

CHAPTER 1

1.0 BACKGROUND AND NEED

1.1. Introduction

“Professional golf is the only sport where, if you win 20% of the time, you’re the best”- Jack Nicklaus.

The goal that any professional, amateur or social golfer strives to achieve is maximum driving performance off the tee-box and an accurate trajectory. To best accomplish this, the club head has to be travelling at a maximum speed at the point of impact between the club head and the ball (Burden et al 1998). According to Myers et al (2008), current teaching philosophy of the golf swing emphasises an increase in rotation of the torso during the backswing, which theoretically results in increased power during the downswing, and subsequent increase in ball velocity and ball flight distance.

The modern golf swing, made famous by Jack Nicklaus, encourages a limited lumbo-pelvic rotation during the back swing resulting in an increase of upper trunk rotation relative to this. The “x-factor” is a term used to describe the relative rotation of the shoulder girdles with respect to the hips during the golf swing (Cheetham et al 2001). This measurement is taken at the top of the backswing and a greater x-factor is thought to facilitate high club head speed at impact. This is based on the movement pattern naturally occurring within muscle - “the stretch-shorten cycle” (Blanpeid et al 1995). An increased separation between the pelvis and the upper trunk creates an increase in stored energy, which results in an increase in power build up for a more forceful downswing (Myers et al 2008). Movements that involve a stretch shortening contraction, utilise stretching a particular muscle (eccentric lengthening), storing potential energy in the muscle in order to increase power output of the same muscle during the final phase of the movement (concentric shortening). Thus the stretch shorten cycle utilises a muscle’s elastic and reactive properties to create a maximal force production, stimulating the joint proprioceptors to facilitate an increase in muscle recruitment (Wilk et al 1993).

With the latest three dimensional technologies, the modern golf swing, in terms of work, power, kinetic energy, energy conversions, efficiencies of the body’s joints, muscles and the club, can be analysed. A specialised Body Motion System (iClub™ Inc., Florida USA) is used to carry out a comprehensive swing analysis. Modern technology is able to measure

even subtle body motions and can be used to highlight muscle and joint inefficiencies in the golf swing. Other outcome measures, ball landing distance and ball accuracy, reflected by the smash factor ratio, can be measured with three dimensional ball tracking radar technology, the FlightScope® (EDH Ltd, South Africa). The smash factor ratio is a means of determining the accuracy with which the club strikes the ball at impact and is calculated as the ratio of the ball speed to the club head speed. The closer this value is to the optimal value of 1.5 (the ball speed being one and a half times faster than club head speed), the closer the ball strike is to the “sweet spot” of the club head. It is a means of being more efficient with the speed created by the club for maximum length and accuracy (United States Golf Academy, 2009). According to David Allen, Equipment and Golf Instruction Editor for GolfChannel.com, an efficient golf swing, using all the components of the body, maximises club head speed and how precisely the club head meets the ball at impact (GolfChannel.com, 2009).

The modern golf swing is a complex, co-ordinated movement of the whole body in order to create power to propel the golf ball a great distance with accuracy (McHardy and Pollard 2005). The function of the golf backswing is to stretch the appropriate joints and muscles and position the body and the club head so that the golfer can perform the downswing with power and accuracy (Hume et al 2005). According to Nesbit and Serrano (2005), the generation of work in the golf swing comes primarily from the spine and hips, generating 68.7 % of the total body work, with much higher work done by the right hip (in a right handed golfer). The limited lumbo-pelvic rotation created by the modern golf swing is due to the stabilisers within the pelvis, including the gluteal muscles and short lateral rotators of the trail hip, acting eccentrically at the top of the back swing. McHardy and Pollard (2005) showed that the gluteal muscles are very active in the down swing and gluteus medius contributes 51% of manual muscle strength testing. The gluteus medius muscle is reported to be the primary abductor of the hip and an important stabiliser to the pelvis in a wide variety of functional activities (Earl 2004). Schmitz et al (2002) showed that gluteus medius is an important stabiliser of the pelvis during closed chain activities. The result of their study showed that gluteus medius activity increased with isometric, closed chain, rotational forces, which all form components of the golf swing. When analysing the backswing biomechanics, weight on the feet is shifted laterally to the back foot (Maddalozzo 1987). This weight shift and trunk turn in the backswing, results in hip rotation, with the lead hip externally rotating and the rear hip internally rotating. Gluteus medius's important role in lateral stability was confirmed by Banerjee et al (2009) while testing torso and hip muscle activity using a 3-D Proffitter Cross Trainer. This lateral stability, provided by gluteus medius, limits the lumbo-

pelvic rotation in the backswing allowing an increased upper torso turn. This results in an increased x-factor, creating a build up of potential energy in the torso to be utilised in the down swing. Transfer of power from the club to the ball, enhances club head speed and ball speed, thus distance and accuracy (Meyers et al 2008). There are other muscles, namely transversus abdominis, external oblique, internal oblique, erector spinae, hamstring group, gluteus maximus, adductor magnus and vastus lateralis that each play an essential role in creating stability for an efficient golf swing (McHardy and Pollard 2005).

Taping is widely used in sports and rehabilitation for prevention of injury and improvement of function (Thelen et al 2008). The Kinesio® Taping (KT) Method, becoming more popular over recent years, gives support and stability to joints and muscles without inhibiting range of motion. It works by activating the neurological and circulatory systems, designed to mimic human skin. Depending on how the KT is applied to the skin, Thelen et al (2008) proposed various benefits including alignment of fascia, stimulation according to position of tape on the skin and providing specific sensory stimulation to the tissues to assist or limit movement. According to Schleip (2003), smooth muscle exists within fascia and is innervated by intrafascial nerves and thereby fascia is able to actively contract. It can thus be postulated that the KT's stimulation of the fascia activates the smooth muscle within it to contract and activate the muscle it envelopes. There is little information available on the proprioceptive effect of KT, but it has been predicted that it will act to facilitate cutaneous mechanoreceptors (Halseth et al, 2004). The skin can be stretched and stimulated, activating the cutaneous mechanoreceptors, signalling information about joint motion and position sense. Because of the KT's ability to mimic human skin it can be hypothesised that it can also contribute to proprioception by the above mentioned mechanism.

There has been very little research carried out on how gluteus medius activity affects the golf swing but this muscle has been well documented as an active pelvic stabiliser and primary abductor of the hip. Posterior fibres of this muscle contribute toward external rotation when acting concentrically (Neumann 2010). The modern golf back swing demands internal rotation of the trail hip (resulting in eccentric action of the corresponding gluteus medius muscle) reducing lumbo-pelvic rotation so the upper torso can rotate further, creating a greater x-factor (McHardy and Pollard 2005).

1.2 Problem Statement

Although gluteus medius has been well documented as an active pelvic stabiliser, very little research has been conducted on the lower limb and pelvic contribution to the golf swing. Pelvic stabilisation has been shown to influence torso-pelvic separation (x-factor) in the golf

swing, affecting distance of ball flight and accuracy. As KT has become popular over recent years, there is little evidence supporting its function and efficacy. It is unclear if gluteus medius strength increases using KT, and if this increased strength contributes to x-factor and therefore driving distance and an accurate trajectory.

1.3 Research Question

What is the effect of gluteus medius KT on the gluteus medius muscle strength, x-factor during the golf swing, and on driving distance and accuracy?

1.4 Hypothesis

H⁰ - Gluteus medius KT will have no effect on gluteus medius strength, x-factor during the golf swing and driving distance and accuracy

H¹ - Gluteus medius KT will have an effect on gluteus medius strength, x-factor during the golf swing and driving distance and accuracy

1.5 Aim of the Study

The aim of the study is to establish the effect of gluteus medius KT on x-factor during the golf swing, and on driving distance and accuracy.

1.5.1 Objectives of the Study

- To determine the gluteus medius muscle strength, x-factor, ball flight distance and the smash factor ratio without KT on gluteus medius in male amateur golfers
- To determine gluteus medius muscle strength, x-factor, ball flight distance and the smash factor ratio with KT on gluteus medius in male amateur golfers
- To compare the gluteus medius muscle strength, x-factor values, ball flight distance values and smash factor ratio before and after the application of KT gluteus medius in male amateur golfers
- To determine the relationship between gluteus medius muscle strength and x-factor, ball flight distance and smash factor ratio in male amateur golfers

1.6 Significance of the Study

There have been a number of studies relating upper limb function to the golf swing and numerous investigations into the relationship between the x-factor and driving distance comparing low and high handicap golfers (McHardy and Pollard 2005). Pending the outcome

of this study, a better understanding of KT's function to facilitate muscle can be used in sport rehabilitation and performance enhancement. A comprehensive exercise program targeting gluteus medius can be developed and researched to improve golf swing execution, should gluteus medius be found a contributing factor. Further studies can be extrapolated from this research on other important pelvic stabilisers and how they affect the golf swing and golfers' function. This will provide clinicians with a better understanding of the role of pelvic stabilisation in x-factor production in the modern golf swing, ball flight distance and accuracy.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

The literature that was reviewed was sourced from the Medline, Pubmed, Cochrane, EPSCO Host and Pedro databases. The key words used in the search strategy included: X-factor, Gluteus Medius, Golf Swing Biomechanics, Pelvic Stability, Ball Flight, Smash Factor Ratio, Kinesio Tape.

The ultimate goal that any professional, amateur or social golfer aims to achieve is maximum driving performance off the tee-box and an accurate trajectory. The modern golf swing, made famous by Jack Nicklaus (McHardy et al 2006), encourages a limited lumbo-pelvic rotation during the back swing resulting in an increase of upper trunk rotation relative to this. The “x-factor” is a term used to describe the relative rotation of the shoulders with respect to the hips during the golf swing (Cheetham et al 2001). Taping is widely used in the sports and rehabilitation arena for prevention of injury and improvement of function (Thelen et al 2008). The Kinesio® Taping (KT) Method, becoming more popular over recent years, gives support and stability to joints and muscles without inhibiting range of motion. All these factors were taken into consideration for the purposes of this study.

The literature review was approached using the following subheadings:

2.2 Golf Swing Biomechanics

2.3 The X-Factor, ball flight distance and accuracy

2.4 Pelvic stability in the golf swing

2.5 Gluteus Medius

2.6 Kinesio® Tape

2.7 Instrumentation

2.8 Future Research

2.9 Conclusion

2.2 Golf Swing Biomechanics

The golf swing, although complex, can be a movement of great power and beauty, especially in the hands of golf champions (McHardy et al 2006). The golf swing has evolved over time resulting from a combination of factors, including the advancement of equipment, human adaptation, skill and physical characteristics of those who play the game, combined with course lay-out and design (McHardy et al 2006).

