference have been associated with poor muscle function and increases the risk of sarcopenia (Park et al. 2014), poor quality of life, and lower back and lower extremity pathologies (Lean et al. 1998). Wong et al. (2004) and Ross et al. (2003) reported that large waist circumference is associated with low cardiovascular fitness.

In this project, it was hypothesised that waist circumference negatively affects core muscle function. Correlation analysis showed that large waist circumference negatively affected bridge times in men ($p < 0.01$) (Table 2). In women, large waist circumference negatively correlated with front bridge times ($p < 0.01$) (Table 3). Correlation analysis revealed significant negative correlation between waist circumference and bridge times for men, and waist circumference and front bridge times for women supporting the hypothesis mentioned above.

Several studies (Lean et al. 1998, Park et al. 2014, Wong et al. 2004, Ross et al. 2003) have reported the negative impacts of increased waist circumference on lower back, quality of life, cardiovascular fitness and physical function. Lean et al. (1998) undertook a large scale cross-sectional study on the impacts of large waist circumference on quality of life and physical function individuals aged 20 to 59. They reported that a large waist circumference was associated with wide range of health issues including high cholesterol, hypertension, diabetes, respiratory problems, impaired physical function and lower back pain. In another large scale study, Park et al. (2014) reported that large waist circumference or abdominal obesity increased the risk of sarcopenia. Wong et al. (2004) and Ross et al. (2003) both reported that abdominal obesity reduces

cardiovascular fitness which in turn can increase other health risks. The above studies report on the detrimental effects of abdominal obesity which indirectly supports my findings.

There is a lack of studies that report on how waist circumference influences core muscle function in young adults. My study attempted to provide cross-sectional evidence on the relationship of these factors. This project found that increased waist circumference has a negative impact on core muscle function in young adults. This project contributes new information to understanding the negative impact of central or abdominal obesity on people's health by showing the negative impact of large waist circumference on core muscle function.

5.2.3 Weight and Core muscle Function

The correlation analysis showed that low front and side bridge time was linked to an increased body weight in men (Table 2, Figure 13). High body weight negatively affected front bridge times in women. However, this was not the case for side bridge times which were not affected by weight in women as side bridge times were regardless of the participants' body weight (Table 2, Figure 17). The result for women is well contrasted in figure 17, showing the scatter pattern of front and side bridge times. An outlier exists in the front bridge times (Figure 17), so the correlation analysis were carried out including and excluding this outlier to observe its effect on the results, the outcomes were the same in both instances.

Results for men and women support the hypothesis that core muscle function is influenced by body weight in young adults aged 18 to 30. Body weight has been proven to be a factor in predicting postural stability in a number of studies (Ervin et al. 2014, Maffiuletti et al. 2005, Hue et al. 2007, Teasdale et al. 2006). Ervin et al. (2014) studied the relationship of core, upper and lower body strength with body weight status in

children and adolescents. They reported that increasing weight negatively impacted on front bridge times in children and adolescent boys and girls. Though, their study was performed on a younger cohort, their results support my finding. Hue et al. (2007) studied the relationship between body weight and postural stability. They reported the body weight was a major predictor of postural stability in men aged 24 to 61 years.

Core muscles play an important role in postural stability (Panjabi 1992a, McGill 2010, Colsten 2012a, Warren et al. 2014, Leetun et al. 2004, Wilson et al. 2005, Ferreira et al. 2007) and increased body weight seems to have a negative influence on this function. Maffiuletti et al. (2005) compared postural stability between obese and lean individuals aged between 20 to 40 years. They found that increased body weight was associated with poor postural balance. Teasdale et al. (2006) studied the influence of obesity on postural stability and the effect of weight loss on balance control in obese men. They reported that obesity has a negative impact on postural stability and body weight reduction improves balance control in obese men. The above studies and my results support the hypothesis that increased weight negatively influences core muscle function.

