Determining the normative value of the Functional Movement Screen™ in weightlifters in participating gyms within the eThekwini municipality, and its association to injury

By

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I, Shaista Singh, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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DEDICATION

“They say that the senses are superior (to the body); superior to the senses is the mind; superior to the mind is the intellect; one who is even superior to the intellect is He.” Bhagavad Gita

All challenges in life need the self-initiative and the guidance of our elders, especially those close to the heart.

My humble effort I dedicate to my parents, Venash and Sheriza Singh. Their boundless love, effortless guidance and constant encouragement provided me with the tools necessary to achieve this.

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ABSTRACT

Background: Weightlifting is an increasing popular form of fitness. Weightlifters train exceptionally hard in their daily training regimes, as well as for competitions. Despite the popularity of this high intensive and explosive training, there is no normative value determined for weightlifters in the eThekwini Municipality, South Africa, to compare themselves against and track their progress or regression or to use as a benchmark when beginners adopt a new training programme. The Functional Movement Screen (FMS™) is a pre-participation assessment which analyses the movements of its participants according to seven exercises, which form the basics of fundamental movement patterns. This assessment allows an analysis of dysfunctional movement patterns to be identified.

Aims: The aim of this study has been to assess weightlifters according to the Functional Movement Screen™ (FMS™), to determine a normative value and examine their FMS™ score in relation to prior injury or musculoskeletal dysfunction.

Methods: The methodology of this study included assessing 89 weightlifters from participating gym on the FMS™ in order to achieve a normative score of weightlifters within the eThekwini Municipality. Thereafter, participants were contacted telephonically and asked to provide information about their age, height, weight, number of years training, and an injury profile, including how long ago any injury occurred, how long the injury took to heal, the severity of the injury according to the pain rating numerical scale and what form of treatment they received for their injury. The mean FMS™ was then determined for the weightlifters within the eThekwini Municipality and an analysis was made between FMS™ score and injury sustained to determine whether the FMS™ is able to predict injury in this population.

Results: The sample population of 89 revealed that the mean FMS™ score for weightlifters in participating gyms within the eThekwini Municipality is 13.88 out of 21. There is no correlation made between FMS™ score and injury and therefore there is no association to injury and FMS™ score in this sample population. There are significant findings in the scoring of the FMS™ exercises showing that weightlifters adapt their own lifting technique in order to lift their desired weight at the velocity expected. The most common recorded injuries are to the shoulder, followed by the knee. The most common injury sustained is musculature in nature and the most common treatment received for injury was physiotherapy.

Conclusion: The normative value for weightlifters in participating gyms within the eThekwini Municipality is 13.88 out of 21 for the FMS™. It has been established that weightlifters deviate from the ideal movement pattern to develop stability and strength to lift their desired weights at explosive outputs. There was no link found between FMS™ score and injury and no correlation made between age, height, weight and number of years training and the FMS™ score.

Keywords: Dysfunctional movement patterns, exercise, Functional Movement Screen™, injury, injury profile, musculoskeletal injury, weightlifting, weight training.

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DEFINITIONS

Actin

Polymers of G-actin that form part of a cells cytoskeleton and are part of the contractile system of muscle cells (Widmaier, Raff and Strang 2011: G-1).

ATPase

An enzymes ability to decompose ATP (Widmaier, Strang and Raff 2011: 255).

Concentric contraction

The muscle tension rises to overcome the amount of resistance being produced by an object. This results in the muscle shortening and the tension within the muscle remaining stable (Padulo *et al.* 2013: 5).

Eccentric contraction

The force being exerted by an object is greater than that of which the muscle can produce resulting in the tension being inadequate to cause contraction. In return, the muscle lengthens to stabilise the joint (Padulo *et al*. 2013: 5).

Functional movements

Functional movements are carried out daily in our activities of daily living subconsciously. These are movements based on real world biomechanics (Cech and Martin 2012: 1).

Functional Movement Screen™

An evaluation tool designed to assess the fundamental movement patterns of an individual so that they can be made aware of any deficits or imbalances that may cause them dysfunction. It is comprised of seven fundamental movement patterns that encompass a balance between stability and mobility (Cook, Burton and Hoogenboom 2006a: 62,63).

Kinematic chain

The term used to explain the relay of forces that occurs in the human body (Richardson 2018: 19).

Macrotrauma

Large amounts of muscle damage and injury that do not contribute to the growth and strengthening of muscles. They cause severe injury that results in pain and prevents the continuation of training. Macrotrauma can affect muscle, joint, nerve and create a biochemical issue and is the usual cause of weight training injuries (Kinakin 2004: 1).

Mechanoreceptors

A sensory neuron specialised to respond to mechanical stimulation, such as touch receptors in the skin and stretch receptors in muscles (Widmaier, Raff and Strang 2011: G-13).

Microtrauma

Small amounts of muscle damage that is important for growth and strength of a muscle allowing (Kinakin 2004:1).

Muscle imbalance

When a muscle is injured, there is weakness, pain and inflammation that arises. If these factors do not resolve after a few days or weeks, adhesion formation occurs within the muscle fibre. The adhesions limit the ease of motion and limit range of motion. Once the normal biomechanics of the muscles lengthening and shortening capabilities are altered, a muscle imbalance is established (Kinakin 2004: 2).

Myofascial trigger point

A tender localised hardening within the muscle causing the muscle bands to become taut and dysfunctional resulting in the inhibition of other muscles (Kinakin 2004: 3).

Myofibril

The striated pattern in skeletal muscle from the light and dark bands is due to the thick and thin filaments within these bands. They are arranged in a regular display within the cytoplasm. These cylindrical bundle arrangements within the cytoplasm are called myofibrils (Widmaier, Raff and Strang 2011:253).

Myosin

Contractile proteins that forms the thick filaments in skeletal muscle fibres (Widmaier, Raff and Strang 2011: G-15).

Nociceptors

A sensory receptor that responds with pain to the body when stimulated (Widmaier, Raff and Strang 2011: G-15).

Over-use injury

When a muscle has been exercised, it needs time to rest and recuperate before being trained heavily again. The activity of not allowing the correct resting time between training sessions and training a muscle group heavily results in macro-trauma. Therefore, injury from over training is deemed as an over-use injury (Kinakin 2004: 7, 8).

Proprioception

The sense of relative position of one's own body parts and the amount of strength and effort being applied for movement (Richardson 2018:20).

Satellite cells

Undifferentiated stem cells are called satellite cells. These cells are quiescent in the normal state but when the muscle undergoes stress or injury, they become active and undergo miotic proliferation. This allows satellite cells to develop into daughter cells and thereafter become the cell that the muscle needs to overcome the stress or injury (Widmaier, Raff and Strang 2011: 252).

Skeletal muscle

A muscle that is attached to the skeleton, and its contraction results in the movement of the skeleton. The contraction of skeletal muscle is initiated by impulses in the neurons to the muscles and occurs due to voluntary control. Under the microscope, the skeletal muscle has a distinct striated pattern due to the alternating light and dark bands perpendicular to its long axis. Therefore, skeletal muscle can also be called striated muscle (Widmaier, Raff and Strang 2011: 250,251).

The "Clean and Jerk"

This is a two part lift that allows heavier weights to be lifted than those in lifted during "The Snatch". The "Clean" requires the barbell to be lifted from the floor, using a shoulder width wide grip to the front of the shoulders in one continuous movement. The "Jerk" then requires the weightlifter to extend their elbows and raise the barbell overhead. The “Clean and Jerk” has 12 phases: first pull; start of second pull; completion of second pull; turnover; catch; recovery from “clean”; start position of jerk; jerk dip; jerk dive; unsupported split under bar; supported split and recovery from “The Jerk” (Storey and Smith 2012: 772,773).

“The Snatch”

Requires the weighted barbell to be lifted from the floor, using the wide grip to an overhead position in one continuous movement. This whole body movement has six phases: first pull; transition pull; second pull; turnover; catch and recovery (Storey and Smith 2012: 771,772).

Tropomyosin

A protein involved in muscle contraction. It is related to myosin and occurs together with troponin in the thin filaments of skeletal muscle. It is also capable of reversing actin binding sites in skeletal muscle (Widmaier, Raff and Strang 2011: G-22).

Troponin

A regulating protein attached to actin and tropomyosin of skeletal muscle thin filaments and acts as a site for calcium binding that allows for contractile activity (Widmaier, Raff and Strang 2011: G-22).

Weightlifter

A weightlifter is expected to carry out the signature moves of weightlifting. They are required to generate extremely high peak forces and contractile rates of force development. They need to obtain high peak power outputs and contractile impulses to be able to lift their desired weight with the correct lifting techniques to obtain maximum range of motion needed to carry out the signature moves (Storey and Smith 2012: 770).

Weightlifting

A dynamic strength and power sport during which two multi-joint, whole body lifts are expected to be carried out. “The Snatch” and the “Clean and Jerk” are the signature moves of weightlifting (Storey and Smith 2012: 769).

LIST OF ABBREVIATIONS

CJ:	Clean and Jerk
FMS™:	Functional Movement Screen™
ASLR:	Active Straight Leg Raise
SMT:	Shoulder Mobility Test
SMCT:	Shoulder Mobility Clearing Test
TSPU:	Trunk Stability Push-Up
ECT:	Extension Clearing Test
QRST:	Quadruped Rotatory Stability
FCT:	Flexion Clearing Test

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

An abundance of scientific evidence exists to support the vast benefits of participating in sports for both men and women. This is not only true for those who are regularly physically active, but also for sedentary individuals who are seeking a more active lifestyle. Physical activity can improve both biological and psychological health and wellness levels. Individuals who partake regularly in physical activity are known to be more energetic, thereby having a greater quality of life. Training regimens that target one's flexibility, posture, cardiorespiratory system and neuromotor control have been specifically designed to ensure one's best wellbeing (Garber *et al.* 2011). Over the years, there have been various exercise programmes aimed at ensuring an individual's supreme physical fitness. These exercise programmes were designed on the premise that weight loss determines fitness, but have shown poor results in weight loss itself (Richardson 2018). The recent literature shows that improving muscle fitness by weight training is more beneficial for both weight loss and general wellbeing (Garber *et al*. 2011). Weightlifting is therefore becoming more popular amongst young and old who seek better health (Burke *et al*. 2014). With regular participation, it allows an increase in strength as well as changes in health-related biomarkers (Garber *et al.* 2011).

Modern weightlifting originated between the 18th and 19th century as circus acts, initially. In 1920, the International Weightlifting Federation was formed to regularize and supervise competitions (Augustyn n.d). Weightlifting is the art of applying both strength and power to perform two whole body lifts known as “The Snatch” and the “Clean and Jerk” (CJ) (Storey and Smith 2012).

“The Snatch” requires the weight lifter to lift a weighted barbell off the floor, preferably using a wide grip, and extending the bar over his/her head in one continuous movement. The “CJ” consists of two parts using a shoulder width grip. “The Clean” refers to the motion of lifting the weighted barbell off the floor to shoulder level. “The Jerk” is then carried through by lifting the bar into full extension over the top of the head. This two-part motion allows for heavier weights to be lifted than those lifted with “The Snatch”. These two lifts form the basis of all weightlifting programmes (Storey and Smith 2012). By performing these two lifts, a weight lifter may exert the greatest human power output of any physical activity. Due to this high power output, contractile impulses and excessive spinal loading injury frequently occurs in the weightlifting industry (Firdaus, Kuan and Krasilshchikov 2018).

Keogh and Winwood (2017) states that there are many injuries that occur throughout various weight training sports. The most common sites of injury are joints of the shoulder, lower back, knee, elbow, wrist and hand. The specific sites of common injury for weightlifting are the knee, lower back and shoulder joints. Tendinitis, sprains and strains are the most common injury types seen in weightlifting. These are all overuse injuries. Therefore, a mix of acute, chronic and recurrent injury types occur in this population group.

Weightlifting injuries are caused due to lack of sufficient recuperation time, resulting in continuous micro-trauma to injured areas. This continuous micro-trauma will eventually cause macro-trauma. When the body is undergoing such stress, compensatory mechanisms and dysfunction develop (Kinakin 2004).

Training injuries are often symptomatic for a period of two weeks during which an individual will train less vigorously. However, once the injury is asymptomatic a more intense training regimen will be engaged (Keogh and Winwood 2017). This continued training without full recovery causes greater dysfunction and pain. Weight lifters are not aware of the compensatory patterns and mechanisms that occur due to injury. The Functional Movement Screen™ (FMS™) will allow weight lifters to determine their own personal score and possible areas of weakness and/or dysfunction.

The FMS™ was designed to bridge a gap between movements used in activities of daily life and exercise. The aim of this screen is to establish a standardized movement pattern. Screening and assessing movements clarifies where change, improvement or rehabilitation is required. This tool will help weight lifters gain information about their bodies which can be used for their overall wellbeing. Determining the normative value for weight lifters in eThekwini will create a reference that can be used to compare physical fitness levels. This allows weight lifters the opportunity to compete with themselves and better their personal score relative to the ideal score. The scores of weight lifters obtained using the Functional Movement Screen™(FMS™) can be compared to injuries sustained. A correlation can be made between scores and injury. This will facilitate an analysis on whether the FMS™ tool can be used to predict injury (Cook *et al*. 2010).

When scoring critical movement patterns, areas of dysfunction and weakness are highlighted. The FMS™ will isolate movement patterns and highlight deficit areas. Areas that are weaker and dysfunctional are more likely to take on excessive strain and inflict pain. Compensation can occur to offload the exertion on these dysfunctional areas, creating a chain of weakness. With prolonged compensatory areas and dysfunction, injury will be more likely (Kinakin 2004 : 1-5). The FMS™ allows weight lifters to prevent this by gaining knowledge on the areas that need attention. Weight lifters can focus on these to ensure their entire biomechanical chain is balanced (Cook *et al.* 2010; Cook *et al* 2006).

The FMS™ consists of seven tests which were designed to assess the athlete's proprioception and kinesiology. These tests put the body under scrutinized positions to ensure stabilization can be obtained from the body. If this does not occur, the movement will be poorly conducted. The FMS™ has been used in various studies to predict future injury and has proven accurate in doing so (Bonazza *et al*. 2016; Dossa *et al*. 2014; Kiesel 2007; Letafatkar *et al.* 2014). With respect to weightlifting, a normative value has yet to be determined, therefore no ideal score presents itself as a guide to be used to predict possible injury. This study will determine the normative value of the Functional Movement Screen™ for weight lifters in the eThekwini municipality and its association with injury.

1.2 AIM

To assess weight lifters according to the Functional Movement Screen™ (FMS™) and determine a normative value and look at their FMS™ score relative to prior injury or musculoskeletal dysfunction.

1.3 OBJECTIVES

1.3.1 To assess movement patterns of weight lifters according to the FMS™;

1.3.2 To identify a normative value for weight lifters in the eThekwini Municipality using the FMS™;

1.3.3 To identify an association between FMS™ scores and injury of weight lifters in the eThekwini Municipality.

1.4 HYPOTHESIS

Hypothesis: the normative value for weight lifters is 14, and a score lower than 14 indicates musculoskeletal injury

Null Hypothesis: the normative value for weight lifters is not 14, and a score lower than 14 does not indicate musculoskeletal injury

1.5 RATIONALE

Weightlifting is a very high loading sport, causing stress and strain on joints and the surrounding soft tissue of the body (Firdaus, Kuan and Krasilshchikov 2018). Injuries are often overlooked by weight lifters who fear prolonged healing time (Kinakin 2004). “The Snatch” and “CJ” are the main movements conducted by weight lifters, which consist of shoulder and trunk stability (Storey and Smith 2012). The overuse of these joints cause musculoskeletal injury that goes untreated. Therefore, performing the FMS™ on weight lifters will allow them to establish their personal score and improve it with correct training techniques, thus preventing injury and limiting healing time.

The Functional Movement Screen™ (FMS™) is a screening tool that is capable of predicting injury in an individual. It can assess athletes prior to, during and post training periods. The information obtained in this study will allow weight lifters to determine the baseline score of a supposedly healthy weight lifter and how they score in comparison. This will then highlight deficit areas to ensure the best training regimen is followed.

The screen consists of several tests, including a Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and a Rotatory Stability Test. The participant will perform each of these movements and be scored based on execution. As mentioned previously, a large overlap exists between the basic movements of weightlifting and the movements of the FMS™ (Cook *et al.* 2006a.).

1.6 BENEFITS

By obtaining a normative value for the weightlifting population in eThekwini, weight lifters can assess themselves and compare their scores with that normative value. Weight lifters will also be able to monitor their training technique by ensuring that their scores are either maintained or improved. Participants that have been injured or recovering from injury can use this tool as a barometer of their healing and recovery progress. The overall information from the FMS™ will allow weight lifters to be more proactive in preventing injury and improve their awareness of proper training techniques. Furthermore, the knowledge obtained from this study will increase the information on the use of the FMS™ (Richardson 2018)

1.7 LIMITATIONS

The limitation of this study is the honesty of participants regarding their injury profiles as this will allow the normative value and association to be made.

1.8 CONCLUSION

According to Garber *et al.* (2011) and Burke *et al.* (2014), weightlifting has increased in popularity vastly and is becoming more common in those that seek fitness and want to improve their quality of life. The type of training that weight lifters are expected to perform is intense and requires maximum effort therefore time allocated to training is imperative and time needed to heal from injuries are often over looked (Kinakin 2004). Weightlifters adopt a specific lifting style to ensure that they are able to execute their specific movements with maximum speed and power therefore their posture and movement patterns can be dysfunctional as correct posture and movement patterns do not aid their performance (Storey and Smith 2012). It is important that a determination of normative value for the FMS™ for weightlifters is made so that their individual progress can be tracked during training and following rehabilitation and their regression can be noted if injured. From the previous literature (Bonazza *et al*. 2016; Dossa *et al*. 2014; Kiesel 2007; Letafatkar *et al.* 2014), an association was made between low FMS™ scores and injury, due to weightlifters wanting to reduce healing time and improve movement patterns to prevent injury an injury predictor would be useful in this sample population, therefore the presence of an association between FMS™ score and injury will be analysed.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Chapter two aims to give the reader a broad overview into exercise, particularly weightlifting and the types of injuries that weight lifters commonly incur. This chapter will include subheadings of injury risk factors for weight lifters and injury prediction strategies. Lastly, the FMS™ is reviewed in terms of its use as well as its relevance to and reliability in the sports industry.

2.1.1 The Physiology and Anatomy of Skeletal Muscle

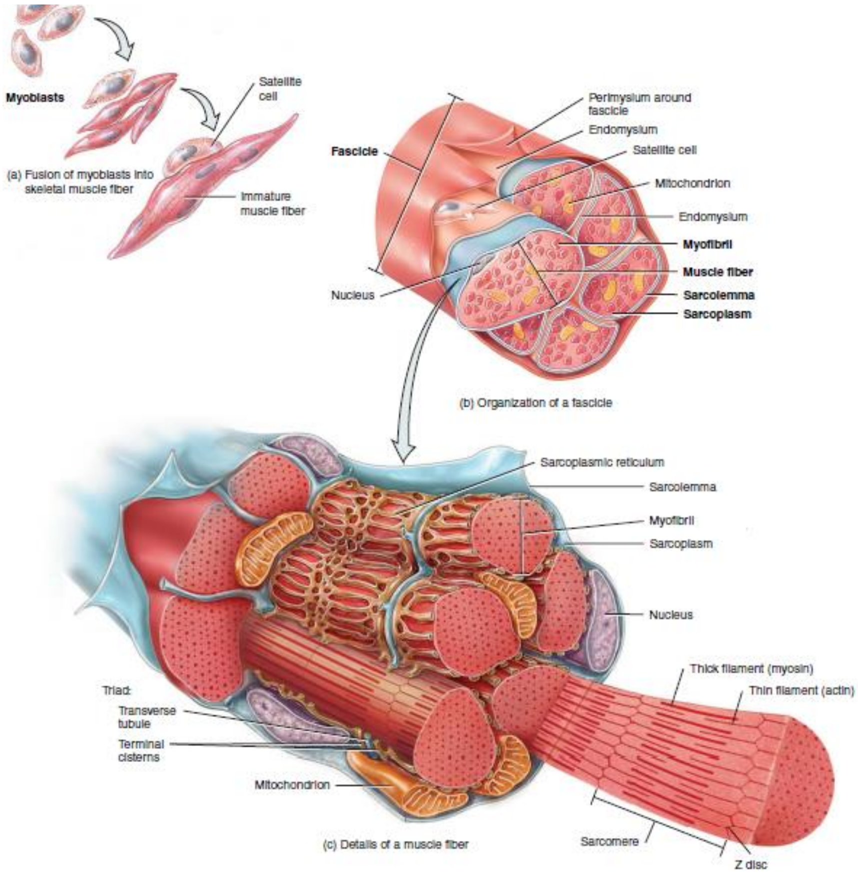


Figure 2.1: Microscopic organization and development of skeletal muscle

(Source: Tortora and Derrickson 2017: 298)

2.1.2 Structure

The most distinct feature of skeletal muscle is the alternating light and dark bands running perpendicular to the long axis, which can be seen through a microscope. This is why skeletal muscle is also known as striated muscle.

The striated pattern occurs due to an arrangement of thick and thin filaments in a structured pattern within the cytoplasm. These filaments form part of smaller cylindrical bundles called myofibrils. The cytoplasm contains multiple myofibrils which extend along the length of the muscle fibre and attach to the tendons at the end of the muscle fibre. The thick and thin filaments are arranged in a repeated pattern along the length of the myofibril. The thick filaments are composed of the protein myosin, and the thin filaments composed of the protein actin as well as troponin and tropomyosin, which regulate muscle contraction. One length of this repeated pattern is a sarcomere (Widmaier, Strang and Raff 2011: 251-253).

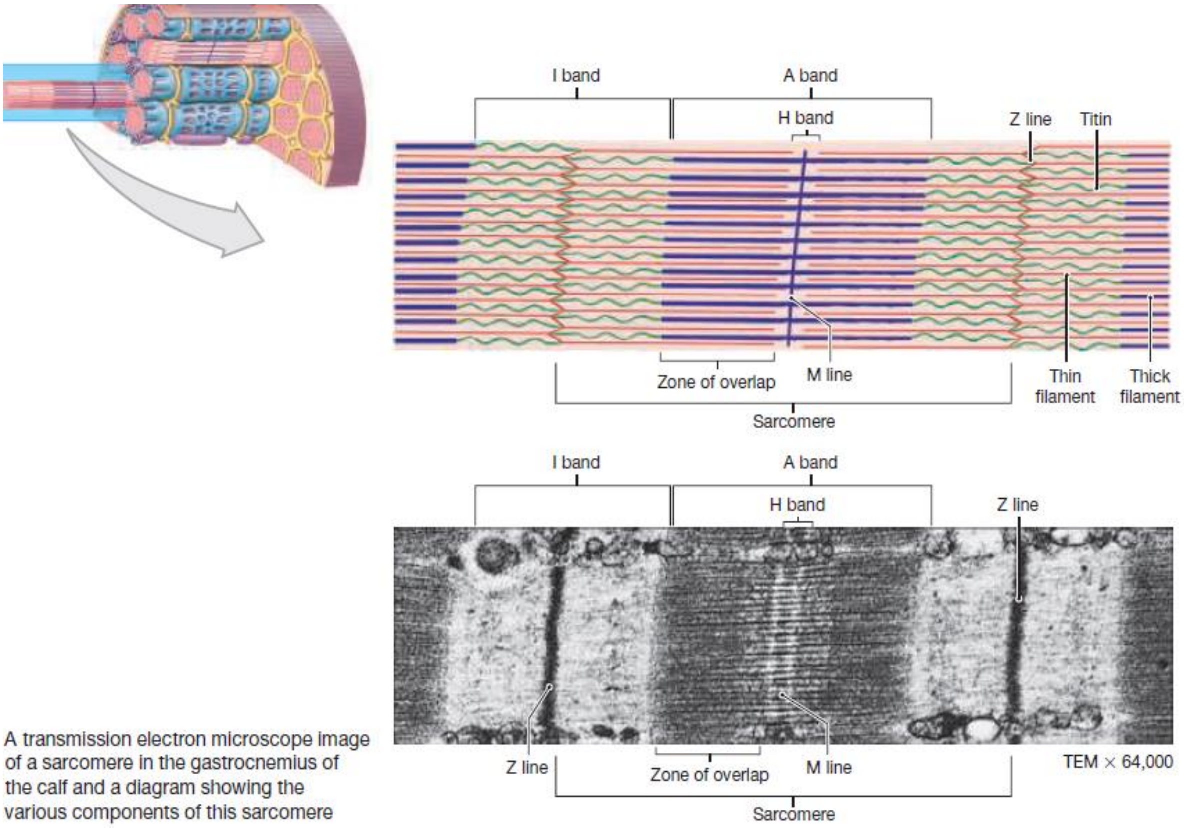


Figure 2.2: Illustration and electron microscope image of a sarcomere

(Source: Martini, Tallitsch and Nath 2018: 240)

Thick filaments are located in the centre of the sarcomere and have a parallel arrangement that is wide and dark. This is known as the A band. Within the sarcomere, there are two sets of thin filaments: one end of the thin filament is anchored to an interconnecting protein network by Z lines while the other end of the thin filament is made to overlap with a portion of the thick filament. Two successive Z lines create the boundaries of one sarcomere. Between the two ends of an A band, in two adjacent sarcomeres, lies a light band called an I band. The I band contains the portion of thin filaments that do not overlap with the thick filaments. The I band is bisected by the Z lines. There are two additional bands present in the A band region, creating the H zone. It corresponds with the two opposing ends of the thin filaments in each sarcomere. The H zone is bisected by a light band called the M line. The M line is the centre of the proteins from the thick filaments. Additionally, there are filaments which contain the elastic protein called titin. These filaments extend from the Z line to the M line and are linked to the thick filaments and the M line proteins. The purpose of this titin filament is to maintain the alignment of thick filaments in the centre of the sarcomere (Widmaier, Strang and Raff 2011: 253).