The golf swing may appear less physically demanding than most sports. Although there is ample literature on the biomechanics of the perfect golf swing, improving and perfecting it is no easy task (Gluck et al 2008). There are also individual factors affecting the outcome of the golf swing including age, height, body type and flexibility (McHardy et al 2006).

The golf swing can be divided into basic components: backswing, forward swing, acceleration and ball strike and follow through. Each individual's swing is considered unique and can be further classified according to the "modern" golf swing, made famous by Jack Nicklaus in the 1960's, by producing shots with greater height and distance, and the "classic" golf swing (McHardy et al 2006). For the purposes of this study, the backswing and top of the backswing will be discussed in the most detail, as this part of the golf swing is pertinent in creating x-factor.

2.2.1 Backswing

In skilled golfers, the backswing is characterised by simultaneous rotation of upper torso, movement of the upper extremities and the club away from the position of address followed by rotation of the hips and pelvic girdle (Myers et al 2008). The backswing is the initial movement of the club away from the ball and in a right handed golfer is characterised by a rotation of both shoulder girdles, together with the upper trunk, to the right.

Electromyographical studies showed that the gluteal muscles were very active during the backswing (Myers et al 2008). Other muscles of the of the trunk and pelvis, including quadratus lumborum, psoas major, internal and external oblique, transverses abdominis and thoracolumbar fascia (Gluck et al 2008), contribute towards stable base on which the trunk can rotate and the body weight moves over onto the right hand side (McHardy et al 2006). This phase ends when the shaft is parallel with the ground and the club head is facing the target.



Figure 2.1: Golf Backswing (perfectgolfswingreview.net)

2.2.2 Top of the backswing and the forward swing

This is characterised by the top of the backswing, just before initiation of the downswing, followed by the downswing. This is illustrated in Figure 2.1, picture five above. The degree of shoulder girdle and trunk rotation at the top of the back swing creates a coil and thus a store of potential energy that can be transferred from the body to the club head at impact, which is then transferred to the ball. In the modern golf swing the upper body (shoulder girdle and trunk rotation) is rotated between eighty and a hundred and ten degrees, depending on the flexibility of the golfer (McHardy et al 2006). McHardy et al (2006) also showed that pelvic girdle is thought to rotate between thirty five and forty five degrees relative to the neutral anatomical position, again dependant on the characteristics of the golfer. At this point sixty to eighty percent of body weight is concentrated on the right hand side and the pelvic muscles (gluteal muscles and short external rotators) are acting to stabilise the pelvis and limit its turn as compared to the shoulder girdles and trunk. This is one of the main differences between the modern and classic golf swing, the latter being characterised by a large hip and lumbo-pelvic turn. The downswing is initiated by turn of the pelvic girdle back towards the target, followed by torso rotation, upper extremity movement and movement of the club (Myers et al 2008).

2.2.3 Other Phases of the Golf Swing (McHardy et al 2006)

2.2.3.1 Acceleration

The acceleration phase is also known as the last part of the downswing, from where the club is horizontal to the ground until the club face impacts the ball.

2.2.3.2 Early Follow Through

This phase of the golf swing starts when the club face impacts the ball and ends when the club is once again parallel with the ground.

2.2.3.3 Late Follow Through

The horizontally orientated club marks the start of this phase and it ends with completion of the swing.

The modern golf swing emphasises an increased shoulder girdle and trunk turn, whilst simultaneously restricting the hip internal rotation on the trail leg and external rotation on the lead leg, with relative rotation of the pelvic girdle. By keeping the front foot still and flat on the ground during the swing, one can accomplish a “quiet” lower body. This would facilitate the clubface to return to the starting position so as to more consistently strike the ball (Gluck et al 2008).

With the enhancement of power and efficiency advocated by the modern golf swing, it has been shown to generate significant forces on different parts of the body (Gluck et al 2008). Due to the asymmetrical mechanics of the golf swing, the lumbar spine has been documented to undergo significant axial twisting forces with rotation, as well as compression, torsion and lateral bending forces (Murray 2008). Particular postures adopted by some golfers using the modern golf swing, can result in increased lateral bending and exaggerated hyperextension in the follow through, potentially aggravating the lumbar facet joints (Murray 2008).

Weakness in gluteus medius, being one of the key pelvic stabilisers (Ward 2010), could lead to poor pelvic stability and thus enhanced strain on the lumbar spine. The ability to stabilise the lower body is directly proportional to the strength of the abdominal muscles, including the obliques, transversus abdominis and rectus abdominus, as well as control of the pelvic musculature, including the gluteal muscles and the short lateral rotators (<http://www.mytpi.com/mytpi05/swing/swingfault.asp>). This will prevent the lower body from thrusting towards the ball during the downswing, allowing early extension of the lumbar

spine. A slide, being excessive lateral body movement towards the target, makes it very difficult to stabilise the lower body. An unstable platform to rotate the torso and shoulder girdles around will cause a loss of power, speed and development of an inefficient kinetic sequence.

Injuries in professional golfers have been attributed to overuse compared to poor technique in amateur golfers (Murray 2008). This emphasises the importance of striving for the most efficient golf swing, maximising the use of the kinetic chain and the body as a whole to project the ball towards the target.

The x-factor is an integral part of this kinetic chain.

2.3 The x-factor, ball flight distance and accuracy

The x-factor can be defined as a separation of the shoulder girdles and trunk, and the hips and pelvic girdle during the golf backswing (Gluck et al 2008). It is calculated at the end of the backswing and the “x-factor stretch” is the transition between the end backswing and the start of the forward swing. Maximising the shoulder girdle and upper trunk rotation compared to the pelvic girdle and concomitant hip rotation, places an increased torsional load on the spine, further increasing the stretch on the visco-elastic elements. This results in an increased store of potential energy that in turn creates an increase in rotational velocity. Blanpied et al (1995) explained this as a pattern in the muscle that involves an initial lengthening through stretching the muscle (eccentric contraction) directly followed by shortening of that muscle with a concentric contraction. Physiologically, enhancement of force using the stretch shortening cycle is achieved in two ways (Blanpied et al 1995). In the first mechanism, reflex potentiation, there is an increase in spindle activity during the stretch phase, resulting in an increased input to the motor neurons. This mechanism thus increases muscle activation. Storage and discharge of elastic energy from the contractile tissues is the second mechanism of force enhancement. Wilk et al (1993) added that the stretch shortening cycle occurs in three phases. The first phase, is the Preloading or Stretching phase, where the muscle spindles of the relevant muscles are being activated when a stretch is applied, creating a store of elastic energy. This can be likened to the x-factor during the backswing. The second (Amortisation) phase is the time between the eccentric contraction before initiation of the concentric force (x-factor stretch at the top of the backswing). The muscle must change over from being stretched to accelerating in the required direction. The third and final phase is a concentric contraction, where the store of potential energy in the previous two phases is utilised for an increase in force output (the

acceleration phase in the golf swing). If the swing is efficient, this potential energy will transfer onto the club head for an enhanced club head speed, thus ball speed and ball flight distance.

Cheetham et al (2001) re-iterated that the greater the x-factor, the greater the ability to generate a higher club head speed and therefore ball velocity (also known as smash factor ratio). Thus a more efficient swing will have a greater x-factor. This was shown in a study conducted by Cheetham et al (2001) comparing the x-factor in professional golfers and mid-skilled golfers with a handicap average of fifteen, with the former having a superior x-factor value.

Further literature shows that the current teaching philosophy in golf is to emphasise an increased torso coiling and subsequent increased force in the downswing (Myers et al 2008). This force would then theoretically be transferred onto the clubface for an increased club head speed, ball velocity and ball flight distance. This torso-pelvic separation can be likened to the stretch shortening principle which utilises eccentric loading to increase the power output in the final phase of the movement (concentric shortening phase). Evans et al (2008) contributed to the literature by finding that an increased torso-pelvic separation resulted in a longer driving distance based on the effective use of stretch shorten principle. This stretch shorten principle was explained by a rapid stretching of the trunk, erector spinae, external oblique, internal oblique, latissimus dorsi, quadratus lumborum, psoas major, transversus abdominus and multifidus, and pelvic muscles, including the gluteal muscles, adductor muscles and lateral rotators, during the back swing, followed promptly by a concentric shortening of these same above mentioned muscles, resulting in an enhanced force production in the downswing.

Cheetham et al (2001), Myers et al (2008) and Evans et al (2008) all used similar methodology when testing their participants. The average range of golfer handicap across all three studies was scratch to 15. Although they used different three dimensional motion analysis instruments to measure x-factor, they all concluded that greater x-factor results in a greater ball flight velocity and distance and that lower handicap players with a more efficient swing have a better x-factor than higher handicap golfers. Cheetham et al (2001) and Evans et al (2008) only had 19 and 29 participants respectively, compared to the 100 participants in Myers et al (2008) study, yet they still all reached the same conclusion, that x-factor is a vital component in driving the ball further. The review article by Gluck et al (2008) reiterated the importance of an increase in x-factor contributing to enhanced rotational velocity, club head speed, ball speed and ball flight distance.

Golf instructors, teaching the modern golf swing, focus on increasing the upper torso rotation whilst simultaneously limiting the pelvic girdle and hip rotation in backswing (Myers et al 2008). This creates a “torso-pelvic separation” increasing stored energy build up that can be utilised in the downswing. It is then postulated that this energy release increases the club head speed, the ball velocity and ultimately the driving distance. As the club head speed can be a valid indicator in determining golf performance and ball flight (Fradkin et al 2004), it is important to discuss further.

Club head speed is defined as the velocity at which the golf club strikes the ball (Fradkin et al 2004). Handicap has long been the preferred measure of golf performance, as it incorporates long and short game performance. Club head speed has however been found to be a reliable indicator of changes in golf performance (Fradkin et al 2004). The study carried out by Fradkin et al (2004) supports the fact that golfers with lower handicaps have higher club head speeds. The efficiency of long game golf shots and therefore golf performance is largely determined by the amount of force that the golfer manages to transfer from the club to the ball and with what degree of accuracy. The club head speed and force with which the club strikes the ball is an essential determinant of ball flight distance.