5.2.4 BMI and Core Muscle Function

BMI is a measure used to determine the ideal weight for certain given height (Gallagher et al. 1996). Though, BMI is limited in its ability to differentiate lean mass and fat mass, it is still a good indicator of anorexia and obesity (Perspective studies collaboration 2009, Gallagher et al. 1996). In addition, as per correlation analysis, increased weight, whether it is lean mass or fat mass, increases the demand on muscle function. Hence, the relationship between BMI and core muscle function was explored. It was hypothesised that high BMI is associated with poor core muscle function. Pearson

correlation analysis demonstrated mixed results between young men and women. BMI significantly correlated with bridge times in men but this was not the case in women.

Pearson correlation analysis found a statistically significant ($p < 0.05$), moderate negative correlation between BMI and bridge times in men (Table 2). This observation is illustrated in figure 14. This result supports the hypothesis that an increased BMI affects core muscle function in young men. There was a non-significant negative correlation between BMI and bridge times in women ($p > 0.05$) (Table 3). Lower bridge times and large variations in women's results could have been a factor in the non-significant results between BMI and bridge times in women.

Increased BMI has been implicated in poor postural stability and balance which is mainly controlled by core muscles. Greve et al. (2007) studied the correlation between BMI and postural balance on 40 men aged between 21 and 29. They found that individuals' with higher BMI performed poorly in the postural stability assessment. Maffiuletti et al. (2005) and Teasdale et al. (2006) found similar results for the relationship between BMI and postural balance. Brady et al. (2014) studied the relationship between BMI and muscle quality in older women. They found that an increased BMI reduced muscle quality in older women. In addition, they reported that muscle quality influences physical function regardless of BMI status. Their study suggests that muscle quality in women is independent to BMI scores, supporting results of this study indirectly.

This project was the first study that reported on the effects of BMI on core muscle function in young adults. It was found that increased BMI in young men were linked with poor core muscle function but this was not the case in women. This finding adds to the body of knowledge on the influence of high BMI on physiological function.

5.2.5 Body composition and side bridge times on women

As mentioned above, significant correlation was only found in body composition parameters and side bridge times in men. In women, there was no correlation between body composition variables and side bridge times. This was an unexpected result as it was hypothesised that side bridge times would be affected by body composition parameters. There are a few factors that may have attributed to these results. Women generally had a higher fat mass than men which may have affected their performance in the side bridge exercise.

Tan et al. (2013) reported that the side bridge exercise showed higher EMG activity in the core muscles for men but they did not test this for women. My results showed that mean side bridge times were very low when compared to front bridge times. As it can be seen in figures 17 to 20, young women performed poorly in the side bridge exercise regardless of their body composition. Leetun et al. (2004) reported that females performed very poorly in the side bridge exercise when compared to men. They suggested that this may be due to an inherent weakness in the female core muscles. This may have been a factor contributing to the low side bridge times for young women in my study. The intrinsic weakness in the female core muscle may reduce their ability to stabilise the core which may predispose them lower back and lower extremity injury due to excessive trunk movement. Further research is required to provide further evidence for this finding.

Therefore, it is suspected that even though the side bridge is an excellent exercise for improving core muscle function, it may not be a good indicator of core muscle function in healthy young untrained women due to the inherent weak core muscles in women and the exercise's demanding nature.

5.3 Physical Activity and Core Muscle Function

Physical activity or exercise has been associated with benefiting multiple facets of human physiology. This study hypothesised that increased physical activity is associated with good core muscle function. Pearson correlation analysis was performed to examine the relationship between physical activity and core muscle function. Although longer exercise duration seemed to have had a positive effect on core muscle function, this finding was statistically significant only in young men

The analysis revealed that a weak positive correlation existed between exercise duration and front bridge times but a moderate positive correlation existed between exercise duration and side bridge times in young men (Table 2, Figure 19). These findings were statistically significant ($p < 0.05$) proving the hypothesis that physical activity level improves core muscle function in young men. For women, the hypothesis that exercise duration improves core muscle function does not hold true (Table 3). However, when analysing figure 20, a trend can be observed showing improvement in core muscle function of women whose exercise duration was higher.