When a cross section is cut through the A band, there is a patterned arrangement of overlapping thick and thin filaments. There is a hexagonal array of six thin filaments surrounding one thick filament and a triangular array of three thick filaments surrounding one thin filament. There are double the amount of thin filaments than thick filaments present at the point of overlap. Cross-bridges are present to merge the gap between overlapping thick and thin filaments. Cross-bridges are portions of myosin molecules that extend from the surface of thick filaments to the thin filaments. Cross-bridges are responsible for making contact between and exerting a force on the thin filaments during contraction.

Each individual skeletal muscle cell contains multiple nuclei, resulting in a skeletal muscle cell being known as a muscle fibre. Muscle fibres are developed during gestation by the fusion of mononucleated, undifferentiated cells called myoblasts resulting in a cylindrical multinucleated cell. Skeletal muscle undergoes differentiation from childhood, which is completed in adulthood. Skeletal muscle fibres are extremely large. To maintain their structure and function, reservation of as many nuclei from myoblasts as possible needs to take place. The nuclei are spread throughout the entire length of the muscle and regulate protein synthesis and gene expression in their individual domains (Widmaier, Strang and Raff 2011: 255).

When skeletal muscle is damaged or injured after birth, it cannot be replaced by any other pre-existing muscle fibres. It contains its own population of undifferentiated stem cells known as satellite cells to aid its repair. Satellite cells are located between the plasma and basement membranes along the length of the muscle and remain dormant until needed. When strain or injury occurs to the muscle fibre, they become active and undergo mitotic proliferation, creating daughter cells. Daughter cells can then either fuse to form new myoblasts or blend with damaged tissue to aid repair. Satellite cells are able to form adequate new skeletal muscle fibres, but cannot repair severely damaged muscle to its original number of fibres. Compensation for this loss occurs due to a satellite-cell mediated increase in size of remaining muscle fibres. This is known as hypertrophy. Satellite cells do not only become active for severe injuries, but also for exercise-induced micro-trauma that causes proliferation and differentiation, in turn causing hypertrophy. Hormones and growth factors such as human growth hormone, insulin-like growth factors and sex hormones regulate this hypertrophy(Widmaier, Strang and Raff 2011: 252).

The term “muscle” refers to multiple fibrous tissue fibres held together by a connective tissue. The connective tissue that binds skeletal muscle together and attaches it to the bone are bundles of collagen called tendons. The individual fibres of tendons can span the entire length of the muscle. More commonly, however, the fibres are short and oriented at an angle to the longitudinal axis of the muscle. The transmission of force from muscle to tendon occurs when the muscle pulls on the tendon, causing its elongation. Tendons can be very long with their attachment to bone being distal from the muscle (Widmaier, Strang and Raff 2011: 253).

2.1.3 Types of Skeletal Muscle Fibres

Skeletal muscle fibres differ in their mechanical and metabolic characteristics. Fibres can be classified according to their velocity of shortening and the pathway that they use to form Adenosine Triphosphate (ATP). Fast and slow fibres contain myosin that differ in the rates that they use ATP, affecting the cross-bridge cycling and shortening velocities. Fast fibres contain myosin with high ATPase (the ability of any enzyme to breakdown ATP) activity, and slow fibres are those which contain low ATPase activity myosin-.

Skeletal muscle can be classified according to the type of enzymatic process used to synthesize ATP fibres. Fibres contain multiple mitochondria and can undergo rapid oxidative phosphorylation are known as oxidative fibres. These fibres are dependent on blood flow to provide adequate oxygen to the muscle and are therefore surrounded by numerous blood vessels. Glycolytic fibres have few mitochondria, but do have a high amount of glycolytic enzymes and store glycogen. These fibres rarely use oxygen and require fewer blood vessels around them. Glycolytic fibres have a much larger diameter than oxidative fibres and can thus develop greater tension within the muscle due to the increase in thick and thin filaments (Widmaier, Strang and Raff 2011: 269-270)

Three principal types of skeletal muscle can be defined as:

1. Slow Oxidative Fibres: these combine low myosin ATPase activity with high oxygen capacity.
2. Fast-Oxidative-Glycolytic Fibres: these combine high myosin ATPase activity with high oxidative capacity and medium glycolytic capacity.
3. Fast-Glycolytic Fibres: these combine high myosin ATPase activity with high glycolytic capacity.

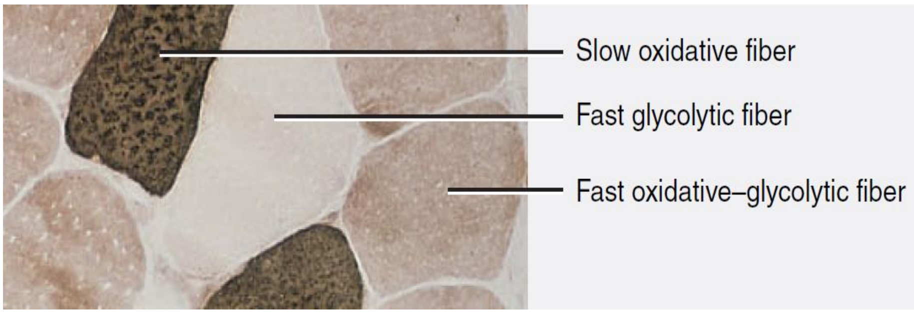


Figure 2.3: Transection of skeletal muscle showing three different fibres

(Source: Tortora and Derrickson 2017: 320)

All skeletal muscle do not have the same mechanical and metabolic characteristics. The different types of fibres are classified according to the rate at which shortening occurs and their ability to form ATP. The table below shows the structural and functional characteristics of the different skeletal muscle fibres (Widmaier, Raff and Strang 2011: 269-270).

Table 2.1 Characteristics of three different types of skeletal muscle fibre

STRUCTURAL CHARACTERISTIC	**Slow oxidative**	**Fast oxidative-glycolytic**	**Fast glycolytic**
Myoglobin content	Large amount	Large amount	Small amount
Mitochondria	Multiple	Multiple	Few
Capillaries	Multiple	Multiple	Few
Colour	Red	Red-Pink	White (pale)
FUNCTIONAL CHARACTERISTICS	**Slow oxidative**	**Fast oxidative-glycolytic**	**Fast glycolytic**
ATP production capacity	High	Intermediate	Low
ATP production method	Aerobic respiration	Aerobic respiration and Anaerobic glycolysis	Anaerobic glycolysis
Rate of ATP hydrolysis by myosin ATPase	Slow	Fast	Fast
Velocity of contraction	Slow	Fast	Fast
Fatigability	Low	Intermediate	High
Amount of creatine	Minute	Intermediate	Highest amount from all fibres
Amount of glycogen stores	Low	Intermediate	High
Order of activation	First	Second	Third
Location of abundancy	Postural Muscles	Lower limb muscles	Extra- ocular muscles
Primary function	Maintain posture and aerobic endurance during activities	Walking and sprinting	Rapid, intense movements of short duration

2.1.4 Mechanisms of Skeletal Muscle Contraction

The term “contraction” is often used when referring to muscle physiology. Contraction does not only mean shortening, but also the activation of the force generating sites within the fibres which in turn activate the cross-bridges. Following contraction, there are mechanisms in place to allow the force-producing mechanisms and tension to be reduced, causing a relaxation of the muscle fibre.

2.1.4.1 Sliding Filament Mechanism

The force that is produced within a skeletal muscle fibre causes shortening and the overlapping of the thick and thin filaments in each sarcomere. These actions are propelled by the cross-bridges. When sarcomeres are shortened, there is no change in the length of the thick and thin filaments. This is known as the sliding-filament mechanism of muscle contraction.

During shortening, individual myosin cross-bridges that are attached to thin filament actin molecules move in an arc. This motion of many cross-bridges causes the thin filaments – attached to successive Z lines – to move towards the centre of the sarcomere, causing its shortening. One stroke of a cross-bridge causes very small movements of the thin filaments in comparison to the thick filaments. The cross-bridges will continue this motion for the entire duration of muscle activation and allow large amounts of movement to occur with the thin filaments. It is important to note that the common pattern of muscle shortening involves one end of the muscle being fixed and the other end contracting towards the fixed end. Therefore, as filaments slide, the sarcomere shorten internally, and the centre of the sarcomere is displaced towards the fixed side of the muscle.

A muscle’s ability to produce force and undergo movement is dependent on two proteins: actin and myosin, which are responsible for contraction. Actin is a globular protein comprised of a single polypeptide that polymerizes with other actin monomers to produce a polymer with two intertwined helical chains. These chains are the core of the thin filaments. Each molecule will have a binding site for myosin. The myosin molecule is composed of two large heavy polypeptide chains and four smaller, light chains. Light and heavy chains combine to form a molecule with two globular heads, and a tail is formed with two intertwined heavy chains only. The tails of myosin molecules lie along the long axis of the thick filaments, whilst the two globular heads extend out towards the sides, creating the cross-bridges.

Each globular head has two binding sites, one for actin and the other for ATP. The ATP binding site serves as an enzyme too. It forms an ATPase that hydrolyses bound ATP to produce energy for contraction. The myosin molecules located at the two ends of the thick filaments are orientated in opposite directions, causing their tail ends to face the centre of the filament. This arrangement allows the movement of the attached thin filaments towards the centre of the sarcomere during shortening.

When a muscle fibre is resting, the cytoplasmic calcium levels are low and the myosin cross-bridges cannot bind to the actin. The cross-bridges are in an energized state produced by splitting ATP. The hydrolysis produces Adenosine Diphospate (ADP), which is an inorganic phosphate and is still bound to myosin. This is the potential energy stored in myosin. A cross-bridge cycle occurs when the entire sequence takes place between the time of cross-bridge binding to thin filaments, the movement occurring, and then a reset to the beginning to repeat.

Each cycle consists of four steps:

Step 1: Attachment of a cross-bridge to a thin filament: Calcium enters the cytoplasm, and an energized myosin cross-bridge is bound to a thin filament actin molecule.

Step 2: Binding energized myosin to the actin triggers the release of the energized cross-bridge, causing movement of the bound cross bridge, which is the power-stroke. Phosphate and ADP is then released.

Step 3: While cross-bridge movement occurs, myosin is bound firmly to actin. This firm attachment must be broken down to allow the cycle to repeat. When new molecules are bound to myosin, the links between actin and myosin are broken.

Step 4: The breakage of the actin-myosin links by ATP is the allosteric regulation of protein activity. The binding of ATP to one end of myosin decreases its attraction to actin on the other side. ATP is not split or acting as an energy source during this step, but as an allosteric modulator. Once there is complete dissociation of actin and myosin, the ATP, which was bound to the myosin, is hydrolysed. This allows for the reformation of the energized state of myosin and the cross-bridge returning to its pre-power-stroke position ATP performs two roles in the cross-bridge cycle: energy released from ATP hydrolysis provides the energy for cross-bridge movement and ATP binding to myosin, and also breaks the strong actin-myosin links during the cycle, allowing the reset of the cycle.

Each cross-bridge undergoes its own individual cycle independent of the others, and at any given moment during contraction some cross-bridges are attached to thin filaments producing tension while others are in the detached portion of the cycle. (Widmaier, Raff and Strang 2011: 254-256)

2.1.5 The Role of Troponin, Tropomyosin and Calcium in Contraction

Tropomyosin is a rod-shaped molecule comprised of two intertwined polypeptides. Chains of tropomyosin are arranged along the length of thin filaments which partially cover the myosin binding site on each actin monomer. This coverage prevents the cross-bridges from making contact with the actin monomer. Tropomyosin holds this blocking position with the help of Troponin.

Troponin interacts with both actin and tropomyosin and is composed of three sub-units, viz. Inhibitory (I), tropomyosin-binding (T) and Calcium Binding (C). Each molecule of troponin binds to tropomyosin and regulates its access to myosin-binding sites. This is the status of a resting muscle fibre with troponin and tropomyosin blocking the interaction of cross-bridges with the thin filaments.

Tropomyosin must move away from their blocking position on actin to begin the cycle. This can only happen when calcium binds with the calcium-binding sites on troponin. The bound calcium alters the shape of the troponin which reduces its inhibitory grip and allows tropomyosin to move away from the myosin-binding site. Controversially, the removal of calcium reverses the process and stops the contractile activity (Widmaier, Raff and Strang 2011: 257).

2.1.6 Excitation-Contraction Coupling

This is the sequence by which an action potential in a plasma membrane of a muscle fibre leading to the cross-bridge cycle. The plasma membrane of skeletal muscle is capable of generating and spreading action potentials. The action potential within the plasma membrane does not act directly on the contractile proteins, but rather increases the amount of cytoplasmic calcium. This will be able to stimulate the contractile proteins even when the action potential is finished. In a resting muscle fibre, the level of calcium in the cytosol surrounding the filaments are very low. This low concentration means that very few calcium-binding sites on troponin are being used and tropomyosin is blocking the cross-bridge binding. With an action potential, there is a sudden increase in calcium levels, allowing calcium to bind to its designated sites and tropomyosin to be blocked. The increase in systolic calcium comes from the sarcoplasmic reticulum within the muscle fibre.

2.1.6.1 Motor Innervation

Stimulation of nerve fibres in a skeletal muscle is the only mechanism that initiates action potentials in this type of muscle. Motor neurons innervate skeletal muscle and their cell bodies are either located in the brain or the spinal cord. The axons of these neurons are myelinated and larger than most. Their size enables them to produce great action potentials to allow signals to travel from the central nervous system to this muscle timeously. When the motor neuron reaches the muscle the axons split into many branches that engage with individual muscle fibres. One motor neuron can innervate many muscle fibres, but each muscle fibre can only be controlled by one single motor neuron. The motor neuron and the muscle fibre it controls is termed a motor unit. Muscle fibres within a single motor unit are scattered throughout the muscle. An action potential in a motor neuron stimulates all the muscle fibres of one motor unit to contract (Widmaier, Raff and Strang 2011: 257-260).

2.1.7 Single Fibre Contraction

Contracting muscle obtains muscle tension when a force is exerted onto it, and the weight it experiences is usually a load. Muscle load and tension are opposing forces. The amount of tension and load determines the extent of the contraction. For movement to occur and the load to be displaced, the muscle tension must be greater than the opposing load. A muscle can develop tension but not shorten. This is referred to as isometric contraction. Isometric contractions occur when the muscle tries to move a load that is in a fixed position or tries to move a load that is greater than the tension it possesses. When the length of a muscle is altered, but the load on the muscle remains constant, it is called an isotonic contraction. Isotonic contractions can either involve a shortening of the muscle – which occurs when the tension exceeds the load on the muscle (concentric contraction) – or a lengthening when the load is greater than the tension produced by the cross-bridges is greater (eccentric contraction). With eccentric contraction, the load pulls the muscle into an elongated position despite the tension created by the cross-bridges. This lengthening occurs due to external forces being applied to the muscle that are greater than the force produced by the contractile proteins. Isometric, concentric and eccentric contractions are activities that occur throughout our daily lives.

2.1.7.1 Twitch Contractions

A twitch is the mechanical response to a single action potential in a muscle fibre. A latent period exists between action potentials during which the excitation-contraction coupling occurs. The period between the beginning of tension development and the peak tension is the contraction time. Skeletal muscle fibres have varied contraction times. Some have fast twitch and others slow twitch. The duration of the contraction is dependent on how long the calcium levels are elevated during an action potential.

Isotonic and isometric contractions have different latent periods that occur. In an isotonic twitch contraction, the latent period is longer. However, the actual shortening of a muscle fibre during isotonic twitch contraction is shorter than the duration that force is being produced for isometric contraction. In isometric twitches, the tension begins to build as soon as one cross-bridge attaches, and therefore the latent period is determined by the excitation-contraction coupling delay.

On the contrary, the latent period of isotonic twitch contractions is determined by the time needed for excitation-contraction coupling and the time accumulated for all cross-bridges to attach. The characteristics of an isotonic twitch depend on the amount of opposing force. With heavier loads, the latent period is longer, velocity of shortening is slower, duration of twitch is shorter and the distance shortened is less. Shortening does not occur until adequate cross-bridges have attached and the muscle tension is greater than the load. Therefore, before contraction there is a period of isometric contraction. The heavier the load, the longer it takes for a muscle to reach its potential tension to create movement. Eventually the fibre encounters a load that is too great and the amount of tension required to overcome this load is not possible. The contraction then becomes isometric (Widmaier, Raff and Strang 2011: 263).

2.1.8 Whole Muscle Contraction

Whole muscles are made up of multiple muscle fibres organized into motor units. All the muscle fibres in a single motor unit are of the same fibre type. A muscle does not have only one single fibre type and various between individuals.

2.1.8.1 Control of Muscle Tension

The amount of muscle tension that a muscle can obtain depends on the amount of tension each fibre gains, including the number of fibres contracting at a time. The nervous system is responsible for the regulation of these factors and thus controls whole-muscle tension and shortening velocity. The number of fibres contracting at any given time is dependent on the quantity of fibres in a single motor unit and the number of active motor units.

Motor unit sizes vary among muscles. When a muscle has small motor units, tension is produced in small increments by the activation of a large amount of motor units. If the motor units are large in a muscle, the tension increases vastly as each motor unit is activated. Thus, muscles with small motor units produce finer motor control. The fibre diameter has a direct influence on force generated. The greater the diameter, the larger the force produced and vice versa.

When the number of active motor units are increased in a muscle at any given time, it is called recruitment. The greater the amount of motor neurons, the greater the amount of motor units, and the greater the tension obtained. The size of a motor neuron is dependent on the size of the neuronal cell body. The smallest neurons are recruited first because they produce action potentials first, and the larger ones are recruited later. During moderate strength contractions in endurance exercise, few glycolytic motor units are recruited due to their large diameter and are only recruited once the force of contraction is greater than the tension produced within the muscles. Most of the activity occurs in the fatigue-resistant oxidative fibres.

Neuronal control of whole muscle tension involves the frequency of action potential in individual motor units and the recruitment of motor units. Motor neuron activity happens in bursts of action potentials and no single twitches. The alteration of frequency of action potential in a muscle allows the tension to build up at varied levels due to recruitment. Therefore, the force that a whole muscle produces can vary from very delicate movements to large powerful contractions depending on the type of motor unit recruitment. Recruitment is the main mechanism of developing tension within a muscle and is controlled by the central nervous system (CNS).

2.1.8.2 Control of Shortening Velocity

The factors that determine the velocity of shortening on a single twitch muscle is the magnitude of the load on the fibre and whether the fibre is a fast or slow fibre. With respect to whole muscles, the factors are the load on the muscle, the types of motor units in the muscle and recruitment. Correct recruitment leads to an increase in force and velocity (Widmaier, Raff and Strang 2011:271-274).

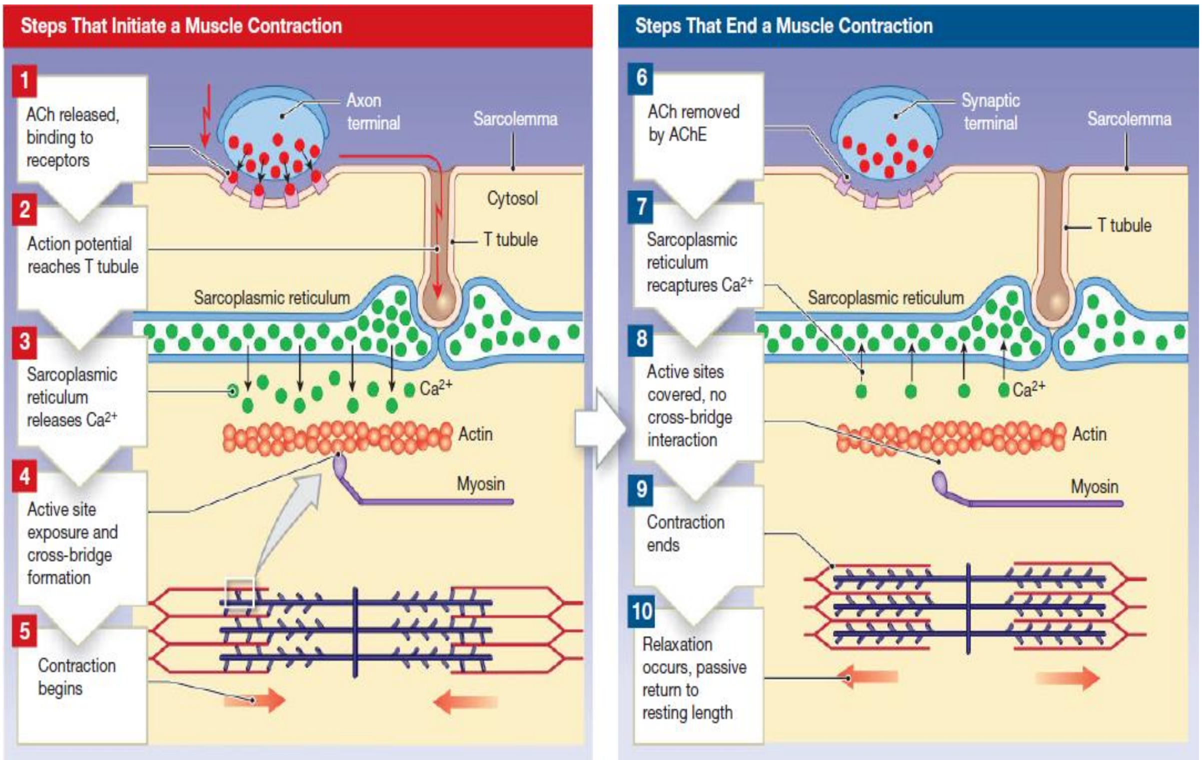


Figure 2.4: The events of muscle contraction

(Source: Martini, Tallitsch and Nath 2018: 246)

2.2 EXERCISE

The obsession with regular exercise and the maintenance of physical fitness is not a recent phenomenon. Exercise began thousands of years ago with each culture developing their own unique purpose for fitness. The Chinese drew a correlation between physical activity and sickness, identifying that those who exercised less were sick more frequently and subsequently developed Kung Fu as an exercise method. In ancient India it was believed that a quieter, relaxed and concentrated form of exercise would benefit the mind more than the body. Thus, Yoga was born. In Egypt, exercise took on a completely different role, where men were trained and kept fit for war. The Greeks realised that being a well-rounded individual was more important than just being mentally or physically strong. Exercise and learning were thus equally important, and the Olympic Games was subsequently born. By the 19th century, the United States of America officially endorsed exercise and sports, and individuals started participating in their own regular fitness programs outside of formal practices. This ushered the need for and establishment of sports clubs (Nardo 1992: 14-21).

According to Casperson, Powell and Christenson (1985: 126), exercise and physical activity are terms commonly interchanged due to their similarity. Physical activity is bodily movement that occurs due to skeletal muscles losing energy. The amount of energy needed to perform activities can be measured in kilojoules or kilocalories. To sustain our daily lives, physical activity needs to take place. The amount of physical activity varies from person to person based on their own needs and requirements. Therefore, each and every individual performs physical activity in their own way (Casperson, Powell and Christenson 1985:127). The difference in physical activity and exercise depends on the timing and amount of physical activity being performed regularly. When physical exercise is planned, structured and purposive it is then termed ‘exercise’.

Exercise is a subcategory of physical activity. Exercise involves movement of the body produced by skeletal muscles with energy loss (measured by kilojoules or kilocalories) but with higher intensity, frequency and duration. The objective in exercise is to maintain or improve any one of those elements.