According to Hume et al (2005), stretching the trunk muscles - erector spinae, external oblique, internal oblique, latissimus dorsi, quadratus lumborum, psoas major, transversus abdominus and multifidus, and hip muscles, gluteal muscles and the short lateral rotators of the trail hip, in the backswing thus maximising the x-factor, will generate a larger angular velocity of the club head and ultimately ball displacement. The authors also found that recruiting muscles in the correct sequence will enhance the optimum effect of the bodies' kinetic chain. Pelvic stability and its contribution to x-factor, has a direct impact on the transfer of energy from the lower body to the upper body, club head and ball.

2.4 Pelvic stability in the golf swing

Mohseni-Bandpei et al (2011) reported on Panjabi's suggestion of three subsystems being responsible for stabilising the spine and pelvis: the bony infrastructure providing intrinsic stability; surrounding muscles providing dynamic stability; the neural component co-ordinating the muscle response. Pelvic stability has been defined as the capability of controlling the motion of the pelvis relative to a distinct neutral position (Mills et al 2005). Mills et al (2005) go on to say that an inability to stabilise the different units of the pelvis with respect to one another, can lead to poor technique and inefficient application of force during movement. The hip joint, a large ball and socket joint, forms the main point of pivot of the

body, allowing for three planes of movement of the femur relative to the pelvis and the pelvis and trunk relative to the femur in closed chain situations (Neumann 2010). Rapid rotation of the trunk and pelvis over a stable and stationary limb requires powerful activation of the strong musculature in association with the hip joint.

Professional golfers and golf instructors have emphasised the importance of the hip muscles including the gluteal muscles and short external rotators and knee muscles' (including semimembranosus, long head of biceps femoris and vastus lateralis, involvement in the golf swing and the hip muscles role in initiating the swing and providing the power for driving the ball forward (Bechler et al 1995). A large proportion of the power for the swing comes from the lower body (Jagacinski et al 2009). The force is generated by pushing against the ground and shifting the body weight from the trail to the lead foot. This is followed by forward rotation of the hips towards the target, followed by rotation of the pelvis and torso and a transfer of the force from the lower body to the trunk, arms and the club, ending ultimately with the ball. This is the full kinetic chain of events that encompasses an efficient golf swing. Hume et al (2005) reiterated that efficient golf backswing motion is as a result of shoulder girdle and trunk rotation around a stable, fixed base of support, enabling the large muscles in the pelvis and hip, including the gluteal muscles and legs, including the biceps femoris, semimembranosus, vastus lateralis and adductor magnus to generate club head speed.

Bechler et al (1995) have found that the golf swing is a full kinematic chain, with the sequential firing of muscles generating power within the pelvis that can be transferred via the trunk to the upper limbs and the club in a harmonious fashion (Bechler et al 1995). The lead leg (left leg in a right handed golfer) provides a fulcrum, thus acting as a pivot point around which the lumbar spine and the pelvis can rotate (Murray 2008).

It is clear that pelvic stability plays an integral role in golf swing performance (Bechler et al 1995). The upper and lower portions of gluteus maximus, gluteus medius, biceps femoris, adductor magnus and vastus lateralis all contribute to the pelvic and hip motion during the golf swing with gluteus medius being the most active during the backswing phase (Bechler et al 1995). The role of gluteus medius muscle in pelvic stability will be discussed in the section below.

2.5 Gluteus Medius

The modern golf swing is a very complex, asymmetrical motion that relies on precisely timed and powerful contraction of a number of muscles (Cole et al 2008). It has been highlighted by Gottschalk et al (1989), that gluteus medius muscle is thought to abduct the hip and

provide stability to the pelvis. These aforementioned authors proposed a new model for the functional anatomy of gluteus medius where it was found to be a segmented muscle (three parts with three distinct muscle directions) with each segment being individually innervated, with phasic action in different directions. This was reiterated by Neumann (2010) finding that gluteus medius is functionally divided into three sets of fibres, anterior, middle and posterior. All the fibres contribute towards abduction, while the anterior fibres contribute towards internal rotation and the posterior fibres contribute towards external rotation and extension, as well as drawing the femoral head into the acetabulum creating stability of the hip joint (Earl, 2005).

The function of gluteus medius together with gluteus minimus was found, through electromyographic (EMG) studies, to be that of hip stabilisation and pelvic rotation as opposed to primary abduction as was the school of thought in the past (Gottschalk et al 1989). In the same study by Gottschalk et al (1989), they found initiation and action of hip abduction to play a secondary role. The gluteus medius was found to have an added function of stabilising the femoral head within the acetabulum in different positions of rotation of the femoral head. Ayotte et al (2007) showed that gluteus medius, in weight bearing, controls the pelvis and the femur in the frontal plane, whereas Neumann (2010) found gluteus medius to be a primary abductor together with gluteus minimus and tensor fascia latae, with gluteus medius being the largest and accounting for 60% of the abductor muscles' cross sectional surface area. Because of gluteus medius' attachments, the muscle is flared, providing the largest abductor moment arm. The gluteus medius and gluteus minimus are capable of producing a combination of abduction and internal rotation torque about the hip in a closed chain environment and also accounts for forces of compression between the acetabulum and femoral head, thus providing stability.

Ward et al (2010) reported that gluteus medius produces a very large force relative to its small surface area, made possible by large amounts of small fibres packed closely in parallel. A consequence of this is that the gluteus medius is not able to produce large forces over a wide range of hip positions. It is thus expertly designed to stabilise the pelvis and the femur when it is in the neutral position. This is important for any clinician when wanting to test the force production of this muscle, as it is shown to be compromised in extremes of adduction and abduction but enhanced in internal rotation (Ward et al 2010).

Earl (2005), study of gluteus medius has looked at its function during the gait cycle. It was found that gluteus medius is very active during single leg stance functioning to prevent a contra lateral pelvis drop. It was noted that when the gluteus medius was not functioning

optimally, it would cause contra lateral pelvic drop, femoral adduction, genu valgus, tibial internal rotation and foot pronation, leading to significant biomechanical and functional abnormalities. This can be applied to gluteus medius function and potential dysfunction in the golf swing. Earl (2005) concluded that the gluteus medius muscle plays a large role in abduction of the hip joint during functional activities. EMG studies have been used to analyse the muscle activity used during the golf swing, including upper body and upper limb as well as lower body and lower limb (McHardy et al 2006). EMG studies conducted have analysed gluteus medius muscle activity during the different phases of the golf swing (Bechler et al 1995). According to a study conducted by Bechler et al (1995), the gluteus medius of the right hip in a right handed golfer was found to contribute 21% of manual muscle test (MMT) during the backswing in an abduction and lateral stabilising role, increased to a peak of 74% during the follow through in a concentric and hip external rotation role, decreasing slightly at acceleration phase to 51%. The muscle activity in the contra lateral (lead) hip did not contribute significantly to golf swing, thus showing the importance of the trail (right hip) in transferring power through the pelvis the club head and the ball.

There are various means of facilitating muscle action and thereby increasing the force output of that muscle. Physiotherapeutic means include, multisensory cue training (auditory, tactile, kinaesthetic and visual cues) (Miller and Medeiros 1987), motor imagery, music therapy (Hummelsheim 1999) and proprioceptive neuromuscular facilitation (Hummelsheim 1999, Nelson et al 1986). KT's ability to carry out the function of muscle facilitation has been tested in few studies on ankle proprioception (Halseth et al 2004) and shoulder musculature (Thelen et al 2008). The efficacy of KT and its ability to facilitate gluteus medius muscle power has not been tested and is the focus of this study. The theories around KT will be discussed in the following section.

2.6 Kinesio®Tape

The use of KT has become increasingly popular over recent years (Thelen et al 2008). Various benefits of KT have been proposed in the literature, including muscle facilitation, muscle inhibition and relief of swelling. These are discussed further in the following text.

Being approximately the same thickness as epidermis, KT is designed to mimic human skin. KT can be stretched between 30-40% of its original length and depending on how much it is stretched it is said to lead to certain benefits (www.Kinesiotaping.com). Potential benefits

include lifting the skin in order to drain lymph to nearest lymph nodes and relief of oedema. KT also provides proprioceptive feedback via the skin. Functional joint stability relies on the proprioceptive feedback from the muscle, ligament and joint mechanoreceptors together with concomitant neuromuscular control mechanisms (Benjaminse et al 2009).

Other benefits include alignment of fascia and limiting or assisting motion via sensory stimulation. Fascia is made up of dense connective tissue sheets, is heavily populated with mechanoreceptors and functions to transmit forces during posture and human movement (Schleip et al 2005, Schleip 2003). There is discussion in the literature that suggests that smooth muscle fibres exist within the fascia thus enabling the fascia to contract and thereby influence musculo-skeletal dynamics. Schleip et al (2005) reported on prior evidence that found connective tissue cells within fascia, displaying contractile behaviour due to the expression of the α smooth muscle actin gene. Fascia forms a true continuum throughout the body and surrounds every muscle. It has been suggested by Schleip (2005) that small interstitial myofascial receptors exist richly in fascia. Research by Schleip et al (2005) and Schleip (2003) has shown that the majority of these are in fact mechanoreceptors that respond to tension or pressure. By taping from the origin to the insertion of the muscle, the tape's function is to facilitate and thereby activate the muscle.

It is important to note the potential allergenic properties that could be associated with any adhesive tapes. The characteristics and use of the various clinical tapes vary depending of the type of fabric and adhesive, as well as the effect that the tape has on the skin surface (Constantinou and Brown 2010). These authors report that studies have linked adhesive tape to allergic contact dermatitis (ACD). It was argued that the literature found ACD due to adhesive tape rare and it was more likely attributed to injuries to the skin such as tension blisters and skin stripping, the removal of stratum corneum, from tape removal (Constantinou and Brown 2010, Rippon et al 2007). The latter was found to be worse in tape with a strong adhesive. It is essential to note that all persons vary in their skin type and skin type varies depending on the part of the body that one is taping (Rippon et al 2007). There are certain factors in the skin that influence the level of adhesion, including sebum levels, sweating, dryness and the presence of creams or ointments (Rippon et al 2007). KT has boasts hypoallergenic properties in that it is latex free, cotton fibre with 100% medical-grade acrylic adhesive (Kenzo 2003). Precautions need to be taken in individuals with skin conditions including ulcers, eczema, fragile skin, haematoma and open wounds (Rippon et al 2007).

There are a limited number of studies (Zajt-Kwiatkoska et al 2007, Basset et al 2010) in the literature that tested the efficacy of KT when applied to specific muscles and its effect on

performance. Huang et al (2011) tested the effectiveness of KT application regarding triceps surae muscle strength measured by EMG analysis, and functional vertical jump performance in healthy inactive people. They concluded that KT application was effective in improving medial gastrocnemius muscle strength and the vertical ground reaction force during the vertical jump. A study conducted by Lee et al (2010), tested whether KT increased grip strength (as measured with a Jamar Dynamometer) when applied to the forearm flexors of the dominant hand. Their results suggested that participants with upper extremity weakness may be improved by the application of KT.

There was not a large sample size in either of the studies conducted by Huang et al 2011 and Lee et al 2010. The outcome measure tools were different, with Huang et al 2011 using EMG analysis to measure muscle strength while Lee et al 2010 used dynamometry, but both shown to be valid and reliable measuring tools. Huang et al 2011 compared KT with a placebo tape when measuring the vertical jump performance, while Lee et al compared KT versus no KT for grip strength performance. Both studies allowed for a wash out period but Huang et al's study (2011) had a much longer gap between testing (3 days as opposed to 5 minutes in Lee et al's study (2010)) to avoid carry over. Both studies gathered baseline data and randomly assigned the procedure of testing to avoid bias. Huang et al 2011 and Lee et al 2012 followed similar methodology and both found a significant increase in strength of the relevant muscles tested and offered important positive evidence of the effect of KT in improving muscle strength immediately after it is applied.

KT can be applied to any skeletal muscle in the body but there is very limited evidence in the literature to support the efficacy of KT in musculo-skeletal disorders, its effect on lower limb strength and function in sportsmen and women. The majority of the evidence found while researching were low level case reports and pilot studies (Zajt-Kwiatkoska et al 2007).

2.7 Review of Instrumentation

The golf swing is one of the most difficult biomechanical movements to perform (Nesbit 2005). Kinematic analysis of the golf swing assesses forces exhibited on different parts of the body, identifying sequences of muscle action and body parts used to produce each unique individual's swing. This gives investigators the opportunity to analyse different golf swings and identify risk factors for injury (McHardy et al 2006). This detailed understanding of the golf swing would be beneficial to the golfer and the golf instructor. There has been

advancement from two dimensional to three dimensional camera systems to gather more complete and accurate biomechanical information of the golf swing.

The iClub™ Body Motion System (BMS), created by iClub™ Inc., Florida USA, provides a three dimensional model of a golfer with the aid of an adjustable Body Motion Vest. This specialised vest is equipped with sensors in key areas. It relays important data, on vital upper-body movement during the golf swing, to a computer (Gary Player Golf Experience Techlab). These sensors are positioned to determine movement of the shoulders, lower trunk, hips and spine as well as the sequence of muscle activation during the swing. The BMS has a Power Sequence Feature whereby the computer is able to accurately measure acceleration and deceleration in the golf swing. It is thus a suitable and precise means of measuring upper torso turn, pelvic turn and thus torso-pelvic separation (x-factor) during the golf swing. Mehta and Mehta (2008), carried out a quantitative study utilising the iClub™ to compare the effect that two different drills had on hip rotation range of motion. The study found that iClub™ 3D motion capture technology is powerful in obtaining swing motion data and is changing golf instruction and research, increasing our understanding of the complex and coordinated motions involved in a successful golf swing. (Figure 2.2, 2.3, Appendix G)

FlightScope®, created by EDH, Ltd., South Africa, is a 3D Doppler Tracking Golf Radar that accurately measures ball-flight, ball trajectory and club tracking (FlightScope® Homepage). It uses phased array and ballistic tracking technology to accurately record the ball flight distance and trajectory and to provide actual launch data. Specialised radars read the ball on 400,000 different points during its flight. It is used for golf instruction, swing analysis, club fitting and club recommendation. This technology was used by Myers et al (2008) to measure club head speed, ball speed and ball distance. The ratio of ball speed to club head speed, the smash factor ratio, is a means of measuring accuracy of the club and ball at point of impact. For the optimal club to ball connection, the ball speed should be one and a half times the club head speed. If a golfer has a club head speed of 160 kilometres per hour, they should have 240 kilometres per hour of ball speed with their driver. The correct launch pattern will result in a ball carry of approximately 240-250 meters. If the ball speed is not one and a half times the club head speed, improved control of the speed already achieved can have an increase in ball flight. (David Allen, Equipment and Golf Instruction Editor, GolfChannel.com, 2009). (Figure 2.4, 2.5, 2.6, Appendix G)

Assessment of muscle strength is one of the fundamental components for assessing the force output of a muscle as part of a physiotherapeutic physical examination (Kolber and

Cleland 2005). It is imperative that the assessment tool be valid and reliable so as to provide accurate and comparative data. Kolber and Cleland 2005 reported various means of measuring muscle strength, including manual muscle testing, isometric testing and hand held dynamometry, with the latter being effective when needing to measure small increases or decreases in muscle strength. Kolber and Cleland's systematic review showed that the Microfet hand held Dynamometer (Hogan Industries, Draper, UT) can accurately measure lower limb and thus gluteus medius muscle strength. The validity and reliability of this instrument to measure muscle strength in healthy individuals is well documented (Kolber and Cleland 2005, Kelln et al 2008). The validity and reliability, however, depends on appropriate adherence to the testing protocol, perpendicular alignment of the hand held dynamometer with the limb, repeated measures being conducted with the same device and that the tester and the device be effectively stabilised (Kolber and Cleland 2005). (Picture 2.7, Appendix G).

The terms used to identify the ability of a muscle to develop tension include muscle strength (Sapega 1990) or muscle torque (Caldwell et al 1974). Another definition of muscle strength is force generated over a single episode at a particular time against a resistance (Kroemer 1972). Knuttgen and Kraemer 1987, define muscle strength as the maximal amount of force that can be generated by a muscle. Thus the words muscle strength and muscle force can be used interchangeably.

2.8 Future Research

There has been minimal research done to date on x-factor, pelvic stability and the golf swing. No specific evidence exists in the literature to show the effect that gluteus medius activation has on the x-factor and pelvic control in the golf swing. The above topics need to be investigated in depth to provide insight into pelvic control in the golf swing and gluteus medius muscle's role in contributing towards this pelvic stability. Further research can be extrapolated from this to ascertain the importance of a strong stable pelvis in relation to ball flight distance and accuracy of the swing in low and high handicap golfers. Other muscles' contribution to pelvic stability as well as the contribution of the different components of the golf swing kinetic chain can be further investigated.

Minimal valid research and only low levels of evidence exist as to the efficacy of KT use in musculoskeletal systems and improvement of muscle strength specifically. The little level of evidence that can be found relates to pain, injury (Gonzales-Iglesias et al 2009) and

proprioception (Halseth et al 2004) and nothing can be found relating to muscle activation in the golf swing.

2.9 Conclusion

The mechanics of the golf swing remains complicated and it is difficult to create and reproduce an efficient golf swing. Gluteus medius plays an important role in maintaining pelvic stability. This plays a fundamental role in x-factor creation and proficient use of the full kinetic chain. The greater the x-factor created, the greater the potential for striking the ball with accuracy and thus having a larger ball carry and landing distance. Recently, KT has become popular amongst clinicians to facilitate muscle function. Taping of gluteus medius and its impact on pelvic stability and x-factor in the golf swing has not been studied and is the area of interest in this research project.

CHAPTER 3

3.0 METHODOLOGY

3.1 Study Design

A one group pre-test-post test quasi-experimental design was used to determine the effect that gluteus medius KT has on torso-pelvic separation in the golf swing, driving distance and accuracy.

3.2 Participants

The participants invited to take part in the study were thirty four registered students from the Golf Academy at the World of Golf sports facility in Woodmead, Gauteng. They have a similar Golf Association handicap, scratch ± 2 and an average of eight years golf experience.

3.2.1 Sample size calculation

A sample size of 28 golfers had 90% power to detect an improvement of 5° as a result of KT on the dominant gluteus medius muscle. The x-factor among the golfers in this study population is expected to range from 40° - 65° (Myers et al 2008) and hence the standard deviation is estimated by $\sqrt{2} * \text{range}/4 = 8.8$.

3.2.2 Inclusion Criteria

- Male participants between the ages of 18-25years
- Golfers with a handicap of scratch ± 2
- Participants must be registered in Golf Academy at The World of Golf

3.2.3 Exclusion Criteria

- Previous trauma or severe injury (including significant fractures, dislocations, vertebral disc, vertebral joint or whiplash injuries, hampering their ability to play golf).
- Suffering from a current injury. Lindsay et al (2000) found spinal, shoulder, elbow and wrist injuries to be the most prevalent in golf.

3.3 Measuring Instruments

3.3.1 i-Club™

The iClub™ Body Motion System (BMS), created and manufactured by iClub™ Inc., Florida USA was used to analyse body angles and speeds of activity of each participant's golf swing, to obtain information relating to x-factor and shoulder and hip rotation angles and speeds.

3.3.2 FlightScope®

FlightScope®, created by EDH, Ltd., South Africa, is a 3D Doppler Tracking Golf Radar that accurately measures ball-flight, ball trajectory and club tracking. Information gathered by the FlightScope® includes club head speed, ball speed, smash factor ratio, ball distance and trajectory mapped out on a computer screen.

3.3.3 Microfet Handheld Dynamometer

Microfet handheld Dynamometer (Hogan Industries, Draper, UT), was used to measure the force of gluteus medius muscle of each participant's trail hip (right for a right handed golfer). The average of three force tests was calculated. The test was conducted with and without the KT.

3.3.4 Validity and Reliability

Force testing of the hip towards abduction, to test for gluteus medius strength, has been shown to be unreliable in literature as the side lying test position could be hard to maintain with the hip in neutral and still trying to produce an abduction force (Benjaminse et al 2009). Participants may have a tendency to externally rotate the hip in order to recruit other muscles, for example, using hip flexors to assist in the motion. Thus it was essential to provide clear instructions to the participants prior to conducting the test. An average of three tests was taken under verbal instruction and the same research assistant conducting the test, in order to maximise on reliability.

Bohannen (1986) concluded that the hand held dynamometer is a reliable assessment tool when used by a single experienced tester. Kolber and Cleland (2005) concluded that hand held dynamometry is both valid and reliable at measuring muscle strength, torque and maximal voluntary force (ICC 0.69-0.95).

There are no studies in the literature regarding the validity and reliability of FlightScope® and iClub™. The World of Golf has used this technology for years and has found the data

collection capabilities of both instruments invaluable for gathering information on countless golfers' swings. FlightScope® South Africa reports that FlightScope® was used in the 2011 British Open for its accurate data collection capabilities.

According to Danie Stover of FlightScope® South Africa, FlightScope® is a 3d tracking doppler radar for sports balls and in particular for golf balls and clubs. Due to the complexity of golf club swing, the accuracy of measurements can usually only be compared with high speed camera measurements, which are themselves only accurate within bounds because of the limitations of cameras measuring high speed objects.

Ball tracking is easier to determine as ball velocity can be measured with great accuracy. Other factors such as carry distance and lateral offset can be determined accurately by observing the drop point and measuring with precision surveying equipment.

Below are some accuracy figures obtained by FlightScope® South Africa, showing the reference systems used to compare and validate FlightScope®:

Table 3.1 FlightScope® validation chart

Measurement	Accuracy	Reference System (Tested against)
Ball speed	1%	Military doppler radar
Ball direction	0.5 deg	Physical position
Ball launch angle	1-2 deg	Physical/camera position comparison
Carry distance	2%	Leica Totalstation
Club speed	2%	CPAS camera system of R&A in Scotland
Ball spin	2%	Physical rotational data analysis

3.4 Variables

3.4.1 Independent

KT application or no KT application was the independent variable.

3.4.2 Dependent

The gluteus medius muscle strength, x-factor, ball flight distance and smash factor ratio were dependent variables.

3.5 Procedure

The World of Golf Operations Director, granted permission to conduct the study at the sports facility (Appendix D). Special arrangements were made in conjunction with the Gary Player School for Champions to conduct the study at a date and time that was optimal for management staff and the students that would act as participants in the study. All the potential participants were provided with information (Appendix A) pertaining to the study and were able to make an informed decision on whether they would participate or not, by signing the consent form (Appendix B).

3.5.1 Pilot Study

3.5.1.1 Objectives of the pilot study

The pilot study was conducted on four healthy golfers, registered amateurs at The World of Golf, to familiarise the researcher and the research assistant with the testing procedure, the KT taping technique and gluteus medius muscle strength testing with the Microfet Hand Held Dynamometer. These golfer's results were not included in the results of the main study. The researcher also became accustomed to the Body Motion Vest adjustment and fitting as well as the data collection procedure with iClub™ and FlightScope® so as to be accurate and time efficient on the testing days. This was carried out in conjunction with the golf professionals and biokineticist in control of the equipment at the World of Golf.

A pilot study was thus conducted to test the participants' understanding of the informed consent form, the data collection instructions, the length of time it took to collect the data and order of the procedure for data collection, familiarisation of testing equipment and to establish the time it took to complete the procedure.

3.5.1.2 Methodology of the pilot study

An information sheet (Appendix A) was provided to all participants containing details on the importance of the study, what to expect when participating, the benefits that the gathered information could provide and an assurance of confidentiality of information collected. The same procedure, as described for the main study, was followed.

3.5.1.3 Results of the pilot study and implications

The informed consent form was well understood by all the participants and was sufficient according to feedback received from those taking part in the pilot study. No questions were raised by any of the participants. An order of procedure was established for each testing day and the testing equipment became very familiar and time efficient. It was established that the iClub™ needed to be given a five minute cool down period and rebooted after every four participants so as to avoid it “crashing” and recording incorrect data.

3.5.2 Main Study Procedure

Informed consent was gained from each participant and permission was obtained from the operations director to carry out the data collection on days that correlated with the academy schedule without interfering with their regular routine.

The data capture procedure formed part of their daily training schedule and each participant was allocated a time. The participants were assigned numbers and the data collected was matched to the respective number. The information from the first day was not looked at again until the study was complete, so as to not introduce bias.

3.5.2.1 Procedure

Each participant carried out a standardised five minute warm up routine, created for the Titleist Performance Institute by R. McMaster (Appendix C). This warm up program is consistent with their standard Academy assigned warm-up, followed by five warm-up swings with their own driver. There are certain characteristics of a driver that affects ball flight distance and accuracy, including shaft stiffness, shaft length and club face loft (Myers et al 2008). This has no impact for the purposes of this one group pre-test-post test quasi-experimental study as each participant's data with KT is being compared to the same participant's data without KT using the same driver in both instances. This warm up was done prior to gluteus medius muscle strength testing and KT application.

3.5.2.2 KT Application

KT application was standardised according to Kinesio® Taping International (2008), as illustrated by Kase (2003) and was applied in exactly the same way on each participant by the research assistant. Two “I” strips of tape were used and the tape was applied proximal to distal. The first strip was applied with the participant in side lying with the dominant hip on top and in adduction (Figure 3.1, picture 1). This strip was anchored, without tension, to the lateral lip of the iliac crest, lateral to the anterior superior iliac spine. The tape was activated at proximal anchor point and laid over the gluteus medius with slight tension due to adduction of the hip. The tape was anchored distal to the greater trochanter laterally. The second “I” strip was anchored to the iliac crest lateral to the posterior superior iliac spine. The hip was placed in flexion and adduction. The distal anchor point was the skin over the lateral greater trochanter (Figure 3.1, pictures 2, 3, and 4).

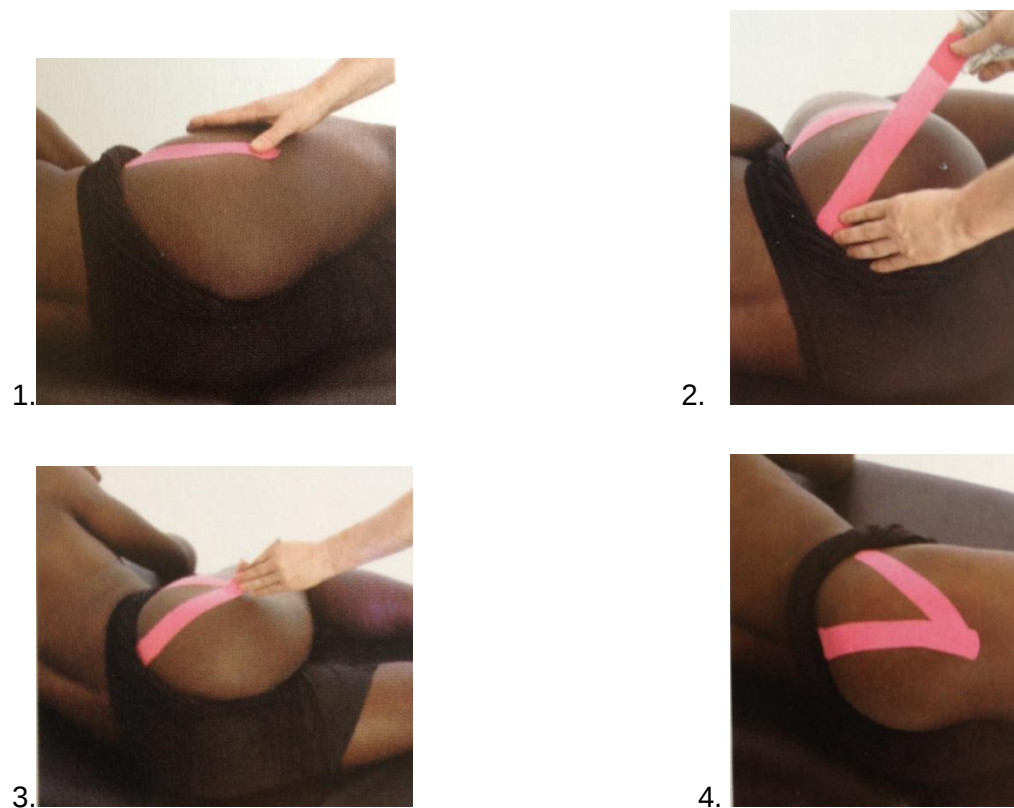


Figure 3.1 Kinesio® Taping technique on Gluteus Medius muscle (Kase Kenzo 2003)

3.5.2.3 Gluteus Medius muscle strength testing

Prior to application of the KT, an isometric hip-abduction strength test was carried out on the participant's dominant gluteus medius muscle (left gluteus medius for left handed golfer and right gluteus medius for right handed golfer – this corresponds to the trail leg in the golf address position). The participant was positioned in side lying, with the dominant hip in slight extension, and asked to abduct the hip to approximately 30°. The researcher stabilised the

pelvis with one hand and applied medially directed resistance with a Microfet handheld dynamometer in the other hand just proximal to the greater trochanter of the femur. This same test was conducted after application of the KT. This process was similar to the one used by Hollman et al (2009) in their study on hip muscle strength and hip muscle recruitment in the single limb step-down

3.5.2.4 Body Motion Vest

Each participant, in turn, was fitted with the Body Motion System vest that was adjusted to fit the participant's body. He stood on the pre-marked testing area in front of the golf driving range. The participant carried out ten shots off an artificial turf tee box and the same standard range ball brand was used by each participant. He used his own driver to represent the swing and ball flights experienced while playing. Using the iClub™ Body Motion System to measure the x-factor and the FlightScope® to measure ball flight distance and accuracy, the data was collected for each participant on the ten shots hit. This data collection procedure was carried out in a similar way as done by Myers et al (2008).

3.5.2.5 Golf Swing

The swing point of interest for the x-factor calculation (calculated as the difference between the upper torso rotation angle and the pelvic rotation angle at the top of the backswing) was the top of the backswing (Myers et al 2008). Point of ball contact, so as to measure club head speed and ball speed, and ball landing distance was focussed on.

3.6 Ethical Considerations

A research protocol was submitted to the Human Research Ethics Committee for medical clearance of research at the University of the Witwatersrand. Clearance (certificate number M10536) was received prior to the commencement of the study (Appendix E). Permission was received from the World of Golf to conduct the research at their facility and to gain access to their equipment for data collection (Appendix D). Each participant was provided with an information sheet explaining the purpose and procedure of the research and inviting them to participate in the study (Appendix A). Signed informed consent was obtained prior to participation (Appendix B). Participants were informed that they have the right to withdraw from the study at anytime without suffering any repercussions. Confidentiality was maintained by assigning numbers to each participant but they received feedback individually, if they requested it.

3.7 Data Analysis

This study set out to assess the change in gluteus medius muscle strength and its impact on the x-factor of the golfer, the ball flight distance and accuracy, as a result of KT application on the dominant gluteus medius. The strength of a pre-test post-test observational study is that each participant is able to act as his own control.

The data gathered in the taped and non-taped groups was analysed using a paired t-test, when testing at the 0.05 level of significance. Correlation between gluteus medius and x-factor, ball flight distance and smash factor ratio with and without KT application, was done using Pearson Correlation analysis. The results will be illustrated in the tables presented in Chapter 4.

CHAPTER 4

4.0 RESULTS

4.1 Introduction

The results will be explained under the following sub-sections:

4.2 Sample size

4.3. Comparison of Mean Variables with and without KT

4.4 Relationship between Gluteus Medius and the Variables with and without KT

4.2 Sample Size

All thirty four (34) participants from the academy were invited to participate in the study. This number included the golfers that participated in the pilot study were also invited to participate in the main study as there were no major changes from the pilot study. Thirty (88%) participants agreed to participate and twenty nine (85%) were able to conduct the study as one participant was taken ill on the day of the commencement.

The Gary Player Golf Academy is run every year at The World of Golf and has a new intake of amateurs at the start of each year. These participants are screened to be of a similar skill level ($\text{Scratch} \pm 2$) and are generally males of all races. These golfers only attend the academy post matric and ages range between eighteen and twenty five. The average age of the participants in this study was twenty years old.

4.3. Comparison of Mean Variables with and without KT

Table 4.1 Comparison of Mean Variables with and without KT (n=29)

VARIABLE	MEAN ($\pm$ SD) - KT *	MEAN ($\pm$ SD) + KT *	MEAN ($\pm$ SD) DIFFERENCE	CONFIDENCE INTERVAL	p VALUE **
GLUTEUS MEDIUS STRENGTH	233.81 ($\pm$ 41.13)	243.52 ($\pm$ 38.63)	-9.71 ($\pm$ 14.7)	(-15.30 to -4.12)	0.00
X-FACTOR	57.4 ($\pm$ 9.6)	58.64 ($\pm$ 8.04)	-1.25 ($\pm$ 5.9)	(-3.54 to 1.05)	0.28
BALL FLIGHT DISTANCE	269.52 ($\pm$ 15.13)	268.48 ($\pm$ 16.92)	1.03 ($\pm$ 8.7)	(-2.26 to 4.33)	0.53
SMASH RATIO	1.43 ($\pm$ 0.03)	1.42 ($\pm$ 0.03)	0.01 ($\pm$ 0.03)	(-0.002 to 0.21)	0.1

* Units: Gluteus medius strength = Newton; x-factor = degrees; Ball flight distance = metres

** (Level of significance = $p \leq 0.05$)

Table 4.1 above summarises the mean values with respect to the outcome measures tested, with and without KT application. The gluteus medius results proved to be statistically significant ($p=0.00$). This shows that gluteus medius muscle strength increased with KT application. However, KT application did not have a significant effect on x-factor ($p=0.28$), ball flight distance ($p=0.53$) and smash ratio ($p=0.1$), despite the increase in gluteus medius muscle strength.

The raw data is portrayed in Appendix F.

4.4 Relationship between Gluteus Medius Strength and the Variables with and without KT

Table 4.2 Relationship between Gluteus Medius Strength and the Variables with and without KT (n=29)

FACTOR	r VALUE - KT	p VALUE - KT**	r VALUE + KT	p VALUE + KT**
X-FACTOR	-0.28	0.15	-0.46	0.01
BALL FLIGHT DISTANCE	0.09	0.66	-0.03	0.9
SMASH RATIO	-0.29	0.13	-0.33	0.08

(** Level of significance = $p \leq 0.05$)

A relationship between gluteus medius and x-factor, ball flight distance and smash factor ratio was determined with and without KT application. The results in Table 4.2 show that as gluteus medius strength increased with KT application, the x-factor degree ($r = -0.46$, $p=0.01$)

and the smash factor ratio ($r = -0.33$, $p = 0.08$) decreased. This shows that an increase in gluteus medius strength had a negative effect on the x-factor degree and the smash factor ratio. There was no significant relationship between gluteus medius strength and ball flight distance. The statistical significance of the smash factor ratio with KT ($p = 0.08$) is noted to be close to the significant value of 0.05. It could be argued that a larger sample size, with consistent results, may have shown a statistical significant result.

CHAPTER 5

5.0 DISCUSSION

5.1 Introduction

The aim of this study was to assess the effect that KT has on gluteus medius strength and how they together impact on the golf parameters of x-factor, ball flight distance and accuracy.

The focus of this chapter is to discuss the results and findings under the following subheadings:

5.2 The effect that KT has on gluteus medius muscle strength

5.3 The effect that KT has on x-factor

5.4 The effect that KT has on ball flight distance

5.5 The effect that KT has on accuracy

5.6 Limitations of the study

5.2 The effect that KT has on gluteus medius muscle strength

The gluteus medius muscle strength improved significantly ($p=0.00$) with application of KT with a mean difference of -9.71Newton ($\text{SD} \pm 14.7$). When applying the theories put forward by Schleip et al (2005) and Kase (1979), a reason for this improvement could be that taping the gluteus medius from origin to insertion, augmenting the pull of fascia and thus the muscle, is effective in enhancing the force of this muscle sufficiently enough to create a positive change. This could confirm that KT application has an effect on the smooth muscle cells within the fascia, facilitating them to contract, without hampering range of motion. As the muscle is attached to the fascia, this facilitation is carried over onto the muscle, assisting it to have an increased force production.

Another possible mechanism for improvement of force production could be KT's effect on the neural pathways by stimulation of afferent neural receptors. KT's ability to re-educate the neuromuscular system was corroborated by Hsu et al (2009) in their study conducted on the effects of taping on scapular kinematics and muscle strength. The results showed that taping

was successful in creating positive changes in scapular motion and muscle strength. Similarly, a study carried out by Huang et al (2011), showed that KT is very useful in applying to muscles to enhance performance.

According to hypothesis (H^1), participants who improved the most in their gluteus medius strength after KT application, should also have shown a concurrent improvement in the other variables tested, being x-factor, ball flight distance and accuracy. This was however not shown to be true in this study. Only one participant who improved significantly in his gluteus medius strength also showed significant increase in his x-factor and ball flight distance, while his accuracy result remained the same. This finding could be reiterating the fact that technique varies greatly among participants, each having their own unique style of coordinating the golf swing components.

An improvement in muscle strength due to KT application can have important implications in the clinical setting to improve function and performance. KT can be used as an adjunct to other treatment modalities to facilitate muscles recovering from injury or to enhance performance in muscles that are weak and imbalanced. This would be particularly important in a sporting environment where muscles are put under strain, depending on the demands of the sport.

A muscle can have a mechanical advantage depending on the line of pull. Moment arms change with the position of the joint, which directly influences the amount of length change undertaken by the muscle as the joint rotates (Ward et al 2010). The force generating capacity will change according to the position of the hip, depending on which position provides the muscle with a mechanical advantage (increased cross-bridge linkage) and disadvantage (decreased cross-bridge linkage). In the case of gluteus medius, internal rotation of the hip will increase the torque-generating capacity of this muscle (Ward et al 2010). This study is looking at the effect of applying KT to a particular muscle and how it affects the Hand Held Dynamometer reading after it has been applied. It cannot be assumed at this stage that KT provides a mechanical advantage or disadvantage to a muscle as it is not investigated anywhere in the literature.

5.3 The effect that KT has on X-factor

The correlation analysis showed an inverse relationship in that an increase in gluteus medius strength had a negative effect on the x-factor, illustrating that the participants with enhanced gluteus medius muscle strength, had a low x-factor value ($r = -0.28$ (without KT); $r = -0.46$ (with KT)). Even though theories put forward by Kase (1979), stating that KT does

not hamper range of motion, applying KT to a participant's pelvis may adversely alter the usual pelvic mechanics as the body set up is different from what he is used to and has practiced. This result may change if the participant practices with the tape on for a period of time, in order to get used to the muscle facilitation that the tape creates.

The results showed that there was no significant effect of KT on x-factor ($p=0.28$) with a mean difference of $-1.25 (\pm 5.9)$, even though there was a significant improvement in gluteus medius muscle strength. One of the reasons for lack of improvement in the x-factor could be the fact that one muscle, despite improvement, may not necessarily improve the golf swing as a whole, due to many muscles acting in unison to create this movement. Stretching the hip and trunk, and muscles of the upper limb, including upper, middle and lower trapezius, levator scapulae, supraspinatus, subscapularis, anterior, middle and posterior deltoid, as part of the backswing, maximises on x-factor produced and used in the downswing. If there is weakness in any one of the hip and pelvic stabilising muscles, like the gluteal muscles, the hip adductors or lateral rotators or the pelvic stabilisers as a whole, the pelvis would not remain as still as possible and will rotate along with the torso and shoulder girdles diminishing the x-factor (Myers et al 2008). Other than gluteus medius, specific pelvic stabilising muscles, like gluteus maximus for its greater volume (Ward et al 2010), or the short external rotators for their large physiological cross-sectional area and short fibres, suggesting a pelvic stabilising design (Ward et al 2010). These aforementioned muscles may play a larger role in pelvic stability and x-factor, by storing potential energy and developing power for the downswing. A lack of trunk rotation range of motion would also alter the required internal or external rotation of the hips, the shoulders girdles together with the upper torso, or all of the above, also adversely affecting the x-factor created.

The lack of a significant result could also be attributed to the fact that the standard deviation among participants was too large due to each golfer having a unique swing. Gluck et al (2008) stated that each golfer's individual swing can be as different and unique as their fingerprint.

Biomechanically, an improvement in x-factor can be attributed to either - an increase in shoulder girdle with upper torso turn, a decrease in hip internal rotation on the right and external rotation on the left with concomitant pelvic girdle turn or a combination of improved shoulder girdle and upper torso turn whilst keeping the hips and pelvic girdle stable and still. Gluteus medius has been well documented as an important pelvic stabiliser (McHardy et al 2005, Ward et al 2010). This study has shown that KT facilitates gluteus medius action to stabilise the pelvis, creating a stable base about which the upper body can turn during the

backswing. Although the x-factor results were not statistically significant, pelvic stabilisers may play a role, but other pelvic stability muscles, like the gluteus maximus and the short lateral rotators could be contributing to x-factor to an equal degree. Thus, a longer term goal would be to carry out an extensive exercise program and amongst other valuable components, include strengthening of the pelvic stabilisers, trunk rotation mobility and scapular stabilisation, focussing on the rotator cuff, serratus anterior and lower trapezius, to enhance x-factor and thereby create a more efficient swing. Lephart et al (2007) conducted a study on recreational golfers, implementing an eight week, golf specific exercise program. The development of the program was based on evidence researched by Lephart et al (2007) that golf specific flexibility, stability, plyometric and balance training improves rotational mobility, core stability, club head speed and driving distance in golfers. When developing their evidence-based eight week training program, they collected data on the strength, flexibility and balance of over 100 golfers of varying handicaps. Lephart et al (2007) found that the main differences between higher and lower handicap golfers included stronger hip abductors, greater power in torso rotation, increased shoulder strength in horizontal abduction and adduction and enhanced balance with single leg stand. This established the key factors that their golf program focussed on, in order to improve the parameters of club head speed, balls speed and driving distance. They concluded that the program improved strength, flexibility and balance in golfers. This program had a positive impact on their x-factor rotational velocity, club head speed, ball speed and ball flight distance.

5.4 The effect that KT has on Ball Flight Distance

Correlation analysis showed a negative relationship between gluteus medius strength and x-factor and smash factor ratio. There was no correlation between gluteus medius and ball flight distance. It can thus be said that with no improvement in x-factor due to the enhanced strength of gluteus medius, there would not be a likely increase in ball flight distance, the latter being largely dependent on x-factor. This is however not the only contributing factor to ball flight distance; swing speed, timing of the kinetic chain and accuracy of ball strike being equally important (Fradkin et al 2004, Hume et al 2005). A change in any of these factors could adversely alter the ball flight.

The effect of KT and change in gluteus medius muscle strength was immediate after application, as was tested in this study. The lack of improvement of ball flight distance could be ascribed to the lack of practice with the KT on the gluteus medius. Gluck et al (2008) found that gluteus medius was highly active in hip stabilisation and force production during the golf swing. Due to the complicated nature of the golf swing and the countless

synchronised components, there is a very small margin for error and many variables (rotation angles, speed of movement, weight shift, timing of ball strike, technique) that could affect the flight of the ball (Jagacinski et al 2009). This aforementioned author asked the important research question of how golfers manage the complex nature of the golf swing and co-ordinate various patterns in order to hit the ball with satisfactory skill, within special constraints of the game. The torso-pelvic separation differential, the rate at which this occurs in the backswing and the rate of turn during the downswing are all considered important variables in achieving further ball flight distances (Evans et al 2008). The increased force of gluteus medius may alter the golfer's usual swing biomechanics and timing of the different components. Thus, practice with the KT on, would allow the golfer to become accustomed to the new found strength and enable him to utilise this to drive the ball further.

It could also be argued that the participant is consciously trying to hit the ball further and with more force because of the knowledge of having the tape on. This "forcing of the swing" will change his normal swing mechanics essentially making his swing less efficient and decreasing the distance that he is hitting the ball. Nesbit and Serrano (2005) observed that swinging the club "harder" would do very little to drive the ball further. They found that it may actually be more difficult to do useful, efficient work with tighter muscles, the cost of this often being a reduction in accuracy.

5.5 The effect that KT has on Accuracy

KT application on gluteus medius had no significant effect on the smash factor ratio ($p=0.1$) and a negative relationship existed between gluteus medius strength and smash factor ratio (r value without KT = -0.29, r value with KT = -0.33). A possible reason for this is that the golfers tested all have a golf association handicap of scratch or ± 2 , their swing being considerably more efficient and consistent than your higher handicap golfers. The mean value without KT was 1.43 (SD ± 0.03) and with KT was 1.42 (SD ± 0.03), a mean difference of only 0.01. An efficient swing will produce a ball speed (BS) as close to one and a half times the club head speed (CHS) as possible ($BS/CHS = 1.5$), indicating that the ball was struck in the sweet spot of the club. An already efficient swing does not leave considerable room for improvement as the smash factor ratio was already good without intervention.

Another reason may be the conscious knowledge of having the tape on and trying to hit the ball harder, essentially changing the biomechanics to force the swing. Despite encouragement to carry out a normal swing, it may at times be counterintuitive as it is a

participant's natural tendency to want to improve, thus losing accuracy due to increased effort (Nesbit and Serrano 2005).

One may find a larger impact of the tape in the higher handicap group as their accuracy is less consistent and further away from the ideal ratio of 1.5. This valuable information can be gathered in future studies.

When reviewing the data, with the hypothesis (H^1) that pelvic stability improves x-factor resulting in an increase in ball flight distance and accuracy, one would expect to see a definite trend in the mean values of these variables in response to an improvement in gluteus medius strength. In contrast to the hypotheses (H^1), the participants showed an erratic trend across the outcome measures.

Although these parameters did not prove to be statistically significant, there is a possibility that the outcome could be considered clinically significant. All participants improved in certain outcomes but the improvements were in different parameters not consistent in each participant. Due to the complexity of the golf swing (Jagacinski et al 2009), it could be argued that an improvement in a parameter, no matter how small, could be beneficial to improving the outcome of the golf shot.

Each golfer has specific aspects of his swing that are his strong points and other aspects that require work, highlighting the importance of specificity with regard to assessments, intervention and training. The KT was only testing gluteus medius and its role in pelvic stability. Not all golfers show weakness in this area and further research would need to be conducted assessing a golfer's weakness and using the tape to improve on these highlighted areas rather than on a particular muscle that may not require increased activation.

5.6 Limitations of the study

The golfers participating in this study are all high level amateur golfers. As this makes up only a small percentage of the general golfing population, consideration should be given to the fact that the golf swings analysed and outcomes measured in this study may not be representative and therefore findings may not be extrapolated to the average golfer. All the golfers had a scratch ± 2 handicap and the study does not compare low and high handicap golfers.

The standard golf driving range was used to best augment the golfers' natural playing environment. This may be argued as a strength of the study as it is realistic and applicable to

a golfer's normal game. This does however come with certain external factors that are changing, including wind speed, direction and temperature. These may impact on the results and would only be able to be controlled in an indoor testing lab.

The golfers all practiced their swing or played golf on the off day between the two test sessions. This could impact on the outcome of their second test day. This could not be avoided as minimal interference with the school schedule was necessary.

Only one muscle was targeted and there are many muscles (and other factors) that contribute to and impact on the golf swing.

The validity and reliability of the equipment, FlightScope® and iClub™, used is not well established in the literature. However, FlightScope® is used in clinical practice worldwide, including Major PGA Golf Tournaments, to gather information regarding ball flight distance and accuracy, amongst other data. iClub™ has been used successfully by World of Golf to test and compare countless golfers' swing angles and speeds. These golf professionals and clinicians continue to use FlightScope® and iClub™ as they find their data capture capabilities invaluable.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The purpose of the study was to show the effect that KT has on gluteus medius and in turn on the x-factor in the golf swing, driving distance and accuracy. Gluteus medius plays an integral role in pelvic stabilisation and has been shown that torso-pelvic separation is enhanced by a stable pelvis. It was thus hypothesised that gluteus medius activation by KT will increase torso-pelvic separation in the golf swing and subsequent increase in ball flight distance and accuracy. The results showed that the gluteus medius KT successfully improved the strength of this muscle but did not impact significantly on x-factor, ball flight distance and accuracy consistently among the participants. A possible reason for this is the complexity of the golf swing and how its precision is built on so many elements of the kinetic chain. The improved strength of one muscle may not be significant enough to change the whole movement and may be reliant on sequential firing and timing of many muscles involved in the golf swing. It is thus essential to assess each individual thoroughly, so as to highlight his problematic areas, so that a specific training and intervention may be implemented.

The overall results of the study have shown that it would be beneficial to incorporate the use of KT to facilitate muscle action. The customised application of KT on each individual golfer may be more beneficial, according to their specific strength requirements.

6.2 Recommendations

6.2.1 Clinical recommendations

This study provides preliminary evidence in the efficacy of KT applied on a specific muscle. However, the muscle power enhancement effects of KT found in this study is of great value clinically, as KT can be used as an adjunct to a customised exercise program to improve performance, or in addition to manual therapy and the rehabilitation process for golfers who are recovering from injury. Even though this current golf study shows that KT has a statistically significant facilitatory effect on gluteus medius, there is ample opportunity for further studies on KT and its effect on different muscles, in golf specifically, and over a wide spectrum of sports.

Regular assessment can also be carried out using the instrumentation to assess and compare individual progress and improvement.

6.2.2 Recommendations for further research

A systematic review was conducted by Basset et al (2010) evaluating and critiquing randomised control trials which examined the therapeutic effects of KT in the treatment of musculoskeletal conditions. Of the three studies that met their inclusion criteria, they concluded that there was limited evidence of clinical significance of the results and stresses the necessity for further research. The anecdotal advantageous functions of KT are based on theories that have been proposed, but still have no evidence based validation (Bassett et al 2010), further highlighting the importance of the positive results achieved in this study. A recommendation for future research is identifying the actual physiological mechanisms of how KT functions as this is very poorly documented.

Golf swing biomechanics differ extensively, even between individuals of similar handicap so it is difficult to obtain statistical information on specific parameters as the standard deviation between the individual golfers is too large. Further studies can be extrapolated from this research on other important pelvic stabilisers and how they affect the golf swing and golfers' function. There have been a number of studies relating upper limb function to the golf swing and numerous investigations into the relationship between the x-factor and driving distance comparing low and high handicap golfers (McHardy and Pollard 2005). Very little research has been conducted on the lower limb and pelvic contribution to the golf swing. Further studies can be conducted on other components of x-factor production to ascertain the most important contributors.

As KT has become popular over recent years, there is little evidence supporting its function and efficacy. The outcome of this study provides a better understanding of KT's function to facilitate muscle can be used in sport rehabilitation and performance enhancement.

This study only looks at short term benefit of KT thus further investigation needs to be carried out in order to determine the long term effects of KT on muscle strength and performance.

CHAPTER 7

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APPENDIX A

STUDY TITLE:

The effect of Gluteus Medius Kinesio® Taping on torso-pelvic separation during the golf swing, ball flight distance and accuracy.

Dear Golfer,

My name is Boudine Pearce. I am currently studying a Masters in Sports Physiotherapy at the University of the Witwatersrand. I am conducting research on the effect that a specialised Kinesio® Taping technique has on a pelvic stabiliser muscle, namely gluteus medius. How this affects the upper and lower trunk rotation (x-factor) in the golf swing and on driving performance and accuracy will be looked at. I would very much appreciate your participation in this study.

What is the importance of this study?

It is very important to have a stable base on which to rotate your upper body during the backswing. If the pelvis is stable due to strong muscular stabilisers, your upper body is able to rotate a lot further. This greater rotation will build up an increased energy store to be used for a more powerful downswing. The result would be a greater driving distance off the tee and improved accuracy at ball strike.

This study aims to show that gluteus medius muscle Kinesio® Taping will facilitate gluteus medius and thus will create a stable base, increase your x-factor, allow you to drive the ball further and strike the ball with improved accuracy.

What are you going to be asked to do?

You will then be asked to warm up with a set program. The gluteus medius muscle strength of your dominant hip will be tested with a hand held apparatus. This same strength test will be conducted after application of the tape on your dominant gluteus medius. You will then be fitted with a special body vest with sensors built within it. Following this you will be asked to hit 10 shots with your own driver and a range ball. Measurements of your x-factor, ball flight distance and accuracy will be taken on your 10 shots hit, with the World of Golf measuring equipment and video analysis.

None of these tests will be invasive, harmful or painful in any way. You will be required to wear comfortable golf attire, golf shoes and a golf glove. This will be incorporated in your normal daily routine at the academy and will take approximately 30 minutes.

Participation in this study is completely voluntary. You may withdraw at any stage and are not required to give any reason for your withdrawal.

What are the benefits of this study?

If this study shows that gluteus medius muscle Kinesio® Taping plays an integral part in pelvic stability, a standard exercise program can be developed and implemented to increase the strength of this muscle, improve your swing, driving performance and accuracy.

Will your details and results be confidential?

All information will be kept confidential and only used for the purposes of this study. Numbers will be assigned to each participant. Your name will only appear on the consent form and will only be available to the researcher. Each participant will get feedback on their personal results should they request it.

If you agree to participate in this study please complete the consent form attached.

If you have any queries or require any further information, please do not hesitate to contact me on 0834452580.

Kind Regards,

Boudine Pearce

APPENDIX B

INFORMED CONSENT

I, _____, hereby agree to participate in the above mentioned study. I understand all the information that has been described to me in the information sheet.

By signing this form I am agreeing to participate in all the physical tests and video analysis required by the researcher.

I understand that there will be no financial compensation for participation in this study and I may withdraw at any time without having to provide a reason.

SIGNATURE: _____

WITNESS: _____

DATE: _____

APPENDIX C

YOUR 5 MINUTE GOLF WARM-UP – Titleist Performance Institute By R. McMaster

29/12/06

1. Combined Hip Trunk & Shoulder Stretch-Using the Flexibility & Mobility Warm-up Drill

Lunge position with right hip stretched back. Keep upright posture and activate core. Hold golf club above head with pistol grip. Bend trunk to left side, keeping head on shoulders.



2. Balance & Static Posture Warm-up drill

Standing upright in the '**angel wings position**' against the wall, place a golf ball between the balls of feet. Keep nose and belly button in line with the ball. Tuck in your chin and look at the bottom of your lower eyelids. Keeping your arms by your side and forming a pistol grip in both hands, slowly lift the ball up with your feet.



3. X-Factor Check-Using Core Stability & Rotation

Keep yourself in an upright and stable posture. Place your elbows in by the side of your ribcage. Slowly rotate your trunk to the right maintaining your hips in a stable position to the front. Keep your elbows into your ribcage, feel the tension between your inside thigh and lower abdominals.



4.Push-Using the Core Stability Golf Drill

Slowly extend your arms and thrust the body in a slow pushing movement against an imaginary truck. Feel your shoulders, neck, abdominals, gluteals and legs all work together as you push.



4.The Cross Over Golf Exercise Drill-Using Core Stability, Rotation & Dynamic Posture

Stand in an upright position and maintaining good spinal posture, cross your right elbow to the top of your left knee. Then cross your left elbow on to your right knee.



APPENDIX D

12 April 2010

To whom it may concern,

This letter serves to confirm that Boudine Pearce (BSc Physiotherapy, WITS) has permission to use the technical analysis equipment at the Gary Player Golf Experience and the Vodacom World of Golf in order to conduct her study.

In particular she has access to the iClub and Flightscope systems for data collection.

Please feel free to call the writer for verification.

Yours truly,

Danny Baleson.
Operations Director.

-

APPENDIX E

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
 R14/49 Ms Boudine Pearce

CLEARANCE CERTIFICATE

M10536

PROJECT

The Effect of Gluteus Medius Kinesio Taping
 on Torso-Pelvic Separation during The Golf
 Swing, Ball Flight Distance and Accuracy

INVESTIGATORS

Ms Boudine Pearce.

DEPARTMENT

Department of Physiotherapy

DATE CONSIDERED

28/05/2010

DECISION OF THE COMMITTEE*

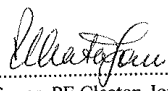
Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE

07/07/2010

CHAIRPERSON.....


 (Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
 cc: Supervisor : B Olivier

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
 I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

APPENDIX F

RAW DATA

Gluteus Medius Strength

Table F1 . Gluteus Medius Muscle Strength as Measured with a Microfet Hand Held Dynamometer, with and without Kinesio® Tape (n=29)

PARTICIPANT	GM STRENGTH *-NO KT (N)	GM STRENGTH * -KT (N)
1	198.3	233.7
2	203.3	224.3
3	231	223.7
4	195	210.7
5	202	205
6	230	198.7
7	177.7	208.3
8	227.7	257.3
9	218.7	232.7
10	274.7	281.3
11	200.3	204.7
12	229.7	254.3
13	211.7	207
14	251.3	264.3
15	228.7	236.7
16	207.3	227.3
17	256.3	280.3
18	383	387.3
19	307.6	304.6
20	232	248.3
21	235.3	236.7
22	248.3	252
23	222	237.3
24	225.3	221.6
25	188.3	218.3
26	208.3	222
27	246.3	236
28	251	262.3
29	289.3	285.3

*Unit: Gluteus medius = Newton

Twenty two out of the twenty nine golfers tested (76%) showed an improvement in force production of the dominant gluteus medius with the KT on compared to no KT on the muscle. Nine participants (31%) improved by more than twenty Newton, seven participants

(24%) improved by more than ten Newton, six participants (21%) showed a marginal improvement and seven participants (24%) showed no improvement.

X-Factor

Table F2. X-Factor measured with and without Kinesio® Tape (n=29)

PARTICIAN	X-FACTOR * -NO KT	X-FACTOR * -KT
1	68.9	61.5
2	46.8	52.3
3	65.4	70.5
4	66.3	58.2
5	66.4	67.9
6	43.1	51
7	59.8	62.9
8	48.8	59.7
9	65.5	56.4
10	49.6	54.7
11	73.7	67.4
12	50.5	49.8
13	56.5	55.3
14	55.8	46.4
15	49.8	53.2
16	61.1	72.3
17	35.1	41.8
18		41.6
19	62.3	62.3
20	37.4	42.8
21	63.8	72.1
22	57.4	57.5
23	68.2	60.6
24	65.7	64.2
25	61.5	61.3
26	57.8	61
27	58.3	59.8
28	50.6	54.1
29	61.1	65.1

*Unit: x-factor = degrees

Eighteen participants out of twenty nine (62%) showed improvements in their x-factor with the KT applied to their dominant gluteus medius. Only two participants (7%) improved by more than ten degrees, while the majority of the participants (n=15 – 52%) improved by less than ten degrees. Ten participants (34%) did not show an improvement and one x-factor result was inconclusive.

Ball Flight Distance

Table F3. Ball Flight Distance as measured with and without Kinesio® Tape (n=29)

PARTICIPANT	BALL DISTANCE *-NO KT	BALL DISTANCE *KT
1	251	245
2	252	254
3	274	267
4	267	262
5	266	277
6	273	281
7	266	273
8	286	289
9	277	294
10	267	260
11	255	245
12	279	265
13	272	268
14	283	295
15	260	259
16	282	278
17	289	301
18	261	246
19	281	278
20	269	268
21	276	267
22	290	278
23	293	280
24	240	247
25	282	278
26	229	231
27	278	277
28	265	275
29	253	248

*Unit: Ball Flight Distance = metres

Eleven out of the twenty nine participants (38%) improved in their ball flight distance with KT applied onto the dominant gluteus medius, however, eighteen participants (62%) did not show any improvement. Out of the participants that improved four (14%) improved by more than ten metres while seven (24%) improved by less than ten metres in their ball flight distance.

Accuracy

Table F4. Accuracy reflected by the smash factor ratio (Ball speed / Club head speed) as measured with and without Kinesio® Tape (n=29)

PARTICIPANT	SMASH FACTOR BS/CHS-NO	SMASH FACTOR BS/CHS-KT
1	1.47	1.4
2	0	1.45
3	1.43	1.45
4	1.38	1.39
5	1.44	1.46
6	1.44	1.43
7	1.44	1.45
8	1.43	1.42
9	1.5	1.43
10	1.41	1.37
11	1.44	1.48
12	1.43	1.42
13	1.49	1.43
14	1.41	1.42
15	1.43	1.42
16	1.42	1.42
17	1.42	1.42
18	1.41	1.39
19	1.41	1.46
20	1.46	1.44
21	1.43	1.4
22	1.43	1.39
23	1.47	1.44
24	1.43	1.4
25	1.43	1.45
26	1.4	1.4
27	1.38	1.4
28	1.44	1.42
29	1.43	1.43

Eleven participants out of twenty nine (38%) showed an improvement of their accuracy depicted by the smash factor ratio and in a further four out of twenty nine (14%) of the participants, the smash factor ratio stayed the same. The measure of accuracy is determined by how close the smash factor ratio (ball speed/club head speed) is to a value of 1.5. In other words, the closer the value is to that of 1.5, the better the accuracy. Eighteen participants (62%) did not show an improvement in their accuracy.

APPENDIX G



Figure 2.2: iClub™ Body Motion Vest (exergamelab.org)



Figure 2.3: Example of iClub™ display (stickgolfonline.com)



Figure 2.4: FlightScope® (Equip2Golf.com)



Figure 2.5: Example of FlightScope® data (golfblogger.co.uk)



Figure 2.6: Example of FlightScope® data (lunagolf.co.uk)



Figure 2.7: Microfet Hand Held Dynamometer (biometricsmotion.intoto.nu)