Although, there is a lack of cross-sectional studies reporting effects of exercise duration on core muscle function in young adults, there are longitudinal studies (Yu and Lee 2012, Ni et al. 2014, Calatayud et al. 2015, Tarnanen et al. 2008, Lomond et al. 2014) that report on the effects of exercise on core muscle function. Yu and Lee reported that Pilates training improved core muscle function and lower extremity muscle function in healthy individuals. Ni et al. (2014) studied the effects of Yoga training on core muscle activity via EMG. They reported that yoga training improves core muscle function and can be used as rehabilitation tool to treat lower back pain. Calatayud et al. (2015) studied the effects of balance exercises on core muscle activity in healthy young adults. They found that an increased EMG activity in core muscles with standing bilateral,

unilateral and resistance exercise. Their study shows that simple balance exercises can improve core muscle function. Tarnanen et al. (2008) reported that upper body bilateral and unilateral exercises have shown to activated core muscles to a certain extent. They reported that most effective upper body exercise was the shoulder extension exercise as it showed the highest core muscle activity when compared with other upper body exercises. Lomond et al. (2014) compared trunk stabilisation exercise with general strength and conditioning exercises in their ability to treat lower back pain and improve core muscle coordination. They reported that both form of exercise were similar in their efficacy. Their finding suggest that exercise in general benefits core muscle function.

Due to the large variation in the type of exercise performed by the participants in this study, it was not possible to compare the effects of different exercises in this project. However, it was found that generally, exercise duration significantly improved core muscle function in men only. A possible factor that may have contributed to the non-significant results in women is the large variance in bridge times in young women. Figure 20 shows a large scatter in the bridge times but a trend can be seen showing a general decrease in bridge times as weekly exercise duration declines. In addition, the subjective nature of the questionnaire was not suitable to record exercise intensity. Further research is needed to study the relationship of exercise type and exercise intensity on core muscle function.

This is the first study that reports cross sectional data on the effects of exercise on core muscle function in young adults adding to the collective knowledge of effects of exercise on core muscle function.

5.4 Core muscle function and lower limb muscle function

There are a number studies that have suggested that poor core muscle function can be one of the factors that lead to lower extremity pain or injury (Colsten 2012, Yu and Lee

2012). In this project, the relationship between core muscle function and lower limb muscle function in young adults was investigated. It was hypothesised that poor core muscle function is associated with poor lower limb muscle function. There was a significant positive correlation between core muscle function and lower limb muscle function in men but this was not the case for women. Men's results support the hypothesis that good core muscle function is associated with lower limb muscle function but this hypothesis is not supported by the women's results.

Several studies have reported on the lower limb injury preventative role of core muscles. Lee et al. (1995) investigated trunk muscle and lower extremity muscle strength in men with lower back pain and healthy control group. They found that trunk and lower extremity muscle strength positively correlated in both groups but muscle strength was reduced in those with lower back pain. Shinkle et al. (2012) studied the role of core muscles in athletic performance in collegiate football players. They reported that good core muscle function enhances the force generation and force transfer abilities of the athlete. The above studies demonstrate an interplay with core muscle function and lower limb muscle function in men.

In young women, bridge times did not correlate with long jump distances. Results of this project and other studies on core muscle function reveal that women generally have weak core muscles (McGill et al. 1999, Leetun et al. 2004). McGill et al. (1999) studied core muscle endurance profiles for men and women. They reported that women had a significantly lower core muscle endurance profile than that of men. Leetun et al. (2004) studied the difference in core stability measures between men and women. They found that women had significantly lower side bridge endurance when compared to men. They suggested an inherent weakness in female core muscle function which seems to have been one of the reasons behind poor front and side bridge times in women. Both studies

report that women naturally possess weaker core muscles than men. This may have been why bridge times were low for the women who had exceptional long jump distances. This in turn could have contributed to the non-significance results for core muscle function and lower limb muscle function in young women.

5.5 Age related difference in core muscle function

Age influences many factors of human physiology and muscle function is no exception to this. There has been many studies (Callahan et al. 2014, Abe et al. 2014, Quirk & Hubley-Kozey 2014, Kienbacher 2015) done on core muscle function and age. However, most of these studies are comparative studies which investigate differences between the young adults and older adults. There is a lack of studies that focus on how age influences core muscle function in young adults. This project attempted to fill this knowledge gap and provide evidence of the effects of age on core muscle function in young adults aged 18 to 30.