Exercising and becoming healthy is a personal choice and offers many benefits to the physical and psychological wellbeing of an individual (Hitchings and Latham 2017: 300). Children begin exercising subconsciously when they play, and this conditions their muscles for development. It also initiates the development of flexibility, coordination and cardiovascular health. As individuals get older they become less active and overweight, increasing the number of people leading sedentary lifestyles. Therefore, it is important that motivation is acquired and upheld (Nardo 1992: 14). The motivation for exercise can either be intrinsic (satisfaction of being fit) or extrinsic (social acceptance). Either way, a motive is present and drives an individual to be active (Hitchings and Latham 2017: 300).

Individuals with intrinsic motivation have personal goals which they aim to achieve and allows them to reduce stress, improving their health and general wellbeing. Those with extrinsic motivation feel the pressure of society and often have more stress. Therefore, it is important to identify what an individual is hoping to gain from an exercise routine to ensure he/she is maximizing their benefit. Motivation is not fixed and can change: an individual that once had the desire for social acceptance may find that exercise makes them more confident, improving their self-worth thus changing their motivation to intrinsic as they begin to enjoy the feeling of physical fitness and the improvement of their self-values (Fisher *et al*. 2016: 1827).

Once an individual identifies their cause and expectations when exercising, the benefits of exercise can be exploited. Exercise will have a significant impact on both the physiological and psychological aspects of their life (Hitchings and Latham 2017: 300).

2.2.1 The Benefits of Exercise

More knowledge about the harmful and sometimes disabling effects of a sedentary lifestyle has driven individuals to make exercise an important part of their daily routines (Nardo 1992: 13). Exercise has many benefits once engaged correctly and proper techniques are applied.

According to Donaldson (2000:409), some of these benefits are:

Physiological benefits:

- Better overall health;
- Reduced risk of coronary heart disease, stroke and/or colon cancer;
- Reduced fatality following a heart attack;
- Reduced risk of hypertension;
- Regulated blood pressure;
- Protection against Type 2 Diabetes Mellitus;
- Weight control;
- Maintenance of bone mass density and reduction the risk of osteoporosis;
- Improvements in balance, co-ordination and endurance;
- Management of chronic conditions such as asthma and arthritis.

Psychological benefits:

- Increased self esteem;
- Decreased the risk of depression.

2.2.2 Types of Exercise

There are four different types of exercise, each with their own unique purpose (Anon. 2015; Anon 2013; Nardo 1992: 50-54):

2.2.2.1 Aerobics - Aims to increase breathing and heart rate. This is one of the main components of any physical activity and builds endurance. Aerobic exercise can be defined as performing a moderate amount of exertion for five minutes or more without causing fatigue. The intensity of aerobic exercise can be measured by the amount of perspiration and one's heart rate during the workout. This form of exercise ensures that the cardiovascular system is conditioned by forcing the heart to work much harder than it usually does, increasing its efficiency. Examples include: brisk walking, jogging and tennis etc.

2.2.2.2 Isotonic Exercise - Allows muscles to encounter and overcome resistance to create a movement. Isotonic exercise increases bone and muscle strength. It also helps older people maintain their independence through a reduced risk of falls and making daily activities easier. It involves the use of free weights or weight machines. Both approaches provide various activities, and weights are interchangeable to suit the individual's capacity. Lifting heavier weights for low reps improves muscle strength and lifting lighter weights for high reps improves muscular shape and definition. Examples of this exercise include weightlifting and Cross-Fit.

2.2.2.3 Calisthenics – These are isotonic type exercises that are performed without equipment and in as many successions as desired. This form of exercise maintains existing muscle strength but does not build further muscle strength. This form of exercise keep the body limber and maintain the range of motion. This assists the elderly because comorbidities such as arthritis often reduce range of motion and increase stiffness. Calisthenic exercises are monotonous and often used in conjunction with other forms of exercise. Examples include stretching and Yoga.

2.2.2.4 Isometrics – This form of exercise involves muscles engaging enough resistance to prevent movement. It aids the body in developing correct muscle tone. These exercises are not time consuming and require little to no equipment. However, they play no role in either muscular or cardiovascular endurance. Isometrics provide strength to the body's core and develops balance and proprioception. Examples include heel-to-toe walking, Tai chi and Stalk Standing.

Aerobic exercise improves the body’s usage of oxygen and often takes place at average levels of intensity over longer periods. These sessions include warm-up, exercising and cool-down. These exercises target large muscle groups. Anaerobic exercise does not use the body’s oxygen for energy. This type of exercise is used to build power, strength and muscle mass. Anaerobic exercise is high intensity (e.g. weightlifting, sprinting, interval training etc.). All exercise is beneficial for the cardiorespiratory system, however anaerobic exercise is more effective in building muscle and improving strength.

Strength, endurance and power are the major parameters of muscular fitness. Many types of resistance training can be used to build muscle strength. Resistance equipment such as free weights, machines with stacked weights and even resistance bands can be used in an appropriate training regimen. Resistance training emphasizes both concentric and eccentric muscle actions that recruit multiple muscle groups. This technique of exercise is multi-joint and targets the major muscle groups of chest, shoulders, back, hips, legs, trunks and arms. Single-joint exercises isolate functionally important muscle groups such as abs, lumbar extensors, calves, hamstrings, quadriceps, biceps, etc. and should be included too.

Recent Phenomena

People have become more interested in exercise and its ability to increase health, well-being and longevity, than ever before (Schoenfeld 2013: 1). High intensity training and resistance training has become very popular in the fitness community. These are forms of functional fitness which are incorporated in our daily (Bellar *et al.* 2015: 315). The flourishing of popular interest in physical fitness practices can be seen daily. Activities such as jogging, cycling, walking, yoga, weight training etc. increasingly occupy many people’s daily activities. Modern popular exercise activities are the response to the corporeal inertia of society (Hitchings and Latham 2017: 300).

2.2.3 Muscle Adaptation to Exercise

The duration and intensity with which a muscle is used will determine its properties. There are two types of muscular atrophy that occur. When neurons to the skeletal muscle are damaged, the neuromuscular junction is broken and the muscle becomes denervated, decreases in size and also decreases the amount of contractile proteins present. This is termed denervation atrophy. When the nerve supply is intact but the muscle is not being used regularly it is termed disuse atrophy. A lack of neuronal stimulation or usage not only desensitizes the nerves but also decreases the muscle mass. This can be avoided with exercise, which is known to cause hypertrophy of the muscle and an increase in the ATP activity.

Low intensity, high duration exercise allows for increased mitochondria in the muscle fibres that are recruited for this activity and increases blood supply. These alterations increase endurance with minimum fatigue. Endurance exercise not only benefits skeletal muscle, but also the cardiorespiratory systems, allowing increased fuel to the muscles.

Short-duration, high intensity exercise such as weightlifting affects the fast-twitch fibres recruited during strong contractions. These fibres cause hypertrophy due to satellite cells which increase actin and myosin synthesis, causing increased numbers of myofibrils. Glycolytic activity spikes due to increased glycolytic enzyme synthesis. These alterations cause an increase in strength and the bulge of muscles in a conditioned weight trainer.

Exercise has little effect on the types of myosin enzymes that the fibres form and therefore a small change in the number of fast and slow fibres in a muscle. Exercise does play a role in the rate at which metabolic enzymes are synthesized and therefore influences the amount of oxidative and glycolytic fibres present. The signals responsible for all these changes are associated with the frequency and intensity of the contraction of the muscle as well as the pattern of action potential bursts and tension produced in the muscle over prolonged periods. There are multiple neural and chemical factors involved with this signalling, however insulin-like growth factor-1 plays a lead role.

The strength and endurance of a muscle is dependent on the type of training activity that the individual is incurring. Most exercises aid both strength and endurance. These changes in muscle occur slowly over a period of weeks. When regular exercise is stopped, the changes that occurred will reverse and the muscle will revert to its original state. As individuals get older, their muscle’s strength and endurance diminishes due to the lack of physical exercise as well as the muscles’ ability to adapt at an older age. Therefore, the same intensity and endurance of exercise in an older adult will not produce the same alterations as a young adult. The effect of aging is partial and can be regulated. Strength training, even at a minimal level can prevent the loss of muscle mass that occurs with aging. More importantly it will maintain bone strength and lubrication of joints.

When an individual performs extensive exercise after not using their muscles for a prolonged period of time, soreness occurs due to the structural damage and inflammatory process. The body releases substances such as histamine to protect itself. The soreness is due to lengthened contractions, indicating that the external force was greater than the tension produced internally. Lowering weights at a steady pace will cause more soreness than rapid movements, therefore most strength gains during weightlifting is due to eccentric contraction (Widmaier, Raff and Strang 2011: 273-274).

2.2.4 Muscle Injury

A muscle injury or lesion is defined as the "loss of functionality of the muscle caused by damage, more or less severe, on a level of muscular structure or on a level of anatomical sites assigned to transmit strength". This allows for the understanding that a muscle injury cannot have loss of function without structural damage as the two are interconnected. Muscle injury is one of the most recurring traumatic injuries that occur in sports. These injuries range from simple strains to complete muscle tears (De Souza 2015: 34). Pain, swelling, deformity and point tenderness are some of the most common signs and symptoms that present immediately at the sight of injury (Page 1995: 30)

Hypotheses of onset of muscular damage

There is no one specific cause of muscle injury and damage. There are two working hypotheses, one based on physical overload and the other on metabolic changes. These two hypotheses often coexist (De Souza 2015: 42).

2.2.4.1 The Hypotheses of Physical Overload

The possibility of physical damage can be divided into two subcategories. The first is the mechanical factors that occur within skeletal muscle and elicit and overload response, and the second is the change in intramuscular temperature during different phases of muscle activity.

a) The Hypotheses of Physical Type: The Theory of Mechanical Factors

This theory is based on the eccentric contraction that occurs during muscle activity. Skeletal muscle is defined as flexible and can incur a great deal of stress and elongation. However, structural weakness can occur at a certain point.

During muscle activity there is a cycle of contraction and relaxation. During the contraction phase the muscle gives way to the tensile forces acting on it to allow for movement. When the tensile forces acting on the muscle are greater than strength, the maximum flexibility and endurance of the skeletal muscle (the “max theoretical stress value” (MTSV)) is reached. When the tensile force overtake the amount of stress that the muscle can endure, the MSTV is overcome and structural damage occurs. This results in an irreversible lesion in the muscle fibre being formed (De Souza 2015: 43).

Mechanical damage will not occur with one single overload but rather with repetitive overuse over a long period of time. The relationship between the flexibility of the muscle and the stress to which it is exposed increases, as does the contraction and relaxation cycle, resulting in increased rate of muscle fatigue (De Souza 2015: 44).

Energy is absorbed by the muscle during the eccentric contraction to carry out the movement. This energy is then emitted through heat or plastic deformation. The plastic deformation results in permanent structural damage that begins with one single point of weakness and ends with complete muscle failure (De Souza 2015: 44).

b) The Hypotheses of Physical Type: Increased Temperature and Muscle Damage

There is an intramuscular temperature difference during muscular negative work and positive work. Boning, Maassen and Steinach (2017: 204) explain that the terms negative work and positive work refer to the composition of ATP during the muscular activity. Negative work results in minimal ATP splitting when compared to the large amount of ATP split during positive work. The rise in temperature increases the risk of structural damage by 50%. The temperature difference results in degradation of the cellular membrane. Although there is an increase in temperature to carry out the muscle activity, the concern is the lack of ability to disperse this heat during eccentric contractions.

Metabolic heat is produced and disposed of through various structures in the human body. This heat is transferred throughout the body by the circulatory system. In response, a cooling effect occurs from the skin. During eccentric contraction, episodic vasoconstriction occurs, limiting the body's ability to transport the produced heat and disperse of it timeously and efficiently. Thus, the great amount of heat produced during negative work is due to the degradation of heat caused by the enhanced vasoconstriction mechanism.

2.2.4.2 The Metabolic Hypotheses: The Role of Insufficient Mitochondrial Respiration

During the course of exercise, the rate of mitochondrial respiration is high along with the synthesis and hydrolysis of ATP. With moderate exercise, the muscle fibres manage to regulate the levels of ATP. During intense and prolonged exercise, the levels of ATP are constantly reduced, causing a muscular lesion. This deficit causes fatigue within the muscle and increases the predisposition for major muscle damage. Decreased mitochondrial respiration in the muscle fibre is the first step toward muscle damage (De Souza 2015: 50).

Biochemical Changes in Muscle Injury

The biochemical markers serum creatine kinase (CK) and lactate dehydrogenase (LDH) enzyme levels are used to monitor muscle damage following eccentric exercises. These markers indicate that an inflammatory response is taking place within the muscle. This fundamental inflammatory response is the body's way to protect itself, to localize and remove injurious structures, and to allow for healing and repair. Histamine, bradykinin, prostaglandin and serotonin are other chemical mediators that surface with inflammation. Their function is to increase capillary permeability, alter blood vessel diameter and stimulate pain receptors. Oedema settles secondary to increased permeability due to the accumulation of fluid and transudate in the interstitial space.

Acute inflammation will continue for three to four days following injury unless the injured tissue has not been given the chance to rest (continuous stretching and usage). This is commonly seen in athletes who cannot afford to have time lost for healing and return to training before complete recovery and progress too rapidly. With continuous use of the injured tissue there is proliferation of fibroblasts, increased collagen production, and degradation of the mature collagen, causing weakening of the muscle. This creates an irritation and limitation which causes chronic strains in the near future. When inflammation subsides, the repair phase will soon begin. This is characterized by increased capillarity and fibroblastic growth to form immature collagen. The immature collagen is delicate and can be easily injured. However, with correct rehabilitation such as tensile loading, this collagen can become strong and complete the muscle repair (Page 1995: 31).

2.2.4.3 Muscle Fatigue

Skeletal muscles can be repeatedly stimulated, reducing their tension even though the stimulation continues. This decrease in contractile ability is known as muscle fatigue. Fatigued muscles have decreased velocity of shortening and slower rates of recovery. Muscle fatigability is dependent on the duration, intensity, fitness level and muscle fibre that is active. When the muscle is given the opportunity to rest after fatigue, it will be ready to contract again upon re-stimulation. Recovery depends on intensity and duration of activity that causes the fatigue. Some muscle are capable of being fatigued and recover quickly. This is seen in high-intensity, short duration exercise such as weightlifting.

2.2.4.4 Types of muscle injury

Injuries vary based on the mechanism of injury. Musculoskeletal injury can be categorized by the cause (Wilson 2002: 3, 4):

a) Traumatic Injury

Macro-trauma: These injuries are due to a clear precipitating event. This event usually involves the stress placed on the tissue being greater than the load-bearing capacity of the tissue, causing failure. The onset of injury presents immediate pain and subsequent symptoms. Traumatic injury can occur due to impact (e.g. a motor vehicle accident), a sudden and unexpected increase in musculoskeletal load (e.g. loss of balance while carrying a heavy object) and attempting to bear a load greater than what the musculoskeletal tolerance allows. This results in acute injury with tissue failure to some degree.

Minor Trauma: these injuries are also caused by a clear precipitating event, however, the event is not of sufficient magnitude to explain the extent of injury. These injuries are due to activities that are done frequently without causing injury.

It provides repetitive strain on areas of the body that eventually result in tissue failure over a longer period. An example would be an overuse injury. Minor Trauma injuries can lead to dysfunction and complications with recovery if not treated correctly, since the cause of injury or predisposing factors are unknown.

b) Insidious Injury

Insidious injuries have no clear cause and can be acute, sub-acute or chronic. Insidious injuries are more dangerous than traumatic injuries because the healing process is not functioning at full capacity as with traumatic injury. These injuries can either stabilize at a level of dysfunction or continue to get worse based on the nature of treatment provided. Insidious injuries will constantly be exposed to musculoskeletal stressors affecting their recovery time.

c) Muscle Strains

A muscle strain can vary between minor muscle strain with minimal damage and a major muscle strain with complete loss of function. This will depend on the degree of fibre damage within the muscle. Strains can be categorized into three degrees:

1. First Degree: minute separation of muscle fibres.
2. Second Degree: partial tearing of some fibres.
3. Third Degree: complete rupture or tendon avulsion.

Partial or incomplete tears occur more commonly and present focal pain and swelling. Full thickness tears do occur but are less common. With these, a palpable bulge or gap will be noted at the point of injury (Page 1995: 31).

2.3 WEIGHTLIFTING

Weightlifting is a form of resistance training that could include both free weights or a weight stack, and the act of lifting these weights. In the late 80s and 90s, South Africa (SA) had master weight lifters but did not have the correct society to maintain them. Weightlifting has become more popular in SA following the CrossFit trend (Graber 2017: 1-5). International credibility was regained in 2015 when Koos Henning placing 6th at the World Masters Weightlifting Championships (WMWC). He created the weightlifting society in the form of South African Masters Weightlifting Federation (SAMWF). In 2016, SA made an impact in World Weightlifting as 13 of its top master weight lifters competed in the WMWC. Within a year SA's master weight lifters went from being average trainers at their gyms to attaining a place among the world's elite athletes, continuing to grow (Henning 2016).

There are two major movements included in weightlifting. These are known as the "snatch" and the "clean and jerk". These two movements are a series of steps which involve high intensity muscular contractions. During these lifts, weight lifters produce power outputs that are unmatched by any other athletes (Storey and Smith 2012: 770).

2.3.1 "The Snatch"

"The Snatch" is a continuous movement during which a weighted barbell is lifted from the floor to an overhead position using a wide grip. It has six phases:

1. The First Pull: extension of the lifter's knees allowing the barbell to be lifted off the floor, to a below knee level.
2. Transition Period (Double-Knee Bend): lifter's knees are re-bent to be positioned below the barbell and their trunk is in a near vertical position. This position allows the lifter to gain maximum force for the next step.
3. Second Pull: the lifter maximally accelerates the lifting of the barbell by shrugging their shoulders and extending their hips, knees and ankles. The velocity of the vertical barbell can range from 1.65m/sec-2.28m/sec. The bar reaches 60-80% of the lifter's height.
4. Turnover: the lifter begins to position their body underneath the barbell.

5. Catch: the barbell is then caught in a straight-arm overhead position whilst the knees and hips are flexed resulting in a full squat position.
6. Recovery: occurs as the lifter moves out of the full squat position into a standing position while maintaining the overhead barbell position.

The entire duration of the process is between 3-5 seconds.

Figure 2.5: The six phases of "The Snatch"

(Source: Storey and Smith 2012: 770-773)

2.3.2 "The Clean and Jerk"

According to Storey and Smith (2012:773), this is a two part lift that allows heavier weights to be lifted than during "The Snatch". "The Clean" involves raising the barbell off the floor, to the front of the shoulders in one continuous movement using a shoulder width grip. There a six phases to the clean. The first three (the first pull, transition and double pull) have the same mechanical principal. During the second pull of a clean vertical, velocities range from 0.88m/sec to 1.73m/sec and the barbell rises in the vertical plane range from 50-70% of the lifters height. The lifter initiates the turnover phase and the barbell is then caught and placed on their shoulders, and the descent occurs to obtain the full squat position in preparation for “The Jerk”.

“The Jerk” has its own six phases:

1. Start: the lifter and barbells are motionless.
2. Dip: lifter flexes at the knee and hips whilst the barbells are over the shoulders.
3. Jerk Drive: this occurs at the lowest portion of dip, where the barbell is accelerated to the vertical plane. During the transition, athletes are exposed to a downward force that is the equivalent to seventeen times their body mass. Outputs during this phase range between 2140 watts for a lifter under 56kg and 4786 W for a lifter greater than 105 kg.
4. Unsupported Split: at the end of the jerk drive, the barbell is lifted off the shoulders and the lifter’s feet leave the ground while there is no support under the bar.
5. Supported Split: this occurs once the lifter’s feet regain contact with the floor and the barbell is held overhead with fully extended arms. There is now support under the bar.
6. Recovery: the lifter is required to stand motionless with their feet parallel to one another.

The entire duration of the complete “Clean and Jerk” is 8-12 seconds.

Figure 2.6: The twelve phases of "The Clean and Jerk"

(Source: Storey and Smith 2012: 770-773)

Figure 2.6 depicts the twelve phases of the "CJ". These phases are: (a) first pull; (b) transition to the start of the second pull; (c) completion of the second pull; (d) turnover; (e) catch; (f) recovery from the clean; (g) start position of the jerk; (h) jerk dip; (i) jerk driver; (j) unsupported split under the bar; (k) supported split under the bar; and (l) recovery from the jerk.

According to Bousquet and Olsen (2018: 54-67), the high demand that these motions require and the increased degree of technical difficulty in performing these movements (Hedrick and Wada 2008: 32) require an assessment to be performed to ensure that correct movement patterns are occurring to limit the rate of injury.

Weightlifting is beneficial for both strength and resistance training. A decrease in the risk of osteopenia, sarcoidosis and low back pain occurs if the correct weight training techniques are used (Burke and Burke 2017: 1, 2). However, the repetitive high loading and overuse increases the prevalence of knee injury, hip pain, shoulder dislocations, disc bulges, as well as muscle and tendon injury (Aasa *et al*. 2016: 212; Jonassan *et al.* 2011: 1540-1545). According to Kinakin (2004: 1-7), dysfunctions are the most common injuries from improper training techniques.

Weight training dysfunctions are due to a lack of healing time. During preparation for a competition or daily training, weight lifters undergo micro-trauma to muscles, which is a small amount of damage that allows for regrowth and strength. If no resting period is allowed, there is macro-trauma causing damage that provides pain and prevents training (Kinakin 2004: 1). These injuries have a strong myofascial component. Myofascial injuries are one of the most common injuries experienced in professional and recreational sports. Major muscle injuries constitute between 10% and 55% of all injuries sustained by athletes depending on the sport code (Kerkhoffs and Servien 2014: 18). Therefore, it is important that these dysfunctions are dealt with urgently to give weight lifters the best training experience.

2.3.3 Weight Training Dysfunction

According to Kinakin (2004: 1-7), a weight training dysfunction is an event the causes an alteration in the body’s normal functioning, which in turn affects an individual’s performance during weight training. A dysfunction can occur from a variety of sources that are often overlooked for a long period of time. These dysfunctions are often due to lack of recuperation, causing repetitive micro-trauma which goes untreated for prolonged periods, leading macro-trauma. Macro-trauma affects muscles, joints, nerves and cause biochemical imbalances which all contribute to weight training dysfunction. One or more of these can present at the same time, causing difficulties such as pain, weakness and decreased joint movement during weight training. It is said that weight training exposes previous injuries that did not heal well.

Four Types of Dysfunction

a) Muscle Dysfunction

   This occurs when there is injury to the muscle fibres and the formation of scarred tissue has occurred. This results in muscular imbalances, shortened muscles and deconditioned muscles.

b) Joint Dysfunction

   This is when damage to the joint has occurred, resulting in abnormal movement, compression or separation of the joint.

c) Nerve Dysfunction

   In this case, the action potential of the nerve has been compromised due to compression or tension on the nerve. Changes in proprioception at the joint can affect muscle strength.

d) Biochemical Dysfunction

   This occurs due to overtraining or a deficiency in global nutrients, causing decreased strength and prolonging recovery time, leading to chronicity.

2.3.3.1 Muscle Dysfunction

This is the first step to weight training dysfunction. Muscle damage causes pain and weakness, which indicates inflammation. When the inflammation is mild it can resolve itself. However, when the inflammation is severe the body responds by producing adhesions or scar tissue. These adhesions are found beneath the muscles' sheath and the fascia, or between muscle fibres. The laying down of adhesions cause the muscle to lose its elasticity and viscosity, affecting its movement as well as implicating its role on the respective joint. This lack of mobility and stiffness causes increased inflammation resulting in a vicious cycle of long term wear and tear.

This fibrous adhesion pattern that is formed will limit the movement during training regimens. The athlete will constantly experience pain in the exact same spot. This is due to chronic inflammation. Taking a break from training will ease the pain and allow the inflammation to subside, but returning to training will restart the process. Fibrous adhesions limit movement and affect functionality, disabling maximum results during training. To break the cycle, all areas of adhesions must be identified and have soft tissue therapy applied to break down the adhesion. This will allow the muscle its best performance.

A second form of muscle dysfunction can be due to myofascial trigger points. These trigger points inhibit surrounding muscles and prevent normal movement patterns. Soft tissue therapy can be applied to trigger points to restore normal functioning.

(Kinakin 2004: 1-7)

2.3.3.2 Joint Dysfunction

This refers to the joint that the muscle crosses. If the trauma is mild, muscular dysfunction can occur without joint dysfunction. When the joint becomes compromised, the ligaments and tendons also experience injury due to the increased pressure they incur to stabilize the joint. Joint dysfunction can be divided into two groups: compression and tearing injuries. These can range from mild to severe, and recovery times depend on severity.

Weight Training Compression Injury

These injuries occur at the joint itself and affect the muscle crossing the joint. There is minimal tearing of tissues. If swelling is present, it is contained within the muscle capsule. The excessive stress and load-bearing experienced during weight training affects the mechano-receptors and nociceptors of the joint. This injury causes major damage to structures within the joint rather than in the muscles. Joints affected by weight training compression injuries are the ankles, knees and entire spine. The exercises that cause these injuries are heavy squats, deadlifts and standing shoulder presses. All these exercises apply a heavy downward force, causing compression of the joints involved. This compression alters the normal firing of joint receptors, thereby altering the tone and strength of surrounding muscles.

Weight Training Tearing Injury

These injuries affect multiple structures. It is the most common type of joint injury and occurs when the joint and its related structures become impaired through twisting or straining. Any exercise can result in a tearing injury, and any joint can be affected by this injury. Tearing injuries cause inflammation and weakness of muscles crossing the joint. The reflex inhibition that occurs in muscles causes muscle weakness. The muscles, ligaments and tendons that cross a joint provide its stability. When there is reflex inhibition of the muscle crossing a joint, the ligaments and tendons bear greater stress to provide stability. The muscle becomes shorter and contracts to try and aid stability as a protective mechanism to prevent further instability and damage. The severity of the injury and the time taken to receive proper treatment will determine the outcome. If improper treatment was obtained, the injured person will adapt to the weakness, and an imbalance will occur. The imbalance will result in secondary pain and weakness when the individual returns to training after the initial injury. Imbalances cause increased stress on other joints and muscles, and this can hamper training (Kinakin 2004: 1-7).

2.3.3.3 Nerve Dysfunction

A nerve that is stretched or compressed slightly can greatly impact the strength of the muscles that it innervates. When the nerve supply to a muscle becomes compromised, there is decreased strength of the muscle as well as pain. When the nerves from the spine to the muscles undergo any form of compression or tension, a visible decline is seen in performance of that muscle. This is an increased risk of injury if heaver weights are used. A minute amount of tension or compression is needed to alter the action potentials within a nerve and affect muscle function. Therefore, taking time off from training without addressing the underlying issue will not work. The individual will need a full examination. Then, with proper treatment and care, gains during training can be obtained.

2.3.3.4 Biochemical Dysfunction

Over-training with inadequate recuperation and nutrient deficiency causes a lack of global strength, which can result in chronic injury. Chronic stress due to over-training impairs normal adrenal production which presents as pain, weakness and the inability to respond to stress. Recovery time is based on the severity of dysfunction. Nutrient deficiencies are seen when there is too much repetition of the same meals. This is often seen in professional athletes. These diets comprise of more protein than fruit and vegetables, resulting in a deficit of certain vitamins and minerals.

The adrenal glands become stressed and do not have adequate nutrients to replenish the stores lost from excessive weight training and cardio work. Chronic stress and overtraining can create a condition called Relative Adrenal Insufficiency, where the adrenal gland fails to produce adequate secretions to meet the body's needs.

During hard training, the adrenal gland releases secretions via two different pathways: Adrenaline and Noradrenaline from the adrenal medulla, and cortisol and testosterone from the adrenal cortex. Adrenaline is secreted when there is known stress to the body, as in weight training. Noradrenaline is secreted when an unknown stress to the body occurs, as in a fight or flight response. The adrenal medulla requires cofactors for the production of both. If these hormones are not at optimum value, difficulty during training will be experienced. Pain and increased risk of injury can be expected (Kinakin 2004: 1-7).

2.3.4 Causes of Weight Training Dysfunction

Weight training dysfunctions can occur due to the following:

a) Poor lifting technique
This occurs due to lack of direct supervision or lack of knowledge. Little attention is paid to biomechanics, resulting in pain and injury.

b) Over-exertion
Ignoring the body's natural limitations and lifting heavier loads increase the risk of soft tissue damage and failure. This can lead to poor conditioning, geological deficits and poor technique.

c) Training too often
Muscles need resting periods so that hypertrophy can occur. When training takes place repetitively, especially of the same area, recovery does not take place. A lack of recovery leads to inflammation and adhesion formation.

d) Insufficient rest and recuperation
A lack of rest prevents the ability for muscle hypertrophy and the power to train hard at the next session. Personal stresses can affect recuperation and should be avoided.

e) Performing the same exercise repetitively
Training the same muscle in the same range of motion can cause dysfunctions within the muscle.

f) Injured areas that have not recovered fully

Training with an injury causes macro-trauma, increasing down time from training and recovery time. It also created dysfunction, which will need to be corrected before proper training is restarted.

2.4 THE ROLE OF HORMONES IN WEIGHT TRAINING

Numerous hormones play a significant role in muscle development. Intense resistance training causes an increase in hormone production for a few hours after training. The growth process is influenced by the activity of satellite cells and hormones. Maximizing these factors allows for optimum muscle growth and development. The three most important hormones are testosterone, insulin-like growth factor and growth hormones.

2.4.1 Testosterone

Testosterone is known for its role in muscle development and does so in a variety of ways. Testosterone increases protein synthesis when needed and decreases protein breakdown. It activates satellite cells and facilitates their effect on muscle tissue. The hormone also indirectly contributes to protein accretion by stimulating other anabolic hormones. These developments can be seen in the normal stages of development, but are magnified with resistance training. Men produce larger amounts of testosterone than the average female, and this why men are able to gain muscle mass much faster.

2.4.2 Insulin-like Growth Factor

This hormone has direct effects on performance during resistance training. There are many types of Insulin-like Growth Factor (IGF-1). Two of these types have a significant impact on muscle adaptation. One type of IGF-1 is released from the liver, and the second, called Mechano Growth Factor (MGF), is a muscle specific type that is activated by muscle contraction. MGF is seen as the primary IGF-1 in muscle development and acts in various ways, such as speeding up the rate of protein synthesis, activating satellite cells and increasing muscle calcium levels. MGF is sensitive to muscle damage, therefore metabolic stress can increase the amount of MGF.

2.4.3 Growth Hormone

Growth hormone, despite its name, plays a larger role in sourcing fat cells for fuel and incorporates the uptake of amino acids into the body's proteins. Hence, this hormone aims to reduce fat rather than gain muscle mass. The minor role that growth hormone plays in muscle–building is its development of a symbiotic relationship with IGF-1 and MGF and up-regulates the production of IGF-1. Given the importance of IGF-1 on protein synthesis, this up-regulation is needed in resistance training.

Due to the increasing popularity of weightlifting and the need to grow SA's local master weight lifters as per Graber (2017; 105), it is important for chiropractors to help this population group as best they can. Weight lifters experience repetitive strain on their spine and muscles frequently, causing a decreased recovery time (Kinakin 2004: 1). By performing a FMS™, each individual will be aware of their personal deficits and can implement precautionary measures when training. This will result in the prevention of injury, which then prevents weight lifters from taking time off to heal.

Weight lifters are expected to produce movements with a triad of high force development, high power output and contractile impulses (Firdaus, Kuan and Krasilshchikov 2018: 1, 2). From this triad, the impulse contractions cause repetitive eccentric contraction of the pectoralis major muscle. Rupture commonly occurs whilst lowering the barbell causing severe pain and dysfunction that could be avoided with proper screening and corrective actions (Kerkhoffs and Servien 2014:96).

Weightlifting is becoming more popular with both young and old (Storey and Smith 2012:782). However, it is predominantly popular among males, and this is the population group that undergoes all the hormonal changes mentioned above as well as experience more resistance training injuries such as sprains, strains and trunk injuries while weightlifting (McBride *et al*. 1999: 50; Quatman *et al*. 2009: 2061) Research needs to be done to ensure safe and effective training programmes are implemented (Storey and Smith 2012: 782). An increase in the weightlifting population results in a simultaneous increase the risk of injury (Burke *et al*. 2014:

216). The FMS™ can provide adequate information required by weight lifters to protect their bodies and improve their training regimen to prevent injury.

2.5 THE FUNCTIONAL MOVEMENT SCREEN™

2.5.1 The Purpose of the FMS™

The desire to be fit and healthy is very common in society. Both fitness enthusiasts and the average individual thrive on improving their flexibility, strength, power and endurance. However, individuals often perform their fitness activities incorrectly, eventually leading to injury and preventing them from achieving their personal fitness goals. The Functional Movement Screen™ (FMS™) was developed to identify dysfunction and weakness in one’s basic functional movements to help prevent the repetitive micro-trauma developing into a compensation pattern and thereafter serious injury and chronic pain (Perry and Koehle 2013: 458). This tool is cost-effective, instantaneous, non-invasive and user-friendly.

The FMS™ assesses trunk and core strength and stability, neuromuscular control, symmetry in motion and dynamic flexibility through seven basic exercises (Perry and Koehle 2013: 458). The quality of movement is measured using a quantitative scale that ensures correct movement patterns are being utilised to prevent overcompensation and dysfunction. The focus of the FMS™ is to correct movement patterns so that the correct muscles are being utilised and firing to produce a movement rather than the amount of weight being lifted or repetitions performed. The FMS™ can provide immediate feedback so that corrective actions can be implemented to prevent further injury (Perry and Koehle 2013: 458)

According to Cook, Burton and Hoogenboom (2006: 62-71) the FMS™ assesses an individual to find areas of weakness and thereafter uses this data to determine the risk of injury. Therefore, the FMS™ is used as a predictive tool based on each individual assessment, and personalised corrective actions are provided which may reduce the risk of injury. Functional movements for athletes should be assessed to gauge their progression and improvements to identify areas that need more attention. They should also be assessed during rehabilitation to monitor their healing and determine whether they are ready to return to training.

2.5.2 Principles of the FMS™

The FMS™ is a screening tool that identifies weak links in movement patterns and then aims to correct them to prevent injury. The FMS™ allows for individualized, specific, functional recommendations for fitness protocols based on an athlete’s requirements. The FMS™ aims to fill the gap between pre-participation and performance by allowing individuals to be assessed according to dynamic and functional capacity. The screen is comprised of seven basic movements that require a relatively significant amount of mobility and stability. The screen puts the individuals being tested into extreme positions so that even minor weakness or imbalances can be identified while the body tries to compensate, manipulate or stabilize areas of deficit. It has been said that athletes who are strong andcompete at high levels are unable to produce these movements correctly because of the compensatory mechanisms that their body has in place. These compensatory mechanisms try to protect the body from injury and elicit the desired movement at maximum force. When incorrect movement patterns are performed, poor biomechanics are developed and the potential of micro-trauma progressing to macro-trauma becomes greater.

The FMS™ tests work along the basis of proprioceptive and kinematic awareness principles. Each test is a unique movement that requires the body’s kinematic system to be intact to deliver the movement well. The kinetic link model which is used to assess movement describes the body as a linked system of interdependent segments. These segments often work from proximal to distal to produce a smooth, uninterrupted movement. If the kinematic chain is interrupted or injury occurs in a segment, other segments will compensate to produce movement, but will not be the correct process of activation.

Proprioception plays a significant role in the screen too. Proprioception is the sensory modality that allows the body to interpret the sensation of joint movement and joint position sense. Proprioceptors in each aspect of the kinematic chain must function optimally to ensure that sensory innervation is processed efficiently to produce effective joint movement that results in perfect movement patterns.

With age, the proximal to distal movement starts losing its efficiency and reverses itself, causing a distal to proximal movement regression. This regression occurs as individuals become accustomed to certain activities, habits or training techniques (Cook, Burton and Hoogenboom 2006: 62-71)

2.5.3 Scoring the FMS™

When an individual is scored using the FMS™, four possible scores can be granted. The scores range from zero to three, three being the best possible score (Cook, Burton and Hoogenboom 2006: 62-71). According to Cook *et al*. (2010: 85), the scoring is as follows:

- 0- Immediate pain upon initiation of the movement pattern of the exercise with complete inability to perform the movement pattern of the exercise. A referral to a healthcare practitioner is suggested.
- 1- Unable to complete the movement pattern of the exercise.
- 2- Able to perform or complete the movement pattern of exercise with compensatory movement present.
- 3- Unquestioned ability to perform the movement pattern of the exercise.

The majority of the FMS™ tests will test both the left and right side. The lower of the two sides will be recorded and is counted towards to the total score. The score of both left and right sides allows the accessor to identify or confirm any imbalances noticed. The lowest scores will be recorded and considered when tallying the total score. The highest total score that one can achieve on the FMS™ is twenty one. (Cook, Burton and Hoogenboom 2006: 65)

2.5.4 Components of the FMS™

The FMS™ aims to measuring the balance between stability and mobility, and this is done by placing the individual in positions that are basic, manipulative and stabilizing. These positions allow areas of weakness, imbalance, asymmetry and limitation to be clearly observed.

The FMS™ can resemble athletic movements, but is not utilised as a training tool nor as a competitive tool. Its sole purpose is to rate and rank efficiency of movement. The user-friendliness of the tool allows performance and durability to be assessed in an effortless manner. The tool was not designed to identify the cause of dysfunction, but rather to highlight the dysfunctional pattern.

Many individuals are able to carry out daily activities but unable to efficiently perform the FMS™. This is due to the use of compensation, which allows the movement to be carried out but not in the correct way. If compensation continues, dysfunctional patterns are reinforced causing altered biomechanics which could eventually cause overuse injury.

The FMS™ consists of seven movements which require a balance between balance and stability to produce perfect movement. These movements are as follows, according to Cook *et al*. (2010: 90-103) (The scoring criteria for each of these movements can be seen in Appendix K):

1. Deep Squat
   Purpose: Performing a deep squat occurs in functional movements throughout the day, but in a more basic variation. By performing this regularly, we are constantly engaging our core stability and extremity mobility whilst our hips and shoulders are in symmetric functioning positions. When performed properly, extremity mobility, postural control as well as pelvic and core stability are all engaged. This movement tests total body mechanics and neuromuscular control. It is used to test bilateral, symmetrical, functional mobility and stability of the hips, knees and ankles. For the purpose of the screen, ensuring that the proper movement occurs, the individual will hold a dowel stick (135.5cm in length) overhead. This assesses the bilateral symmetry of the shoulders, scapular and thoracic spine. Pelvic and core stability must be obtained throughout the movement to create the perfect movement pattern.
   Description: the individual must assume the correct position before carrying out any movement. The individual's feet must be shoulder width apart, facing forward in the sagittal plane. The dowel stick must be held overhead with elbows at 90°. Next, the individual extends their elbows, allowing the shoulders to be flexed and adducted, resulting in the dowel overhead. Once the upper extremity positioning has been completed, the individual should lower themselves into the squat position as close as possible to the ground. The heels of the foot should be firmly on the ground, with the chin up, and the chest and head facing forward. The dowel then reaches a maximum overhead position. If this movement cannot be carried out, the individual can

repeat the movement with the aid of a 15.5cm wide and 147.5cm long wooden board under their heels (Cook *et al.* 2010: 90).

Figure 2.7: The deep squat

(Source: Lui 2009)

2. Hurdle Step

   Purpose: although stepping as high as a hurdle is not common throughout people's daily activities, the hurdle step exposes weakness seen in stepping motions. It is an important part of locomotion and acceleration. It assesses stride and step mechanics whilst observing stability and control of the single leg stance.

   Co-ordination and stability needs to occur due to the asymmetrical movement of the hips, with one bearing the load of the body and the other moving freely. Pelvic and core stability must be engaged throughout the movement pattern to ensure perfect movement.

   For the purposes of this screen, the arms will be still and a dowel held across the shoulders, allowing an observation of the upper extremity and trunk. Excessive upper body movement during stepping is known as compensation. The Hurdle Step tests bilateral mobility and stability of the hips, knees and ankles, as well as pelvic and core stability.

Description: the correct position starts with the individual placing their feet together against the wooden base of the hurdle, which is made up of two vertical beams (59.5cm) and a rubber band. Once this position is obtained, the researcher then adjusts the rubber band to the height of the individual's tibial tuberosity. Next, the dowel is placed behind the neck to rest on top of the shoulders. The individual must now step over the hurdle with one limb, the stepping limb, and complete this motion by touching the heel to the ground on the other side of the hurdle. The stepping limb must now be returned to the starting position and the process repeated with the opposite limb. The test will be done on both right and left limbs and the lower score on both sides will be recorded (Cook *et al*. 2010: 92).

Figure 2.8: The hurdle step

(Source: Lui 2009)

3. The Inline Lunge

Purpose: the inline lunge assesses the deceleration and direction changes needed in sports, activity and exercise. It assesses complex movements bilaterally. The narrow base tests starting core and pelvic stability with dynamic testing of the hip sharing the load.

The lower extremities are in a split stance position whilst the upper extremities are in an opposite pattern throughout movement. The counterbalance that the opposing limbs creates helps stabilise the spine. This test challenges hip, knee, ankle and foot stability, including the flexibility of multi-articular muscles.

Description: this movement begins with a measurement of the length of the individual’s tibia. This is obtained whilst the individual is standing. The researcher uses a tape measure to mark the distance between the tibial tuberosity and the floor. The individual must then take up the correct starting position: the hind foot is placed on the edge of the wooden board that is closest. This is now the planted foot. The measured distance of the tibia is marked from the toes of the planted foot on the board. A dowel stick is held behind the back, against the head, thoracic spine and sacrum. The hand that holds the cranial aspect of the dowel is opposite the lunge leg and vice versa. The lunge motion is then initiated with the heel of the lunge leg on the marked point. The planted leg is now flexed at the knee joint, such that the knee touches the board and then extends back into the starting position. The dowel must be in contact with the body throughout movement, and the heel of the hind foot must stay firmly planted onto the board. Both right and left sides will be assessed, and the lower score on either side will be recorded (Cook *et al.* 2010: 94).

Figure 2.9: The in-line lunge

(Source: Lui 2009)

4. Shoulder Mobility

Purpose: the movement during this test activates the natural rhythm of the scapula in co-ordination with the thoracic spine and rib cage during shared upper extremity movements. The full range of motion is not seen in normal daily activities. However, each segment is used to reach the range of motion required for the activity. There is very little room for compensation. The cervical spine, the associated musculature and the thoracic spine should be in a neutral position before proper upper extremity movement can occur. This movement assesses the bilateral shoulder range of motion and extension, internal and adduction in one extremity and flexion, external rotation and adduction in the other.

Description: before any activity begins, the length of the individual's hand needs to be obtained. This is done by measuring the point of the distal wrist crease to the tip of the third digit. The individual will then be asked to make fists with the thumbs enclosed and keep this position throughout the movement, ensuring that the fists are in contact with the spine. Next, the shoulder must be adducted, internally rotated and extended maximally while the opposite shoulder is adducted, externally rotated and flexed maximally. When the movement is carried out correctly, the distance between the two fists will be equal to the initial hand length. If the distance is increased, it implies poor mobility, and if it is decreased it implies hypermobility. The test will be done on both right and left sides with the lowest score recorded on either side (Cook *et al*. 2010: 97).

Figure 2.10: Shoulder mobility

(Source: Lui 2009)

5. Active Straight Leg Raise

   Purpose: this test identifies the individual’s ability to maintain core stability, hip extension and hip flexion of the opposite hip. Its purpose is to assess the separation of the lower extremities in an unloaded position. When multi-articular muscle flexibility is lost, this ability is reduced.

   Description: the individual lies supine on the floor, with their arms by their sides and the palms facing upwards. A board is placed under their knees. Both feet should be in a neutral position with soles perpendicular to the floor. A point midway between the anterior superior iliac spine (ASIS) and the joint line of the knee is marked and a dowel is placed vertically there. The test limb is extended while maintaining the position of the knee and ankle. Throughout movement, the knee of the opposite leg should remain in the neutral position. The position of the medial malleolus of the test leg in comparison to the dowel is observed. The perfect movement would be if the medial malleolus is beyond the dowel and over the ASIS (Cook *et al.* 2010: 98).

Figure 2.11: Active straight leg raise

(Source: Lui 2009)

6. Trunk Stability

   Purpose: this test allows us to assess core stability and does not measure upper extremity strength. It tests the stability of the spine in the sagittal plane during a closed kinematic chain. The goal is to initiate movement with the use of the upper extremities and core while not engage the spine or hips at all. Rotation of the trunk and extension of the spine are compensatory patterns that occur easily with this test.

   Description: the individual is prone with arms shoulder width apart and overhead. This is the starting position. Men and women have different starting positions. Men will be prone with arms at the top of their heads, thumbs and forehead aligned. Women assume the prone position, arms overhead with thumbs at chin level. Knees are fully extended, ankles are in a neutral position and the soles of the feet are perpendicular to the ground. A push-up will be performed. If a straight lower back is maintained the movement is done correctly. If the push-up cannot be performed, the hands can be moved to the level of the clavicle (Cook *et al*. 2010: 100).

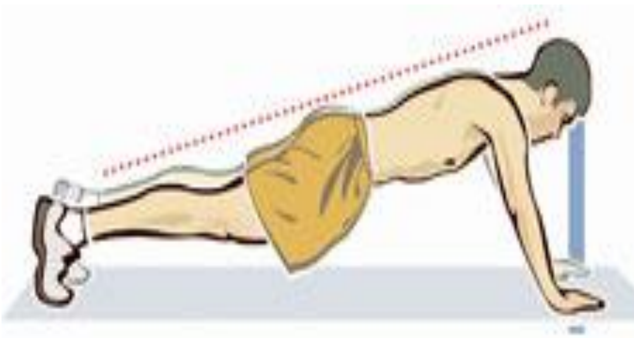


Figure 2.12: Trunk stability

(Source: Lui 2009)

7. Rotatory Stability

Purpose: this test is a combination of co-ordination between upper and lower extremity, highlighting multi-plane pelvic, core and shoulder stability. The motion is complex and requires proper neuromuscular control and energy transfer throughout the body. Reflex stabilisation and weight shifting in the transverse plane as well as co-ordinated efforts of mobility and stability are the two purposes of this test.

Description: For the starting position, the individual assumes the quadruped position with the hips and shoulders at 90°. The ankles are in a neutral position, with the soles of the feet perpendicular to the ground and knees resting at 90° on the ground. The test is then to flex the shoulder girdle, extend the elbow and the wrist out in front of them on one side, and to extend the hip and knee while maintaining the neutral position of the ankle behind them on the same side. The arm and leg is displaced 15cm off the ground. The shoulder of the raised arm is extended and the elbow, hip and knee joint flexed, allowing the elbow and the knee to touch on the same side. If this movement cannot be performed, a diagonal pattern of raising opposite arm and leg may be performed. The test will be done on both right and left sides, with the lowest score on either side recorded (Cook *et al.* 2010: 102).

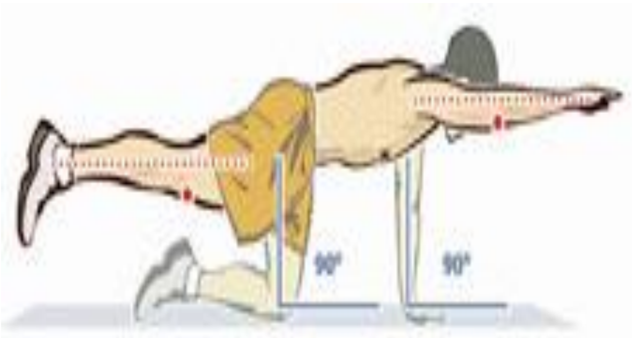


Figure 2.13: Rotatory stability

(Source: Lui 2009)

8. Clearing Tests

When performing the FMS™, three of the seven exercises have clearing exams accompanying them. These tests are not done for scoring purposes, but to identify pain by ensuring that the body part being tested is put into the utmost susceptible position. These exams are only marked with a positive (+) if there is pain. The score for the exercise to which the particular exam is related will then receive zero, irrespective of the total score. Clearing exams are performed after the exercise has been completed (Cook *et al.* 2010: 96,100,102). The clearing exams are as follows:

8.1 Shoulder Mobility Clearing Exam

The participant is asked to place their palm onto the opposite shoulder and to lift their elbow as high as possible. This indicates if there is any impingement that has been missed by the shoulder mobility test.

Active Scapular Stability (Shoulder Clearing Test)

Figure 2.14: Shoulder clearing exam

(Source: Cook *et al.* 2010: 97)

8.2 Spinal Extension Exam

A trunk stability push-up is cleared with the participant pressing up from their push-up position.

Spinal Extension Test

Figure 2.15: Spinal extension clearing exam

(Source: Cook *et al.* 2010: 100)

8.3 Spinal Flexion Clearing Exam

The participant is cleared from the rotatory stability by asking them to rest their buttocks onto their heels and to extend both arms forward as far as possible before coming out of the quadruped position.