In young men, a non-significant trend was observed showing that mean bridge times plateaued at the 21 to 23 age group and decreased as age progressed (Figure 23). One-way ANOVA revealed that there are no statistically significant differences in the mean bridge times in the four age groups in men and women (Table 4 & 5). There were no trends associated with age related difference in core muscle function of young women (Figure 24).

The number of participants in each age group for men (Table 4) and women (Table 5) differed greatly and group sizes were small. This may have affected the statistical power of the findings. In addition, there was large variance present in bridge times for men and women (Table 4 & 5 respectively) in each age group. This may have led to the non-significant nature of the trend observed men's results and may have affected the women's results.

To date, there have not been any studies reporting on the age related difference in core muscle function of young adults. However, there are studies that have compared core muscle function of young adults and older adults that report the effects of age on core muscle function. Abe et al. (2013) investigated age related muscle loss in the trunk and lower extremities of the body in men and women. They found that age was inversely related to trunk muscle mass in men and women. The results of their study support the existence of age related changes in core muscle function. The age bracket in their study is great. However, they reported a significantly greater muscle mass in the age group of 20-29 when compared to the age group of 30-39. Quirk and Hubley-Kozey (2014) studied the changes in the neuromuscular recruitment pattern of core muscles in healthy young (mean age = 29.7) and older adults (mean age = 67.8). They found that trunk muscle recruitment patterns in older adults were different to that of their younger counterparts during a functional lifting task. Their study demonstrated the neuromuscular differences in the core muscle function of young and older adults. Similarly, Kienbacher et al. (2015) found neuromuscular differences between young and older adults in their investigation of age related differences in muscle activation pattern during trunk flexion and extension. They found that lumbar extensor muscle activity in older adults is reduced when compared to younger adults and suggested that this could be due increased muscle activity in the psoas major and quadratus lumborum reducing load on the back extensor muscles. Their study suggests that age related difference exists in core muscle function between young and old adults.

As mentioned above, there is a lack of studies that investigate age related differences in core muscle function of young adults. The studies mentioned above compare core muscle of young adults and older adults but do not highlight differences within the young cohort. However, they support the notion that age influences core muscle function. It is suspected that core muscle function in men plateaus at the age bracket of

22 to 23 and gradually decreases but no relationship exists for age related differences in core muscle function in women. However, further studies are needed with a larger sample size to investigate the effects of age on core muscle function.

5.6 Limitation and Future Direction

There were a number of limitations associated with this study. Reporting on the relationship between exercise intensity and core muscle function would have increased the understanding of the effects of exercise on core muscle function. However, due to the subjective nature of the answers in the questionnaire, it was not possible to gain an accurate measure of exercise intensity. For this reason, the only viable way to report physical activity was to use exercise duration only. Future studies are needed to study the relationship between exercise intensity and core muscle function. These studies must be longitudinal studies that implement core muscle training and general muscle training at different intensities in order to study the relationship between exercise intensity and core muscle function.

Hilton et al. (2008) and Bittel et al. (2015) reported that intermuscular adipose tissue infiltrating calf muscle is associated with impaired muscle function. Effects of abdominal intermuscular adipose tissue were beyond the scope of this project and there is a lack of studies that investigate it. Understanding the effects of abdominal intermuscular adipose tissue on core muscle function may prove important in improving core muscle function and needs to be researched. Future research must investigate fat infiltration in core muscles and its effects on core muscle function, lower back and lower extremity pathologies.

Being a cross-sectional study, exercise type could not have been controlled as the variety of physical activities reported by the participants was very high. For this reason, effects of exercise type on core muscle function could not be investigated. It is widely

understood that different types of exercises and sports have varying effects on the body and previous studies (Yu and Lee 2012, Ni et al. 2014, Calatayud et al. 2015, Tarnanen et al. 2008, Lomond et al. 2014) have shown that different physical activities affect core muscle function differently. Future studies need to focus on the effects of specific sports and exercise modalities on core muscle function in young adults. Understanding how a certain sport influences core muscle function gives clinicians, physicians and coaches the ability to tailor specific training programs that will benefit their clients and patients.