Figure 2.16: Spinal extension clearing exam

(Source: Cook *et al.* 2010: 102)

2.4.5 The FMS™ as a Predictor of Injury

The FMS™ is a common tool utilised throughout various aspects of the sports industry to ensure players perform efficiently and prevent injury. It is a series of basic exercises that one would use in their normal training regimen and normal daily activities (Cook *et al*. 2014: 23). These exercises aim to expose the individual's muscle imbalances, areas of weakness and dysfunctions that can predispose them to injury or have caused injury previously (Cook *et al*. 2014: 87). The test is performed in a controlled environment in which participants can be scored from zero to three. A score of zero indicates immediate pain upon exertion, where further medical investigation is required. A score of one indicates the inability to complete the movement due to pain. Two indicates the completion of the movement with compensatory mechanisms, and three indicates completion of the movement with no pain or compensation (Cook *et al*. 2010: 85). Each sport code has a mean score that is calculated from participants without injury. A score lower than the mean value has been indicative of possible injury. It is an easily administered tool that does not pose an economic burden on those being tested (Frost *et al*. 2015: 324-330).

The purposes of the FMS™ is to establish a qualitative movement standard to identify individuals at risk for possible injury, to create balanced and effective personal training protocols to fit an individual's deficits and to monitor progress in a rehabilitation program (Cook *et al*. 2014: 23, 31). It aims to improve movement quality by ensuring that movements are done with the correct posture and muscle activation thereby improving movement quantity.

Kiesel *et al*. (2007:150) performed a study on football players, pre- season and post season testing. The results indicated that those who scored 14 out of 21 or less on the FMS™ had a 15% chance of injury occurrence in pre-season testing. Post-season, the results increased to 51%, indicating that overuse injuries occur more commonly than noted. Measures can be put in place to correct imbalances and weakness due to injuries to keep players fit and healthy throughout the season.

Bushman *et al*. (2015: 297) stated that when soldiers were asked to perform the FMS™ tests they excelled due to their level of fitness. The normative value for the screen will vary per group being tested and will need to be discussed and reported accordingly. There were positive results showing that soldiers who scored less than 14 had an almost twice as high risk of overuse and traumatic injuries. Those that scored between 15 and 21 were not at risk of injury. A score of 19 to 21 indicates the highest level of fitness, supporting the fact that the FMS™ can predict sport injury and act as a preventative tool. However, the sensitivity and positive predictive values (PPV) can be improved.

Jooste (2014: 36) indicates that although the studies show great reliability in many sport codes, the sample sizes that were evaluated in this particular study and the sensitivity was not large and high enough. The FMS™ failed to be predictive in the female premier hockey league, showing that there is a contrast and a gap in the literature that needs to be explored further.

The FMS™ has yet to be used in the weightlifting community in the eThekwini Municipality. Weightlifting is described as a high loading sport and can cause weight lifters to incur a great deal of knee injuries, hip pain, shoulder dislocations and disc bulges (Jonassan *et al*. 2011: 1540-1545). It is a sport that requires both dynamic strength and power. If either are not balanced, a risk for injury arises. Weightlifting at a competitive level comprises of two full body lifts, meaning that the upper and lower extremity is strengthened simultaneously (Suchomel, Comfort and Stone 2015:823-824) The two full body lifts are the “Snatch” and the “Clean and Jerk” (“CJ”). The “Snatch” consists of lifting the weighted barbell off the floor with a wide grip to an overhead position in a continuous motion. The “CJ” involves lifting the barbell off the floor with a shoulder width grip to the front of the shoulders in one smooth movement, following through with a barbell push over the top of the head. Weight lifters regularly incur overuse injuries due to excessive exertion of their muscles and increased stress on their joints (Storey and Smith 2012: 782).

The exercises performed in the FMS™ are very similar to exercises performed by weight lifters like the deep squat, the line lunge and the hurdle step. This screening tool can correct the irregularities seen in muscles and posture and improve their performance (Cook *et al*. 2014: 400-406). Weight lifters can be taught corrective actions immediately and can perform them every day while they undergo their daily training routine. This is convenient for the patient and practitioner who need not worry about the patient’s compliance. Should chiropractors provide this option, it would mean discovering preventative measures for weight lifters as well as improve the literature on the FMS™.

Letafatkar *et al*. (2015: 22, 26) indicates that muscular imbalances and deficits are often missed in traditional assessment methods, but can be identified using the FMS™. Prevention of injury is more likely when the FMS™ is performed prior to a sudden increase in the level of activity. In this study, the FMS™ was performed on athletes at the Kharazmi University. Athletes included those that had participated in soccer, handball and basketball for five years. Those with low scores were shown to be 4.7 times more likely to sustain injury to the lower extremity.

Weightlifting is becoming more popular with both young and old. Research needs to be done to ensure safe and effective training programmes are implemented (Storey and Smith 2012: 782). An increase in the weightlifting population results in a simultaneous increase in injury risks (Burke *et al*. 2014:216) The FMS™ can provide the adequate information required by weight lifters to protect their bodies as well as improve their training regimen and prevent injury.

The increase in interest of weightlifting and the continuous need for people to be healthy and live better lives suggests that chiropractors need to learn more about this industry to ensure that we can better aid these types of patients by performing the FMS™, weightlifters can use their personalised score to improve themselves and track progression, as well as note areas of deficit and weakness and take precautionary measures towards this to prevent injury.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss the research design, sampling method, research procedure, measurement tools and the statistical analysis. This will allow further insight into how the normative value for weight lifters in the eThekwini Municipality was obtained.

3.2 RESEARCH DESIGN

This study design is a mixed methods approach (Creswell 2015: 1-22) of an experimental qualitative nature involving 89 male participants (Esterhuizen 2019) that provided permission to be studied. The study was conducted in local gyms once permission had been granted from gym managers (Appendix A). All participants were asked to complete each of the seven tests of the FMS™ and were scored using the FMS™ scoring criteria (Appendix K) on the FMS™ score sheet out of 3 for each individual exercise (Appendix H). The participants performed the once in their gyms. Due to the Covid-19 pandemic the country faced a nationwide lockdown and an amendment had to be made to this study to allow for telephonic interviews to be conducted instead of re-meeting participants to allow them to answer the participant questionnaire (Appendix I) Following the telephonic interview, a brief case history in the form of a questionnaire (Appendix I), indicating whether they had sustained injury previously, during the duration of the study, or not at all. Once all participants completed their tests and questionnaires, a total score was calculated out of 21 (Appendix H). The normative value for this study population was determined and an association between FMS™ scores and each injury profile (from the correlating completed questionnaire) was made. Those at risk of injury were provided with appropriate preventative strategies.

3.3 SAMPLING

The Letter of Information and Consent was requested from all gym managers in which the FMS™ was conducted (Appendix A). Once this permission was obtained, all participants signed and accepted their own Letters of Information and Consent (Appendix B and Appendix C respectively) and therefore became eligible to participate in this study.

3.4 SAMPLE SIZE

All the individuals approached, and those who volunteered, agreed to participate and meet the inclusion criteria. The total sample was 88 male weight lifters was the minimum requirement for the study to be statistically significant. Group sample sizes of 13 and 75 achieve 82,118% power to reject the null hypothesis of equal means when the population mean difference is μ1 - μ2 = -2,0 - 0,1 = -2,1 with a standard deviation for both groups of 2,4 and with a significance level (alpha) of 0,050 using a two-sided two-sample equal-variance t-test. The software used was PASS version 12 (Appendix G) (Esterhuzen 2019).

3.4.1 Inclusion Criteria

The inclusion criteria were as follows:

- Individuals will only be included if they signed the Letter of Information and Informed consent (Appendix B and Appendix C).
- Individuals will have to be male weight lifters aged between 20 and 50 years of age (McBride *et al.* 1999).
- Individuals must have two years of training experience (Storey and Smith 2012).
- Both previously injured and non-injured candidates will be included to allow a comparison in scores to be made (Jonasson *et al.* 2011: 1540-1546)
- Weight lifters that are training in the eThekwini Municipality in KwaZulu-Natal only.

3.4.2 Exclusion Criteria

The exclusion criteria were as follows:

- Individuals who presented with pain from current injury (Jooste 2014: 39).
- Individuals currently receiving treatment for previous injuries, as this could alter results.

3.5 PROCEDURE

3.5.1 Research Procedure

The managers at 10 local gyms were contacted to gain permission to conduct the study on their gym premises (Appendix A). Once managers had agreed to meet the researcher, the researcher then travelled to each gym and obtained a signed Gatekeeper Permission Letter. Having received all 10 signed Gatekeeper Permission Letters, the researcher submitted them to IREC and received full ethical clearance. Data collection then commenced.

A focus group was held at the DUT Chiropractic Board room on 06 February 2020 for selected professionals to review the questionnaire. After the discussions and careful thought the researcher formulated the final questionnaire(Appendix I) based on the advice given.

Following their signed permission, the researcher visited the 10 local gyms in Durban, KwaZulu-Natal and placed advertisements in their gyms (Appendix D), encouraging weight lifters to partake in the upcoming study.

The FMS™ was then set up within an enclosed space and conducted prior to the participant’s regular training regimen.

Each individual who had agreed to participate and signed all relevant documents, i.e. the letter of information and consent Appendix B and Appendix C respectively, performed the series of exercises (pre-screen) and was scored by the researcher using the FMS™ scoring criteria (Appendix K), between 0-3, on the FMS™ score sheet (Appendix H).

0. Immediate pain upon initiation of the movement pattern of the exercise with complete inability to perform the movement pattern of the exercise, referral to a health care practitioner is suggested.
1. Unable to complete the movement pattern of the exercise.
2. Able to perform or complete the movement pattern of exercise with compensatory movement present.
3. Unquestioned ability to perform the movement pattern of the exercise (Cook *et al.* 2010: 81)

Scores were recorded on the FMS™ score sheet (Appendix H) and a mean score for each weight lifter was noted.

Following the initial assessment, the participants were asked to note any injuries that they incurred from weight training

Each participant was contacted telephonically after a period of nine months due to the national lockdown and IREC amendment approval and asked to answer the participant questionnaire (Appendix I)

the questionnaire enquired about the participant's demographics as well as how long they had been training and any injuries sustained previously from weightlifting and those sustained during the duration of the study from weightlifting.Participants whose scores and history were indicative of injury were informed of their risk and provided with preventative strategies to improve movement patterns and prevent further injury

Participants who had sustained injuries during the duration of the study were given a treatment voucher from the DUT Chiropractic Day Clinic, which were valid for one year from the date of issue (Appendix J). The purpose of this voucher was to ensure that participants receive adequate treatment and rehabilitation for their injuries and to promote the DUT Chiropractic Day Clinic.

Analysis of the questionnaires and FMS™ scores were made by the researcher and a statistician to determine the FMS™ normative values and its association to injury profiles of weight lifters in the eThekwini Municipality.

The layout and necessary component of the methodology were according to Creswell (2015: 1-22) and Hesse-Biber (2010: 3-6).

3.5.2 What is the Functional Movement Screen™?

The FMS™ is a screening tool aimed at predicting injury which comprises of seven exercises. Each of these exercises aim to isolate a single area of deficit. The participants are asked to perform the test in a controlled environment where the researcher can score them accordingly. If the individual cannot complete the screening test they are scored a zero for that entire section, and the maximum that they could score was 21.

3.5.3 The Scoring System

The screen consists of several tests, such as a Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and a Rotatory Stability Test. The participant will perform these tests and will be scored from 0-3 using the FMS™ scoring criteria (Appendix K) for each test resulting in a total out of 21. The scores are indicative as follows:

0. Immediate pain upon initiation of the movement pattern of the exercise with complete inability to perform the movement pattern of the exercise, referral to a health care practitioner is suggested.
1. Unable to complete the movement pattern of the exercise.
2. Able to perform or complete the movement pattern of exercise with compensatory movement present.
3. Unquestioned ability to perform the movement pattern of the exercise.

The highest that a participant can score is 21 and the lowest being 0 (Cook *et al*. 2010: 81).

The exercises are as follows:

For any of the seven tests, if pain is noted the following should occur:

The athlete receives a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area (Cook *et al*. 2015:373-379).

3.5.3.1 The Deep Squat

The purpose of the deep squat is to demonstrate extremity mobility and core stability due to the hips and shoulders functioning in a symmetrical pattern. The deep squat challenges total body biomechanics and neuromuscular control when performed correctly. The deep squat is scored according to the FMS™ scoring criteria as follows:

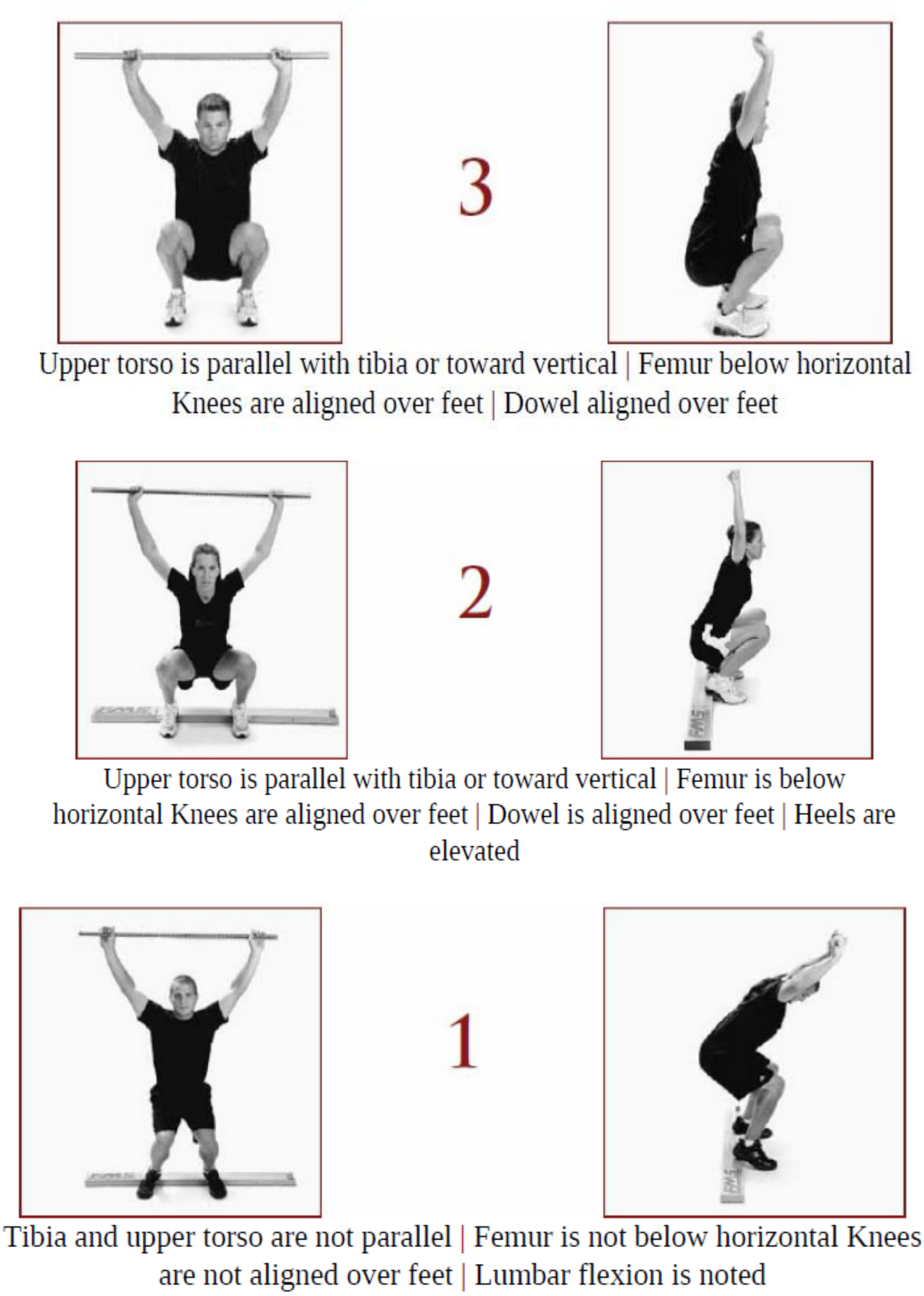


Figure 3.1: FMS™ scoring criteria - deep squat

(Source: Cook *et al.* 2015: 373)

3.5.3.2 The Hurdle Step

This aims to assess locomotion and acceleration. It allows exposure of compensatory movement patterns in stepping functions. The Hurdle Step tests the stability and control of the hips, knees and ankles. The Hurdle Step is scored according to the FMS™ scoring criteria as follows:

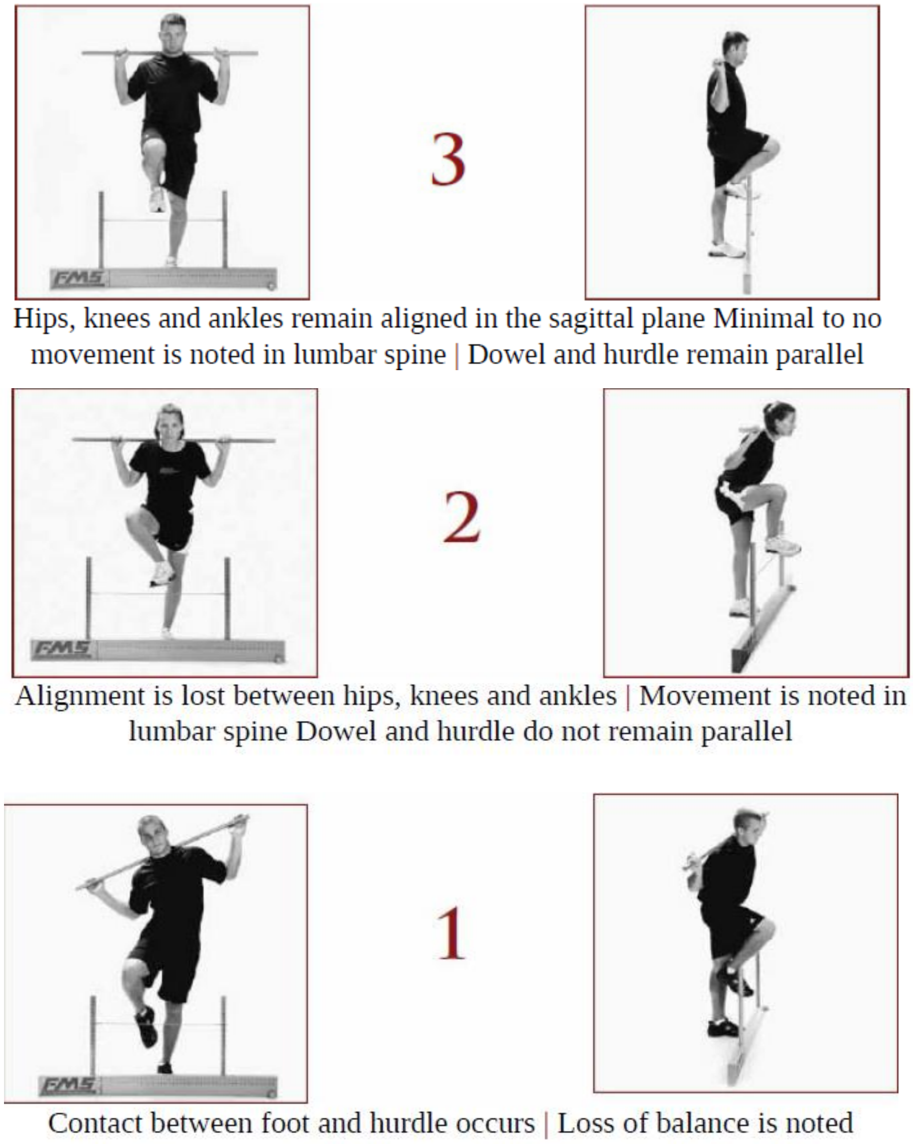


Figure 3.2: FMS™ scoring criteria - hurdle step

(Source: Cook *et al.* 2015: 374)

3.5.3.3. Inline Lunge:

This exercise demonstrates a deceleration and change in direction during exercise, activity and sport. This movement simulates the balance needed between the upper and lower extremities as it uniquely acquires spine stabilization. The Inline Lunge is scored according to the FMS™ scoring criteria as follows:

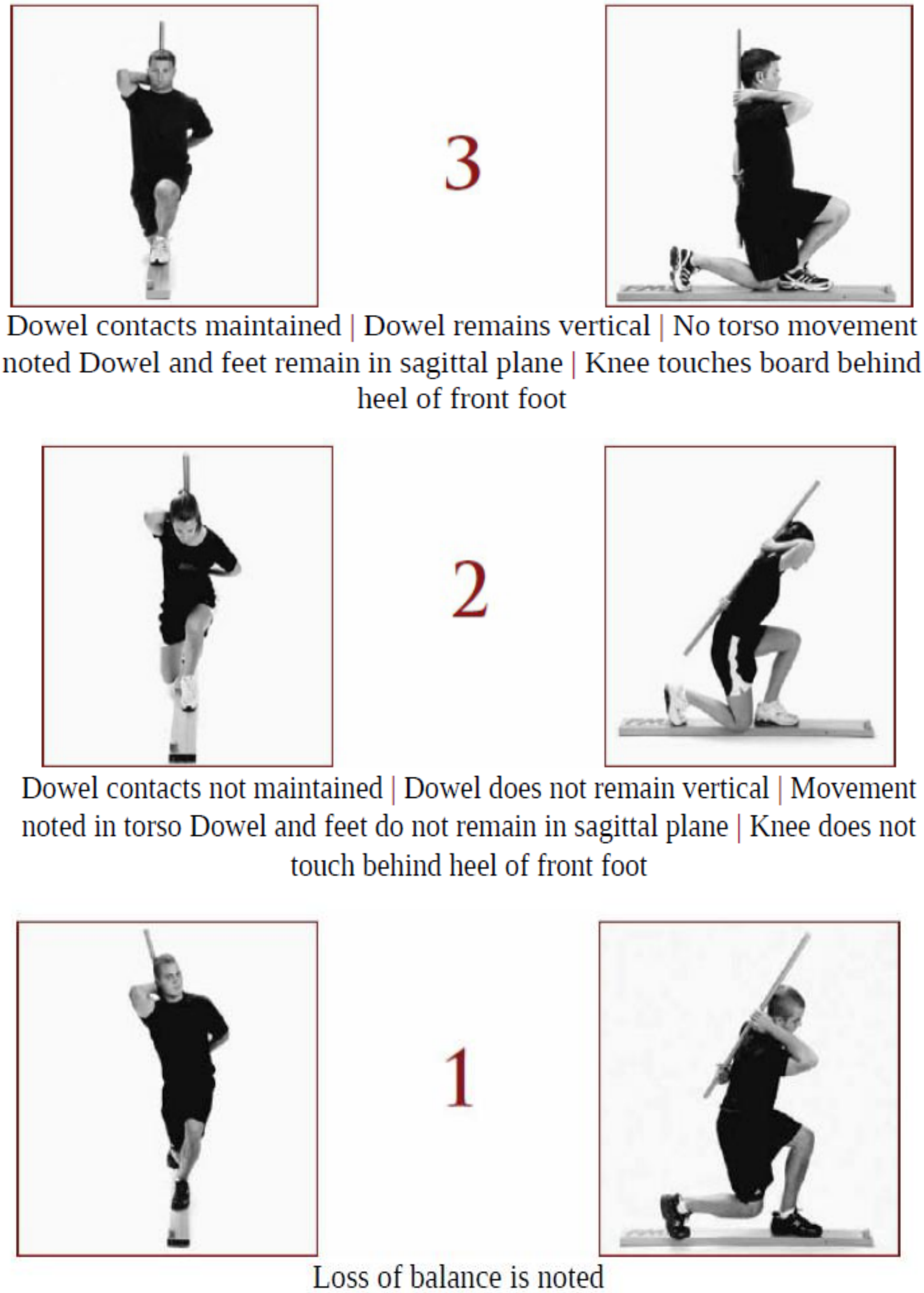


Figure 3.3: FMS™ scoring criteria - inline lunge

(Source: Cook *et al.* 2015: 375)

3.5.3.4 Shoulder Mobility

This demonstrates the normal rhythm obtained between the scapula-thoracic region, thoracic spine and rib cage during upper extremity shoulder movements. It uses a segmental approach, leaving little room for compensation. The Shoulder Mobility is scored according to the FMS™ Scoring Criteria as follows:

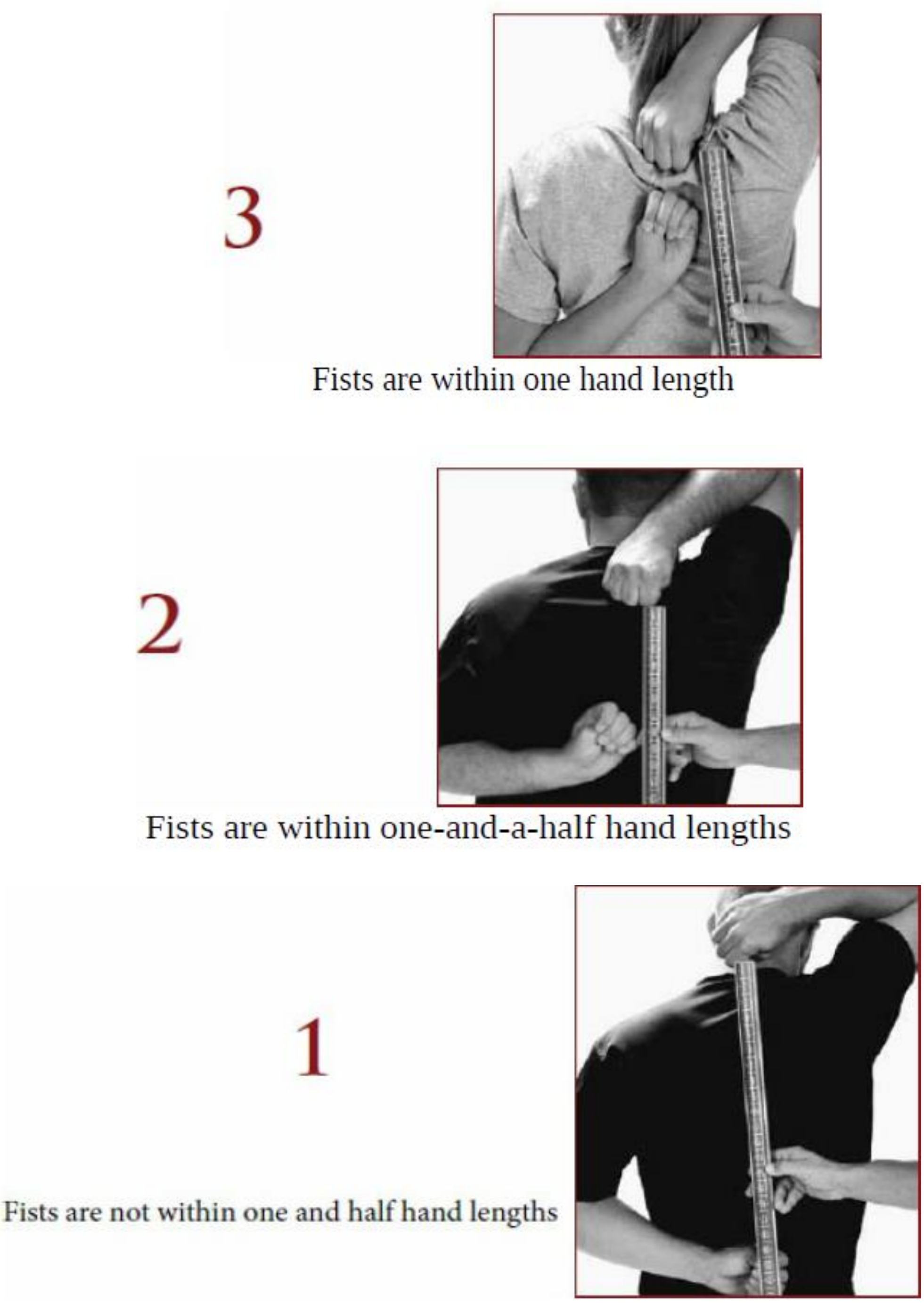


Figure 3.4: FMS™ scoring criteria - shoulder mobility

(Source: Cook *et al*. 2015: 376)

CLEARING TEST

Perform this clearing test bilaterally. If the individual does receive a positive score, document both scores for future reference. If there is pain associated with this movement, give a score of zero and perform a thorough evaluation of the shoulder or refer out.

Figure 3.4.1: Shoulder clearing test

(Source: Cook *et al.* 2015: 376)

3.5.3.5 Active Straight Leg Raise

This pattern identifies the active mobility of a flexed hip whilst assessing the core stability and hip extension of the contralateral hip. A challenge is created to isolate the lower extremity while maintaining pelvic and core stability.

The Active Straight Leg Raise is scored according to the FMS™ scoring criteria as follows:

3

Vertical line of the malleolus resides between mid-thigh and ASIS The non-moving limb remains in neutral position

2

Vertical line of the malleolus resides between mid-thigh and joint line The non-moving limb remains in neutral position

1

Vertical line of the malleolus resides below joint line The non-moving limb remains in neutral position

Figure 3.5: FMS™ scoring criteria - active straight leg raise

(Source: Cook *et al.* 2015: 377)

3.5.3.6 Trunk Stability Push-Up

The goal is to achieve movement of the upper extremities without engaging the spine or the hips. The two common compensation movements seen are extension and rotation. The Trunk Stability Push-Up is scored according to the FMS™ scoring criteria as follows:

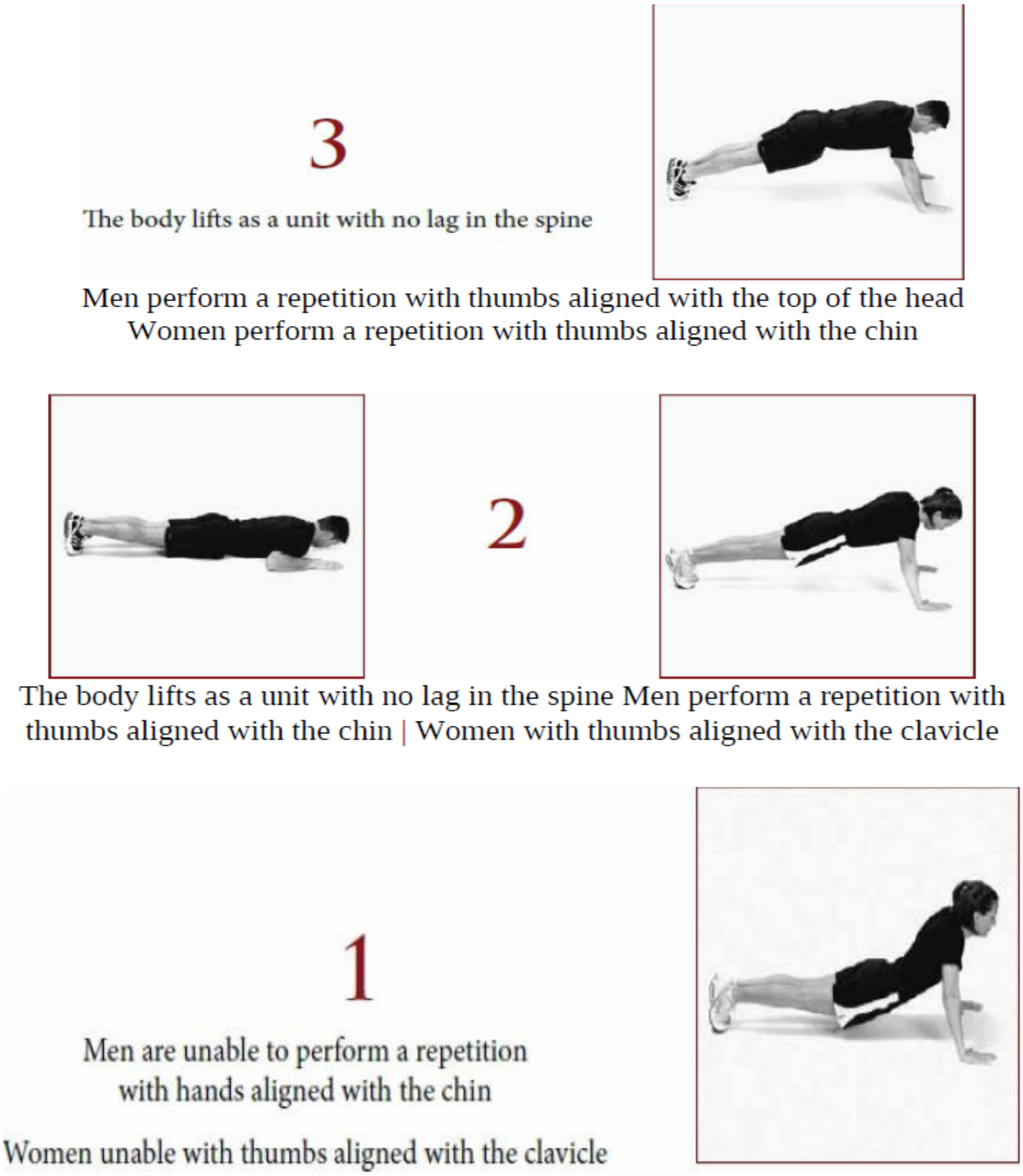


Figure 3.6: FMS™ scoring criteria - trunk stability push-up

(Source: Cook *et al.* 2015: 378)

SPINAL EXTENSION CLEARING TEST

Spinal extension is cleared by performing a press-up in the pushup position. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual does receive a positive score, document both scores for future reference.

Figure 3.6.1: Spinal extension clearing test

(Source: Cook *et al*. 2015: 378)

3.5.3.7 Rotatory Stability

This is a multi-plane exercise. Rotatory stability is quite complex and requires proper neuromuscular co-ordination and energy transfer through the torso. The Rotatory Stability is scored according to the FMS™ scoring criteria as follows:

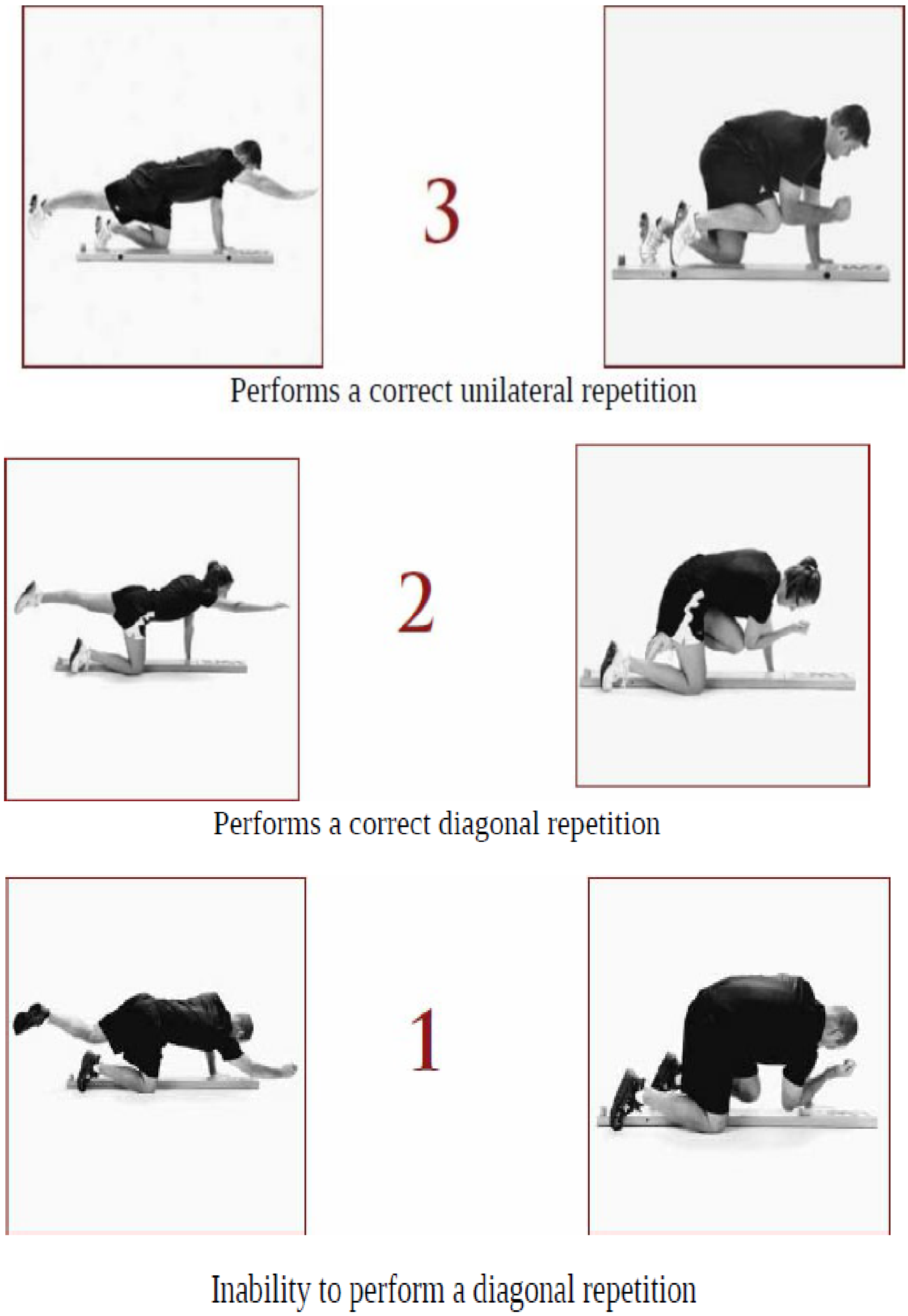
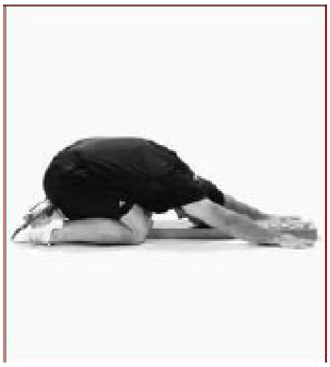


Figure 3.7: FMS™ scoring criteria-rotatory stability

(Source: Cook *et al.* 2015: 379)



SPINAL FLEXION CLEARING TEST

Spinal flexion can be cleared by first assuming a quadruped position, then rocking back and touching the buttocks to the heels and the chest to the thighs. The hands should remain in front of the body, reaching out as far as possible. If there is pain associated with this motion, give a zero and perform a more thorough evaluation or refer out. If the individual receives a positive score, document both scores for future reference.

Figure 3.7.1: Spinal flexion clearing test

(Source: Cook *et al.* 2015: 379)

3.5.4 Weightlifters' Injury Questionnaire

The injury questionnaire (Appendix I) provides a brief case history of any injury that the weight lifter has sustained prior to the study or during the four week duration between the Pre- and Post-Screenings.

3.5.5 Measurement Tools

FMS™ Kit comprised of the following (Cook *et al.* 2015: 88):

1 x wooden dowel (135.5cm);

1 x 15.5cm x 147.5 cm wooden board;

1 x hurdle (two vertical wooden beams (59.5cm) and rubber band); and

1 x measuring tape (1m).

3.5.6 Statistical Analysis

IBM SPSS version 27 will be used to analyse the data.

To determine the normative value, the normally-distributed data was presented with means, ranges and standard deviations. Where the distribution is skewed, medians and inter-quartile ranges were used. Categorical data is displayed as frequencies and percentages.

The association between FMS™ scores and injury was analysed using a *p* value of less than 0.05, which is considered statistically significant. Pearson's chi squared tests and correlation coefficients, as well as ANOVA, t-tests and Fisher's exact tests were used to assess associations between risk factors and injury prevalence. Scores of the components of the FMS™ were compared with injury susceptibility using non-parametric Mann-Whitney tests since the scores are ordinal and not normally distributed (Esterhuizen 2019).

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

This chapter presents the results from the research conducted. The information will be displayed in the form of tables and graphical representations with a brief analysis of the data findings. The results were obtained from the data collected to determine the normative value of the FMS™ in weight lifters in participating gyms (within the eThekwini Municipality) and its association to injury from the participant questionnaire (Appendix I).

To answer the research question and achieve the objectives a primary analysis using IBM SPSS version 27 was used. A *p* value of < 0.05 was regarded as statistically significant. The statistics produced from this analysis was summarised into the form of means and standard deviations to describe continuous data and frequency counts, and percentages were used to describe categorical data. Using the FMS™, the normative values to a 95% interval, standard deviation and a 95% reference range was calculated (Esterhuizen 2020).

Using the t-test, the association between FMS™ score and the categorical variables were assessed, and the Pearson's correlation analysis assessed the relationship between the FMS™ score and continuous variables (Lakin 2010: 105-121).

4.2 METHODOLOGICAL FLOW

The following flow diagram is a summary of the procedure that was followed to obtain the required results for this study.

Figure 4.1: Methodological flow diagram

4.3 RESPONSE RATE

The table below depicts the response rate as a percentage.

Table 4.1: Response rate

Total Population	**97**
Sample available for research	97
Minimum sample size	88
Total responses	89
Usable response rate	91.75%

A total of 10 gyms were approached within different areas of the eThekwini Municipality and gatekeeper's permission obtained to conduct research on their premises. These areas were Glenwood, Musgrave, Berea, Durban North, Morning Side and Riverside. Of these 10 gyms, 97 participants volunteered to partake in the study at 8 of the gyms. The initial FMS™ assessment was conducted on all 97 participants at their gyms respectively. Participants were asked for their contact details so that they could be contacted for the follow up assessment. Due to the Coronavirus pandemic and the President's announcement of a national lockdown, telephonic interviews were conducted for the participants to complete the questionnaire (Appendix I). Telephone numbers were obtained from all participants, however, only 89 participants responded to the phone calls and were willing to perform the telephonic interview. Thereafter, data was captured from the initial assessment in conjunction with the telephonic interview from the 89 participants, and an analysis of data was made.

4.4 DEMOGRAPHICS

A total of 89 weight lifters (n=89) were included in this sample from 7 gyms. A maximum number of 25 participants were recruited in Gym A and a minimum number of participants were recruited from Gym C. The age of participants varied from 21 to 50, with a mean age of 33. Regarding participant height, the variance was from 1.5m to 1.98m. The mean height was 1.77m. The weight range was between 54kg and 155kg, with a mean weight of 90kg. Participants have been training from a minimum of 2 years and a maximum of 34 years. The mean age for the number of years' training is 8.2. The above mentioned information is depicted in the forms of tables below.

Table 4.2: Participant demographics

	Mean	Standard Deviation	Minimum	Maximum
Age (years)	33	8	21	50
Height (metres)	1.77	.10	1.50	1.98
Weight (kilograms)	90	19	54	155
Number of years training	8.2	7.5	2.0	34.0

Table 4.3: Number of participants per participating gym

Gym		Frequency	Percent
Valid	A	25	28.1
	B	10	11.2
	C	7	7.9
	D	18	20.2
	E	8	9.0
	F	13	14.6
	G	8	9.0
	Total	89	100.0

4.5 FMS™ SCORES

The FMS™ parameters were scored and the total score was analysed to determine a normative value for weight lifters within the eThekwini Municipality. The score was normally distributed with a mean of 13.88 and a standard deviation of 2.4. Participants' scores ranged between 9 and 19 with no participant scoring a perfect score of 21. The mean score was 13.88. Therefore, the normative value of the

FMS™ in weight lifters in the participating gyms within the eThekwini Municipality is 13.88.

The 95% Confidence interval (CI) as well as the 90% and 95% reference ranges are shown in the graphical presentations below. The 95% CI was 13.37-14.38, which means that there is 95% certainty that the true population mean lies between these values. The 95% reference range was 10-18.75. This means that 95% of the sample values lay between these two values. Values outside this range constitute 5% of the sample and are therefore not considered as "normal values".

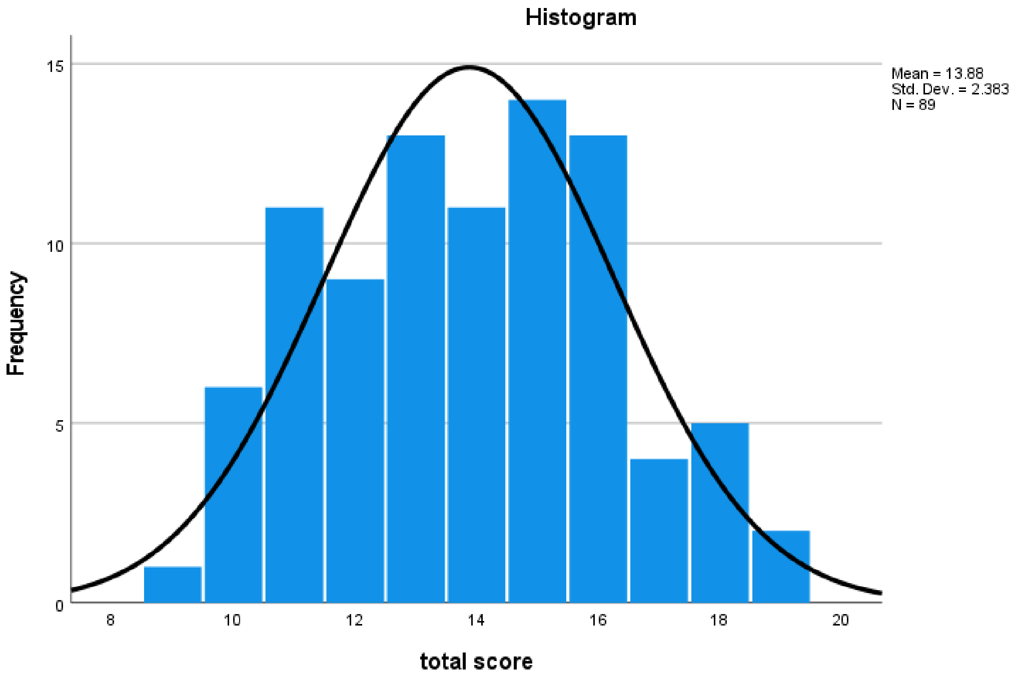


Figure 4.2: Histogram demonstrating participants FMS™ scores

Table 4.4: Mean, minimum and maximum FMS™ scores

			Statistic
Total score	Mean		13.88
	95% Confidence Interval for Mean	Lower Bound	13.37
		Upper Bound	14.38
	5% Trimmed Mean		13.85
	Median		14.00
	Variance		5.678
	Std. Deviation		2.383
	Minimum		9
	Maximum		19
	Range		10
	Interquartile Range		4
	5th percentile		10
	95th percentile		18
	2.5th percentile		10
	97.5th percentile		18.75

4.6 ANALYSIS OF MOVEMENT PATTERNS OF WEIGHTLIFTERS ACCORDING TO THE FMS™

Each participant was scored from 1 to 3 based on how well they performed the exercises. Certain exercises required a score to be allocated to the right and left side, and the lower of the two scores was used as the final score for that exercise (Cook *et al*. 2010: 155). The table below displays the number of people who scored in each category and the percentage reflects the percentage of the total sample that those participants represent.

Table 4.5: Number of participants and score achieved per FMS™ exercise

	1		2		3	
	Count	Row N %	Count	Row N %	Count	Row N %
deep squat	31	34.8%	39	43.8%	19	21.3%
hurdle step left	10	11.2%	69	77.5%	10	11.2%
hurdle step right	10	11.4%	65	73.9%	13	14.8%
in line lunge left	18	20.2%	49	55.1%	22	24.7%
in line lunge right	16	18.0%	54	60.7%	19	21.3%
ASLR left	18	20.2%	51	57.3%	20	22.5%
ASLR right	16	18.0%	55	61.8%	18	20.2%
SMT left	40	44.9%	29	32.6%	20	22.5%
SMT right	24	27.3%	45	51.1%	19	21.6%
SMCT left	34	38.2%	44	49.4%	11	12.4%
SMCT right	29	32.6%	50	56.2%	10	11.2%
TSPU	5	5.6%	34	38.2%	50	56.2%
ECT	15	16.9%	56	62.9%	18	20.2%
QRST left	19	21.3%	40	44.9%	30	33.7%
QRST right	20	22.5%	39	43.8%	30	33.7%
FCT	24	27.0%	48	53.9%	17	19.1%

4.7 INJURY PREVALENCE AND PROFILE

The sample population consisted of 89 participants, and of this 89 only 35 participants had been injured. All 35 participants had obtained injury prior to the study. There were no injuries noted during the course of the study.

The 24 participants reported only one previous injury, while 11 participants reported having two previous injuries, and only one participant had three previous injuries.

Concerning the participants that incurred one and two previous injuries, most occurred in the shoulder first and thereafter an injury to the knee. The participant that experienced three previous injuries had experienced injury to the ankle and foot.

Participants were asked about the injury type that they experienced in their previous injuries, and the most common injury type was muscle injury.

The participants were asked to describe how long ago the injury occurred, how long the injury lasted, the severity of injury and what treatment option they used to treat them. Most injuries occurred 3 months prior to the study and lasted a period of three months. They were rated a 7 out of 10 on the numerical pain rating scale with 0 being no pain and 10 being maximum severity of pain. Most participants received physiotherapy or no treatment at all for their injuries.

The above mentioned information is displayed in tables below.