Chapter Six: Conclusions

This project aimed to understand the nature of core muscle function in young adults aged 18 to 30. Firstly, this project revealed that core muscle function and lower limb muscle function in men differed greatly to that of women. It was found that men performed better in the front bridge, side bridge and standing long jump (figure 10). Therefore, the hypothesis that gender related differences existed in core and lower limb muscle function of young adult was supported.

Secondly, it was found that body composition influenced core muscle function in young adults. It was found that high sum of skinfolds, waist circumference and body weight were associated with poor core muscle function in young men and women. However, high BMI negatively influenced core muscle function in young men only. These results support the hypothesis that poor body composition parameters negatively impact core muscle function.

Thirdly, the project revealed that increased exercise duration was associated with good core muscle function in young men only. Exercise duration did not influence core muscle function in young women. Therefore, the hypothesis that increased physical activity level improves core muscle function was only supported for young men but not young women. However, as a non-significant trend was observed in women's results.

Finally, age did not affect core muscle function in young adults significantly. However, a non-significant trend was observed in men's results showing that bridge times plateaued between the ages of 21 to 23 then decreased. No such trend was observed in the women's results. The hypothesis that age influences core muscle function in young adults was not supported by the results of this study. This may have been due to the small sample size in each age group.

Core Muscle Function in Young Adults Aged 18 to 30

This project provides previously unknown knowledge about the variables that affect core muscle function in young adults. This information can be used to assess core muscle function in young adults and assist them in maintaining good core muscle function in order to reduce the occurrence of lower back and lower extremity pathologies and injury.

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Appendices

Appendix 1: Information sheet

		University of Southern Queensland	
Participant Information for USQ Research Project Questionnaire			
Project Details			
Title of Project:	Core muscle function in young adults aged 18 to 30		
Human Research Ethics Approval Number:	H15REA102		
Research Team Contact Details			
Principal Investigator Details		Other Investigator Details	
Dr Jianxiong Wang Email: wangj@usq.edu.au Telephone: 07-4631 2363 Mobile: 0458929279		Mr Hazheer Rasif Email: w0010157@uemail.usq.edu.au Telephone: 07 4634 8338 Mobile: 0458588488	
Description			
<p>This project is being undertaken as part of the Health Study in local young adults. The core muscle function refers to the collaborated skeletal muscle strength and endurance around the abdominopelvic region. This function is important to maintain body stability, prevent lower back pain, and avoid sports injuries during exercise.</p> <p>The purpose of the project is to understand how does core muscle function change in young adults and whether body composition and exercise training state affect core muscle strength and function? The research team requests your assistance in order to make some simple body composition measurements, complete a short questionnaire, and do a set of physical tests.</p>			
Participation			
<p>Your participation will involve some simple body composition measurements, a completion of a questionnaire and a set of physical tests that will take approximately 30 to 40 minutes of your time.</p> <p>Measurements will include height, weight, body mass index, body fat percentage - skinfold measurement, waist circumference, length of time holding a bridge, length of time holding a side bridge and distance of long jump.</p> <p>The questionnaire will consist of questions relating to your lifestyle, type of work you do, physical activity details and medical conditions that you may have that will affect your participation in the project. A copy of the questionnaire is provided for your reference.</p> <p>Your participation in this project is entirely voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. Please note, that if you wish to withdraw from the project after you have submitted your responses, the research team will remove your data from the project up until data has been analysed. If you do wish to withdraw from this project, please contact the research team (contact details at the top of this form). Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.</p>			
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Expected Benefits

The core muscle function assessment will give you an indication of how well your core muscles function and cope with stress during physical activity. In addition, this project will provide experimental evidence regarding the development pattern of core muscle function in young adults between the ages of 18 to 30. This will increase our knowledge of core muscle function and help in designing exercise programs and interventions to reduce lower back pain and increase core muscle capacity to cope better with stresses of physical activity.

Risks

There are no anticipated risks beyond normal day-to-day living associated with your participation in this project. However, existing medical conditions may pose some risk, this is the reason why the questionnaire includes some medical history queries. This will help in determining whether it would be safe for you to take part in the project. In addition, it helps us provide you with better support if needed during the core muscle function assessment. The assessment included two fairly easy to perform exercises, the exercises will take about 5 to 10 minutes to perform and you will be supervised throughout the activity. In addition to the core muscle function assessment, you will be asked to perform a simple long jump. This will provide a baseline for skeletal muscle function assessment.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law.

The data collected will be treated as anonymous. Your name has only been asked in the questionnaire so that the researchers may identify and omit the information you provided, in case you wanted to withdraw from the project at a later date.

Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy.

Consent to Participate

The return of the consent form and completed questionnaire is accepted as an indication of your consent to participate in this project.

Questions or Further Information about the Project


Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project. If you wish to obtain a copy of the research project summary, please contact Dr Jianxiong Wang, email: wangj@usq.edu.au. Please note that summary results may not be available for some time as data collection will be undertaken over the next three year period.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au. The Ethics Coordinator is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this sheet for your information.

Appendix 2: Consent form



University of Southern Queensland

**Consent Form for USQ Research Project
Questionnaire**

Project Details

Title of Project: "Core Muscle function in young Adults aged 18 to 30"
Human Research Ethics Approval Number: H15REA102

<p>Principal Investigator Details</p> <p>Dr. Jianxiong Wang Email: wangj@usq.edu.au Telephone: 07-4631 2363 Mobile: 0458929279</p>	<p>Other Investigator/Supervisor Details</p> <p>Hazheer Rasif Email: w0010157@umail.usq.edu.au Telephone: 07 4634 8338 Mobile: 0458588488</p>
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Statement of Consent

By signing below, you are indicating that you:

- Have been informed and explained of the nature and purpose of the research project. I understand and agree to take part.
- Understand the purpose of the research project and my involvement in it.
- Understand that my participation in this research project is voluntary, that I may withdraw at any stage, and that this will not affect my status now or in the future.
- Understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
- Have read and understood the information document regarding this project.
- Have had any questions answered to your satisfaction.
- Understand that if you have any additional questions you can contact the research team.
- Understand that you are free to withdraw at any time, without comment or penalty.
- Understand that you can contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au if you do have any concern or complaint about the ethical conduct of this project.
- Are over 18 years of age.
- Agree to participate in the project.

Participant Name

Participant Signature

Date

Please return this sheet to a Research Team member prior to undertaking the questionnaire.

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Appendix 3: Participant Questionnaire

Participant Questionnaire

"Core muscle function in young adults aged 18 to 30"

Participant Personal Details

Name: _____ Gender: _____ Date of Birth: _____

Lifestyle

How often do you normally drink alcohol?

Never Rare (< once/week) Regular (> once/week) Heavy (> twice/day)

Do you smoke?

Never Rare (< once/week) Regular (> once/week) Heavy (> twice/day)

Employment

Occupation: _____ Hours per week/day: _____

Physical Activity Details

Please list the main types physical activities, exercise or sport training you take part in, detailing how often, type of activity and the duration of each session:

Medical History

Tick all which apply and provide details. These questions are asked so that we have an understanding of underlying medical condition so that we may provide assistance during core muscle function assessment. This information will not be used in the study and will not be kept.

- Hypertension Details: _____
- Heart Disease Details: _____
- Spinal Issues Details: _____
- Lower Back Disorders Details: _____
- Asthma Details: _____
- Osteoarthritis Details: _____
- Epilepsy Details: _____
- Allergies Details: _____
- Regular Medications Details: _____
- Other Details: _____
- Pregnancies and Births Details: _____

Data Table for Body Composition and Core Muscle Function Assessment

Description	Measurement	
Height		
Weight		
Body mass Index		
Skinfold Measurements	Body Part	Measurement
	Triceps	
	Subscapular	
	Abdomen	
	Thigh	
Waist circumference		
Length of time holding a bridge		
Length of time holding a side bridge		
Distance of long jump.		

Researcher _____ Date _____