Table 4.6: Number of participants who obtained previous injuries

Injuries number		Frequency	Percent
Valid	0	54	60.7
	1	24	27.0
	2	11	11.2
	3	1	1.1
	Total	89	100.0

Table 4.7: Percentage of area of injury for each previous injury

		Count	Column N %
Injury 1: Area	Neck	1	2.9%
	Shoulder	19	54.3%
	Elbow	1	2.9%
	Hand and Wrist	1	2.9%
	Back	2	5.7%
	Chest	1	2.9%
	Hip	2	5.7%
	Knee	6	17.1%
	Ankle and Foot	2	5.7%
Injury 2: Area	Shoulder	3	27.3%
	Elbow	1	9.1%
	Hand and Wrist	2	18.2%
	Chest	1	9.1%
	Hip	1	9.1%
	Knee	3	27.3%
Injury 3: Area	Ankle and Foot	1	100.0%

Table 4.8: Percentage of injury type for each injury obtained

		Count	Column N %
Injury 1: Type	Muscle	17	48.6%
	Joint	5	14.3%
	Bone	5	14.3%
	Ligament	6	17.1%
	Tendon	2	5.7%
Injury 2: type	Muscle	6	54.5%
	Joint	3	27.3%
	Bone	1	9.1%
	Ligament	1	9.1%
Injury 3: Type	Bone	1	100.0%

Table 4.9: How long ago injuries were obtained in months

	Median	Percentile 25	Percentile 75
Injury 1: How long ago (months)	3.0	1.0	9.0
Injury 2: How Long ago (months)	2	1	6
Injury 3: How long ago (months)	1	1	1

Table 4.10: How long injuries lasted in months

	Median	Percentile 25	Percentile 75
Injury 1: Duration (months)	3.0	1.0	12.0
Injury 2: duration (months)	3	1	6
Injury 3: Duration (months)	3	3	3

Table 4.11 Participants perception of severity of injury

	Median	Percentile 25	Percentile 75
Injury 1: Severity	7	6	8
Injury 2: Severity	7	4	9
Injury 3: Severity	8	8	8

Table 4.12 Treatment received for Injuries

		Count	Column N %
Injury 1: treatment	None	9	25.7%
	General Practitioner	5	14.3%
	Chiropractor	7	20.0%
	Physiotherapist	12	34.3%
	Biokineticist	2	5.8%
Injury 2: Treatment	None	4	36.4%
	General Practitioner	2	18.2%
	Chiropractor	1	9.1%
	Physiotherapist	4	36.4%
	Biokineticist	0	0.0%
Injury 3: Treatment	None	1	100.0%
	General Practitioner	0	0.0%
	Chiropractor	0	0.0%
	Physiotherapist	0	0.0%
	Biokineticist	0	0.0%

4.8 THE ASSOCIATION BETWEEN FMS™ SCORE AND INJURY

The minor difference between the means of the FMS™ scores between those who had and those who didn't have a previous injury was noted. This difference was not statistically significant (p = 0.834). The estimate of the mean difference was 0.110 with a 95% confidence interval from -0.924 and 1.143 and with the injured population scoring 0.11 points higher than the non-injured population. Therefore, no association between the FMS™ score and the presence of previous injury can be made. The table below illustrates the group statistics of the entire sample population with injuries obtained, no injuries and FMS™ score.

Table 4.13: Group statistics revealing number of participants who obtained injury and their FMS™ and those that did not obtain injury and their FMS™ score

Group Statistics						
	Injury Obtained	N	Mean	Std. Deviation	Std. Error Mean	P value
Total score	No	54	13.83	2.238	.305	0.834
	Yes	35	13.94	2.623	.443	

There was no correlation made between age, height, weight, number of years' training and the FMS™ score. The table below shows the different statistical analyses that were completed to determine a correlation with their results.

Table 4.14: Analysis between FMS™ score and participant demographics using Pearson's correlation

Correlations		Total score
Age	Pearson Correlation	-.026
	Sig. (2-tailed)	.807
	N	89
Height	Pearson Correlation	-.138
	Sig. (2-tailed)	.198
	N	89
Weight	Pearson Correlation	-.091
	Sig. (2-tailed)	.397
	N	89
Number of years training	Pearson Correlation	-.104
	Sig. (2-tailed)	.333
	N	89

According to Esterhuizen (2020), the above information is statistically significant and has been analysed and assessed to obtain the desired results for this study.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

In this chapter, expansion on the graphical representation of data from Chapter Four and other necessary information will be discussed. The objectives of this study will be discussed with support from the literature covered in Chapter two.

5.2 OBJECTIVE ONE

5.2.1 Assessing the Movement Patterns of Weightlifters According to the FMS™

According to Storey and Smith (2012: 770-774), as discussed in Chapter two, weightlifting is an art of its own. The expectancy of weightlifters is unique due to the high peak forces and rate of force resulting in their altered movement patterns. Weightlifters need to obtain specialised techniques in order to achieve their goal; which is the completion of the “The Snatch and “The CJ” with the maximum desired weight.

These two primary movement of weightlifting can be broken down into the functional movements of the FMS™.

The squat is a basic movement in athletics and an integral part of weightlifting. It forms the basis of both “The Snatch” and the “CJ”. The squat is also a functional movement required in performing daily activities. The motion of the squat allows the athlete to propel themselves vertically and horizontally through space simultaneously. This allows for development for an athlete as it assess their muscle strength, endurance and balance.

The deep squat, which is what is required of weight lifters and is tested in the FMS™, is an advanced squat during which the hip crease is positioned below the top of the knee at the end of the movement if done correctly (Bousquet and Olsen 2018: 57).

According to Cook *et al.* (2010: 373) the ideal deep squat would be scored a value of 3 on the FMS™ scoring criteria. It requires the upper torso to be parallel with the tibia or toward vertical, the femur to be below horizontal, knees to be aligned over feet and the dowel (used for the FMS™ and resembles the similar act of holding barbell overhead) aligned over feet. From the data represented in Chapter four, 43.8% of participants scored a 2. This means that their upper torso is parallel with the tibia or toward vertical, that the femur is below horizontal, that the knees are aligned over feet, that the dowel is aligned over feet and that heels are elevated (Cook *et al.* 2010: 37).

During a deep squat, the objective is to keep the tibia as vertical as possible to avoid excessive tibiofemoral shear. This is taking into consideration the biomechanical perspective. However, when a weighted barbell is added to the deep squat, maintaining maximum tibial vertical position becomes more difficult and the athlete dorsiflexes their ankle to allow for compensation and ease of movement. If the deep squat is performed without adequate dorsiflexion, there will be increased flexion of the hips, lumbar spine and trunk as compensation. These compensations make the athlete more vulnerable to spinal injury. Although it may not be apparent to the athlete initially, the biomechanical issues described above demonstrate how a deep squat with incorrect compensation patterns can increase the risk of potential injury (Bousquet and Olsen 2018: 58-59).

The deep squat increases joint laxity, shear force and compressive force at the hip and knee. The FMS™ includes a hurdle step, an in-line lunge and an active straight leg raise. These three exercises assess both the hip and knee mobility and the ability to perform functional movements. A score of 2 was allocated to 77.5% (left) and 73.9% (right) of the total sample population for the hurdle step. 55.1 % (left) and 60.7 (right) scored 2 for the in-line lunge, and for active straight leg raise on the left, 57.3% (left) and 61.8% (right) scored a 2. Therefore, participants are not achieving ideal hip and knee movement and could be increasing their risk of injury.

The anterior translation seen at the tibiofemoral joint during a deep squat results in shearing forces at the knee. This shearing force is said to decrease as the squat depth increases due to the contraction of the quadriceps and hamstring musculature. The greatest shearing force is seen at the anterior cruciate ligament during flexion of 0° -60°. Compressive forces on the other hand at the tibiofemoral and patellofemoral joints are believed to increase as the squat depth increases.

Therefore, if injuries arise at the hip and knee during weightlifting movements they are more likely to be caused from soft tissue injury rather than bone injury. This is because soft tissue limits the flexibility and mobility of a joint (Bousquet and Olsen 2018: 60).

To complete both "The Snatch" and the "CJ", the athlete must move out of the squatting position and into an erect position to lift the barbell overhead. This requires shoulder stability and mobility. This cannot be undermined with regards to preventing injury. Scapulothoracic stability is necessary to create a stable base for glenohumeral joint function. The FMS™ includes a shoulder clearing test which assesses the scapula-thoracic movement. The results from this study showed that most participants scored a 2 on both the left and right hand sides. This indicates that their shoulder mobility is restricted to a certain degree and they may not be able to perform the shoulder mobility test correctly since the scapula-thoracic joint and shoulder complex need to work in conjunction to achieve perfect weightlifting movements. 44.9% of participants scored a 1 on the shoulder mobility test and 51.1% scored a 2.

The surrounding musculature of the shoulder joint can stabilise the shoulder complex with contributions from the acromioclavicular joint, sternoclavicular joint, the scapulothoracic articulation and the thoracic spine. Stability can be achieved since the biomechanical chain is a relay of movement to obtain a kinematic movement. Therefore, adequate stability in one joint can cause a relay of stability in the subsequent joints. The biomechanical chain described above must function optimally to achieve the desired range of motion to successfully perform "The Snatch" and the "CJ".

Although the biomechanical chain can provide stability to other joints to achieve desired movements, dysfunctions at one joint can also be relayed onto the biomechanical chain and lead to injury elsewhere. Shoulder injuries in a resistance sport such as weightlifting is well documented, and reduced shoulder flexion in conjunction with incorrect technique while training has been identified as a risk factor for this type of injury.

To complete “The Snatch” and the “CJ”, the shoulder provides the majority of the stabilisation. However, the wrist contributes significantly in a dual purpose by allowing the large range areas movement which is necessary for object manipulation, and, more importantly, it provides a stable base to withstand the large forces required to complete these lifts.

A trunk stability push-up is included in the FMS™ and allows for assessment of the strength of the wrist. In this study, 56.2% of the population scored a 3 for their trunk stability push-up, indicating that their wrist strength and mobility is ideal according the FMS™ criteria and their risk of wrist injury is minimal.

During weightlifting movements, the wrist adopts a hyperextended and compressed position known as the front rack position. This position contributes to the success they achieve in their sport because it allows them to better handle the excessive load and force applied on their joints (Bousquet and Olsen 2018: 63).

“The Snatch” and the “Clean and Jerk” allow for the development of muscle synchronization, co-ordination, power, speed and strength. These two movements require the athlete to move a weighted barbell from either their shoulder or ground to the overhead position. The lower extremity needs to assume the correct position and have adequate strength and mobility to support the movement. In the overhead position of “The Snatch” and the “CJ”, the shoulder joint complex, thoracic spine and wrist must form the perfect biomechanical chain to achieve the desired range of motion and limit the injury risk. Therefore, weightlifting uses both upper extremity and lower extremity, and the perfect dynamic between the two must exist to achieve the movements and reduce injury. The rotatory stability, flexion clearing and extension clearing tests allow for this dynamic to be assessed according to the FMS™. The results from this study show that most participants scored a 2 for each of those exercises respectfully. This indicates that dynamic stability can be improved on to reduce the risk of injury and improve movement patterns.

The FMS™ was able to assess each participant according to their mobility, stability, endurance, strength and motor control in a deconstructed manner that ultimately comes together as the two primary movements achieved during weightlifting. The FMS™ allowed the participants to note areas of weakness, imbalances and asymmetries. These mistakes predispose them to injury and can be avoided if correct training techniques are used. Participants are now aware of these areas and canfocus on them during training to reduce injury.

Athletes can also use this assessment to determine whether they are ready to return to training following an injury (Bousquet and Olsen 2018: 64-65).

5.3. OBJECTIVE TWO

5.3.1 Identifying the FMS™ Normative Value for Weightlifters in the eThekwini Municipality

The FMS™ was designed as a cost effective, user friendly, quick method to observe and analyse the movement patterns of individuals (Frost *et al*. 2015: 324). This allows any limitations, asymmetries in movement that can contribute to dysfunction and incorrect movement patterns to be identified. The FMS™ rates and ranks the movement patterns on a numerical scale to compare each individual against the ideal movement pattern (Cook *et al*. 2010: 131).

The sports profession has been shying away from the traditional method of isolated assessment and strengthening. The understanding of fundamental aspects of human movement has developed, causing individuals to realise that different athletic activities all have to originate from a set of basic movements. Physical activity is becoming more focused on whole body participation rather than isolated movements. Individuals want whole body fitness rather than to just be fit in one aspect. Individuals have realised that the body is a biomechanical chain and that dysfunction and injury does not necessarily present at the site of fault. The site at which the dysfunction presents could be due to dysfunction and imbalance either further up or down the biomechanical chain. By using an integrated, functional, movement-based approach, incorporating the principles of neuromuscular function, muscle synergy and motor learning, a better understanding of the FMS™™ and the entire body is made, improving movement patterns and improving athletic performance (Cook *et al*. 2014: 396-397).

Flexibility, strength, passive range of motion, motor patterns, core stability and proprioception are all very important factors that weight lifters need to ensure are in optimal condition to perform their very high demanding movements. The FMS™

analyses these aspects in great detail for these individuals so that they can be made aware of areas of dysfunction and limited mobility and improve on them (Frost *et al*. 2012: 1620).

When the FMS™ is used with additional information provided by the individual (Appendix I), it allows for customised, participant-specific, functional recommendations for physical fitness protocols in athletic activities. The participants can acknowledge for themselves the areas of deficit and imbalance when compared to the ideal movement. Participants can track their progress and ensure all movements are being done correctly to ensure development of the entire muscle mechanical chains. They can also track their progress following rehabilitation to ensure their mobility and range of motion has returned to normal, or identify which key movements of daily activity continues to be limited and continue rehabilitation on these areas. This will ensure that participants do not begin training excessively without being ready, risking injury.

The popularity of weightlifting increased from 1998 to 2007 to 65% of the population and has continued to rise over the years. The reason for this increase in popularity is the realisation that weightlifting improves the physique, cardiovascular fitness and overall fitness levels. The population has become more health-conscious and interested in improving their quality of life and increasing their longevity (Mattson 2018: 1-47). Therefore, it is important to create a normative value that individuals can use when beginning to lift weights and determine whether they fall below, above or in the normative category. It will also allow individuals who have been training for many years the opportunity to track their progress and understand why they find difficulty in performing certain movements, to identify whether their training is balanced, whether they are paying too much attention to certain areas, and if they have a dominant side that is stronger and developing more than the other side.

The normative value is a baseline that all weight lifters in the eThekwini Municipality can use to compare themselves with and track progress made during active training, including if they have been undergoing rehabilitation. The normative value is important for the following reasons:

- It creates a standard normal for a specific population;
- The value can be used to track progress;

- The value can be used to compare with other populations;
- It helps identify repetitive movement patterns;
- It allows for an understanding of the movement patterns to be made; and
- It allows for improvement and correction of incorrect movement patterns.

The FMS™ has been used in a number of fields to determine the normative value. The FMS™ normative value was thereafter used as a reference value to score athlete mobility and fitness, and determine athletes' ability to return to sporting codes following an injury and rehabilitation. The FMS™ score has been used in sporting fields as a baseline for new entries into the field to compare themselves to and determine whether they are ready to partake in the sport or require further training. According to Cook *et al.* (2010: 15), certain sports fields find it difficult to measure results due to the fact that power output, speed and strength as well as movement screens need to be assessed. Athletes need to be verified to lift their loads, have sufficient power, correct individual and position-specific body composition, anaerobic endurance, adequate mobility and good sport nutrition. This was a reference to a football team from a strength and conditioning coach. Conversely, weightlifting comprises of similar if not exactly the same measurements that need to be taken into consideration. Each sporting field will have their own normative value dependent on the nature of the sport and demands of that specific sport. While the normative values vary, the predictive nature of this tool does not change.

The average FMS™ score which calculated from the total sample population (n=89) was 13.88 out of 21. These results indicated that this population of athletes had an overall score that was lower than the average grading of the FMS™ tests. The value is minimally lower that the normative value that had been previously established in other sport fields where the FMS™ had been used. This can be expected due to the fact that weight lifters are focusing their attention in being able to lift an expected weight and carrying out their signature movements ("The Snatch" and "The Clean and Jerk"). Weight lifters are only expected to carry out these movements once and hold this position for a short period of time to be scored. Therefore, their attention is solely on lifting the weight and ending in the correct position. If they are not aware of the correct movement pattern needed to execute this movement, they just focus on finding a movement pattern that allows them the most ease and support to lift the significantly heavy weights.

When this value was compared to the normative value determined in different physical activities performed by football players, hockey players, soldiers and fire-fighters, it was found that the score for weight lifters in the eThekwini Municipality was lower than those. The above mentioned populations scored a normative value of 14 out of 21.

When compared to CrossFit athletes, their normative value is at a high of 17.73 due to the fact that they focus on a multitude of functional movements performed at high intensity and high frequency. This allows them to have generalised and comprehensive fitness. The fact that they have to perform their exercises repetitively at a high intensity calls for their form to be correct to avoid injury and increase endurance. This allows CrossFit athletes to be in a higher fitness category than most other physical activity participants (Richardson 2018: 64)

The results from this study regarding the normative values determined for weight lifters using the FMS™ differed slightly to various studies where the mean scores were 14 out of 21 and greatly where the mean score was 17 out of 21 (Kiesel 2007: 147-158; Jooste 2014: 1-122; Dossa *et al.* 2014: 421-427; Richardson 2018: 58; Frost *et al.* 2012: 1620-1630; Bushman *et al.* 2015: 297-298). These studies also used the FMS™ as an injury prediction tool. This study aims at identifying whether there is an association between the FMS™ score and injury.

From these studies, one was observed on soldiers and the other on fire-fighters. These professions require extreme strength and endurance with constant repetitive training and improvement in skill. These professions require a certain standard of fitness by those who join it, which could attribute to the score being slightly higher than that which was achieved in this study.

The above mentioned athletes require functional fitness to perform their daily activities, whereas weight lifters require the development of a technique that allows them to lift the desired weight for a short period of time only once and when they are training they use much lighter weights which are easier to handle and execute the movements with (Firdaus, Kuan, and Krasilshchikov 2018: 1-120).

A study conducted by Cowen (2010: 50-54) stated that both male and female fire fighters scored a mean of 13.25 on the FMS™ and very highly on a stress screening test that she conducted. This indicates that various factors play a role on FMS™ scores and need to be investigated further.

Weight lifters have a lower score than other fields because they are taught a specific technique on how to lift specific weights and are expected to lift those weights in those specific ways to increase strength and power and improve their performance. When asked to perform the FMS™ according to the ideal movement patterns created by Cook *et al*. (2010: 373-379), they could not do so because this is not the technique that they were using in their daily training. Although they are completing the same movements required of the FMS™, they are not performing them in the ideal way described. Therefore, their body has undergone an adaptive stage and is now accustomed to moving in the pattern that allows them to lift the heaviest weight at the highest velocity without taking into consideration the correct movement pattern to protect their body from injury.

5.4 OBJECTIVE THREE

5.4.1. Identifying an Association Between FMS™ Scores and Injuries of Weightlifters Within the eThekwini Municipality

Weightlifting is a high loading sport that requires the weight-lifter to perfect two specific movements and perform them perfectly. Weight lifters are expected to lift as much weight as possible in “The Snatch” and the “Clean and Jerk”. These two movements are explosive exercises. Before the weight-lifter can be able to perform these two movements with the maximum weight for their body, they need to undergo extensive training (Hedrick and Wada 2008: 26).

Therefore, weight lifters exercise and train daily to ensure that their muscles have undergone adequate muscle adaption as explained in Chapter two so that they are able to increase the load they are lifting. However, repetitive high loading (Jonassan *et al.* 2011: 1540-1545) and over use increases the prevalence of knee injury, hip pain, shoulder dislocations and disc bulges as well as muscle and tendon injury (Aasa *et al*. 2016: 212). According to Kinakin (2004:1-7), dysfunctions are the most common injury occurring due to improper training techniques.

Weight training dysfunctions are due to a lack of healing time. During preparation for a competition or daily training, weight lifters undergo micro-trauma to muscles, which is small amounts of damage that allows for regrowth and strength, if no resting period allowed there is macro-trauma causing damage that provides pain and prevents training (Kinakin 2004:1). These injuries as mentioned have a strong myofascial component. Myofascial injuries are one of the most common injuries experienced in professional and recreational sports. Major muscle injuries constitute between 10 and 55% of all injuries sustained by athletes depending on the sport code (Kerkhoffs and Servien 2014:18). Therefore, it is important that these dysfunctions are dealt with in an urgent manner to allow weight lifters the best training experience.

There are four types of dysfunctions that arise in weight training: muscle, joint, nerve and biochemical dysfunctions. These dysfunctions have been discussed in detail in Chapter Two.

The results from this study show that out of 89 participants, 35 sustained injury in total. This is 39.3% of the total population which means that less than 50% of the population sustained injury. Of these 35 participants, 24 had one previous injury, 11 sustained two previous injuries and 1 sustained three previous injuries. 60.7% of the total population had never sustained any injuries while weight training.

The literature suggests that the most common injuries found in weight lifters are to the knee, hip and shoulders and spine. The results from this study stated that 19 participants experienced their first weightlifting injury to the shoulder and 6 experienced their first injury to the knee.

A total of 11 participants experienced two previous injuries while weight training. Three participants experienced their second injury to the shoulder and three experienced their second injury to the knee.

The most common type of injury sustained was musculature in nature because weight lifters often train extremely hard and have no rest days (Kinakin 2004:1). This results in repetitive micro-tears continuously that are meant to aid strength and muscle growth. However, when there is no rest for that muscle, the micro-tears develop into macro-tears that become painful. When the muscle starts to produce pain, weight lifters try and train through the pain, causing dysfunction and altered movement patterns, in turn causing serious injury. 48.6% of the injured participants reported muscle injury as their one previous injury and 54.5% of the injured participants reported muscle injury as their second previous injury

Participants reported that the majority of their injuries took place 3 months prior to the study, and those who experienced two previous injuries had an injury sustained 2 months prior to the study. The one participant who experienced three previous injuries was injured one month prior to the study. All participants reported that it took them 3 months to heal their injury fully. They continued training during this time thereby preventing adequate healing at a faster rate.

The participants were asked to rate the severity of injury based on the pain they experienced when the injury occurred. Using the numerical pain rating scale (Kahl, and Cleland 2013: 125), participants who experienced one previous injury rated their injuries from 6 to 8 with a median of 7. Participants who experienced two previous injuries rated their second injury from a low of 4 to a high of 8 and 7 being the median too. The one participant who experienced three previous injuries rated his third injury at a level of 8.

Receiving the correct form of treatment for injury is important. This will ensure that the body receives the best treatment and management plan. Participants mainly experienced muscle injury followed by ligament, joint and bone injuries respectively. The most common treatment option for participants with one previous injury was physiotherapy. 25.7% of this population received no treatment for their injury and continued training. 20% of this population received chiropractic care. The population that received two previous injuries had an equal response to no treatment and physiotherapy at 36.4% each. The participant who had three previous injuries received no treatment for his third injury.

This objective focuses on determining whether there is an association between FMS™ and injury. Previous studies have conducted the FMS™ on participants pre-season and thereafter tracked their injuries throughout that season. A correlation was then made between low FMS™ score and injuries sustained. Those that scored poorly on the FMS™ sustained injury or more injuries than those that score higher on the FMS™ (Kiesel 2007: 147-158)

Kiesel (2007:147-158), performed a study on professional football players, the participants were tested pre-season and scored on the FMS™. The group scored a median of 14 on the FMS™. However, those that scored below 14 had an increased risk of injury by 51%.

In 2014, the following studies were conducted and required further investigation into the FMS™ as a predictor of injury:

- At Kharazmi University, a total sample population of 100 was used which consisted of 50 males and 50 females. Participants were athletes of soccer, handball or basketball. The mean composite score of the FMS™ in this study was lower than that of the football players from the previously mentioned study. Letafatkar *et al.* (2014: 25-26) suggests that although the results from that particular study showed a relationship with the athletes of Kharazmi University, further research needed to be conducted. The relationship is not statistically significant to deem the FMS™ as a injury predictor.Due to the cost efficiency and simplicity of implementation it should be considered by researchers and clinicians as a screening tool.
- Dossa *et al*. (2014: 426) stated that the results of the study did not support the hypothesis that an FMS™ score of less than 14 predict the risk of incurring injuries. This study was performed on hockey players and was conducted over the hockey season. A lower score on the FMS™ was not significantly associated with injury. The literature suggests that this could be due to different definitions of injury.
- A study performed in South Africa by Jooste (2014: 68) suggests that the FMS™ is its own metric, it is not affected by the number of years training, height, weight or BMI. She suggested that the results from her study show that the FMS™ is a specific measure of relevance to the movement dysfunction of the participants rather than an injury predictor. The result from her study showed that the score of those who experienced injury and those who had not was statistically insignificant and further research was recommended.

Bushman *et al.* (2015: 297-308) performed a study investigating the FMS™ association and predictive value in active men which comprised of 30 soldiers undergoing the FMS™. These participants had medical record data stating that they had previous overuse injuries and traumatic injuries. This article stated that research should be focused on quantifying measures of the predictive value using the FMS™ as a screening tool for the injury risk and determining whether a score of less than 14 is indicative of injury based on injury type. The predictive value is regarded as low and it may be that a numerical scoring model is insufficient to assess injury risk.

According to a systematic review by Bonazza *et al*. (2017: 731) the FMS™ as a composite score has great inter-rater and intra-rater reliability. This is because the tool is easy to use and instructions are easy to understand. It required very little knowledge about the FMS™ to be conducted as long as instructions were given correctly. However, the validity of this tool is questionable due to the lack of structure as a composite score of multiple subtest scores and its ability to accurately and sensitively measure any dysfunctions in the body.

In this study, there was no association between FMS™ score and injury. The study aimed to look at previous injuries and injuries occurring during the time of the study. However, due to the nationwide lockdown that South Africa went into, gyms were closed and participants were not training. Therefore, no injuries were sustained. A Pearson correlation was performed on participants and no correlation was found between age, height, weight, number of years training and total FMS™ score.

5.5 CONCLUSION

The movement patterns of participants were analysed and it was found that weight lifters adopt a specific lifting technique which allows them to lift heavier weights at higher velocities, and they may be unaware of their dysfunctional movement patterns because they are solely focused on lifting their desired weight.

The hypothesis stating that the normative value of the FMS™ in weight lifters in participating gyms within the eThekwini municipality is 14 is incorrect. The normative value is 13.88. This is due to the specific movement patterns that the population is expected to produce and the technique that participants are taught to achieve the desired goal.

There is no association between injury and weight lifters in the eThekwini Municipality. This could be due to lack of validity and reliability of the tool that can be further researched, or due to an inconsistent definition of injury occurring in all the previous studies.

Further research needs to be conducted in a larger sample consisting of males and females. The study can incorporate a pre-test and post-test over a period of time, thereby tracking participant injury.

CHAPTER SIX

CONCLUSION

6.1 INTRODUCTION

This chapter draws the study to a close and outlines all the significant and relevant findings from the data collected. Furthermore, the recommendations are described for further research, based on the limitations that were encountered during this study.

6.2 CONCLUSION

This study found that most weightlifters scored a value of 2 for the specific exercises of the FMS™. The reason for this was that weightlifting requires the participant to adopt a specific lifting technique that is specific to the sport and this technique has many variants that are different to the ideal movement patterns created by the FMS™. The participants rarely received a perfect score of 3 for their movement patterns. This did not mean that they experienced pain or were unable to perform the exercise but rather that they performed the exercise with their preferred lifting technique. Therefore, the normative value of the Functional Movement Screen in weightlifters in participating gyms within the eThekwini Municipality was 13.88 out of 21.

The reason for the lowered score is due to the fact that weightlifters have to adopt a movement pattern that best supports their body during the lifting, as their aim is to lift the heaviest weight possible with maximum power and velocity. There was no link found between average FMS™ score and injury for this sample population. It has been found that the most common injury incurred by weightlifters in this sample population was to the shoulder, followed by injuries to the knee.

The FMS™ has shown great interrater and intrarater validity in identifying altered movement patterns but, however, its use as an injury prediction tool requires further research.

This study revealed that age, height, weight and the number of years training, in conjunction with the FMS™, cannot reliably indicate injury susceptibility in male weightlifters in the eThekwini Municipality. Having said this, the association of FMs™, height, weight and number of years training warrants further investigation into its relationship to injury susceptibility.

The researcher found that it is a low cost, user friendly tool, that is also light weight, and can be transported to the necessary location and participants find the instructions and exercises easy to perform.

6.3 LIMITATIONS

6.3.1. The nationwide lockdown due to the Covid-19 pandemic prevented participants from training during the course of the study and, therefore, they did not incur any injury during this time.

6.3.2. It was required that participants inform the researcher of any injury previously sustained. Reliability and honesty were acknowledged when collecting data from the sample.

6.3.3 The diagnosis of injury was based on a combination of participant description and clinical understanding by the researcher and, therefore, the diagnosis is limited by the researcher's scope and participant perception.

6.4 RECOMMENDATIONS

6.4.1. By performing the study during a time that there is no nationwide pandemic will allow better results as the sample population will be able to continue training and report any injuries sustained during the course of the study.

6.4.2. A more in-depth rating of injury should be included to gain insight into the severity of injuries.

6.4.3. An injury definition needs to be designed so that both the researcher and the participants can be clear when reporting and recording injuries sustained.

6.4.4. A follow-up study including both male and female weightlifters is suggested. This will allow for a higher sample size to be analysed, as well as comparison made between the two normative values within the eThekwini Municipality.

6.4.5 Further investigation into the reason behind the shoulder and knee having higher susceptibility is required.

6.4.6 Further investigation into the association between the FMS™ score and injury susceptibility needs to be concluded to deem the FMS™ a valid injury prediction tool.

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APPENDICES

APPENDIX A: GATEKEEPER PERMISSION TO GYM MANAGER

Permission by exercise gym manager to conduct the research and place advertisements on the premises.

Dear Sir/ Madam
Thank you for considering this letter and taking the time to read it.

My name is Shaista Singh and I am currently completing my M.Tech Chiropractic at the Durban University of Technology. I am requesting your approval to conduct my research and permission to place advertisements on the premises of your gym to recruit participants.

Title of Study: Determining the normative value of the Functional Movement Screen™ in weightlifters in participating gyms within the eThekwini municipality, and its association to injury

The Functional Movement Screen™ (FMS™) is a screening tool that is capable of predicting injury in an individual. The screen consists of several tests, such as a Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and a Rotatory Stability Test. The participant will perform these tests and will be scored from 0-3 for each test. The score of zero indicates that the individual has pain and was unable to perform the test and a score of three indicating perfect movement.
Weightlifting is a very high loading sport, causing stress and strain on joints of the body. The sport comprises of two major movements, “the Snatch and the “Clean and Jerk”. These movements comprise of shoulder mobility, trunk stability and deep squats, which are signature moves of the FMS™. Injuries are often overlooked by weightlifters due to the fear of prolonged healing time. Therefore performing the FMS™ on weightlifters will improve their daily training regime’ and reduce the risk of injury.

The study design will be of an observational qualitative nature and will involve 88 participants that are willing to provide permission to partake in the study. All participants will be asked to complete each of the seven tests and will be scored on the FMS™ score sheet out of 3 for each individual test. The participants will be performing the test series twice over a period of four weeks. In the first week participants will be assessed and scored (Pre-Screen) and then following four weeks of training activity they will be assessed and scored again (Post-Screen). Following the Post-Screening, participants will be asked to provide a brief case history indicating whether they have sustained injury previously, during the four week duration or not at all. Once all participants have concluded the exercises a total score will be made resulting in a figure out of 21. An analysis of scores and case history will be made. Those at risk will be provided with preventative strategies.

Using Pearson's Chi Squared tests and correlation coefficients, ANOVA, t-tests and Fisher's exact test will allow the descriptive as well as our p value to be determined. In doing so, a normative value and an association between FMS™ scores and injury will be made of Weightlifters in the eThekwini Municipality. The aim of this study is to determine the FMS™ normative values of Weightlifters in the eThekwini Municipality and to determine if an association exists between a low FMS™ score and predisposition to injury as well as provide those at risk with advice to prevent injury.

Should you have any further questions or queries please do not hesitate to contact me (0724411330/shaistasingh79@gmail.com)

I, Mr/ Ms/Mrs ____ (full name printed), (I.D number)___________________________ as the current manager of the ____________________(name of gym), herewith grant permission to Ms Shaista Singh to conduct her study here on the premises and interact with our customers.
It is to our understanding that this interaction with customers is purely for research purposes and will only proceed once the research has been approved by the DUT IREC and a copy of the approved proposal and the letter of approval (copy) to ourselves for record and reference purposes.

Signature: ____

Date: ____

Place: ____

Witness (Full name printed): ____________________ Signature: ___________________

Date: ______________________________________ Place: ______________________

APPENDIX B: LETTER OF CONSENT

DUT DURBAN UNIVERSITY OF TECHNOLOGY

INSTITUTIONAL RESEARCH ETHICS COMMITTEE

CONSENT

Statement of Agree to participate in the Research Study:

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

____________________	_______	______	________________________
Full name of Participant	Date	Time	Signature/ Right Thumb print

I, _____________ __________ (name of researcher) hereby confirmed that the above participant has been fully informed about the nature, conduct and risks of this study.

__________________	_______	________	__________________
Full name of Researcher	Date	Time	Signature
__________________	_______	________	__________________
Full name of Witness	Date	Time	Signature

APPENDIX C: LETTER OF INFORMATION

DUT DURBAN UNIVERSITY OF TECHNOLOGY
INSTITUTIONAL RESEARCH ETHICS COMMITTEE

<u>LETTER OF INFORMATION</u>

Dear participant,
Welcome to my study.

Title of Research Study: <u>Determining the normative value of the Functional Movement Screen™ in weightlifters in participating gyms within the eThekwini municipality, and its association to injury</u>

Primary Researcher: Shaista Singh
Supervisor: Dr Praveena Maharaj
(M.Tech Chiropractic)

Brief Introduction:
The Functional Movement Screen™ (FMS™) is a screening tool that is capable of predicting injury in an individual. The screen consists of several tests, such as a Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and a Rotatory Stability Test. The participant will perform these tests and will be scored from 0-3. The score of zero indicates that the individual has pain and was unable to perform the test and a score of three indicating perfect movement. (Cook *et al*. 2006a). An analysis of scores and case history will be made. Those at risk will be provided with preventative strategies

Purpose of the Study:
Determining the Functional Movement Screen ™ normative value and its association to injury of Weightlifters in the eThekwini Municipality.

The researcher will set up the FMS™ on the gym premises' that have agreed to let us use their vicinity and partake in the study. You will be asked to perform all seven tests that make up the FMS™ before and after a four week duration. A score of 0-3 will be granted based on your ability to perform each of the tests. A score of; zero is given if there is pain and the inability to perform the exercise, one if unable to perform the exercise, two means able to complete the exercise by using compensatory mechanisms and three being a well-executed exercise without compensation. A score of 0 will be given immediately if any exercise elicits pain at any point. All your individual scores will be tallied to give us a total score out of 21 which will then be recorded.

Risks or Discomforts to the Subject:
There is minimal risk involved as this is a non-invasive study procedure however if you experience pain during the process of a test, the test will be immediately stopped and a score of zero will be recorded.

Benefits:
You will benefit by learning about the functional movement system which is essentially the manner in which our body works as well as discovering your deficits and strengths that lie within your functional movements. The greater population of weightlifters will benefit significantly if normative values can be determined and injury risk be developed. If the study is successful, an injury prevention program can be put in place for those who score low on the FMS™ reducing the amount of injury incurred.
The benefit for the researcher is to produce a dissertation and publication in a peer reviewed journal.
Reason/ Reasons why the Subject may be withdrawn from the study:

- You will be withdrawn from the study should you incur any injury that was not sustained while weight training
- You will be withdraw from the study should you present with any illnesses that prevent you from performing the tests
- You can withdraw at any time during the study and there will be no penalty

Remuneration:
You will not receive payment for participation in this study.

Costs of the study:
There will be no costs.

Confidentiality:
Your information will be kept confidential throughout the process of the study and will remain anonymous in the reporting of the results of the study. Your injury profile and FMS™ score will not be available to the manager of the gym or any of your colleges.

Research Related Injury:
There are no expected injuries during the duration of the study. As noted above if you feel any pain during any exercise the test will be stopped immediately to prevent injury.

Persons to contact in the event of any queries or issues:
Please contact the researcher (Shaista Singh- 072 441 1330 or shaistasingh79@gmail.com). The supervisor (Dr Praveena Maharaj- 031 262 7490) or the Institutional Research Ethics Administrator on 031 373 2375.
Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za.

APPENDIX D: ADVERTISEMENT FOR PARTICIPANTS

How do you move?

A study is being conducted in local gyms in the eThekwini Municipality.

Title of the Study: Determining the normative value of the Functional Movement Screen™ in weightlifters in the eThekwini Municipality, and its association to injury.

APPENDIX E: GATEKEEPER PERMISSION TO CLINIC DIRECTOR

Dear Clinic Director

My name is Shaista Singh and I am currently completing my M.Tech Chiropractic at the Durban University of Technology. I am requesting your approval and permission to place advertisements on the DUT premises to recruit participants.

Title of Study: Determining the normative value of the Functional Movement Screen™ in weightlifters in participating gyms within the eThekwini municipality, and its association to injury

The Functional Movement Screen™ (FMS™) is a screening tool that is capable of predicting injury in an individual. The screen consists of several tests, such as a Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and a Rotatory Stability Test. The participant will perform these tests and will be scored from 0-3 for each test. The score of zero indicates that the individual has pain and was unable to perform the test and a score of three indicating perfect movement.
Weightlifting is a very high loading sport, causing stress and strain on joints of the body. The sport comprises of two major movements, “the Snatch and the “Clean and Jerk”. These movements comprise of shoulder mobility, trunk stability and deep squats, which are signature moves of the FMS™. Injuries are often overlooked by weightlifters due to the fear of prolonged healing time. Therefore performing the FMS™ on weightlifters will improve their daily training regime’ and reduce the risk of injury.

The study design will be of an observational qualitative nature and will involve 88 participants that are willing to provide permission to partake in the study. All participants will be asked to complete each of the seven tests and will be scored on the FMS™ score sheet out of 3 for each individual test. The participants will be performing the test series twice over a period of four weeks. In the first week participants will be assessed and scored (Pre-Screen) and then following four weeks of training activity they will be assessed and scored again (Post-Screen). Following the Post-Screening, participants will be asked to provide a brief case history indicating whether they have sustained injury previously, during the four week duration or not at all. Once all participants have concluded the exercises a total score will be made resulting in a figure out of 21. An analysis of scores and case history will be made. Those at risk will be provided with preventative strategies.

Using Pearson’s Chi Squared tests and correlation coefficients, ANOVA, t-tests and Fisher’s exact test will allow the descriptive as well as our *p* value to be determined. In doing so, a normative value and an association between FMS™ scores and injury will be made of Weightlifters in the eThekwini Municipality. The aim of this study is to determine the FMS™ normative values of Weightlifters in the eThekwini Municipality and to determine if an association exists between a low FMS™ score and predisposition to injury as well as provide those at risk with advice to prevent injury.

Should you have any further questions or queries please do not hesitate to contact me (0724411330/shaistasingh79@gmail.com)

Warm Regards
Shaista Singh
21348863

APPENDIX F: GATEKEEPER PERMISSION TO DIRECTOR OF RESEARCH

Dear Director of Research

Thank you for your time and consideration of this letter.

My name is Shaista Singh and I am currently completing my M.Tech Chiropractic at the Durban University of Technology. I am requesting your approval and permission to place advertisements on the DUT premises to recruit participants.

Title of Study: Determining the normative value of the Functional Movement Screen™ in weightlifters in participating gyms within the eThekwini municipality, and its association to injury

The Functional Movement Screen™ (FMS™) is a screening tool that can predict injury in an individual. The screen consists of several tests, such as a Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up and a Rotatory Stability Test. The participant will perform these tests and will be scored from 0-3 for each test. The score of zero indicates that the individual has pain and was unable to perform the test and a score of three indicating perfect movement.
Weightlifting is a very high loading sport, causing stress and strain on joints of the body. The sport comprises of two major movements, "the Snatch and the "Clean and Jerk". These movements comprise of shoulder mobility, trunk stability and deep squats, which are signature moves of the FMS™. Injuries are often overlooked by weightlifters due to the fear of prolonged healing time. Therefore, performing the FMS™ on weightlifters will improve their daily training regime' and reduce the risk of injury.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC).

Should you have any further questions or queries please do not hesitate to contact me (0724411330/shaistasingh79@gmail.com)

Warm Regards
Shaista Singh
21348863

APPENDIX G: SAMPLE SIZE CALCULATION

2019/05/03 9:08:35 AM 1

Two-Sample T-Tests Assuming Equal Variance

Numeric Results for Two-Sample T-Test Assuming Equal Variance

Alternative Hypothesis: μ1 ≠ μ2

Power	N1	N2	R= N2/N1	μ1	μ2	μ1-μ2	σ	Alpha	Beta
0.82118	13	75	5,70	-2.0	0,1	-2.1	2.4	0.050	0.17882

References:

Julious, S. A. 2010. *Sample Sizes for Clinical Trials*. Chapman & Hall/CRC. Boca Raton, FL.

Chow, S.-C., Shao, J., and Wang, H. 2008. *Sample Size Calculations in Clinical Research* (2nd ed.). Chapman & Hall/CRC. Boca Raton, FL.

Machin, D., Campbell, M., Fayers, P., and Pinol, A. 1997. *Sample Size Tables for Clinical Studies* (2nd ed.). Blackwell Science. Malden, MA.

Zar, J. H. 1984. *Biostatistical Analysis* (2nd ed.). Prentice-Hall. Englewood Cliffs, New Jersey.

Report Definitions:

Power is the probability of rejecting a false null hypothesis.

N1 and N2 are the number of items sampled from each population.

μ1 and μ2 are the assumed population means for power and sample size calculations.

μ1 - μ2 is the difference between population means at which power and sample size calculations are made.

σ is the assumed population standard deviation for each of the two groups.

Alpha is the probability of rejecting a true null hypothesis.

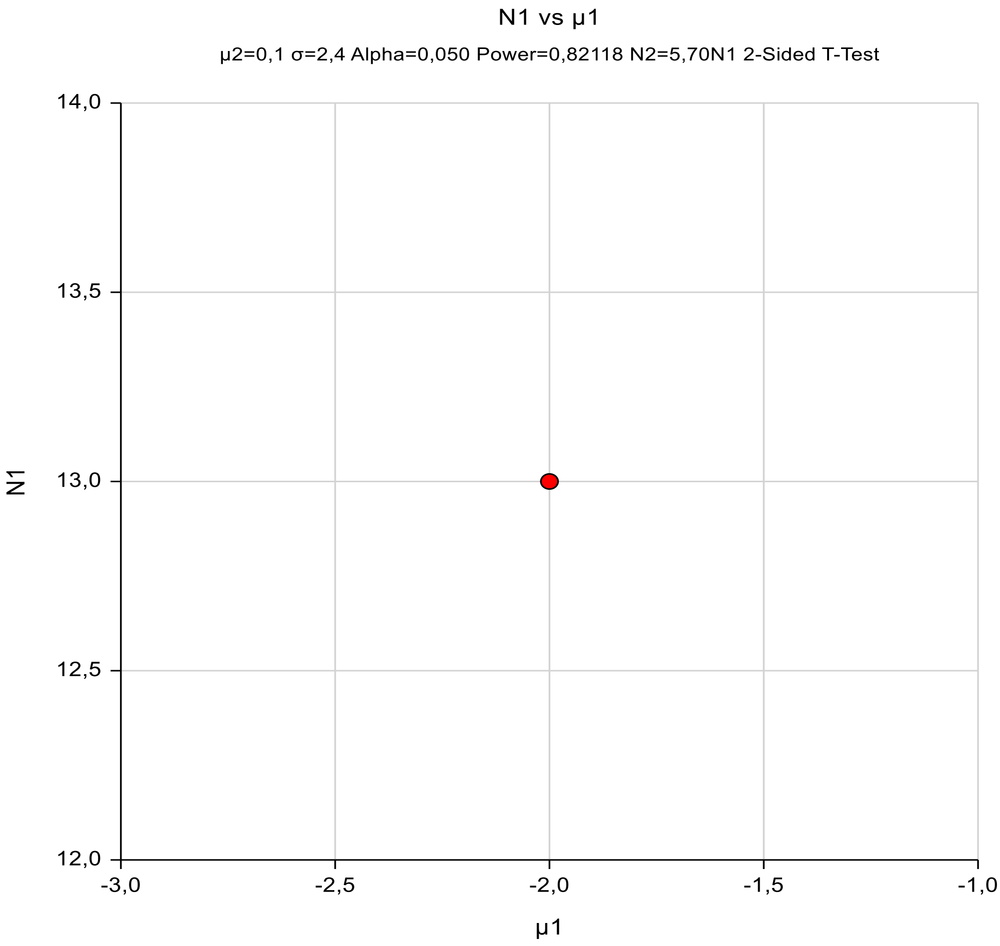
Beta is the probability of accepting a false null hypothesis.

Summary Statements:

Group sample sizes of 13 and 75 achieve 82,118% power to reject the null hypothesis of equal means when the population mean difference is μ1 - μ2 = -2,0 - 0,1 = -2,1 with a standard deviation for both groups of 2,4 and with a significance level (alpha) of 0,050 using a two-sided two-sample equal-variance t-test.

Two-Sample T-Tests Assuming Equal Variance

Chart Section



APPENDIX H: FMS™ SCORE SHEET

WEEK 1
Participant No: _______________ Gym: ______________________

TEST	RAW SCORE		FINAL SCORE	COMMENTS
Deep Squat				
Hurdle Step	L			
	R			
In-Line Lunge	L			
	R			
Active Straight Leg Raiser	L			
	R			
Shoulder Mobility Test	L			
	R			
Shoulder Mobility clearing test	L			
	R			
Trunk Stability Push Up				
Extension Clearing Test				
Quadruped Rotatory Stability Test	L			
	R			
Flexion clearing test				
TOTAL SCORE				

*For tests that are scored on both the right and left sides, the lower score is used when calculating the Functional Movement Screen™ composite scores

APPENDIX I: PARTICIPANT QUESTIONNAIRE

Gym Code:

To be completed by participant:

Please note that all of the information collected from this questionnaire will be confidential. The information obtained will be used solely for the purpose of this study.

Please mark the appropriate box with an X where applicable

1. **I.D Number:**
2. **Age (years):**
3. **Weight (kilograms (kg)):**
4. **Height (meters(m)):**
5. **Number of years that you have been weight training at the gym in total:**
6. **Have you obtained any injury whilst training at the gym? (Previously, during the duration of this study, or not at all) (If no injury was obtained, you do not need to complete the following three questions)**

Previously	During the this four week study duration	Not at all

7. **If you have obtained more than one injury, please answer the following questions based on your three most recent injuries**

INJURY 1:

7.1.1 Please indicate how long ago the injury was obtained (days/ months):____

7.1.2 Please indicate the duration that the injury lasted (days/months/years):____________________________________

7.1.3 Please rate the severity of pain experienced from the injury

Please circle the suitable number

0= No pain 5= moderate pain 10= extreme pain

0 1 2 3 4 5 6 7 8 9 10

7.1.4 Please specify the location as well as the type of injury

AREA OF BODY	**TYPE OF INJURY**				
	Bone	**Muscle**	**Joint**	**Tendon**	**Ligament**
Head					
Neck					
Shoulder					
Elbow					
Hand & Wrist					
Chest					
Abdomen					
Hip					
Knee					
Foot & Ankle					

7.1.5 If you received treatment for this injury , please specify what treatment:____

7.2

INJURY 2:

7.2.1 **Please indicate how long ago the injury was obtained(days/ months):**

____

7.2.2 Please indicate the duration that the injury lasted(days/months/years):____

7.2.3 Please rate the severity of pain experienced from the injury:

Please circle the suitable number

0= No pain 5= moderate pain 10= extreme pain

0 1 2 3 4 5 6 7 8 9 10

7.2.4 Please specify the location as well as the type of injury

AREA OF BODY	TYPE OF INJURY				
	Bone	**Muscle**	**Joint**	**Tendon**	**Ligament**
Head					
Neck					
Shoulder					
Elbow					
Hand & Wrist					
Chest					
Abdomen					
Hip					
Knee					
Foot & Ankle					

7.2.5 If you received treatment for this injury, please specify what treatment:

____

7.3

INJURY 3:

7.3.1 Please indicate how long ago the injury was obtained (days/ months):

7.3.2 Please indicate the duration that the injury lasted (days/months/years):

____

7.3.3 Please rate the severity of pain experienced from the injury

Please circle the suitable number

0= No pain 5= moderate pain 10= extreme pain

0 1 2 3 4 5 6 7 8 9 10

7.3.4 Please specify the location as well as the type of injury

AREA OF BODY	**TYPE OF INJURY**				
	Bone	**Muscle**	**Joint**	**Tendon**	**Ligament**
Head					
Neck					
Shoulder					
Elbow					
Hand & Wrist					
Chest					
Abdomen					
Hip					
Knee					
Foot & Ankle					

7.3.5 If you received any treatment for this injury, please specify what treatment:

____

Thank you for your participation in this study!

APPENDIX J: VOUCHER FOR FREE TREATMENT

<u>Durban University of Technology Chiropractic Day Clinic</u>

VOUCHER FOR ONE FREE TREATMENT

Recipient of Voucher: