The effect of manual therapy and exercise on range of motion, biomechanics, club performance and ball flight – a randomised controlled trial on elite golfers

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DECLARATION

I, Samantha-Lynn Quinn, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Physiotherapy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

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Samantha-lynn Quinn

_________ day of ___________________ 2013

DEDICATION

To the Lord for his incredible grace.

To my husband, Phil, and my beautiful boys, Connor and Judah.

ABSTRACT

Aim: The aim of this study was to compare the effect of myofascial trigger point therapy and stretching to myofascial trigger point therapy and medicine ball exercises on elite golfers' range of motion, biomechanics, club performance and ball flight.

Methods: This was a randomised control trial. One hundred male elite golfers (having a handicap of less than six), between the ages of 16 and 25 years old were recruited. They were randomly assigned into two intervention groups and one control group. The first intervention group (stretch group) received trigger point therapy of iliopsoas and a static stretch of iliopsoas followed by a one-week static, iliopsoas stretching home programme (was added to their routine training). The second intervention group (ball group) received trigger point therapy of iliopsoas and medicine ball exercises followed by a one-week medicine ball exercise home programme (which was added to their routine training). The control group continued with their routine training and received no intervention. Range of motion (lumbar spine rotation, lumbar spine lateral flexion and hip extension), biomechanics (hip alignment at address, hip bending at address, hip "tilting" at address:, backswing hip turn, X-factor, X-factor stretch, hip drop during the backswing, hip sway during the backswing, hip turn during the downswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, transition sequence, timing sequence), club performance (club head speed and smash ratio) and ball flight (distance and accuracy) were measured at various stages during the study. Range of motion, biomechanics, club performance and ball flight were measured before and after the first intervention and again one week later (after the week of home exercises for the stretch and ball group and a week of routine training for the control group). Compliance to the home exercises was monitored throughout the week of training by using an Compliance tool. The participants were also asked to complete a log book during the week of additional exercising (stretch and ball group) added to their routine training, and routine training (control group) so that differences in training could be taken into account.

Results: The group that received the trigger point therapy combined with ball exercises (ball group) showed an improvement in accuracy relative to the control group and the stretch group (Fisher's Exact=0.016) and an improvement in backswing hip turn (a measure of hip rotational biomechanics) relative to the control group (p=0.0248). After a week of ball exercises the ball group showed an improvement in downswing hip turn (a measure of hip rotational biomechanics) relative to the control group (p=0.0328). The group that received the trigger point therapy and iliopsoas stretches (stretch group) showed an improvement in accuracy (Fisher's Exact=0.016) relative to the control group. After the week of home stretch exercises the stretch group showed no significant change in range of motion, biomechanics, club performance and ball flight. Compliance to the home programmes was poor (stretch group Compliance = 61.64%, ball group Compliance = 52.66%). When differences in training were adjusted for no significant changes to the results were seen.

Discussion: Trigger point therapy combined with ball exercises positively affected accuracy and rotational hip biomechanics. The week of home ball exercises positively affected hip rotational biomechanics (even when Compliance was poor). Improved hip rotational biomechanics has been associated with decreased injury risk and improved performance (Hume et al., 2005, Sherman and Finch, 2000). Trigger point therapy combined with stretching only had a positive effect on accuracy. The week of home stretching did not have any effect on range of motion, biomechanics, club performance and ball flight. A possible reason for this was the poor compliance to the stretch exercises. The results of this study advocates the use of trigger point therapy combined with a week of ball exercise over trigger point therapy combined with a week of stretching. The significance of the results remained unchanged when differences in training were adjusted for. Although the changes to biomechanics and ball flight were positive, even positive changes to biomechanics can affect consistency by increasing degrees of freedom (Newell, 2003, Marek et al., 2005). This is an important finding for a physiotherapist to take into consideration when using these interventions to treat elite golfers.

Conclusion: The trigger point therapy combined with medicine ball exercise resulted in positive changes to rotational biomechanics and ball flight. The trigger point therapy combined with stretch exercise resulted in positive changes to ball flight. Even positive changes to biomechanics and/or ball flight needs to be carefully periodised so as not to affect performance by decreasing consistency. (Newell, 2003)

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OPERATIONAL DEFINITIONS

Angle of incidence: refers to "the angle at which the ball strikes the bat relative to a line drawn perpendicular to the bats surface." (Blazevich, 2012)

Angle of projection: This describes the angle of the projectile relative to the ground (horizontal axis.) (Blazevich, 2012)

Angular momentum: "Angular momentum is the product of moment of inertia (I) and angular velocity (v)" (Blazevich, 2012)

Ball Flight: In this study refers to distance and accuracy of the golf shot.

Central Sensitization: "an increase in the excitability of the neurons within the central nervous system." (Dommerholt et al., 2006)

Coefficient of Restitution: "Describes the proportion of total energy that the remains with the colliding object after the collision". The coefficient of restitution is reduced by increased velocity and increased temperature. (Blazevich, 2012)

Club Performance: In this study this refers to club head speed and smash ratio.

Degrees of freedom: The number of ways a system can independently vary. (Rosenbaum, 2009)

Draw: "is a flight path of the ball in which the ball curves gently right-to-left. At impact, the ball starts out slightly to the right of the target, before gently curving back to the left to arrive at its target" (Kelly, 2012)

Fade: is a flight path of the ball in which the ball curves gently left-to-right. At impact, the ball starts out slightly to the left of the target, before gently curving back to the right to arrive at its target" (Kelly, 2012)

Ground reaction force: "A Vertical force is applied when the foot contacts the ground. The ground exerts an equal and opposite reaction force." *F (force) = m (mass) x a (acceleration)* (Blazevich, 2012)

Hook: “Describes ball trajectory where a ball starts out right and then curves excessively left missing the target” (Kelly, 2012)

Loft of the club: “is a measurement in degrees of the angle at which the face of the club lies with respect to the vertical plane.” (www.ehow.com/how-does_4655444_angle-golf-club-affecct-shot.html, date accessed: December 2012)

Moment of force (torque): “the result of a force acting at a distance from a centre of rotation; rotational action of a force” (Blazevich, 2012)

Moment of inertia: “Tendency for a rotating body to remain in its present state of motion; equal to the product of the mass of an object and its radius of gyration.”(Blazevich, 2012)

Periodisation of Physiotherapy techniques: In this study this refers to selection of physiotherapy techniques not just based on pathology, but also on the golfers current training schedule. I.e. Selection of techniques used to treat an golfer before a tournament may be different to those used to treat a golfer during the off-season (even if the pathology is the same).

Peripheral Sensitization: “reduction in threshold and an increase in responsiveness of the peripheral ends of nociceptors.” (Dommerholt et al., 2006)

Provocation Position Lumbar Spine: Lumbar spine extension, lumbar spine rotation, lumbar spine lateral flexion and compression.(Lyle et al., 2005)

Pull: “Describes a ball flight in which the ball starts to the left of the intended target line and continues traveling left in a straight line, ending up well left of the target.” (Kelly, 2012)

Push: “Describes a ball flight in which the ball starts out right of the target line and then continues travelling right on a straight line, winding up to the right of the intended target.” (Kelly, 2012)

Radius of Gyration: “distance from the axis of rotation to a point where the centre of mass of the object could be located without altering its rotational characteristics.” (Blazevich, 2012)

Slice: “Describes a ball trajectory where a ball starts out left and then curves excessively to the right missing the target.” (Kelly, 2012)

Spasm: “Electromyographic (EMG) activity as the result of increased neuromuscular tone in the entire muscle, they are the result of nerve-initiated contractions.” (Dommerholt et al., 2006)

Training: In this study, this refers to the routine training that the participants undergo on a regular basis, depending on their personal preferences and the instruction of coaches and other supporting advisors and professionals, and which may include putting practice, short game practice, driving range practice, flexibility training, postural training, weight training, cardiovascular training and actual rounds of golf played. All participants were permitted to continue with their routine training with limited interference from the study.

Trendelengberg Sign: “An ‘uncompensated’ positive test result is described as pelvic tilt occurring towards the non-weight bearing side and a ‘compensated’ positive test as trunk lateral flexion towards the weight bearing side during single leg stance.” (Grimaldi, 2011)

CHAPTER 1: BACKGROUND AND NEED

1.1 INTRODUCTION

Physiotherapy currently forms an integral part of the professional golf tours, with physiotherapists travelling with and treating players before and during golf tournaments (www.europeantour.com/tourgroup/physiomedical/index.html, date accessed: December 2012, Smith and Hillman, 2012). The goal of physiotherapy intervention is to reduce injury incidence and treat existing injuries (www.physiosa.org.za/, date accessed: December 2012). The concern with elite athletes is the effect physiotherapy could potentially have on performance. Ideally physiotherapy should decrease the risk of injury and treat existing injuries without hampering performance. If physiotherapy has an effect on performance this should form part of the therapists clinical reasoning when assessing risk versus benefit and the golfer should be made aware of the potential performance effects of physiotherapy interventions before receiving a physiotherapy intervention

Elite gofers have a high incidence of injury to the lumbar spine (see Chapter 2, Section 2.2: Epidemiology and need; pg.7 and Section 2.12: Lumbar spine rotation and lateral flexion; pg.33). The biomechanics of the golf swing predispose golfers to shortened hip flexors (see Chapter 2, Section 2.9: Iliopsoas; pg.27). Muscle shortening of the hip flexors has the potential to increase the risk and severity of back injury by increasing the compressive load the iliopsoas exerts on the lumbar spine. Injury prevention and treatment of the lumbar spine would include techniques that help to lengthen the iliopsoas. Physiotherapists currently use manual techniques (such as trigger pointing) and exercises (such as stretching and ball exercises) to achieve muscle lengthening (Witvrouw et al., 2004, Dommerholt et al., 2006, Wilkinson, 1992). Lumbar spine and hip biomechanics are key areas when it comes to performance (Hume et al., 2005) (see Chapter 2, Section 2.9: Iliopsoas; pg.27-30). Injury prevention and treatment is essential for longevity in sport, but lengthening the hip flexor may increase the degrees of freedom that the athlete has about the lumbar spine and hip, thereby decreasing consistency (Newell, 2003). Swing consistency is essential for good golf performance. The purpose of this study was to find out if myofascial trigger point therapy (a type of manual therapy) of the iliopsoas, stretching of the iliopsoas and medicine ball exercises had an effect on range of motion (ROM) (lumbar spine lateral flexion, lumbar spine rotation and hip extension), biomechanics (hip alignment at address, hip bending at address, hip "tilting" at address:, backswing hip turn, X-factor, X-factor stretch, hip drop during the backswing, hip sway during the backswing, hip turn during the downswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, transition sequence, timing sequence), club performance (club head speed), and ball flight (distance and accuracy) .

1.2 PROBLEM STATEMENT

The lumbar spine and hip are essential regions where it comes to golf performance (Hume et al., 2005, Myers et al., 2008). The biomechanics of the golf swing predisposes golfers to tight iliopsoas (see Chapter 2, Section 2.9: Iliopsoas; pg.27-30). This shortening has the potential to increase the risk and severity of injury in the lumbar spine (see Chapter 2, Section 2.9: Iliopsoas; pg.27-30). There remains much controversy over how to increase muscle length. Trigger point therapy, exercises and stretches are currently used by therapists in an attempt to restore normal muscle length (Fletcher and Hartwell, 2004, Smith and Hillman, 2012), but there have been very few studies on the effect of exercising on golf performance and the researcher is not aware of any published works on the effect of myofascial trigger point therapy on golf performance (Gergley, 2010, Moran et al., 2009). Therefore the effect of these techniques on golf performance (measured by biomechanics, club performance and ball flight) is largely unknown. This is of ethical concern as the performance effects of an intervention are an essential consideration when establishing the risk-benefit ratio of performing a physiotherapy intervention on an elite golfer.

1.3 RESEARCH QUESTION

The research aims to address the following questions:

- What is the effect of myofascial trigger point therapy followed by stretching on the ROM, biomechanics, club head performance variables and ball flight, compared to the control group that received no intervention?

- What is the effect of myofascial trigger point therapy followed by medicine ball exercises on ROM , biomechanics, club head performance and ball flight, compared to the control group that received no intervention?

- Is there a difference between the results obtained from athletes who were treated with myofascial trigger point therapy with stretching versus those who received myofascial trigger point therapy followed by medicine ball exercises?

- How well did the participants comply to the home exercises? If they were unable to perform the exercises was this due to non-compliance and/or pain?

- Did differences in training affect the outcomes (ROM, biomechanics, club performance and ball flight) of the study?

1.4 AIM OF THE STUDY

To compare the effect of myofascial trigger point therapy with stretching to myofascial trigger point therapy followed by medicine ball exercises on elite golfers' range of motion (ROM), biomechanics, club performance, and ball flight.

Secondarily to (i) establish the degree of compliance to the home programmes and the reasons for non-compliance, and to (ii) assess if differences in training had an effect on the outcomes of treatment.

1.5 OBJECTIVES OF THE STUDY

1. To compare the change in ROM in participants who received myofascial trigger point therapy and stretching versus the change in ROM of participants

who received myofascial trigger point therapy and medicine ball exercises versus the change in ROM in the control group.

2. To compare the change in biomechanics in participants who received myofascial trigger point therapy and stretching versus the change in biomechanics in participants who received myofascial trigger point therapy and medicine ball exercises versus the change in biomechanics in the control group.

3. To compare the change in club performance in participants who received myofascial trigger point therapy and stretching versus the change in club performance in participants who received myofascial trigger point therapy and medicine ball exercises versus the change in club performance in the control group.

4. To compare the change in ball flight in participants who received myofascial trigger point therapy and stretching versus the change in ball flight in participants who received myofascial trigger point therapy and medicine ball exercises versus change in ball flight in the control group.

5. To establish if differences in training had an effect on the results of the home exercise programmes' effect on ROM.

6. To establish if differences in training had an effect on the results of the home exercise programmes' effect on biomechanics.

7. To establish if differences in training had an effect on the results of the home exercise programmes' effect on club performance.

8. To establish if differences in training had an effect on the results of the home exercise programmes' effect on ball flight.

9. To establish the degree to which the participants complied to their home exercise programme.

10. If compliance was poor, to establish if this was due to non-compliance and/or pain.

1.6 SIGNIFICANCE OF THE STUDY

By determining the effects (ROM, biomechanics, club performance and ball flight) of myofascial trigger point therapy, stretching and ball exercises for the iliopsoas, physiotherapists will be better equipped to assess the risk-benefit ratio of performing these interventions on elite golfers.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

A literature search was performed using Pubmed, Ebsco Host, Google Scholar Database, Science Direct, various websites (as referenced in Chapter 6, References, Pg 118), academic textbooks (as referenced in Chapter 6, References, Pg 118), direct referencing. When accessing databases several keywords and key phrases were used when performing the search. This included, but was not limited to, the following key words/phrases: golf swing, golf biomechanics, golf epidemiology, golf injury, golf performance, club head speed, club performance, golf swing faults, sway swing fault, slide swing fault, static stretching, stretching, trigger point therapy, medicine ball exercises, golf South Africa, motor learning. The search period ranged from 2011-2013.

The literature review was approached using the following subheadings:

- Epidemiology and need
- The golf swing
- Swing faults
- Important kinematic variables that predict performance
- Measurement of biomechanics
- Club performance and ball flight variables
- Measurement of club performance and ball flight
- Iliopsoas
- Rationale for focusing on lumbar spine range of motion
- Hip extension: measurement of hip flexor length
- Lumbar spine rotation and lateral flexion

- Trigger point therapy
- Stretching
- Medicine ball exercises
- Motor learning
- Confounding variables
- Relevance to South Africa
- Conclusion

2.2 EPIDEMIOLOGY AND NEED

Myofascial trigger point therapy, stretches and exercises are currently being used by physiotherapists and sports conditioning specialists in an attempt to reduce injury in golfers (Smith and Hillman, 2012). In a study undertaken by Smith and Hillman (2012) on the physiotherapy unit at the European tour they found that over two years 7430 golfers approached the unit. This equated to 206 golfers per event. A total of 9933 treatments were performed over the two year period. This equated to 276 treatments being administered per event. 71.3% of treatments included massage, 15.6% included manipulation and 15.6% included stretching (Smith and Hillman, 2012). The effect of these techniques on the golfers' ROM, ball flight and swing biomechanics is unknown. Ideally, in elite golfers, physiotherapists should aim to reduce injury without adversely affecting performance.

Elite golfers (professionals and those with a handicap of less than six) sustain a large number of injuries. A study performed on 226 elite, experienced golfers showed an average injury rate of two injuries per golfer and an injury prevalence of 88.5% (Teriault and Lachance, 1998). Many of these injuries become chronic. A prevalence study showed that 54% of professional golfers complained of chronic ailments that prevented them from playing golf for five weeks every year (Teriault and Lachance, 1998). Most of these injuries take six months to resolve (Teriault and Lachance, 1998). This long injury recovery period means that injury prevention is essential to an elite golfer. The high incidence of injury also necessitates investigation into techniques that may resolve or prevent injury. The question, however, while managing injuries in elite golfers is what the risk-benefit ratio of receiving physiotherapy interventions is; i.e. could physiotherapy interventions affect the golfer's performance? If yes, then is it worth receiving the physiotherapy interventions, and moreover, when is the best time to receive these interventions?

2.3 THE GOLF SWING[1]

In order to assess the impact of physiotherapy techniques on biomechanics a thorough understanding of the golf swing is necessary.

The golf swing is an entire body movement (Hardy and Pollard, 2005), the main purpose of which is "to create a multi-lever system that generates maximal speed from the club head in a precise trajectory and in a wide arc of motion to hit a fixed object on the ground." (Teriault and Lachance, 1998).

The golf swing is broken into several different phases (please note that the following description is taken from the perspective of a right handed player; "left" and "right" should be reversed for a left handed player):

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[1] Please note that this analysis is based on the 'modern golf swing' and not the 'classical golf swing' or a 'stack and tilt approach'. The 'modern golf swing' places emphasis on rotation of the shoulders while the hip turn is fairly restricted. It encourages a weight shift from trail to lead leg during the follow through (Gluk et al 2008) (also see Appendix A: Modern Golf Swing' versus 'Classical Golf Swing; pg.103). The 'stack and tilt approach' encourages the player to be centred over the ball during the backswing. (Gluk et al 2008, Jenkins 2008).

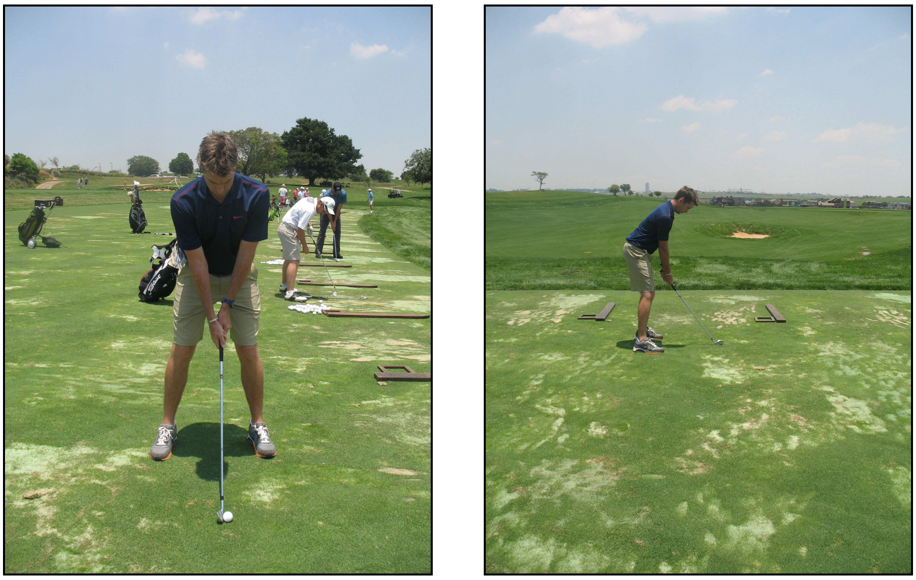

Figure 2.1: Golf swing biomechanics – the address

- **Address**: The purpose of this position is to align the golfer properly with the target, establish static and dynamic balance, to be in good biomechanical golf posture and to provide for effective grip of the club. During set up 50-60% of the golfer's weight is on the back foot[2]. The knees should be flexed to 20-25º, the trunk should be flexed to 45º from the hips (primary spine angle), there should be a lateral shoulder tilt of 16º (secondary spine angle) (this movement is produced by a combination of right lateral flexion of the spine and slight downward rotation of the right arm and scapula) (Hume et al., 2005).

- **Backswing**: The purpose of the backswing is to position the body and club in the optimum position for the downswing so as to generate the most efficient, consistent and powerful downswing. It should provide a base for the downswing's kinetic chain. It should also position the body so as to allow for the best stretch shortening cycle. It is similar to the winding up of a coil. On average the backswing takes 0.82 seconds. The backswing starts with a unified, one piece take away. The chest and arms form a triangle that is maintained for the first 40-60 cm of the backswing. The first 40-60 cm of the

[2] The ranges given in the swing description are not the precise ranges for every player, but rather they are an approximate range seen in an ideal 'modern golf swing'.

backswing occurs along an imaginary line from the ball perpendicular to the line of the golfer's toes. After this point the shoulders continue to rotate, this rotational force exerted on the spine rotates the hips, and the arms elevate. When the hands reach the level of the hips the right shoulder abducts and externally rotates and the right elbow flexes, while the left shoulder adducts and internally rotates. At the top of the backswing the difference between an imaginary line drawn across the shoulders and the hips forms what is commonly known in golf as the x-factor. Elite players then produce a quick stretch at the top of the backswing. This is often referred to as x-factor stretch or leading with the hips. "This movement pattern allows an eccentric-concentric sequence of the spinal rotator, in which the hips and shoulders rotate in opposite directions before both rotate back towards the flag." (Burden et al., 1998)

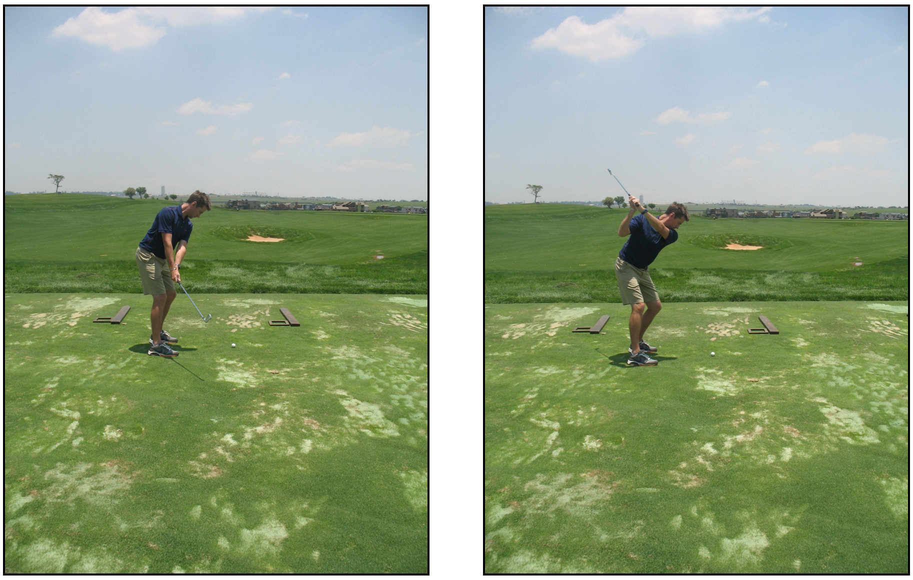

Figure 2.2: Golf swing biomechanics – the backswing

Most players use shoulder and pelvic rotation around a fixed base of support rather than a lateral weight shift to produce club head speed. At the top of the backswing: shoulder rotation is 78º-102º; hip rotation is 47º-55º; the right shoulder is abducted 75º-90º; the right shoulder is externally rotated to 90º; the left elbow is extended; the left shoulder is internally rotated and horizontally adducted across the chest; the left scapula is abducted, elevated and outwardly rotated; the wrist and hands are cocked (wrist extended). The range of motion in the spine and shoulders determines the length of the backswing and the subsequent torque created by the golfer. At the top of the backswing 40% of the body's weight is on the left leg and the left leg is passively externally rotated due to right pelvic rotation (Hume et al., 2005).

Figure 2.3: Golf swing biomechanics – downswing and impact

- **Downswing**: At the top of the backswing the golf swing is in a "loaded" position. The purpose of the downswing is to return the club head to the ball in the correct plane with the most velocity. The downswing lasts approximately. 0.23 seconds. During the downswing the left arm controls the plane of the movement and the right arm provides power in the later part of the downswing. Ideally the downswing plane should be shallower than the backswing. Before the arms have reached the top of the backswing, left pelvic rotation begins. During the downswing: the left shoulder externally rotates and moves towards the midline; the right shoulder internally rotates and adducts; and the right elbow extends. The wrists should remain cocked until the last moment. The average angular velocities for professional golfers are: hips=498º/sec; shoulders=723º/sec; arm=1165º/sec and club head=2090º/sec. (Hume et al., 2005).

- **Impact:** At impact the primary spine angle is at 34º (compared to 45º at address). The secondary spine angle is at 28º (compared to 16º at address). At impact: the shoulder rotation is approximately 27º; hip rotation is approximately 43º to the left. 0.2 seconds after impact the left leg sustains very large lateral forces (133N); vertical compression forces (950N); and rotatory torques (23Nm) (Hume et al., 2005).

- **Follow through:** The purpose of this phase is to decelerate the body and club head. During follow through: the hands and wrists follow the plane of the swing path; the left shoulder and arm abduct and externally rotate; the right shoulder and arm adduct and internally rotate. When the hands reach shoulder height both elbows flex so as to decelerate the arms and trunk rotation. This should occur while maintaining postural stability. The trunk and hips rotate to the left. The left leg internally rotates and the left ankle supinates. The finish position should be: a balanced position; the torso should be facing the target and in slight hyperextension and lateral flexion; the hands should be behind the left ear; the head should be rotated to the left (Hume et al., 2005).

Figure 2.4: Golf swing biomechanics – the follow-through

2.3.1 THE KINEMATICS OF THE GOLF SWING AND "SUMMATION OF SPEED" PRINCIPLE

The golf swing can be seen as consisting of two levers as illustrated in Figure 2.5. below.

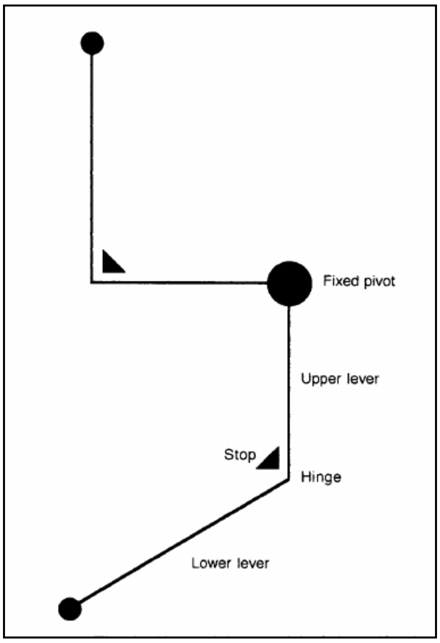

Figure 2.5: The double pendulum model of the golf swing (adapted from Cochran and Stobbs, 1968) (Burden et al., 1998)

“The upper lever” consists of the shoulders and arms. “The lower lever” is the golf club. The two levers are connected by the hinge. The hinge is the golfer’s hands and wrists (Burden et al., 1998). This double pendulum movement starts from the top of the golfer’s backswing. The whole system is rotated about the upper level’s pivot during the start of the downswing (Burden et al., 1998). At the top of the backswing the hips start rotating towards the target before the upper body. This sequential pattern of hip and shoulder rotation followed by the rotation of the club indicates that the swing of an elite golfer conforms to the “summation of speed principle” (Burden et al., 1998). This principle states that, ‘to maximise the speed of the club head at the distal end of the system, the golf swing should start with movements of more proximal segments.’ (Burden et al., 1998). This concept can be understood when looking at activities such as fishing. Angular momentum is imparted to the base of a fishing rod. When the fisherman stops the rotation of the base the angular momentum is transferred to the top of the rod and it now moves at a very high velocity (Blazevich, 2012). This is why it is often observed in movements that involve this principle that the proximal segments (e.g. the hips in the golf swing) slow down by the time the distal segment (the club head) reaches maximum velocity (Burden et al., 1998). This is termed as “cracking the whip” in golf. This is particularly relevant to this study as changes to the hip’s muscle length or peak force may result in changes to timing sequence and transition sequence (see Chapter 2, Section 2.6: Measurement of biomechanics; pg.18).

Summation of speed, however, is not the only reason that “swing-like” movements produce high velocities. Another possible reason is that swing-like movements make the best use of muscle-tendon elasticity. Tendons store elastic potential energy. When they are placed on stretch and then released (as during a swing-like movement pattern) they recoil at much higher velocities than the shortening speed of muscle (Blazevich, 2012). This is especially relevant to the distal segments (such as the forearm and hand) that have very long tendons (Blazevich, 2012). This is of clinical relevance to this study as stretching muscles may result in changes to elastic potential which would result in changes in speed.

2.3.2 GROUND REACTION FORCES OF THE GOLF SWING

Although the golf swing is primarily an upper-body movement (see Chapter 2, Section 2.3.1: The kinematics of the golf swing and "summation of speed" principle; pg.14); the lower body plays an important role in providing a solid base from which to derive power. In order to increase ground reaction force the legs should be "pushed into the ground". This enhances the transfer of ground reaction forces, the body segments should remain as stable as possible (e.g. the hips and trunk). The weight shift during the golf swing from the trail leg to the lead leg, results in a force being produced in the direction of the projectile (i.e. the ball). When the player's momentum is travelling in the intended direction of the projectiles displacement the velocity of the ball increases. This is true for all hitting and throwing sports. (Hume et al., 2005) In order to maximise velocity large, well timed (timing of the ground reaction force is more important the amount of force produced (Hume et al., 2005)) ground reaction forces should be produced by the golfer. This is of particular interest to this study as the hips are involved in providing a stable base and they assist in the production of ground reaction forces by controlling lateral weight shift. Ground reaction forces are also important in that a golfer who is unable to produce rotational torques (by rotating the spine and hips) may default to producing power by excessively increasing ground reaction forces. This produces two swing faults known as "sway" and "slide". These swing faults are not beneficial in terms of performance or injury risk.

2.4 SWING FAULTS:

2.4.1 SWAY

This is "an excessive lower body lateral movement away from the target during the backswing" (Titlest Performance Institute, 2006). This swing fault leads to poor weight shift during the transition and downswing. This results in loss of power and an inability to develop speed in an efficient sequence (Titlest Performance Institute, 2006). In a "sway" the golfer's centre of mass is moved towards the outer margin of the base of support. This results in the swing being difficult to control and accuracy worsens (Hume et al., 2005, Baker and Newton, 2005).

Figure 2.6: Swing faults - Sway

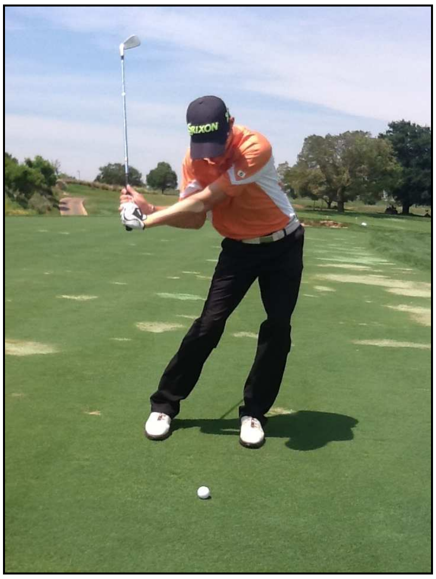

Figure 2.7: Swing faults - Slide

2.4.2 Slide

This is “any excessive lower body lateral movement toward the target during the downswing”(Titlest Performance Institute, 2006). This fault makes it very difficult to stabilise the lower body during the downswing (Titlest Performance Institute, 2006).

The role of the lower body is to create a stable base for the upper body during the downswing (Titlest Performance Institute, 2006, Burden et al., 1998). When the lower body does not provide this “stable base” the result is a loss in power due to an inefficient sequence. In a “slide” the golfer’s centre of mass is moved towards the outer margin of the base of support. This results in the swing being difficult to control and accuracy worsens (Hume et al., 2005, Baker and Newton, 2005).

2.5 IMPORTANT KINEMATIC VARIABLES THAT PREDICT PERFORMANCE

From the above analysis of the swing it is clear to see that the following factors are key indicators of good golf performance: good rotational biomechanics of the hip and lumbar spine (achieved by having good lumbar spine mobility and stability, hip mobility and stability), summation of speed (achieved by good transition sequence and timing sequence) and well timed ground reaction forces.

In order to compare a golf swing before and after an intervention, quantifying the golf swing becomes essential.

2.6 MEASUREMENT OF BIOMECHANICS

Measurement of body movements during the swing was done using golf bio-dynamics 3D Electromagnetic Analysis System. A six sensor system was used. In a study done by Evans et al (2011) on this particular 3D system it was found to have high repeatability irrespective of whether the tests were performed indoors or outdoors, on the same day or different days, by the same user or different users. Repeatability was assessed using the coefficient of multiple determination (CMD). All the CMDs, except for forward bending of the pelvis (i.e. anterior pelvic tilt), were above 0.98. Forward bending of the pelvic CMD=0.93. The author suggests that special care be given when identifying the anatomical landmarks of the pelvis when calibrating the system (Evans et al., 2012).

The 3D Golf Bio-dynamics Electromagnetic System produces a large report with many variables. The researcher decided to focus on the variables that related to rotational biomechanics of the hip and lumbar spine, those that related to summation of speed and production of ground reaction forces. The researcher selected the following variables and their “acceptable corridors” (Please note that the source of the acceptable corridors for all the variables and detailed information regarding this appears on Pg 20):

- Hip alignment at address: This variable can either be “open” or “closed”. As the hips rotate towards the target (open) or away from the target (closed). The acceptable corridor for this study is 0º to 8º (negative = closed; positive = open).

- Hip “bending” at address: This refers to pelvic tilt. It can either be “forward” (anterior pelvic tilt) or “backwards” (posterior pelvic tilt). The acceptable corridor for this study is 13º to 26º (positive = forward; negative = backwards). This corridor is supported by the study performed by Horan et al (2010). The adjusted mean for elite male golfers fell in this parameter.

- Hip “tilting” at address: This refers to pelvic lateral drop at address. It can be depressed either on the (left) or the right. The acceptable corridor for this study is 0º to 3º. (positive = right; negative = left)

- Backswing hip turn: This refers to pelvic rotation on the backswing (measured from address to the top of the backswing). The acceptable corridor for this study is -37º to -48º. This corridor measurement is similar to the one set by the study performed by Egret et al (2006).

- X-factor: This refers to the difference between a line drawn across the torso and another line drawn across the shoulders at the top of the backswing (Hume et al., 2005). This is the biggest source of power in the golf swing. The acceptable corridor for this study is -40º to -50º.

- X-factor stretch: This refers to the quick stretch performed on the x-factor at the top of the backswing. This is the second biggest power source in the golf swing. It is also one of the measurement that separates the top professional golfers from the average professional golfers (Hume et al., 2005). The acceptable corridor for this study is -15º to -25º.

- Hip drop during the backswing: refers to left hip lateral drop (for a right handed player) during the backswing. The acceptable corridor for this study is -3cm to 0 cm

- Hip sway during the backswing: refers to lateral translation of the pelvis during the backswing. The acceptable corridor for this study is -1.5cm to 1.5cm

- Hip turn during the downswing: refers to the movement of the pelvis from the top of the backswing until impact. The acceptable corridor for this study is 35º to 55º. This corridor is supported by the mean obtained in a study performed by Horan et al. (2010).

- Hip tilt during the downswing: refers to downward tilt of the pelvis (towards the right for a right handed player) during the downswing. The acceptable corridor for this study is 10º to 15º. This corridor is supported by the mean obtained in a study performed by Horan et al. (2010).

- Hip bend during the downswing: refers to the anterior tilt (forward) or posterior tilt (backward) of the pelvis during the downswing. The acceptable corridor for this study is 0º to 10º. This corridor is supported by the mean obtained in a study performed by Horan et al. (2010).

- Hip sway during the downswing (address to impact): refers to the lateral movement of the pelvis toward to ball. The acceptable corridor for this study is -11cm to -14cm. This value is supported by the study performed by Horan et al. (2010).

- Hip thrust: Refers to the lateral movement of the hips when hip rotation is equal to zero. The acceptable corridor for this study is -2 to 2cm

- Hip speed: refers to the maximum speed reached by the hips during the downswing. The acceptable corridor for this study is equal to or above 430º/sec

- Transition sequence: This refers to the order in which the body segments change direction. This was measured using a classification system.

Transition sequences were marked as either good or bad. A value of one was given for a good transition sequence and zero was given if the participant deviated from the prescribed transition sequence.

- Timing sequence: This refers to the order in which the various body segments peak in time. Timing sequences were marked as either good or bad. A value of one was given for good timing sequences and zero was given for any deviation from the prescribed timing sequence

The importance of the corridors of acceptable range mentioned above is to be emphasised when interpreting data. There is an acceptable corridor set according to the applicant's age and gender for each biomechanical parameter. The idea of a different acceptable corridors for each gender is supported by studies undertaken by Egret et al (2006), Horan et al (2011) and Horan et al (2010).

The corridors used in this study were based on those determined by Dr. Rob Neal. He established these corridors by measuring the biomechanical parameters of 75 leading golf professionals on the Australasian and European tours. After these measurements were taken six leading coaching and teaching professionals from Australia were consulted and they were asked to rank these golfers on ball striking ability. The average of the top ten male and female ball striker's biomechanical parameters were used as a starting point for the setting of these corridors. Thereafter, Golf Biodynamics measured 250 professional golfers using their system and they found that 75% of them fell within Dr. Neal's corridors. Further research on 5000 amateur players showed that the closer they were to these acceptable corridors the better their performance (www.totalgolfanalysis.co.uk, date accessed: December 2012).

In this study if the confidence intervals of the analysed data did not move in to or out of the acceptable corridors from one assessment to the next then the change in parameter was considered to be clinically irrelevant; just as a small change in blood pressure within the acceptable range may be statistically relevant (e.g. a medication may have a side effect that causes a change of BP=120/80mmHg to BP=125/75mmHg. This be statistically relevant if there are enough participants and the standard deviations are small, but it is clinically irrelevant), but if it does not have a clinical effect it is clinically irrelevant (see Figure 4.2; pg.78, 4.3; pg.79, 4.4; pg.85, 4.5; pg.86 for examples of this principle being applied).

Backswing hip drop, backswing hip sway, downswing hip sway and hip thrust were also used as indicators of pelvic stability (as advocated by Dr. Neal in the software package). Increased backswing hip sway, more negative downswing hip sway and increased hip thrust would indicate an instability "sign" for the pelvis called 'hanging on one hip". This is the most common lateral instability sign of the pelvis (Grimaldi, 2011). In this position the forces of gravity are resisted primarily by the facia of the iliotibial band and not eccentric muscle control (Grimaldi, 2011). More negative values for downswing hip drop would indicate a Trendelenberg type sign on the trail leg. This too is a sign of pelvic instability (Grimaldi, 2011). More positive hip sway values during the downswing would indicate poor weight shift during the downswing. These movements served as functional movement assessments. For functional movement a participant requires both mobility and stability (Cook et al., 2010). Functional movement screening is of more clinical importance than dynamometer readings of the iliopsoas (as muscle strength improvements may not always lead to improved motor patterns) (Peterson et al., 2006). The downfall in functional movement assessment in research is that it usually very difficult to quantify. The 3D biodynamics system enables the researcher to quantify this measure.

2.7 CLUB PERFORMACE AND BALL FLIGHT VARIABLES

Body movement during the swing (measured by the 3D swing biomechanical analysis) is important to a golfer, but club performance and ball flight are far more important as they determine how well a golfer scores on the day. Although good body movement through the swing is certainly of benefit to a golfers performance and injury prevention (Hume et al., 2005, Teriault and Lachance, 1998), the best golf swing, from a biomechanical perspective, does not always equate to the best ball striking ability. An example of such a player is 2012 US Open winner Babba Watson. He has very unconventional swing biomechanics (he relies primarily on hand action to hit the ball straight) and yet he has amazing ball striking ability(www.golfdigest.com, date accessed January 2013). For this reason the researcher decided to focus, not only on biomechanics, but also on club performance and ball flight. The performance indicators in golf are: club head speed (which is the raw determinant for distance); smash ratio (the measure of transference of kinetic energy produced by the club into the ball); distance; and accuracy.

Club head speed is directly dependent on torque (torque = moment arm x force) (Hume et al., 2005). Torque is generated by both the strength of the body segments and their ability to produce velocity and the flexibility of the body segments. This is a good measurement of overall body performance from a biomechanical perspective. It is also the raw determining factor for distance. Without sufficient club head speed being produced a golfer cannot generate distance (even if he has a good smash ratio). (Thompson and Wayne, 2004)

The ball speed is a function of the momentum of the system before the collision (which is described by the velocity of the club: club head speed) and the energy lost from the system (coefficient of restitution). Ball speed is also affected by the angle of incidence (this effect, however, is relatively small compared to the momentum of the system before impact and the coefficient of restitution) (Blazevich, 2012). The coefficient of restitution is represented by the smash ratio or smash factor “which is the ratio of the initial ball launch speed divided by club head speed.” (Nakajima, 2006). Tour players can achieve smash factors of 1.48. The theoretical maximum is 1.5 (www.calgolftech.com, date accessed: December 2012). Smash factor is a measure of efficiency and of “how well the player hits the ball”. Does he make contact with the “sweet spot” or not? This is a key to performance. As such it has been included in the measurements taken in this study (ball speed, however, was not included as this was accounted for in the smash ratio in which ball speed is a determining factor).

Ball speed is a determinant of distance, but it is not the only determinant of distance. The angle of projection is also an important determinant of distance. In general distance is maximised when the angle of projection is 45º. At 45º the vertical velocity is equal to the horizontal velocity (Blazevich, 2012). The loft of the club and the angle of attack can affect the angle of projection. The loft on a six iron is 32º to 36º (www.ehow.com/how-does_4655444_angle-golf-club-affecct-shot.html, date accessed: December 2012). The angle of attack “of the golf club on the golf ball is the angle at which the club head travels at the point of contact with the golf ball”. A zero figure means that the club head is travelling level with the ground. A positive figure results in greater loft being created. A negative angle of attack results in less loft being created. As this study was primarily concerned with overall performance effects and not with in-depth technical changes to the swing (which vary considerably from player to player) the club head speed and distance and not angle of attack (a function of distance) was measured.

Ball spin and the angle of club (open or closed) at impact both affect accuracy. The angle of the club face is determined largely by the wrist and hand position. Unfortunately, the equipment used in this study was unable to measure this, but it was able to measure total accuracy using the swing path classification. Ball spin has been associated with transverse force and explains why a golf ball can initially start travelling straight and then curve to the left or to the right. (Magnus, 1852) showed that the sideways force was always proportional to the speed of the air over the ball and the speed of the spin of the ball. There are two hypotheses as to why a ball spins. The first is the “Bernoulli” effect and the other is the more recent, “Newton effect”. In the Bernoulli Effect it has been hypothesised that as a ball travels through the air it “collides” with air and this forms friction between the ball and the air, and the particles that have experienced the friction start to spin with the ball creating a “boundary layer” of air around the ball. The movement of the boundary layer of air in a circular motion means that on one side of the ball it is moving in the same direction as the air travelling past it and on the other side it is moving in the opposite direction to the air moving past it. The slower moving air (where the boundary layer is moving in contrary to the air around it) creates a higher pressure and the faster moving air (where the boundary layer moves in the same direction as the air around it) creates a lower pressure. This results in a pressure differential. The force created by the pressure differential is called the “Magnus Effect”. The ball will move towards the side with the lower pressure. More recent research has shown that the boundary layer of air that spins with the ball is very small and is unlikely to be the cause of the pressure differential. It is hypothesised that the small boundary of slow moving air on the one side of the ball collides with the oncoming air and this causes the oncoming air to deflect off the ball sooner than the air on the other side of the ball. The air on the side of the ball with the boundary of faster moving air deflects later and moves toward the low pressure created behind the ball. According to Newton's third law, since the mass and velocity of the air have changed, force must have been applied. There must therefore be an equal, opposite force that pushes the ball in the opposite direction. The conclusion though (no matter which view you take on how spin creates transverse movement) is that spinning the ball causes the ball to swerve off-line (Blazevich, 2012). Ball spin and accuracy are intimately intertwined. Some golfers play with a straight shot (little ball spin), others use some ball spin effectively using a draw or a fade. These are all acceptable golf shots. However, ball spin can become excessive resulting in a hook or a slice which are poor golf shots. For this reason ball spin on its own was not used in this study (although it was measured by the Flightscope), but rather each shot was classified as either acceptable (a draw, straight, or a fade), or unacceptable (a push-fades, pull-draw, hook or slice).

2.7.1 THE RELATIONSHIP BETWEEN CLUB HEAD SPEED AND ACCURACY

There have been many studies looking at the effect of speed on accuracy. They show that as speed increases, accuracy decreases (Wilson and Sherwood, 2008). It has also been postulated that spatial error in rapid aiming tasks is directly related to amplitude and inversely related to movement time, and that spatial error is positively related to the ratio of amplitude/movement time (average velocity) (Wilson and Sherwood, 2008). For a golfer this means that increasing club head speed affects accuracy. (Wilson and Sherwood, 2008).

Muscle force produced relative to maximal muscle force production also has an effect on accuracy. The more force (relative to the participants total force) that a golfer has to produce the worse the accuracy of the movement (Etnyre, 1998); i.e. a golfer will hit a ball more accurately at 60% maximum force output than he will at 90% maximum force output. This is relevant to the study as changes to peak muscle strength may have an effect on maximum muscle output.

2.8 MEASUREMENT OF CLUB PERFORMANCE AND BALL FLIGHT

The measurement of club variables and ball flight was achieved using Flightscope. Flightscope was developed by EDH, South Africa. It is a 3D Doppler tracking radar with a golf application. It incorporates ballistic and phased array tracking technology (www.thegolfacademyla.com/Coaching/Technology/FlightScope.aspx, date accessed: December 2012). An oscillator produces a microwave signal. The antenna then radiates the signal. The ball then interferes with the signal and reflects some of the energy and creates a movement/Doppler shift. The phased array antenna then deflects the signal and compares phase direction. Flightscope measures a number of different parameters of the ball at thousands (400,000) of different points during its flight (www.thegolfacademyla.com/Coaching/Technology/FlightScope.aspx, date accessed: December 2012). It is able to analyse flight and track a golf ball's entire trajectory (Flight Scope, 2011).

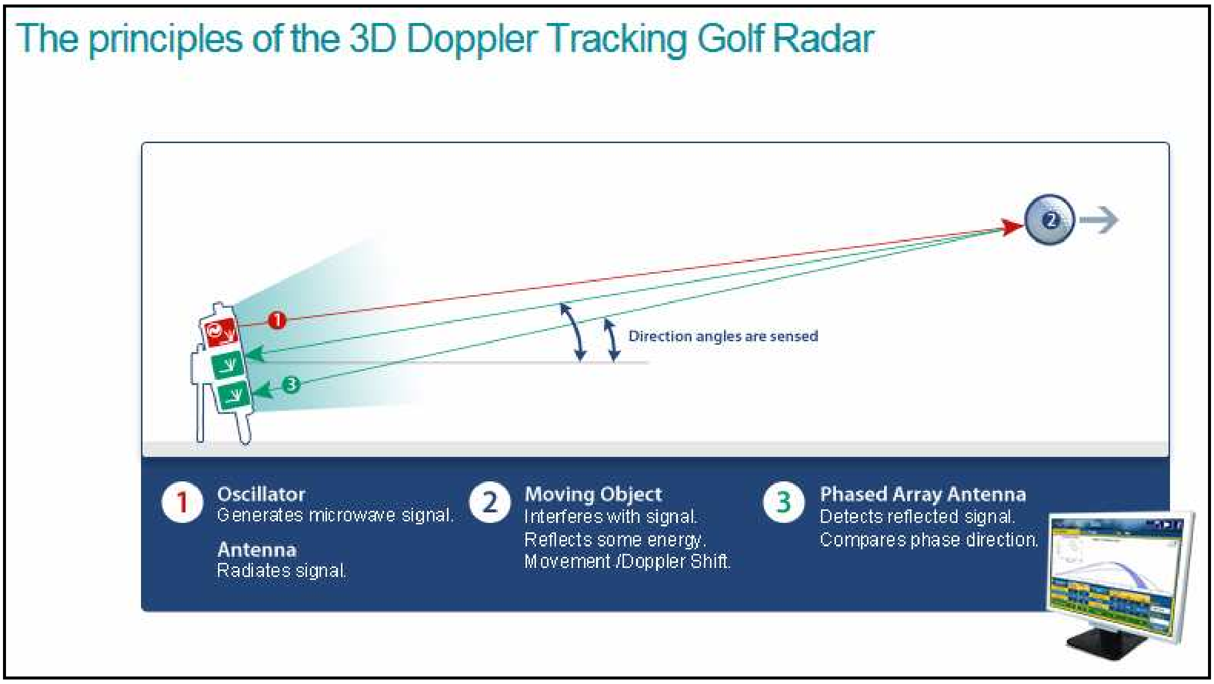

Figure 2.8: How Flightscope works

Flightscope is able to measure the following ball variables: real time tracking, ball speed, vertical and horizontal launch angles, sidespin and backspin. Flightscope is also able to measure the following club variables: club head speed, angle of attack, club path, club face angle and dynamic loft.

This measuring tool has face- and construct- validity. Flightscope was used in the study performed by Myers et al (2008).

2.9 ILIOPSOAS

2.9.1 RATIONALE FOR FOCUSING ON ILIOPSOAS

From the analysis of the swing it is evident that muscles that are involved in both the hip and lumbar spine would be of particular concern where it came to physiotherapy interventions and their effects on biomechanics and performance (These muscles are at risk of overuse. Overuse predisposes skeletal muscle to maladaptions such as altered performance and muscle shortening (Grobler et al., 2004))*[3]. The lumbar spine is the most frequently injured (Clapis et al., 2008) and treated area (Smith and Hillman, 2012) and from a clinical relevance perspective it would be useful to look at a muscle of the lumbar spine. The iliopsoas is the only muscle that has attachments from the spine and the hip. The biomechanics and training schedule of the elite golfer predisposes them to overuse of the hip flexors (see section 2.3 The Golf Swing Pg 8). When skeletal muscle is overused its adaptive abilities become compromised and this places the muscle at risk of shortening/stiffness, excessive delayed onset muscle soreness, tenderness, muscle cramps and poor performance(Grobler et al., 2004). Therefore elite golfers may be at risk of muscle shortening of the hip flexor. The address posture in golf is a flexed one. The iliopsoas is active in this position. During the backswing the left hip externally rotates (iliopsoas contracts concentrically) and the right hip internally (iliopsoas controls this movement by eccentrically lengthening) rotates (Burden et al., 1998). During follow-

[3] Most of the electromyographic (EMG) studies during the golf swing focus on upper limb, lower limb and superficial muscles of lumbar spine (Hardy and Pollard, 2005). There has been very little research into muscle activation of the deep global movers of the lumbar spine (such as the iliopsoas and the quadratus lumborum). This is as a result of the very invasive procedures that would need to be used in order to measure EMG activation and timing of the deep lumbar spine muscles (McGill et al, 1996). It is therefore essential to look at swing biomechanics in order to decide which global movers to focus on.

through the right hip externally (iliopsoas contracts concentrically) rotates and the left hip internally rotates (iliopsoas controls this movement by eccentrically lengthening). At the end of follow-through the right hip is in an extended position (iliopsoas length needs to allow for this) (Flight Scope, 2011). The iliopsoas has a vertical orientation across the lumbar spine (McGill et al., 1996) and as a result is able to exert compressive forces on the lumbar spine (Nachemson, 1966), which may become excessive when iliopsoas flexibility is compromised, which would increase the risk and severity of lumbar spine injury. The iliopsoas is involved in both spinal and hip stability and mobility. The vertebral portion of the psoas is involved in maintaining upright posture (Nachemson, 1966).

Hip external rotation of the left hip (aided by contraction of the left iliopsoas) and internal rotation of the right hip (good ROM of internal rotation allowed for by full length of right iliopsoas) is essential for correct loading of the trail leg during the backswing. Hip external rotation of the right hip (aided by contraction of the right iliopsoas) and internal rotation of the left hip (good ROM of internal rotation allowed for by full length of left iliopsoas) is essential for good weight shift onto the lead leg during the downswing (Titlest Performance Institute, 2006). When an elite golfer is unable to load the trail leg during the backswing and the lead leg during the downswing, he is unable to produce large torques using angular momentum created by the lumbar spine and hip rotation. As a result, the golfer will need to create large ground reaction forces in order to produce power and maximise distance. Although ground reaction forces are useful (see Chapter 2, Section 2.3.2: Ground reaction forces of the golf swing; pg.16) excessive lateral motion in the swing is technically problematic. This produces what is commonly termed a “sway” or a “slide”.

A “sway” and “slide” do not only have the potential to produce poor performance they also have the potential to increase the risk of injury. When the hip rotational range of motion is decreased, other regions such as the lumbar spine must compensate for the decreased rotational torque. There have been studies to show a positive relationship between poor swing mechanics and lumbar spine injuries (Sherman and Finch, 2000). This is especially true for faults that result in a swing with decreased hip range of motion and poor spinal control (Lindsay et al., 2009). In a “sway”, the centre of mass would move more towards the trail leg. This increases the ground reaction force produced by the right leg (see Figure 9). This results in increased compression force needing to be generated during the downswing to combat the large ground reaction force produced. Compression of the lumbar spine is associated with disc herniation and facet joint injury (Gluk et al., 2008). In a “slide” the centre of mass moves towards the lead leg. This increases the amount of compressive force on the lumbar spine in the position of lumbar spine rotation and lateral flexion (this position is a provocation position of the lumbar spine (Lyle et al., 2005)). This position increases the risk of disc herniation, facet joint capsule disruption and muscle strains (Gluk et al., 2008). These injury concerns give strong support to physiotherapists using techniques to lengthen iliopsoas.

Figure 2.9: Slide and sway in injury risk

Both from a clinical relevance perspective (injury management and prevention) and from a biomechanical performance perspective looking at techniques that aim at lengthening the iliopsoas would be useful.

2.9.2 ILIOPSOAS: ANATOMY AND FUNCTION

- **Anatomy:** The iliopsoas compartment comprises of the: psoas major, psoas minor and iliacus. Psoas minor is small slender muscle located anteriorly to psoas major. It originates from the sides of T12-L1 and inserts into the illiopectineal eminence of the innominate bone. It is present in 40% of the population and its action on the spine and hip is seen as very slight (Morling, 2009). As such it is not included in the study. Psoas major originates from the transverse processes of T12 to L5. The deepest most medial parts of the psoas major originate from the sides of the intervertebral discs and adjacent vertebral bodies. Psoas major is comprised of individual fascicles that have constant, discrete areas of origin. These fascicles are aggregated in a concentric, laminated manner. The fibres from higher levels spiral anetromedialy around those from lower levels (Bogduk et al., 1992). It then descends inferiorly and merges with iliacus to form the iliopsoas muscle. Thereafter it passes beneath the inguinal ligament and inserts into the lesser trochanter of the femur via the psoas tendon (Gladys et al., 1994).

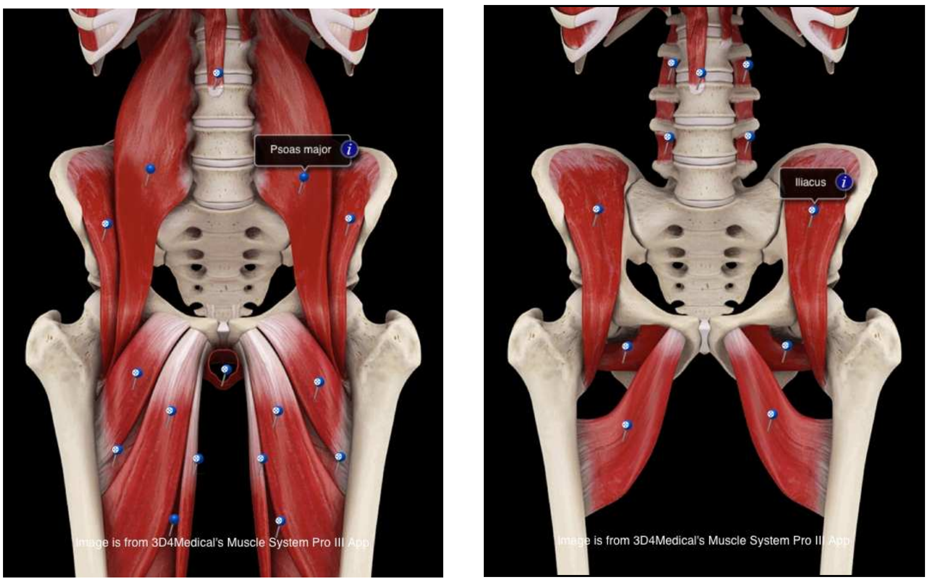

Figure 2.10: The iliopsoas

- **Function:** The primary function of the iliopsoas compartment is to flex the hip or to flex the trunk (Gladys et al., 1994, Morling, 2009). It also contributes to external rotation of the hip (3D4Medical, 2012, van de Graaf, 1998). The effect the iliopsoas has on the lumbar spine remains a highly controversial topic (Sajko and Stuber, 2009, Morling, 2009). It has the ability to exert large compressive forces on the lumbar spine (Nachemson, 1966). The question, however, is, are these forces good? Do they offer stabilisation to the lumbar spine or are they pathological? Excessive anterior compression would place anterior compression forces on the disc, which may increase the risk of disc herniation. On the other hand compression forces are by nature stabilisation forces (Nachemson, 1966). The answer to the question may have something to do with the length and muscle firing of the psoas major. If the psoas major is shortened the compressive force it exerts may become excessive. If it is inactive or over-stretched it may not exert sufficient compression force to provide adequate lumbar stabilisation. This provides further support to this studies investigation into techniques that are used to restore correct muscle length and functioning of iliopsoas.

2.10 RATIONALE FOR FOCUSING ON LUMBAR SPINE ROM

From the analysis of the swing it is clear that lumbar spine mobility is essential to performance. The lumbar spine is also, however, the most commonly treated region on the European tour over the last two years (66.6%) (Smith and Hillman, 2012). The average of four cohort studies showed the lumbar spine as the most frequently injured region (Teriault and Lachance, 1998). The primary reason for this is the large forces that are applied through the lumbar spine during the swing (Teriault and Lachance, 1998). Professional golfers can reach club head speeds of 160km/hour within 0.2 seconds (Teriault and Lachance, 1998). Club head speed is directly dependent on torque (Hume et al., 2005), and if one considers the torque (torque = moment arm x force) that the body must generate to produce a club head speed of 120km/hour it is easy to understand why the injury prevalence rate is so high. Elite golfers usually repeat this action 50 times within a round of golf (18 holes) or 300 or more times each practice session. Elite golfers play or practice golf for up to 10 hours a day six days a week (Teriault and Lachance, 1998).

Computer simulated studies have looked at the forces distributed through the various joints during the golf swing. In the study undertaken by Nesbit et al (2005) the lumbar spine was found to have the greatest torques exerted through it (Nesbit and Serrano, 2005). The lumbar spine experiences the following forces: lateral flexion, anterior posterior traction, rotation and compression (Teriault and Lachance, 1998). Compression of the lumbar spine is resisted by the nucleus of the disc and the facet joints (Gluk et al., 2008). A study published by Hosea and Gatt (1996) showed lumbar spine compressive forces in professional golfers to be 7584N (±2442N). This is especially important as disc prolapse often occurs at 5448N (study done on cadaver specimens) (Gluk et al., 2008). The anterior-posterior shear force is resisted by the facet joints of the lumbar spine. Anterior-posterior shear values of 596N (±594N) have been recorded in golfers. This is particularly relevant as shear loads of 570N (±190N) were able to produce fractures at the pars articularis (in cadaver specimens). Rotation is resisted by the facet joints posteriorly and the annulus anteriorly. The most common cause of disc herniation in young healthy individuals is lateral flexion combined with rotation and torsion (Gluk et al., 2008). This movement (often called loading of the spine in golf) is taught and encouraged as it maximises performance in golfers. The most common injuries sustained by golfers in the lumbar spine are: muscle strain, internal disc disruption and facet joint capsule trauma. (Gluk et al., 2008). These studies show that even in a technically good swing the golfer is predisposed to injury through these large compressive and shear loads.

Studies have shown a positive relationship between poor swing mechanics and lumbar spine injuries(Sherman and Finch, 2000). This is where physiotherapy may have an influence in preventing golf injuries. If physiotherapy interventions can positively affect golf swing biomechanics then injury prevalence to the lumbar spine should decrease. This gives support to the use of physiotherapy in the treatment of lumbar spine injuries and restoring hip flexor length. This helps to establish the clinical significance of the study and provides support for the benefit aspect of elite golfers receiving physiotherapy interventions to restore iliopsoas muscle length. It does not, however, provide support to the risk side of the equation. Any medical intervention must be carefully weighed according to the risk-benefit ratio. Is there any benefit in receiving physiotherapy interventions that did restore ROM? The answer is yes, but this study was helps to ascertain if there were any biomechanical or ball flight affects (positive or negative) of receiving this benefit (while at the same time ascertaining if the techniques did achieve their desired therapeutic outcome, namely, increased hip ROM).

2.11 HIP EXTENSION: MEASUREMENT OF HIP FLEXOR LENGTH

Hip flexor length was measured to establish if the goal of the physiotherapy intervention was achieved (i.e. improving the ROM of the hip flexor). Measurement of hip flexor length (i.e. hip extension) was done using the modified Thomas test with a goniometer. This instrument has face validity and the use of the Thomas test has construct validity (Gabbe et al., 2004). In a study done by Clapis et al (2008) this technique of measuring hip extension was shown to have good inter-rater and inter-examiner reliability. It was found to be a reliable instrument to measure hip extension flexibility (Clapis et al., 2008).

2.12 LUMBAR SPINE ROTATION AND LATERAL FLEXION

Lumbar spine rotation and lateral flexion measurements were taken to establish if interventions performed on the vertebral portion of the hip flexor had an effect on the ROM of the lumbar spine rotation and lateral flexion[4]. Good lumbar spine rotation and lateral flexion is essential to good golf performance. The BROM II was used to measure lumbar spine rotation and lateral flexion. The BROM II uses a compass and magnetic reference, which is placed on the sacrum thereby eliminating unwanted movement below the sacrum from the compass reading. This measurement was made in a vertical position. When the examiner grasped the rib cage the unit moved with the patient thereby reducing tracking errors. The normal range for rotation of the lumbar spine using the BROM II is 10º.

[4] Although this was not the primary goal of the intervention, muscles that cross two joints have the potential to increase ROM at either joint (Please see Section 2.9: The iliopsoas Pg 26-30 and Section 2.10: Rationale for focussing on the lumbar spine Pg30-32)

Measurement of lumbar spine lateral flexion and rotation was done using the BROMII. When used to measure lateral flexion the instrument makes use of a modified protractor. It is attached to T12 by the examiner grasping the patients' ribs. This instrument has face validity and a study performed by Breum et al. (1995) showed the instrument to have good inter-rater and inter-examiner reliability for lumbar spine lateral flexion and rotation. The normal range for lateral flexion of the lumbar spine using the BROM II is 25º. It is important to note that in the study done by Tousignant et al (2002) the BROM II was found to be highly reliable in predicting changes in range of motion of lumbar spine flexion and extension. It did not, however, correlate well to the double inclinometer method (the gold standard of measuring lumbar spine flexion and extension) of lumbar spine flexion and extension (Tousignant et al., 2002), but as this study was primarily concerned with change in motion, and as no double inclinometer method of measuring lumbar spine rotation or lateral flexion has been found in the literature, this method of measurement was seen as satisfactory.

2.13 TRIGGER POINT THERAPY

Trigger point therapy for the iliopsoas was used in this study in an attempt to restore shortened hip flexors to normal length. Trigger point therapy is being used widely by therapists in an attempt to increase ROM (Borg-Stein and Simons, 2002, Hanten et al., 2000). 40.7% of treatments that elite golfers received on the European tour over the last two years included myofascial type treatments (Smith and Hillman, 2012).

A myofascial trigger point (MTrP) is defined as "a hyperirritable spot in skeletal muscle that is associated with a hypersensitive palpable nodule in a taught band" (Dommerholt et al., 2006). MTrPs are classified into active (pain causing) and latent (does not cause pain unless it is stimulated). Both active and latent MTrP cause motor, sensory and autonomic dysfunction (Dommerholt et al., 2006). In terms of motor dysfunction they may cause: disturbed motor function, muscle weakness as a result of motor inhibition, muscle stiffness and subsequent loss of range. Sensory dysfunction can include: local tenderness, referred pain, peripheral and central sensitization. Autonomic dysfunction can include: vasoconstriction, vasodilatation, lacrimation and piloerection (Dommerholt et al., 2006). These taught bands are best understood as a type of “contracture” and not a “muscle spasm”. They are an involuntary shortening of the muscle without electromyographic (EMG) activity (Dommerholt et al., 2006).

It has been postulated[5] that MTrP are caused when part of the muscle (especially the slow twitch fibres of a muscle) is damaged (either due to overstretching, overuse or a sudden violent movement). The damage to the muscle fibril results in damage to the sarcoplasmic reticulum which subsequently results in leakage of Ca^{2+}, which is responsible for low level muscle contractions. This persistent low level muscle contraction causes the release of interleukin 6 and other cytokines. These low level muscle contractions may also slightly increase intra-muscular pressure and decrease the capillary perfusion to the area. This could potentially cause ischemia and an energy crisis in the region. Removal of pain causing substances would then also be impaired (Dommerholt et al., 2006). Trigger points may also occur as a result of excessive acetylcholine (Ach) release by dysfunctional motor endplates.

To the researcher’s knowledge there are no published works looking at the effects of trigger point therapy on ROM or performance. In the study performed by (Fernandez-de-las-Penas et al., 2006) a weak link between trigger points and ROM was established. Participants that had myofascial trigger points were shown to have decreased mobility, but no range of motion measurements were taken before and after trigger point therapy. In the study performed by (Hanten et al., 2000) ischaemic pressure followed by sustained stretch was shown to decrease pain, but ROM was not measured. It is possible, however, that if a trigger point is in fact a type of muscle “contracture” that treating it may increase ROM. If trigger point therapy was able to improve the other parameters of a trigger point (namely sensitivity and pain) then it may have an effect on decreased ROM. This provides an evidenced based motivation for the use of trigger point therapy in the treatment of shortened hip flexors. In this study ROM measurements of the hip flexor and lumbar spine rotation

[5] Please note that there remains much controversy over MTrP etiology. DOMMERHOLT, J., BRON, C. & FRANSSEN, J. 2006. Myofascial Trigger Points: An Evidence-Informed Review. *Journal of Manual & Manipulative Therapy (Journal of Manual & Manipulative Therapy),* 14**,** 203-221.

and lateral flexion were taken to see if the intervention changed flexibility. Increasing ROM of iliopsoas may have an effect on rotational biomechanics, which could alter golf performance (Myers et al., 2008). There is no published data (to the best of the researcher’s knowledge) on the effect of trigger point therapy on golf performance. Performance effects are a critical ethical concern for a physiotherapist performing an intervention on an elite golfer. This study aims to establish the effects of trigger point therapy on golfers ROM, biomechanics, club performance and ball flight.

2.14 STRETCHING

Static stretching of the hip flexor was used in this study in an attempt to restore ROM in the hip flexor. Stretching is used extensively by elite athletes in an attempt to increase ROM. Over the past two years 15% of treatments on the European tour have included stretching (Smith and Hillman, 2012). Typically a sports warm up includes: sub maximal aerobic activity, stretching and sports specific movements (Behm and Chaouachi, 2011).

There is a large body of evidence that shows that static stretching increases ROM (Wilkinson, 1992, Radford et al., 2006, Magnusson, 1998, Shrier and Gossal, 2000), but stretching has also been shown to decrease peak torque (PT), mean power (MP) and EMG amplitude (Marek et al., 2005). Clinically, however, this change in PT, MP and EMG has been shown to be very small and Marek et al. (2005) says that this should only affect elite athletes. Therefore, the question is whether the decrease in force (decreased EMG, PT and MP) would have an effect on golf performance (ball flight and biomechanics)? In the study performed by Nesbit and Serrano (2005) it was shown that “The data suggests that the generation of joint work is mostly dependent upon ROM of the joint, and the ability to maintain smooth consistent torques over the ROM”. This study showed that trying to hit the ball harder (generating greater EMG activity, MP and PT) may do little to improve club head speed, but that it was smooth consistent torque that really matters. This gives support to the idea that stretching may increase the moment arm of the torque thereby altering golf performance.

Research on the effects of stretching on golf performance is polarised. In the study performed by Gergely (2010) stretching was shown to worsen golf performance. This study was only performed on nine male elite golfers and as a result the generalisability of the results to the elite male golfing population is not possible. This study also involved a 20 minute stretch routine. This is an excessive amount of stretching for a warm up and is dissimilar to the kind of warm up an elite golfer would do (Behm and Chaouachi, 2011, Taylor et al., 2009). This may be the reason that the athletes worsened significantly. As such the researcher decided to perform only one stretch to a key muscle in the swing (namely iliopsoas) for 60 seconds. A study undertaken by Moran et al (2009) on eighteen male golfers, with handicaps lower than six, showed significant improvement in performance with dynamic stretching. No improvement was noted in the group that received static stretching. The possible reason for this was that the static stretch group received nine stretches for different regions of the body. No mention was made of whether the participants had muscle shortening in one or all of these regions. Static stretching increases muscle length. There is little biomechanical use in stretching muscle that is at normal length. As such the researcher decided to stretch the hip flexors of participants who had shortening of the hip flexor (hip flexor shortening was an inclusion criteria set for the study). In this study ROM, ball flight and swing biomechanics were measured before and after the intervention to see if stretching had an effect on golf performance. The effect that stretching has on golf performance is an important consideration for physiotherapists performing interventions on elite golfers.

2.15 MEDICINE BALL EXERCISES

Medicine ball exercises were used in this study to help treat shortened hip flexors. The past few years have seen a significant increase in the number of elite golfers doing medicine ball type exercise training (pylometric resistance training) (Doan et al., 2006). There is good support for using resistance training to reduce the incidence of lumbar spine injuries and to treat lumbar spine injury. Resistance training has been shown to decrease pain in patients with lumbar spine pain (Barr et al., 2005). In golf, resistance training that is combined with pylometric exercises is far more useful than resistance training by itself (Fletcher and Hartwell, 2004), the reason being that resistance training combined with pylometric exercises mimics the explosive, powerful movement of the golf swing. It also makes use of stretch-shortening cycles which are essential for good swing biomechanics (Fletcher and Hartwell, 2004). Medicine ball exercises recruit significantly more muscles than some commonly used muscle strengthening activities such as crunches, lunges, squats and sit ups (Petrofsky et al., 2008). They also increase muscle work in the muscles they recruit relative to these commonly used exercises (crunches, lunges and squats). The medicine ball exercise that was chosen in this study is particularly well suited to golfers in that it involves movement elements of the swing, thereby facilitating muscles important to the swing. It is an open chain exercise which further helps support transference of the muscle activation. The participant starts in a squat with the ball held lateral to the body next to the knees. As the participant extends out of the squat the ball moves across the body to the opposite side above the head (see Figure 3.10; pg.61). The researcher was not primarily using the exercise to improve muscle tensile strength[6], but as a movement preparation that encourages correct neural firing. The traditional warm up centres primarily on flexibility (Swanson, 2006). Newer warm up techniques centre on functional movement preparation and increasing heart rate. An increased heart rate brings about performance enhancing physiological responses (Swanson, 2006). This was the reason for the high number of repetitions (50 reps either side). Swanson (2006) states that “the warm-up should be considered an integral part of the training session and therefore should contribute to the development of balance, core strength, body control, running mechanics, agility, and efficient sport-specific movement” (Swanson, 2006). The medicine ball exercise chosen promoted balance, co-ordination, agility, core strength, body control and was sport specific (as discussed above). The medicine ball exercises also encouraged squatting and extending of the hip within the golfers’ normal competition

[6] It is important to note that one week of ball exercises is not sufficient to produce hypertrophic changes to the muscle. Visible hypertrophic muscle change usually occurs after approximately 8 weeks of resistance training (it is, however, important to note that protein synthesis occurs after the first resistance training session) (Bird et al 2005). The week of medicine ball exercises can, however, result in increased muscle strength by means of neural adaptation. Possible neural adaptations are: increased motor neurone firing rate, double firing of the motor unit, motor unit synchronisation. Several studies have shown muscle strength improvements over a few days (Bird et al 2005)

range. Contraction of the gluteus during extension from the squat would result in reciprocal inhibition of iliopsoas. The hip extension produced when coming out of the squat acts as a dynamic, movement-specific stretch on iliopsoas. Dynamic reciprocal-inhibition stretching has been shown to increase ROM (Baker and Newton, 2005, Wilkinson, 1992). This gives clinical support to the use of this intervention in the treatment of shortened hip flexors. ROM of hip extension, lumbar spine lateral flexion and rotation was measured before and after the intervention and a week later to see if the intervention had an effect on ROM.

Now that the possible benefit of the intervention has been established, the possibility of performance changes needs to be considered. Shortening of the hip flexors (a condition present in all participants in this study – see Chapter 3, Section 3.2.2: Inclusion criteria; pg.44) predisposes golfers to a “sway” or a “slide” (see Chapter 2, Section 2.4: Swing faults; pg.16). In both of these faults the golfer will move their hips laterally as opposed to rotating them. This ball exercise encourages lengthening of the iliopsoas and controlled weight shift left to right and right to left while at the same time encouraging rotational biomechanics. This may result in improved rotational biomechanics about the hip and lumbar spine. Improved rotational biomechanics have been shown to improve golf performance (Myers et al., 2008). This gives support to the possibility that this intervention may affect golf performance. Numerous studies have shown that resistance training results in improvements in driving performance in recreational players (Alvarez et al., 2011). There is however a gap in the literature regarding resistance training in elite golfers (Alvarez et al., 2011). The study performed by Doan et al (2006) on 16 elite collegiate golfers (ten men and six women) showed a significant improvement with strength training exercises on club head speed. In the study performed by Doan et al 2006 the participants were given a golf specific resistance training programme (that included a medicine ball exercise). These exercises were done over 11 weeks. After 11 weeks both the men and women groups experienced an improvement in club head speed, but this was less than they had predicted to be significant (Doan et al., 2006). The exercise routines were not individually tailored nor were the programmes designed to address a specific need. Doan et al (2006) give this as a possible reason for the club head speed not improving as much as they had anticipated. For this reason the researcher decided to only include participants if they had shortened hip flexors. The ball exercise that was chosen is designed to address shortened hip flexors. The study performed by Alvarez et al. (2011) on 10 elite golfers showed an improvement in club head speed over an 18 week strength training programme (this included strength and pylometric type training- which is similar to the medicine ball exercises). There were two groups: a control group and an intervention group. The study, however, was only performed on a small number of golfers and as such may not be generalisable. It also did not include the analysis of 3D swing biomechanics. This study gives support to the use of medicine ball exercises in this study, but it does not form a conclusive link between pylometric type strength training and performance. In the study performed by Fletcher and Hartwell (2004), 11 male golfers who were good club golfers (handicap 5±3.7 – not quite elite golfers) were recruited. Each participant received an eight week pylometric resistance programme. After eight weeks a significant improvement in club head speed and ball distance was observed. The concern, however, was that there was no control group and improvements may have been as a result of technical training and practice over the eight weeks (Fletcher and Hartwell, 2004). The studies performed by Doan et al (2006), Fletcher and Hartwell (2004) and Alverez et al (2011) provide evidence that medicine ball exercises have the potential to change club head speed and distance, but their findings still leave a large gap in the evidence, in that their results are not generalisable and they did not measure some essential performance indicators and injury risk predictors such as quantitative 3D swing biomechanics. Therefore the researcher decided to measure numerous essential golf performance indicators including biomechanics, club performance and ball flight before and after the medicine ball intervention and a week later to establish if this exercise had any effect on golf performance. This study also recruited a much larger number of participants (100 participants were recruited), thereby aiding generalisability of the results to elite male golfers between the ages of 16-25 years. This study helped to provide more information regarding the effect of ball exercises on swing biomechanics and ball flight. Potential changes to performance are an essential consideration for a physiotherapist when prescribing an exercise for an elite golfer.

2.16 MOTOR LEARNING:

2.16.1 TRANSFERANCE AND DEGRESS OF FREEDOM

Another question, which this study addressed, is the issue of transference. If myofascial trigger point therapy, stretching and/or medicine ball exercises were able to increase ROM, did it automatically lead to a change in biomechanics and performance? Just because an athlete has improved his available ROM does not necessarily mean that he/she will use it.

If, however, transference did occur, when is the ideal time for this? According to Bernstein "Physical activity requires the organization of a system with many 'degrees of freedom', a good proportion of which may be redundant to satisfy the immediate task demands of the activity or sport in question (Bernstein, 1967)" (Newell, 2003). In the process of motor learning an athlete develops a deep "groove" of motor learning. In this process the athlete moves from many degrees of freedom (see Figure 2.11) to a consistent pattern of movement where certain degrees of freedom are limited so as to improve consistency. Anatomy (such as muscle length) and physiology provide the natural patterns of organisation. These tend to be the most stable of all factors determining motor learning (Newell, 2003). When an athlete undergoes a change in motor pattern this is termed 'searching'. This is essential for the development of an athlete. If an athlete is to undergo 'searching', they should be careful when they do this as changes to motor patterning often leads to poor outcomes initially (Newell, 2003). We see this clearly in the example of a toddler learning to walk. This initial phase is fraught with difficulty and numerous falls, but the eventual outcome of walking rather than crawling is desirable. During this time, consistency (i.e. the groove of learning the athlete has formed) needs to be broadened(Newell, 2003). This often results in decreased consistency. Learning almost always takes time. Cortical organisation occurs via use and disuse. An elite golfer requires a stable, but continually evolving dynamical solutions to satisfy the varied tasks at hand. If myofascial trigger point therapy, stretches and/or medicine ball exercises do in fact change the physiology and anatomy of a golfer, and this change is transferred to the golf swing, the golfer will experience a change in biomechanics and possibly club and ball flight. The issue, then, is to determine when the best time to perform these techniques is; i.e. periodisation of physiotherapy.

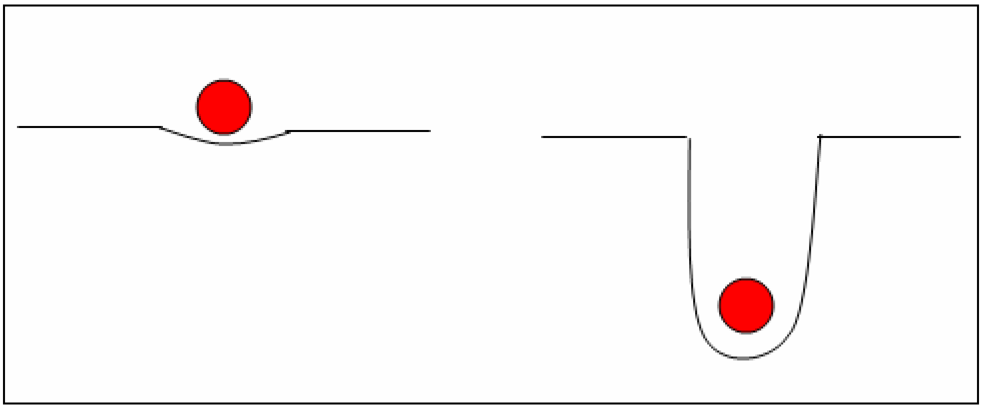

Figure 2.11: The groove of motor learning

2.16.2 PERIODISATION

To adjust a golfers' biomechanics, club performance or ball flight just before playing a big tournament would be undesirable as consistency would decrease (even if the change in anatomy, physiology and swing biomechanics was a good one). Periodisation in sport is a well established concept in coaching. Coaches do not make swing changes (even good swing changes) just before a major competition. Swing changes are reserved for off-season times. This is of particular interest to this study as techniques that resulted in changes to biomechanics, club performance and/or ball flight may affect swing consistency and performance. As such these interventions would need to be carefully periodised (i.e. it would be preferable to perform these interventions during off seasons and not during major tournaments).

2.17 CONFOUNDING VARIABLES

The intensity of training and the compliance to the home exercise programmes were considered confounding variables. The researcher attempted to account for these by using a training logbook, a stretch compliance tool and a medicine ball exercise compliance tool. The reason the researcher opted not to have directly observed training is that golf is an individual sport and as such athletes are usually responsible for their own training (unlike team sports where the team may train as a unit).

Pain was also seen as a confounding variable. If a participant experienced pain he was requested to stop the home exercises and make a note on his Compliance tool that he had stopped due to pain. If a golfer exercises in spite of pain he may worsen in stead of improve.

2.18 RELEVANCE TO SOUTH AFRICA

Now that the scientific rationale behind the study has been justified the relevance question remains, 'Why do such a study in South Africa?'

South Africa has a particular heritage in golf. South Africa is ranked third in the number of winners of major golf tournaments (after the United States and the United Kingdom) (http://golfmajorchampionships.com/byCountry, date accessed: December 2012). South Africa has consistently produced excellent players. To name a few: Bobby Locke (1950s and 1960s), Gary Player (1950s and 1970s), Ernie Els (1990s-current), Retief Goosen (2000s-current), Trevor Immelmen (2000s-current); Charl Schwartzel (2010s-current); Louis Oosthuizen (2010s-current) (http://golfmajorchampionships.com/byCountry, date accessed: December 2012). This is a heritage that can inspire young South African athletes. The Sunshine Tour is a South African based tour that has co-sanctioned events with the European tour. The top nine earners on this year's Sunshine Tour all earned in excess of 1 million rand (www.sunshinetour.com/home.asp, date accessed: December 2012). These statistics show that golf in South Africa is a viable career option (even if players are only successful on the local tour). In order to continue to promote golf in South Africa, knowledge about the performance effects of therapeutic interventions (such as trigger point therapy, stretching and ball exercises) is essential. If these techniques do result in changes in performance then periodisation of South African golfers as regards physiotherapy interventions is essential in order to maximise performance.

South Africa has 465 golf courses that are playable for an average of 335 days per year (www.engineeringnews.co.za/article/survey-shows-that-sa-green-fees-are-far-lower-than-those-in-europe-the-middle-east-2007-05-18, date accessed: December 2012). Green fees in South Africa are the cheapest in the world (www.engineeringnews.co.za/article/survey-shows-that-sa-green-fees-are-far-lower-than-those-in-europe-the-middle-east-2007-05-18, date accessed: December 2012). These aspects have resulted in a rapid growth in golf tourism in South Africa (www.engineeringnews.co.za/article/survey-shows-that-sa-green-fees-are-far-lower-than-those-in-europe-the-middle-east-2007-05-18, date accessed: December 2012). Tourism is an important source of revenue to South Africa. The courses employ the largest number of staff per course in the world (www.engineeringnews.co.za/article/survey-shows-that-sa-green-fees-are-far-lower-than-those-in-europe-the-middle-east-2007-05-18, date accessed: December 2012). Promoting growth of golf through producing exceptional athletes will result in job creation (www.engineeringnews.co.za/article/survey-shows-that-sa-green-fees-are-far-lower-than-those-in-europe-the-middle-east-2007-05-18, date accessed: December 2012).

It is also desirable to encourage growth in sport as it has huge health and social benefits. This is clearly stated in the National Department of Sport and Recreation, (1998) "Getting the nation to play" which states that: "Sport is an investment. It is firstly an investment in the health, vitality and productivity of one's people. It is secondly an investment in their future. The social benefits include an overall improvement in the quality of life and physical, mental and moral well-being of a population.". The issue with golf, however, is that even the 'perfect swing' predisposes golfers to lower back injury, and poor swing mechanics compounds the problem. Back pain remains one of the biggest causes of disability in the western world and is one of the leading causes of time taken off work (Jensen et al., 2003). This study aims to see if trigger point therapy or exercises effects swing biomechanics. If these physiotherapy techniques have a positive effect on swing biomechanics it may result in a reduction in injury. This is in line with priority one of the Medical Research Council (MRC) which focuses on the burden of disease. It is also in line with the mandate of the MRC which is 'through research, development and technology transfer, to promote the improvement of the health and quality of life of the population of the Republic.' (South African Medical Research Council; Strategic plan 2012/13-2016/17.) and with the MRC Health Outcome Area of 'A Long and Healthy Life for All South Africans'.

This study encompasses the five key values of the MRC:

1. **Excellence and innovation:** This is a high quality study. It is a randomized controlled trial (level 1 evidence). It is, to the best of the researcher's knowledge, an original study. It also has scientific integrity (www.engineeringnews.co.za/article/survey-shows-that-sa-green-fees-are-far-lower-than-those-in-europe-the-middle-east-2007-05-18, date accessed: December 2012).
2. **Relevance:** It is relevant to the South African community in that it supports sports development and injury prevention.
3. **Accountability:** It is accountable in that it is done by the University of the Witwatersrand. It demonstrates teamwork in that it crosses many different professions: golf professionals, biokinetics (rehabilitation aspect), physiotherapy and physiology (biomechanical analysis).
4. **Respect and communication:** The study was reviewed by the University of the Witwatersrand.
5. **Capacity development:** As golf is such a popular sport world wide this study may draw recognition from other countries.

2.19 CONCLUSION

Physiotherapy has become a stable part of elite golf. Most physiotherapy interventions focus on the lumbar spine, as this is the most frequently injured region. The lumbar spine and hip region are key areas when it comes to golf performance (swing biomechanics and ball flight). Restoring the length of a muscle that has origins in the lumbar spine and hip (such as the iliopsoas) may result in changes in performance. Changes to golf performance are an important consideration that therapists and elite golfers need to be made aware of so that they can carefully weigh the risks and benefits of the intervention. In order to improve ROM in elite golfers physiotherapists regularly use trigger point therapy, stretching and ball exercises. This study has aimed to establish if these common physiotherapy interventions had an effect on ROM and if this effect on ROM had any influence on swing biomechanics, club performance and/or ball flight. This study will add to the body of literature on performance effects of physiotherapy interventions on elite golfers.

CHAPTER 3: METHODOLOGY

3.1 STUDY DESIGN

This was a quantitative, experimental, randomised controlled trial with two experimental groups. One group received routine training (control).

3.2 PARTICIPANTS

3.2.1 SAMPLE SIZE CALCULATION

The participants were elite golfers drawn from the greater Johannesburg area. According to a statistical analysis of a similar study performed by Thompson and Wayne (2004) this study required at least 20 participants per group to be powered at 90%. In order to account for drop out, a total of 100 participants were recruited for the study (33 participants in two of the groups and 34 participants in one group – the group that received the additional participant was be randomly allocated).

3.2.2 INCLUSION CRITERIA

- Shortening of the iliopsoas. If the participant's hip extension (using the Thomas Test) was not full i.e. 0 degrees, then the participant was classified as having "shortened hip flexors"
- Handicap of less than six
- Ages: 16-25 years
- Male
- Engaged in regular and ongoing, golf related training for at least 2 hour per week (practice at the range, playing golf)

3.2.3 EXCLUSION CRITERIA

- Currently receiving physiotherapy interventions
- Known serious spinal or hip pathologies (including disc herniations, Scheuermans, fractures at the pars)

3.2.4 RATIONALE FOR INCLUSION AND EXCLUSION CRITERIA

Table 3.1: Rationale for inclusion criteria

Criteria	Rationale
Hip Flexor shortening	Participants were included in the study if they had muscle shortening referred to in the study as "shortening" of the iliopsoas". If the participants hip extension (using the Thomas Test) was not full i.e. 0 degrees, then the participant was classified as having "shortened hip flexors". The reason for this was that physiotherapy interventions should have a specific purpose. There is little point in using techniques aimed at lengthening a muscle that does not require lengthening. This is especially true if the concern is that intended treatment outcome may alter biomechanics, club performance or ball flight. Moran et al. (2009) did not set this as an inclusion criteria in their study and this may be the reason that they did not get significant performance changes after golfers performed a 'static stretch'.
Handicap < 6	This was criteria was included due to the understanding that elite athletes sustain more injuries than recreational golfers and as such are more likely to require this kind of intervention (Sherman and Finch, 2000). These athletes also tend to have less variance in their swing than recreational golfers (Hume et al., 2005). Less variance helps improve the reliability of measurement of change in biomechanics and performance.
16-25 years	Age limits were set as different ages have different responses to stretch (Hollard et al., 2002). Different age groups also have different biomechanics (Lathey et al., 2009). If the age bracket was too large this may have made the standard deviations large. 16-25 years was selected as this is usually the age that many golfers in the Gauteng area attend intensive training at golf academies (such as the Golf School of Excellence, Observatory; the Golf School of Excellence, Pretoria and Centurion Academy, Centurion). This is a crucial time in most golfers' lives and as such it is as important time to be aware of techniques that may alter performance.
Male	Only males were selected for this study because males and females have different responses to stretch (Thompson and Wayne, 2004)
Minimum of 2 hours per week of golf activity	The reason for setting a time frame of minimum golf activity is that the primary cause of injury is overuse. (Lindsay et al., 2009). This is the group of golfers at risk of injury and therefore generally the group that requires physiotherapy.

Table 3.2: Rationale for exclusion criteria

Criteria	Rationale
Currently receiving physiotherapy	The long term effects of the manual and exercise physiotherapy interventions from another therapist would introduce too many confounding variables to the study
Serious spinal or hip pathologies	Spinal pathologies may have introduced biomechanical anomalies of their own (e.g. stiffness of the thoracic spine in Scheuermans often results in compensation in the lumbar spine: the lumbar spine compensates by increasing its' ROM). Serious spinal or hip pathologies may also have posed as a safety concern when performing the exercises (e.g. a patient with a disc prolapse would aggravate the disc when performing the medicine ball exercises.)

3.3 VARIABLES

3.3.1 INDEPENDENT:

- Stretching
- Myofascial release
- Compliance to one week stretching programme
- Compliance to one week medicine ball exercise programme

3.3.2 DEPENDENT

- Lumbar spine lateral flexion and rotation ROM
- Hip extension ROM
- Biomechanics (hip alignment at address, hip bending at address, hip "tilting" at address:, backswing hip turn, X-factor, X-factor stretch, hip drop during the backswing, hip sway during the backswing, hip turn during the downswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, transition sequence, timing sequence)
- Club performance (club head speed and smash ratio)

- Ball flight (distance and accuracy)

3.3.3 CONFOUNDING VARIABLES

- Differences in intensity and type of training. To help account for this, a training logbook was used.
- Differences in Compliance to home stretching programme. To help account for this, a stretch Compliance diary was used.
- Differences in Compliance to the home hip muscle activation programme. To help account for this, an exercise diary was used.
- Pain experienced when performing the exercises. The participants were asked to stop and mark on their Compliance tool if they experienced pain while performing an exercise.

3.3.4 OUTCOME MEASURES AND INSTRUMENTS USED

Table 3.3: Instruments Used to Measure Outcomes

Variable	Outcome Measure	Instrument Used
ROM	Hip extension flexibility	Modified Thomas test & Inclinometer
	Lumbar spine lateral flexion ROM	BROMII
	Lumbar spine rotation ROM	BROMII
Biomechanics	Hip alignment at Address	Electromagnetic 3D Analysis System
	Hip bending at Address	Electromagnetic 3D Analysis System
	Hip tilting	Electromagnetic 3D Analysis System
	Backswing Hip turn	Electromagnetic 3D Analysis System
	X-factor	Electromagnetic 3D Analysis System
	X-factor stretch	Electromagnetic 3D Analysis System
	Backswing Hip drop	Electromagnetic 3D Analysis System
	Backswing Hip sway	Electromagnetic 3D Analysis System
	Downswing Hip turn	Electromagnetic 3D Analysis System
	Downswing Hip tilt	Electromagnetic 3D Analysis System
	Downswing Hip bend	Electromagnetic 3D Analysis System
	Downswing Hip sway	Electromagnetic 3D Analysis System
	Downswing Hip thrust	Electromagnetic 3D Analysis System
	Downswing Hip speed	Electromagnetic 3D Analysis System
	Transition sequence	Electromagnetic 3D Analysis System
	Timing sequence	Electromagnetic 3D Analysis System
Club Performance	Club head speed	Flightscope
	Smash ratio	Flightscope
Ball Flight	Distance	Flightscope
	Accuracy	Flightscope
Differences in training	Flexibility training	Log book
	Weight training	Log book
	Total training	Log book
Compliance	Stretch Compliance	Stretch Compliance tool
	Medicine Ball exercise Compliance	Medicine ball Compliance tool
	Pain experienced during stretch exercises	Stretch Compliance tool
	Pain experienced during ball exercises	Ball Compliance tool

3.4 PROCEDURE

3.4.1 ETHICAL CLEARANCE

Ethical clearance was applied for and granted (see Appendix I: Ethical clearance certificate; pg.149).

3.4.2 PILOT STUDY

A pilot study was performed.

3.4.2.1 OBJECTIVES OF THE PILOT STUDY

To familiarise the research assistants with the study methodology.

To 'test' and 'troubleshoot' the research methodology and make the necessary adjustments.

3.4.2.2 METHODOLOGY OF THE PILOT STUDY

Six participants were recruited for the pilot study. The methodology for the pilot study was precisely the same as the methodology used in the main study (please see Chapter 3; Section 3.4.2. Main study procedure; pg.52), except for the measuring tool used to measure hip extension ROM. It was initially thought that an inclinometer would be a superior tool to the goniometer in the measurement of hip extension ROM.

3.4.2.3 HIP EXTENSION ROM MEASUREMENT: PILOT STUDY

In the pilot study participants were asked to sit on the edge of a plinth (as close to the edge as possible). They were then asked to flex their left leg and hold it close to their chest. The researcher then helped the participant roll gently onto their back whilst keeping their leg close to their chest. The right leg was allowed to hang off the bed. The researcher then palpated the lumbar spine to ensure that the lumbar spine lordosis was flattened. The researcher then corrected any abduction or adduction of the right thigh. Once the correct test position was achieved the extension arm of the inclinometer was placed between the greater trochanter and the lateral condyle along the lateral midline of the femur. (Clapis et al., 2008) The hip extension value was then recorded. Positive values for hip extension were recorded for values above the bed. Negative values for hip extension were recorded for values below the bed. The same procedure was repeated for the participant’s other leg.

3.4.2.4 RESULTS OF THE PILOT STUDY AND IMPLICATIONS

The pilot study yielded some useful insight into the methodology. Participant 3’s second ROM measurement was found to be missing from his file. The most likely reason for this was that he left to go home before his second ROM assessment had been performed. As a result of this the researcher decided to give five stickers to each of the participants in the main study that were labelled: ROM Assessment 1, Swing Assessment 1, Physiotherapy intervention, ROM Assessment 2, Swing Assessment 2. The participants in the main study were asked to submit a sticker at each station and not to leave to go home until they had submitted all their stickers.

The physiotherapy research assistants that were employed are considered to be competent therapists. Both had accumulated more than seven years experience in orthopaedic manipulative therapy by the time the study was undertaken and have received post graduate qualifications in Orthopaedic Manipulative therapy. As such they had no concerns or problems performing the interventions. The PGA research assistants were competent in 3D analysis and Flightscope analysis and as such had no problems performing the assessments. The lumbar spine rotation and lateral flexion assessments were satisfactory.

The inclinometer, however, proved to be a fairly cumbersome device to use. After the pilot study revealed this concern, the researcher did further investigation into the different methods used to measure hip extension and found that gonoimeter readings are as accurate at measuring hip extension as the inclinometer (Clapis et al., 2008). In the study by Clapis et al. (2008) it was also found that the inclinometer is slightly more difficult to use than the goniometer. They gave familiarity with the equipment as a possible reason (goniometers are routinely used by therapists in monitoring treatment, whereas inclinometers are seldom used by practicing therapists). The researcher, therefore, decided to use the goniometer instead. It should be noted that this was a preference of the researcher and is not a reflection on the validity or reliability of using an inclinometer in measuring hip extension ROM.

As inclinometer and goniometer readings of hip extension using the Modified Thomas Test can be used interchangeably (Clapis et al., 2008) and there were no other changes to study methodology, the researcher included the six pilot study participants into the data analysis of the main study.

3.4.3 MAIN STUDY PROCEDURE

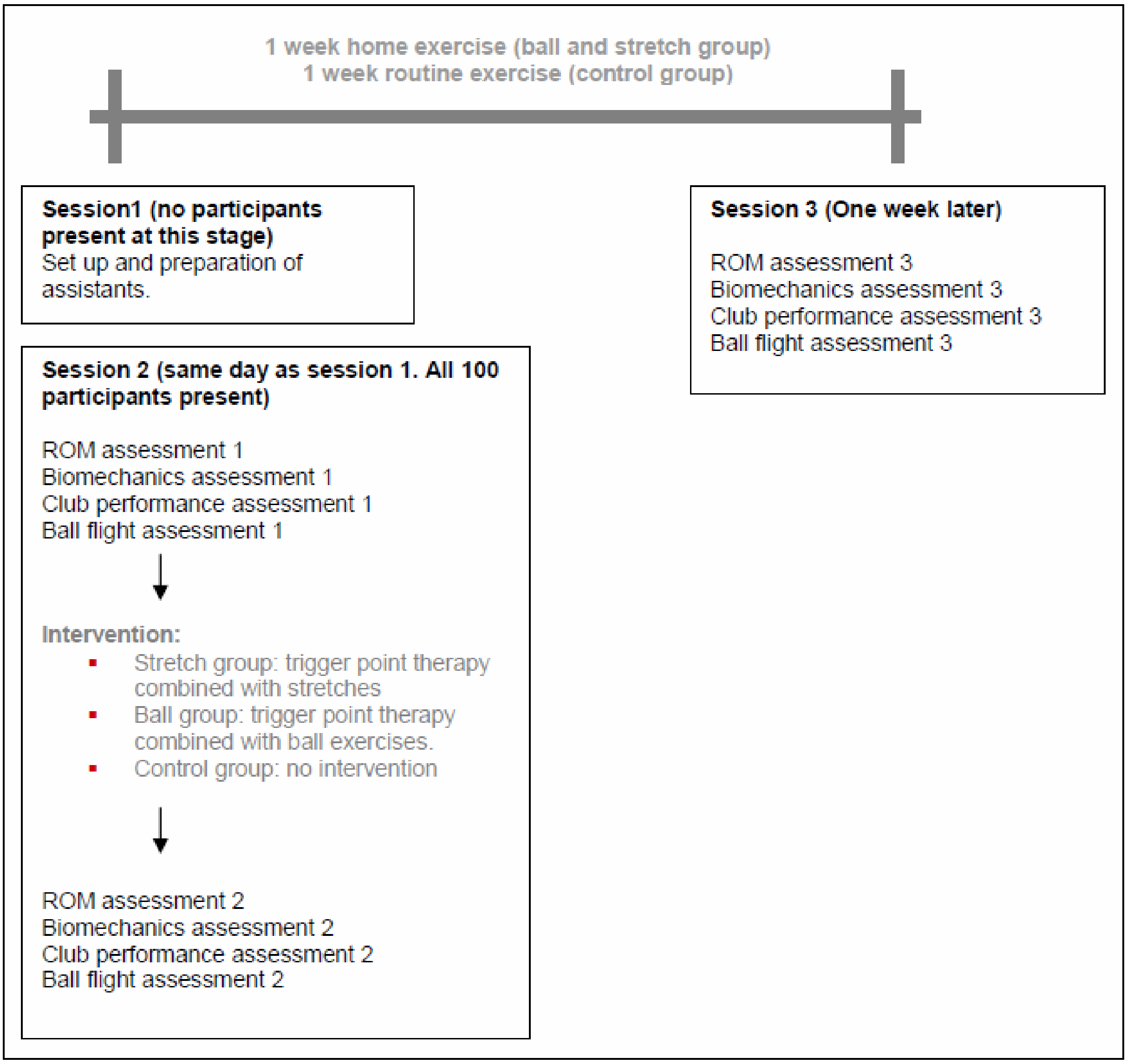

Figure 3.1: Diagram illustrating the main procedure

Table 3.4: Variable measurement and blinding

Variable	Measured By	Blinded Yes/No
Hip Flexibility	Researcher	Yes
Lumbar Spine ROM	Researcher	Yes
Swing Biomechanics	PGA research assistant.	Yes
Ball Flight	PGA research assistant.	Yes

3.4.3.1 *SESSION 1: PRIOR TO THE STUDY*

3.4.3.1.1 Preparation of the research assistants

The research assistants were trained in the following areas:

- Inclusion and exclusion criteria
- Study methodology
- Interventions. The interventions were explained and demonstrated: trigger point therapy with stretching and myofascial trigger point therapy with muscle training.

The researcher prepared all data collection documents (see Appendices B; pg.125, C; pg.127, D; pg.128, and E; pg.129) and the computer-generated, random, concealed group allocation. Participants were recruited from the Serengeti Golf Academy, the Golf School of Excellence, Fanie Viljoen's Academy and Louis Coetzee's Academy.

3.4.3.1.2 Set up

Two rooms were set up at the Serengeti Golf Academy, Kempton Park, South Africa. One room was used for screening participants, training participant's on filling in the log book and performing the interventions. This room was known as the Intervention Room. The other room was used to assess (Ax) the participants ROM. This room was known as the Assessment Room. The Assessment Room was equipped with: a plinth, BROM II, small stool and one large towel. The Intervention Room was equipped with: a plinth, aqueous cream, four towels, and a stopwatch to keep time (fifteen minutes were allocated per treatment session). The distance, accuracy and swing analysis area was set up in an area next to these two rooms. The Flightscope was positioned behind the space in which the player would stand when taking a shot. The 3D-analysis system was set up in the same area.

3.4.3.2 *SESSION 2: PREPARATION, ASSESSMENT 1, INTERVENTION, ASSESSMENT 2*

3.4.3.2.1 Preparation

Informed consent/assent was obtained from all participants (see Appendices F; pg.130 and G; pg.139). The research assistant screened participants for inclusion and exclusion criteria. Participants filled in a basic demographic questionnaire (see Appendix B; pg.125) and their contact details were recorded. The participants were then given a numerical code reference that was be used for all data collection. The research assistant labelled each data collection sheet with their code reference; e.g. Participant 1, Participant 2, etc. The research assistant then allocated the participants into one of three groups. This was done using a computer-generated, randomised, concealed allocation.

3.4.3.2.2 Assessment 1

3.4.3.2.2.1 Range of motion: Assessment 1

The participants included in the study went to the Assessment Room one at a time. The researcher took the following measurements for each participant:

- Lumbar spine rotation – Measurement 1

  The researcher measured lumbar spine rotation using the BROM II. All ROM measures were performed in the same position. For lumbar spine rotation the participants were asked to sit on a non-rotating stool facing west. The researcher demonstrated lumbar spine rotation to the participant. Two marks were then made on the participant's spine using removable ink markers. The first on T12 and the other on S1. The belt of the BROM II was then placed around the participants' trunk between S1 and T12. The magnetic reference of the BROM II hung approximately four centimetres below S1, pointing North. The measuring compass' feet were then placed either side of T12. The researcher grasped the participant's rib cage on either side so that the unit would move as a whole. The participant was then instructed to place their hands on their opposite shoulders. The compass was zeroed. The participant was then requested to turn slowly and smoothly to the left and then to the right (measurements were noted). The participant was then instructed to repeated this movement (measurements were noted a second time). If the difference between the two measurements was less than 2° then the higher of the two measurements was recorded. If the difference was greater than 2° then the measurements were taken again until both measurements were within 2° of one another (Performance Attainment Associates, 2012) .

Figure 3.2: The measurement of (i) rotation; and (ii) lateral flexion using the BROMII (Performance Attainment Associates, 2012)

- Lumbar spine lateral flexion – Measurement 1

The researcher measured lumbar spine lateral flexion using the BROM II. The researcher demonstrated lateral flexion of the lumbar spine to the participant. The participant then stood erect facing the wall with their nose almost touching the wall. The feet of the BROM II were then placed either side of T12 (marked for previous assessment). The researcher then grasped the participant's rib cage and adjusted the unit until it read zero. The participant was then requested to 'bend to the side' as the researcher had demonstrated. Emphasis was given to smooth, slow movements. The reading was noted.

Then the participant was requested to repeat the movement. If the difference between the two measurements was less than 2° then the higher of the two measurements was recorded. If the difference was greater than 2° then the measurements were taken again until both measurements were within 2° of one another. (Performance Attainment Associates, 2012)

Figure 3.3: The measurement of hip extension (Clapis et al., 2008)

- Hip extension – Measurement 1

Each participant was asked to sit on the edge of the plinth (as close to the edge as possible). They were then asked to flex their left leg and hold it close to their chest. The researcher helped the participant roll gently onto their back whilst keeping their leg close to their chest. The right leg was allowed to hang off the bed. The researcher then palpated the lumbar spine to ensure that the lumbar spine lordosis was flattened. The researcher corrected any abduction or adduction of the right thigh. Once the correct test position was achieved the fulcrum of the goniometer was placed over the lateral aspect of the greater trochancter of the right leg. The moveable arm was aligned with the lateral midline of the pelvis and the immovable arm was aligned with the lateral midline of the femur (the lateral condyle of the femur was used as a reference for the midline of the femur) (Clapis et al., 2008). The hip extension value was then recorded. Positive values for hip extension were recorded if the leg position was above the bed. Negative values for hip extension were recorded if the leg position was below the bed. The same procedure was repeated for the participant's other leg.

3.4.3.2.2.2 3D analysis and Flightscope analysis: Assessment 1

The participants were directed to the 3D analysis and Flightscope analysis area. The Professional Golf Association (PGA) research assistant measured each participant's club head speed, ball flight, angle of attack and ball spin using the Flightscope. The PGA research assistant simultaneously measured each participant's swing biomechanics using the 3D analysis system. This was achieved as follows.

The 3D analysis system was individually calibrated to each participant. Each participant was individually calibrated using the following anatomical markers: medial and lateral wrist markers, medial and lateral elbow epicondyle markers, shoulder markers, head markers, thorax markers, pelvis markers and hip markers (Evans et al., 2012). The participants were given time to get used to the equipment and hit as many practice shots as they felt necessary (Gabbe et al., 2004). The Flightscope system was set up between 2.4 to four meters behind the tee. The Flightscope sensor was positioned on level ground, pointing towards the tee and slightly up at an angle of approximately 10º and it was ensured that there was no roll.

Once the systems had been calibrated for the participant and the participant felt comfortable with the equipment, he was given a six iron and asked to hit five balls as though he was participating in a competition where both distance and accuracy were important (Gabbe et al., 2004). The 3D analysis system automatically recorded the parameters it was measuring and then calculated an average value for each parameter over the participant's five shots and generated a report. The Flightscope also calculated an average value for each of the parameters it was measuring over the participant's five shots and generated a report. Both the Flightscope report and the 3D analysis report were entered into the participant's file.

3.4.3.2.2.3 Physiotherapy intervention

The participants were then moved to the Intervention Room. The physiotherapy research assistant performed the interventions on the experimental groups and no intervention was performed on the control group.

3.4.3.2.2.3.1 Stretch group: Trigger point therapy of the hip flexor and 60 second static stretch of iliopsoas

Trigger point therapy

The physiotherapy research assistant was requested to treat any trigger points found in the hip flexor. Common locations (see Figure 3.4; Figure 3.5; Figure 3.6; Figure 3.7; Figure 3.8) of trigger points in the hip flexor include:

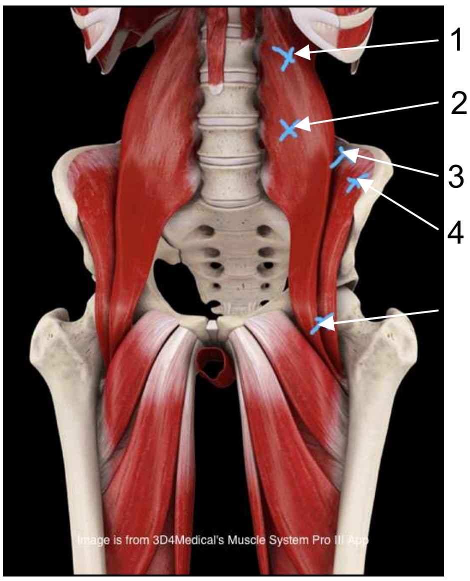

Figure 3.4: Common trigger point locations for the hip flexor

- Two trigger points are often found two centimetres lateral to the midline of the spine (see Figures 3.5 and Figure 3.6).

- Two trigger points are often found in iliacus (see Figure 3.7). This trigger point is found by the therapist cupping their hand around the illium into the iliac fossa.
- One trigger point is often found near the insertion of iliopsoas (see Figure 3.8.). This usually lies two centimetres inferiorly to the inguinal ligament and two centimetres lateral to the femoral artery (Petrofsky et al., 2008).

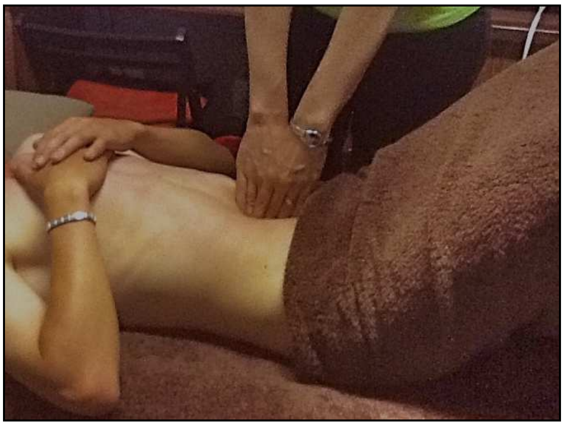

Figure 3.5: Trigger point 1 (per Fig 3.4)

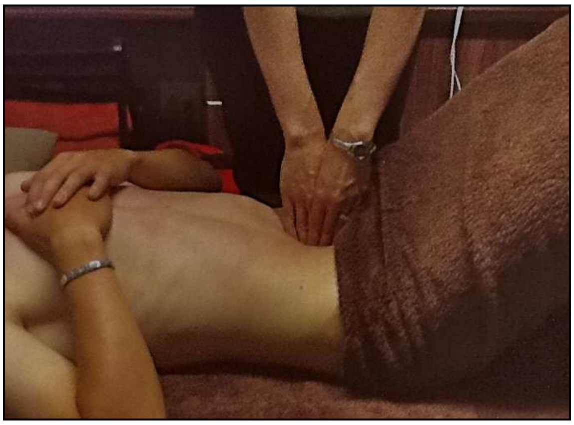

Figure 3.6: Trigger point 2 (per Fig 3.4)

Figure 3.7: Trigger points 3 and 4 (per Fig 3.4)

Figure 3.8: Trigger point 5 (per Fig 3.4)

It should be noted that the "common trigger point locations" served as a guideline to the physiotherapy research assistant, but not as an absolute rule. The physiotherapy research assistant palpated and diagnosed the trigger point. In order to diagnose a trigger point the therapist looked for the following: a hyper-irritable point in a taught band located by palpation, the participant reported pain that referred to a distal point when pressure was applied to the trigger point, a local twitch response in the muscle was elicited when pressure was applied to the trigger point, the participant flinched away from palpation. This method of diagnosing trigger points is reliable (Dommerholt et al., 2006). The research assistant then treated the trigger point using ischaemic pressure (minimum of 45 seconds of pressure per trigger point). After the ischaemic pressure the participants received a 60 second stretch of the iliopsoas (it is essential to combine trigger point therapy with a stretch as this is how the technique is usually performed) (Petrofsky et al., 2008, Kostopoulos, 2001). This stretch was done by the participant placing one leg on the plinth while the rest of the body remained erect. The participant's pelvis remained in neutral alignment and the participant was instructed to move his centre of mass anteriorly until he felt a stretch in the iliopsoas, but no pain (see Figure 3.9). This stretch was then repeated for the participant's other leg.

Figure 3.9: Stretching the iliopsoas

60 second iliopsoas stretch

The participants in the stretch group were then instructed to do one additional 60 second static stretch of iliopsoas (left and right). This stretch of iliopsoas is done in half kneeling. The participant moves their pelvis forward without producing pelvic tilt (see Appendix C; pg.127). Each participant performed this 60 second stretch in front of the therapist and she corrected any poor body alignment or incorrect stretching. The participants were then instructed to perform this stretch of iliopsoas for 60 seconds each side three times a day, as a home programme each day for the following week. The research assistant gave the stretch group their exercise Compliance tool and explained how they ought to fill it in (see Appendix C; pg.127). The participants were asked to mark the day and circle 'yes' or 'no', 'yes' if they did the exercise and 'no' if they did not do the exercise. They were instructed to stop if they experienced any pain and to mark 'no' and then draw a P with a circle around it. Honesty in filling out their tool was strongly encouraged. The participants were then given their log book. The researcher explained how the log book should be completed (see Appendix E; pg.129). The participants were asked to use their logbook to record the amount of time (in 15 minute intervals) spent on each routine training activity (e.g. postural training, weight training, practice at the driving range) which they undertook on each day for the following week. Honesty was again encouraged.

The participants were given an opaque folder. They were asked to keep the training logbook and stretch Compliance tool in the folder. The stretch group was allowed to continue with their routine training to which they were to add the prescribed iliopsoas stretch three times per day. The stretch group were shown the ball exercise that the ball group was given and they were asked not to perform this specific exercise for the week of the study.

3.4.3.2.2.3.2 Ball group: Trigger point therapy and static stretch followed by a muscle activation exercise

Trigger point therapy

The physiotherapy research assistant was requested to treat any trigger points found in the iliopsoas (same procedure as for the stretch group - see Section 3.4.2.2.2.3.1 Trigger point therapy; pg.57).

Ball exercises

Immediately after each participant in the ball group had received trigger point therapy he was asked to perform a medicine ball exercise. This served as a functional movement preparation. This was performed using a 4kg ball. The proprioceptive neuromuscular facilitation (PNF) pattern starts in a squat with the hands holding the ball to the side of the body the participant then stands up, raising the ball above the head to the opposite side of the body as shown in Figure 3.10.

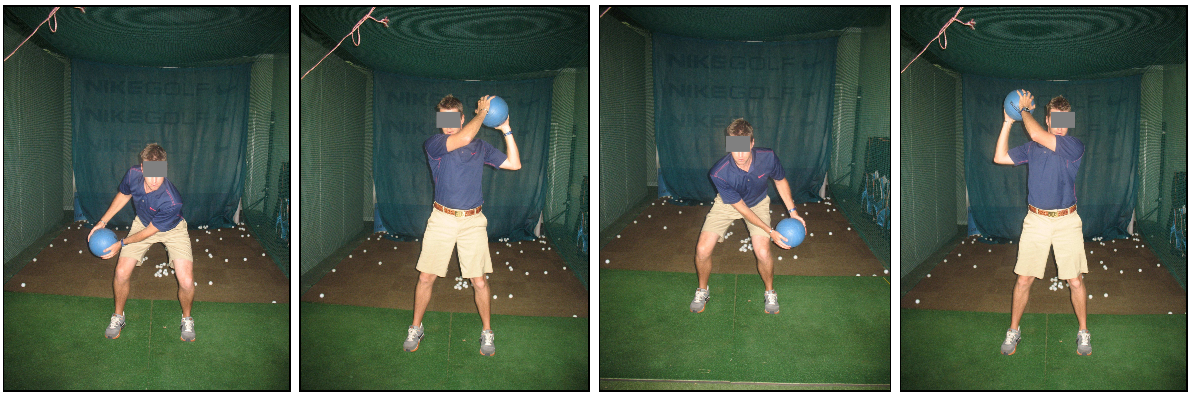

Figure 3.10: The Prescribed Ball Exercise for Muscle Activation

Applicants were instructed to repeat this movement 50 times to the one side and 50 times to the other side. The ball group were then instructed to perform the ball exercise as a home programme three times per day for one week. The research assistant gave the ball group their exercise Compliance tool and explained how they ought to fill it in. (see Appendix D; pg.128). The participants were asked to mark the day and circle 'yes' or 'no': 'yes' if they did the exercise and 'no' if they did not do the exercise. They were instructed to stop if they experienced any pain and to mark 'no' and then draw a P with a circle around it. Honesty in filling out their tool was strongly encouraged. The participants were then given their log book. The researcher explained how the logbook should be filled in (see Appendix E; pg.129). The participants were asked to use their logbook to record the amount of time (in 15 minute intervals) spent on each routine training activity (e.g. postural training, weight training, practice at the driving range) which they undertook on each day for the following week. Honesty was again encouraged.

The participants were given an opaque folder. They were asked to keep the training logbook and exercise Compliance tool in the folder. The ball group was allowed to continue with their routine training to which they were to add the prescribed medicine ball exercise three times per day. They were shown the specific stretch that the stretch group had been given and they were asked not to perform this specific stretch for the week of the study.

3.4.3.2.2.3.3 Control group: Control; no intervention

Each participant from this group remained in the treatment room for the same period of time (15 minutes) as participants from the other groups. The physiotherapy research assistant explained to each participant how they ought to fill in their training log book. The participants were asked to use their logbook to record the amount of time (in 15 minute intervals) spent on each routine training activity (e.g. postural training, weight training, practice at the driving range) which they undertook on each day for the following week. Honesty was encouraged. The control group were shown the ball exercise that the ball group was given and they were asked not to perform this specific exercise for the week of the study. The control group were shown the stretch the stretch group was given and they were asked not to perform this specific stretch for the week of the study.

3.4.3.2.3 Assessment 2

Immediately after the physiotherapy intervention each of the participants returned to the Assessment Room. The researcher then retook the following measurements (second measurement):

- Hip extension (same procedure as for Assessment 1)
- Lumbar spine rotation (same procedure as for Assessment 1)
- Lumbar spine lateral flexion (same procedure as for Assessment 1)

The PGA golf professional then re-performed (second measurement) the following analyses for all participants:

- 3D swing analysis (same procedure as for Assessment 1)
- Flightscope ball flight analysis (same procedure as for Assessment 1)

All participants then returned home. The participants in the experimental groups (the ball and stretch groups) performed their home programmes and filled in their respective Compliance tools. The participants in all three groups filled in their log books.

3.4.3.3 SESSION 3: ASSESSMENT 3 AND HAND IN OF TOOLS

3.4.3.3.1 Assessment 3

One week later all the participants returned to the Serengeti Golf Academy. The participants returned to the Assessment Room. The researcher re-measured (third measurement) all participants:

- Hip extension (same procedure as for Assessment 1)
- Lumbar spine rotation (same procedure as for Assessment 1)
- Lumbar spine lateral flexion (same procedure as for Assessment 1)

The PGA golf professional then re-measured (third measurement) all participants:

- 3D swing analysis (same procedure as for Assessment 1).
- Flightscope ball flight analysis (same procedure as for Assessment 1).

3.4.3.3.2 Hand in of Compliance tool and log book

The stretch group handed in their log book and stretch Compliance tool. The ball group handed in their log book and exercise Compliance tool. The control group handed in their log book.

Any drop outs were noted. Enquires were made as to why a particular participant dropped out of the study.

The data was then tabulated for analysis.

3.5 ETHICAL CONSIDERATIONS

Informed consent was obtained from each adult participant (aged 18 years and older). Informed assent was obtained from each minor (ages 16-17 years) and informed consent was obtained from their parents for their child to partake in the study (see Appendices F; pg.130 and G; pg.139). The protocol was also verbally explained to all the participants. Questions were answered. Extra time was taken with minors between the ages of 16-18 years to make sure they understood what was required from them and to assure them that their participation was entirely voluntary and that they did not have to participate if they did not want to (even if their parents were happy with them doing it). Each participant was informed of their right to withdraw from the study at any time without suffering any consequences. They were further informed of the process of withdrawing. Should they wish to withdraw they needed to provide the researcher with a letter declaring their withdrawal.

Ethical considerations as regards the interventions were: mild discomfort caused by the trigger point therapy, stretches and ball exercises. Patients were warned about these.

The other concern was possible interference with training. This interference could have come by way of time away from training to take part in the study, and the minor adjustments to their routine training: the stretch group were asked not to perform the specific ball exercise for the week of the study (they could, however, do other ball exercises); the ball group were asked not to perform the specific iliopsoas stretch for the week of the study (they could, however, do other stretches); the control group were asked not to perform the specific iliopsoas stretch (they could, however, do other stretches) and the specific ball exercise (they could, however, do other ball exercises) for the week of the study. Interference with routine training could result in negative performance outcomes. For this reason the study was mostly performed during the amateur off-season time in August. Scheduling of the study was discussed at length with the various academies to ensure that it caused as little disruption as possible. The 3D biomechanical assessment combined with the Flightscope measurements would usually cost a player approximately R900.00 per assessment. They received three of these free of charge (irrespective of the group they were assigned to). This information is very useful to the coach and the team working with the golfer as it helps to quantify and confirm areas of weakness and strength in the golfer. This helps the coach to design specific, technical drills for the player. If the participant wished, copies of their biomechanical assessment and Flightscope analysis were given to their coach after the participant had signed a Release of Medical Information form (see Appendix J; pg.155). At the end of the study the researcher educated each participant individually on how to improve the muscle length of their hip flexor and on the potential risk of injury if they do not. Long term personalised home exercise programmes were given to each participant. This was done after the Assessment 3 and was free of charge. The researcher hopes that these benefits adequately compensated the participants for any interference with their training that resulted from their participation in the study.

3.6 DATA ANALYSIS

3.6.1 PARAMETRIC AND NON-PARAMETRIC DATA

All data (other than accuracy, timing sequence and transition sequence) was parametric data. Where applicable, this data was then interpreted within the accepted corridors and clinical significance was given to the finding.

The non-parametric data: (accuracy, timing sequence and transition sequence) were recorded on the data sheet with a '1' or a '0', with '1' being good and '0' being bad. If a participant stayed bad or worsened from the one assessment to the next assessment they were put in the "bad category" (which was scored as +1). If a participant improved or stayed good they were put in the "good category (which was scored as -1).

The researcher assessed pain by asking each participant to indicate the presence of pain while performing an exercise. If the participant experienced pain he was instructed to stop the exercise at that point and mark his Compliance tool with a P next to that's days exercise. Pain was not graded in intensity.

3.6.2 STATISTICAL TESTS USED

Tests were performed using the STATA computer package.

Parametric data tests:

- **Means and standard deviations** were calculated for all parametric data variables.
- **One way analysis of co-variance test (ANCOVA)** was used. This test adjusts for differences in baseline while comparing the variables of interest between the control group and the stretch group; between the control group and the ball group; and between the ball and the stretch group. The third comparison (between the ball and stretch group) was only applied if there

were significant differences between the intervention groups and the control. While the variables of interest were being compared the following confounding variables were statistically controlled: (i) differences in baseline (see Tables 4.3; pg.78, 4.4; pg.79; 4.7; pg.83, 4.9; pg.85, 4.10; pg.86; 4.13; pg.90); (ii) differences in baseline and differences in training (see Tables 4.15; pg.92, 4.16; pg.93, 4.17; pg.95). No within group analysis was done. The groups never served as their own controls.

- **Confidence intervals** were calculated for statistically significant results in order to find out if the 'true value' was within the accepted clinical corridors or not. This was done to determine if the results were clinically significant or only statistically significant (see Figure 4.2; pg.80, 4.3; pg.80, 4.4; pg.87 4.5; pg.87).[7]

- .**Simple percentage tests** were used to calculate the following for each participant in the stretch and ball groups: (i) percentage Compliance to the total number of exercises that that particular group was required to perform, (ii) percentage of exercises discontinued due to pain, (iii) and percentage exercises discontinued due to non-compliance (see Table 4.13; pg.90, 4.14; pg.91).

Non-parametric data tests

- **The Fisher's Exact Test** was performed on the non-parametric data in order to compare the stretch group with the control group and the ball group (see Tables 4.5; pg.82, 4.6; pg.82, 4.8; pg.84, 4.11; pg.89, 4.12; pg.89).

[7] "It is common practice to take a statistically significant result as a real effect, and often by implication, as a clinically important effect too. Neither interpretation is necessarily justified… The presentation of both the actual p-value and the confidence interval is desirable… It is important to understand that statistical significance and clinical importance are not the same thing." Altman (1999)

3.6.3 SIGNIFICANCE

Significance was set at $p \leq 0.05$.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

The results are explained under the following sub-sections:

- Sample Size
- Demographics
- Between-group changes in ROM from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)
- Between-group changes in biomechanics from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)
- Between-group changes in club performance and ball flight from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)
- Between-group changes in ROM from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)
- Between-group changes in biomechanics from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)
- Between-group changes in club performance and ball flight from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)
- Between-group changes in ROM when ANCOVA adjusted for differences in weight training, flexibility training and total training from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)
- Between-group changes in biomechanics when ANCOVA adjusted for differences in weight training, flexibility training and total training from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)
- Between-group changes in club performance (club head speed and smash ratio) and ball flight (distance) when ANCOVA adjusted for differences in

weight training, flexibility training and total training from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

- Compliance to home exercise programmes
- Reasons for non-Compliance to home exercise programmes
- Summary of results from Assessment 1 to Assessment 2
- Summary of results from Assessment 1 to Assessment 3

4.2 SAMPLE SIZE

One hundred participants were recruited for this study. Eighteen participants dropped out after Assessment two. Reasons given for dropping out were: illness (the study took place during winter and some of the participants that dropped out of the study had fallen ill with colds and flu and therefore did not return for Assessment 3), transportation issues, personal problems, and competing in a golf tournament. Participant 3's data sheet for his ROM measurements for Assessment 2 was not in his file. The participant either did not have a second physiotherapy assessment or the documentation was removed. All study documentation remained locked in an office when the research was not in progress. At the end of each day the researcher and a research assistant signed off that all documentation was present. No other documentation was misplaced. The most reasonable explanation was that the participant left before having his second physiotherapy assessment (see Chapter 3, Section 3.4.2.4: Results of the pilot study and implications; pg.49). Six potential participants did not meet the inclusion criteria, and as such were not assigned numbers or included in the study. Reasons for non-inclusion were: three of the participants did not meet the inclusion criteria because their hip flexor length was normal; two participants did not meet the criteria because they did not have handicaps of less than six; one subject did not meet the inclusion criteria because he was older than 25 years. No participants formally withdrew from the study after the Assessment 1. 18 participants withdrew from the study after the Assessment 2 (nine from the stretch group, five from the control group and four from the ball group)

(Please see figure 4.1. to follow study population. Please table 4.1. for a detailed description of each participants reason for withdrawl.)

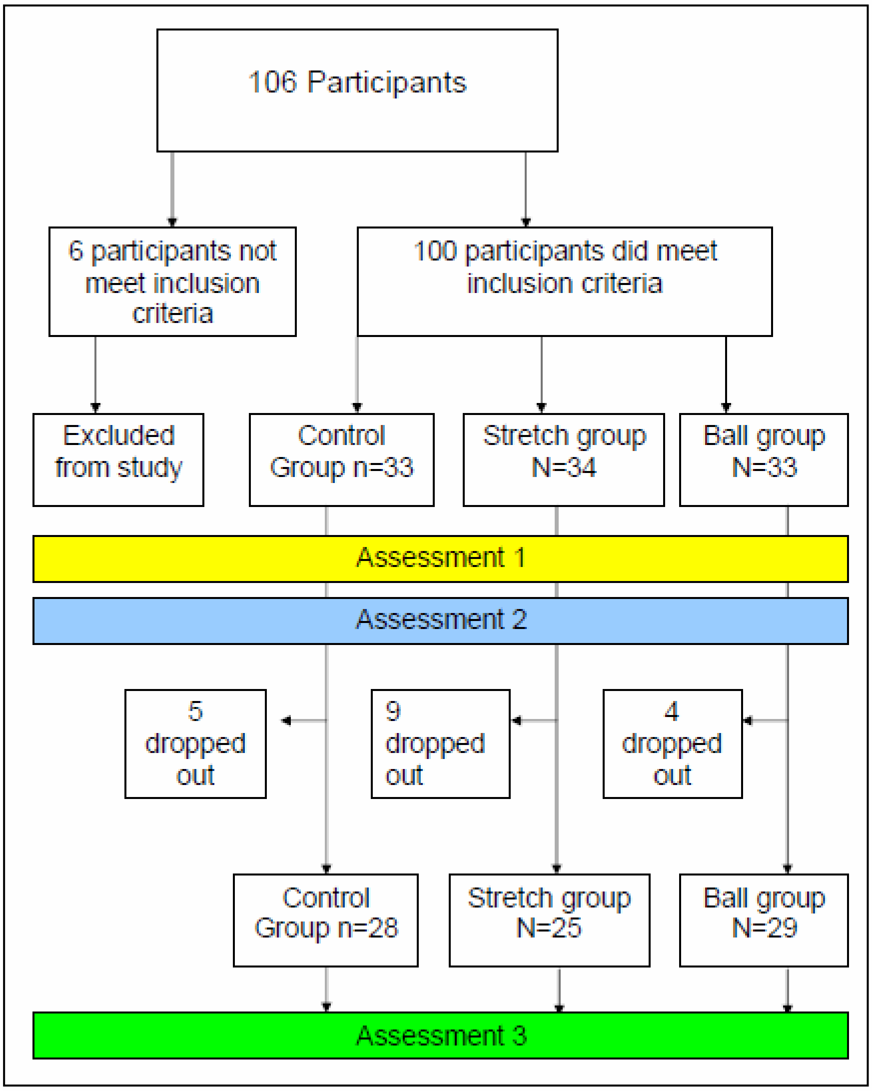

Figure 4.1. Flow chart following study population drop out

Table 4.1: Reason for withdrawal after Assessment 2

Participant Ref. Code	Group	Reason
8	Stretch	The participant withdrew from the study due to illness (influenza)
16	Stretch	The researcher called the participant on the day of the third assessment and subsequently. The participant did not answer the phone or provide a reason for withdrawal.
18	Control	The participant withdrew due to back pain.
23	Stretch	The participant withdrew from the study due to illness (influenza)
37	Ball	The participant withdrew due to personal reasons.
41	Stretch	The researcher called the participant on the day of the third assessment and subsequently. The participant did not answer the phone or provide a reason for withdrawal.
46	Control	The subject withdrew due to injury (fractured clavicle)
48	Ball	The subject withdrew because he found the exercises too difficult to perform.
49	Stretch	The subject withdrew due to lower back pain.
50	Ball	The researcher called the participant on the day of the third assessment and subsequently. The participant did not answer the phone or provide a reason for withdrawal.
52	Control	The researcher called the participant on the day of the third assessment and subsequently. The participant did not answer the phone or provide a reason for withdrawal.
56	Stretch	The participant withdrew as he was invited to play a tournament on the day of the third assessment.
58	Stretch	The participant withdrew due to transport issues.
60	Stretch	The researcher called the participant on the day of the third assessment and subsequently. The participant did not answer the phone or provide a reason for withdrawal.
63	Control	The participant withdrew as he was invited to play a tournament on the day of the third assessment.
68	Ball	The researcher called the participant on the day of the third assessment and subsequently. The participant did not answer the phone or provide a reason for withdrawal.
74	Control	The participant withdrew as he was invited to play a tournament on the day of the third assessment.
78	Stretch	The participant withdrew as he needed to go out of town and as such was too far away to attend the third assessment.

4.3 DEMOGRAPHICS

Table 4.2. contains the demographics of the sample population. It includes the means and standard deviation for age, handicap, weight, height and BMI.

Table 4.2: Demographics

Variable	**Statistic**	**Control (Group3) n=33**	**Stretch (Group1) n=34**	**Ball (Group2) n=33**
Age	Mean (SD)	20 (2.0)	20 (1.5)	20 (2.0)
Handicap	Mean	-2 (2.6)	-1 (2.3)	-3 (2.2)
Weight	Mean (SD) (kg)	80.70 (11.57)	77.85 (11.78)	74.58 (11.73)
Height	Mean (SD) (m)	1.80 (0.06)	1.80 (0.08)	1.77 (0.09)
BMI	Mean (SD) (kg/m^2)	25 (3.7)	24 (2.9)	24 (3.3)

Please note that the groups did differ at baseline. All comparisons between groups were done using ANCOVA where differences in baseline were adjusted for.

4.4 BETWEEN-GROUP CHANGES IN ROM FROM ASSESSMENT 1 TO ASSESSMENT 2 (STRETCH VERSUS CONTROL; BALL VERSUS CONTROL)

Table 4.3: Between-group changes in ROM from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)

Variable	**Statistic**	**Control (Group3) n=33**	**Stretch (Group1) n=34**	**Ball (Group2) n=33**
Change in Left Hip Extension	Mean (SD) (°)	2.27 (5.18)	2 .00(3.91)	1.60 (4.15)
	p-value		0.98	0.61
Change in Right Hip Extension	Mean (SD) (°)	1.91 (5.81)	3.71 (4.66)	3 (5.59)
	p-value		0.22	0.43
Change in Right Lumbar Spine Rotation	Mean (SD) (°)	0.21 (2.69)	-0.32 (2.85)	0.34 (2.61)
	p-value		0.68	0.38
Change in left Lumbar Spine Rotation	Mean (SD) (°)	-0.06 (2.60)	-0.32 (2.28)	-0.19 (2.53)
	p-value		0.55	0.49
Change in Right Lumbar Spine Lateral Flexion	Mean (SD) (°)	-1.18 (5.03)	-0.88 (3.94)	0.34 (3.59)
	p-value		0.68	0.38
Change in Left Lumbar Spine Lateral Flexion	Mean (SD) (°)	-0.58 (4.66)	-1.15 (4.15)	0.50 (5.34)
	p-value		0.64	0.70

Negative values indicated an increase in the variable measured. Positive values indicated decrease in the variable measured. P value was determined by ANCOVA (adjusted for baseline)

There were no statistically relevant changes in left hip extension ROM (control to stretch p=0.98; control to ball p=0.61); right hip extension ROM (control-stretch p=0.22; control-ball p=0.43); right lumbar spine rotation (control-stretch p=0.68; control-ball p=0.38); left lumbar spine rotation (control- stretch p=0.55; control-ball p=0.49); right lumbar spine lateral flexion (control-stretch p=0.68; control-ball p=0.38); left lumbar spine lateral flexion (control-stretch p=0.64; control-ball p=0.70).

4.5 BETWEEN-GROUP CHANGES IN BIOMECHANICS FROM ASSESSMENT 1 TO ASSESSMENT 2 (STRETCH VERSUS CONTROL; BALL VERSUS CONTROL)

Table 4.4: Between-group changes in biomechanics from Assessment 1 to Assessment 2. (stretch versus control; ball versus control)

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Change in Hip Alignment at Address	Mean (SD) (°)	-0.33(4.01)	0.91(4.34)	0.39(5.95)
	p-value		0.46	0.46
Change in 'Pelvic bending' Tilt (AP)	Mean (SD) (°)	-3.27 (14.05)	-1.12 (16.32)	3.52 (11.30)
	p-value		0.21	0.69
Change in Pelvic tilting' (Lateral Flexion at Address)	Mean (SD) (°)	-0.82 (2.86)	-0.03 (2.33)	-0.36 (4.39)
	p-value		0.62	0.61
Change in Backswing Hip Turn	Mean (SD) (°)	2.58 (6.99)	0.88 (6.77)	-1.58 (6.39)
	CI_1 (°)**	-49.48<μ<-43.07		-52.18<μ<-45.03
	CI_2 (°)**	-51.67<μ<-46.02		-50.54<μ<-43.52
	p-value		0.21	*0.02
Change in X-Factor	Mean (SD) (°)	-0.82 (7.97)	-2.56 (7.46)	1.00 (6.53)
	p-value		0.61;	0.49
Change in X-Factor Stretch	Mean (SD) (°)	0.82 (3.20)	1.06 (3.21)	-3.36 (10.14)
	p-value		0.95	0.18
Change in Backswing Hip Drop	Mean (SD)	-0.03 (0.75)	0.17 (0.80)	-0.10 (0.88)
	p-value		0.25	0.63
Change in Backswing Hip Sway	Mean (SD)	-0.11 (1.57)	0.20 (1.88)	0.06 (1.5)
	p-value		0.57	0.89
Change in Downswing Hip Turn (Impact Zone)	Mean (SD) (°)	0.79 (6.65)	1.56 (6.65)	3.30 (6.45)
	p-value		0.74	0.34
Change in Downswing Hip tilt Lateral Flexion	Mean (SD) (°)	-0.55 (2.98)	0.088 (3.60)	0.24 (5.12)
	p-value		0.60	0.60
Change in Downswing Hip bend	Mean (SD) (°)	-2.52 (14.57)	-0.41 (15.92)	2.64 (13.37)
	p-value		0.36	0.58
Downswing Hip Sway (Address to Impact)	Mean (SD)	-0.22 (1.38)	-0.12 (1.51)	-0.06 (2.23)
	p-value		0.81	0.75
Change in Downswing Hip Thrust	Mean (SD)	0.20 (1.21)	-0.02 (0.79)	-0.15 (0.98)
	p-value		0.40	0.16
Change in Downswing Hip Speed	Mean (SD)	-10.97 (36.12)	11.15 (98.28)	23.73 (83.60)
	p-value		0.30	0.43

Table 4:4: Negative values indicated an increase in the variable measured. Positive values indicated decrease in the variable measured. P value was determined by ANCOVA (adjusted for baseline). **Confidence level set at 95%

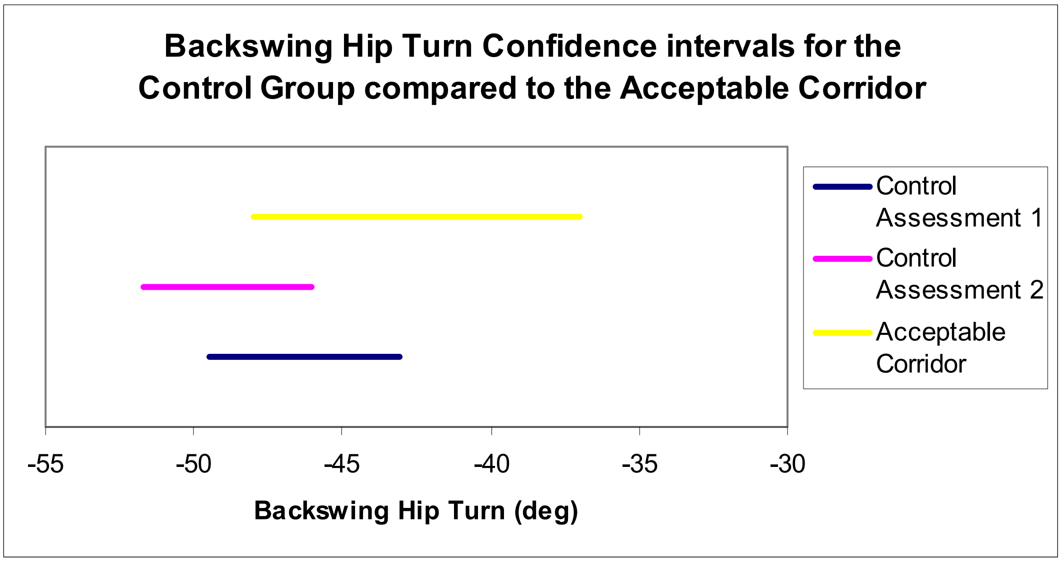

Figure 4.2: Backswing hip turn intervals for the control group (Group3) at Assessment 1 and Assessment 2 compared to the acceptable corridor

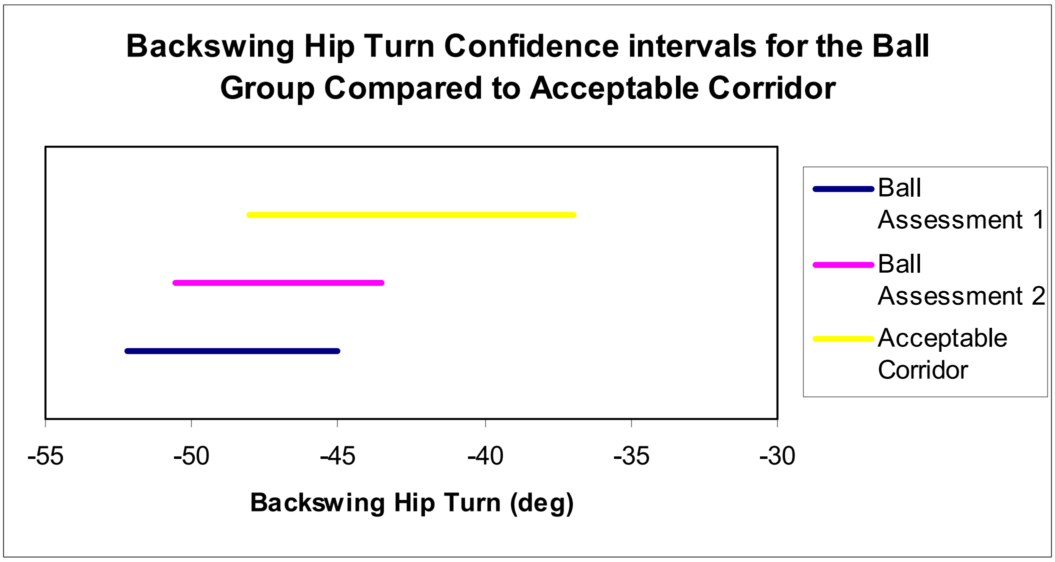

Figure 4.3: Backswing hip turn intervals for ball group (Group2) at Assessment 1 and Assessment 2 compared to the acceptable corridor

There is a relationship between the trigger point therapy of the iliopsoas followed by the ball exercises and backswing hip turn. Backswing hip turn increased (i.e. less hip turn was created therefore the number was more positive) in the group that received the trigger point therapy followed by the ball exercises relative to the control group (p=0.03). Table 4.4 contains the confidence intervals for backswing hip turn. The confidence interval for the mean in the control group are Ax1: -49.48°<μ<-43.07° to Ax2: -51.67°<μ<-46.02°. The confidence intervals for the mean in the ball group are Ax1: -52.18°<μ<-45.03° to Ax2: -50.54°<μ-43.52°. The corridor for acceptable backswing hip turn is -37° to -48°. In the control group the confidence interval was predominately in the corridor at Ax1. At Ax2 there was a greater variance in the control group's confidence interval outside the acceptable corridor. Clinically this indicates a worsening of backswing hip turn (see Figure 4.2.). In the ball group the confidence interval change from Assessment 1 to Assessment 2 saw less variance outside the acceptable corridor (see Figure 4.3.). Clinically, this indicates an improvement in backswing hip turn; i.e. backswing hip turn increased in the ball group (was less negative, therefore less hip turn), and this change brought about an improvement in backswing hip turn (moved from being too negative into the acceptable corridor). The ball group's backswing hip turn improved relative to the control group (This was both statistically and clinically relevant).

There were no statistically significant changes in the following biomechanical variables from Assessment 1 to Assessment 2: hip alignment at address (control-stretch p=0.46; control-ball p=0.46); hip "bending" at address (control-stretch p=0.21; p=0.69); hip "tilting" at address (control-stretch p=0.62; control-ball p=0.60); X-factor (control-stretch p=0.61; control-ball p=0.49); X-factor stretch (control-stretch p=0.95; control-ball p=0.18); hip drop during the backswing (control-stretch p=0.25; control-ball p=0.64); hip sway during the backswing (control-stretch p=0.57; control-ball p=0.89); hip turn during the downswing (control-stretch p=0.74; control-ball p=0.34); hip tilt during the downswing (control-stretch p=0.60; control-ball p=0.60); hip bend during the downswing (control-stretch p=0.36; control-ball p=0.58); hip sway during the downswing (control-stretch p=0.81; control-ball p=0.75); hip thrust (control-stretch p=0.40; control-ball p=0.16); and hip speed (control-stretch p=0.30; control-ball p=0.43)

Table 4.5: Between-group changes in downswing transition sequence from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)

Downswing transition sequence		**Control (Group3)**	**Stretch (Group1)**	**Ball (Group2)**	**Total**
Improved or stayed good from Assessment 1 to Assessment 2 (-1)	No. participants	11	13	13	37
	Percentage of group (%)	33.33	38.24	39.39	37.00
Worsened or stayed bad from Assessment 1 to Assessment 2(+1)	No. participants	22	21	20	63
	Percentage of group (%)	66.67	61.76	60.61	63.00
Total	No. participants	33	34	33	100
	Percentage of group (%)	100	100	100	100

Fishers exact = 0.90

There is no relationship between the manual techniques combined with the stretch or ball exercises and the downswing transition sequence from Assessment 1 to Assessment 2.

Table 4.6: Between-group changes in changes in downswing timing sequence from Assessment 1 to Assessment 2. (Stretch versus control; ball versus control)

Downswing Timing Sequence		**Control (Group3)**	**Stretch (Group1)**	**Ball (Group2)**	**Total**
Improved or stayed good from Assessment 1 to Assessment 2 (-1)	No. participants	13	5	7	25
	Percentage of group (%)	39.39	14.71	21.21	25.00
Worsened or stayed bad from Assessment 1 to Assessment 2(+1)	No. participants	20	29	26	75
	Percentage of group (%)	60.61	85.29	78.79	75.00
Total	No. participants	33	34	33	100
	Percentage of group (%)	100	100	100	100

Fishers exact=0.057

This is an almost statistically significant result**.** From Assessment 1 to Assessment 2 the stretch group timing sequence worsened the most (85.29%), then the ball group (78.79%) and finally the control group (60.61%). This indicates that the physiotherapy manual techniques combined with both the stretch and ball exercises possibly had negative effects on timing sequence relative to the control group.

4.6 BETWEEN-GROUP CHANGES IN CLUB PERFORMANCE AND BALL FLIGHT FROM ASSESSMENT 1 TO ASSESSMENT 2 (STRETCH EVRSUS CONTROL; BALL VERSUS CONTROL)

Table 4.7: Between-group changes in club performance and distance from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Change in Distance	Mean (SD) (m)	0.18 (9.59)	-1.03 (10.40)	2.39 (12.73)
	p-value		0.76	0.14
Change in Club Head Speed	Mean (SD) (km/h)	-1.27 (6.58)	0.12 (4.80)	0.67 (6.66)
	p-value		0.19	0.10
Change in Smash Ratio	Mean (SD)	0.01 (0.04)	-0.01 (0.06)	-0.00 (0.06)
	p-value		0.35	0.37

Negative values indicated an increase in the variable measured. Positive values indicated decrease in the variable measured. P value was determined by ANCOVA (adjusted for baseline)

No significant changes were seen in the following parametric club performance variables between Assessment 1 and Assessment 2: club head speed (control-stretch p=0.19; control-ball p=0.10); smash ratio (control-stretch p=0.35; control-ball p=0.37). No significant change was seen in the parametric ball flight variable between Assessment 1 and Assessment 2: distance (control-stretch p=0.76; control-ball p=0.14).

Table 4.8: Between-group changes in accuracy from Assessment 1 to Assessment 2 (stretch versus control; ball versus control)

Accuracy		Control (Group3)	Stretch (Group1)	Ball (Group2)	Total
Improved or stayed good from Assessment 1- Assessment 2 (-1)	No. participants	16	26	26	68
	Percentage of group (%)	48.48	76.47	78.79	68
Worsened or stayed bad from Assessment 1- Assessment 2 (+1)	No. participants	17	8	7	32
	Percentage of group (%)	51.52	23.53	21.21	32
Total	No. participants	33	34	33	100
	Percentage of group (%)	100	100	100	100

Fishers exact = 0.02*

The trigger point therapy combined with the stretch exercises had a significant effect on accuracy. The trigger point therapy combined with the ball exercises had a significant effect on accuracy. From Assessment 1 to Assessment 2 the ball group's accuracy improved the most (78.79%) then the stretch group (76.47%) and finally the control group (16%). This indicates that the trigger point therapy combined with the stretch and ball exercise interventions in both the stretch and ball groups had positive effects on accuracy relative to the control group.

4.7 BETWEEN-GROUP CHANGES IN ROM FROM ASSESSMENT 1 TO ASSESSMENT 3 (STRETCH VERSUS CONTROL; BALL VERSUS CONTROL)

Table 4.9: Between-group changes in ROM from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Change in Left Hip Extension	Mean (SD)	2.96 (7.10)	0.64 (6.78)	1.86 (5.59)
	p-value		0.23	0.55
Change in Right Hip Extension	Mean (SD)	5.00 (8.03)	5.48 (5.28)	3.86 (6.42)
	p-value		0.92	0.44
Change in Right Lumbar Spine Rotation	Mean (SD)	-0.61 (2.77)	-1.48 (3.32)	-0.52 (3.23)
	p-value		0.39	0.83
Change in Left Lumbar Spine Rotation	Mean (SD)	0.43 (3.26)	-0.40 (2.90)	0.31 (2.94)
	p-value		0.32	0.81
Change in Right Lumbar Spine Lateral Flexion	Mean (SD)	0.00 (4.73)	-0.32 (4.84)	0.72 (4.23)
	p-value		0.82	0.88
Change in Left Lumbar Spine Lateral Flexion	Mean (SD)	-0.43 (3.95)	-1.44 (5.56)	1.52 (5.85)
	p-value		0.50	0.45

Negative values indicated an increase in the variable measured. Positive values indicated decrease in the variable measured. P value was determined by ANCOVA (adjusted for baseline)

There were no significant changes in flexibility of left hip extension (control-stretch p=0.23; control-ball p=0.55), right hip extension (control-stretch p=0.92; control-ball p=0.44), right lumbar spine rotation (control-stretch p=0.39; control-ball p=0.83), left lumbar spine rotation (control-stretch p=0.32; control-ball p=0.81), right lumbar spine lateral flexion (control-stretch p=0.82; control-ball p=0.88), and left lumbar spine lateral flexion (control-stretch p=0.50; control-ball p=0.45).

4.8 BETWEEN-GROUP CHANGES IN BIOMECHANICS FROM ASSESSMENT 1 TO ASSESSMENT 3 (STRETCH VERSUS CONTROL; BALL VERSUS CONTROL)

Table 4.10: Between-group change in biomechanics from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Change in Hip Alignment at Address	Mean (SD)	0.00 (4.23)	1.32 (6.05)	0.45 (6.57)
	p-value		0.66	0.49
Change in 'Pelvic bending' (AP)	Mean (SD)	-1.46 (12.76)	0.96 (11.70)	6.97 (12.33)
	p-value		0.23	0.318
Change in Pelvic tilting' (Lateral Flexion at Address)	Mean (SD)	-0.79 (3.80)	-0.72 (3.13)	-0.66 (4.10)
	p-value		0.40	0.70
Change in Backswing hip turn	Mean (SD)	-0.04 (6.27)	-0.52 (7.34)	-2.45 (7.60)
	p-value		0.70	0.30
Change in X-Factor	Mean (SD)	0.00 (9.47)	-2.12 (5.60)	-0.21 (9.42)
	p-value		0.65	0.28
Change in X-Factor Stretch	Mean (SD)	0.64 (3.17)	0.96 (3.93)	-3.00 (6.76)
	p-value		0.87	0.20
Change in Backswing Hip Drop	Mean (SD)	-0.07 (0.71)	-0.01 (0.90)	-0.04 (0.90)
	p-value		0.64	0.89
Change in Backswing Hip Sway	Mean (SD)	0.43 (1.81)	0.66 (2.47)	0.30 (2.07)
	p-value		0.99	0.517
Change in Downswing Hip Turn (Impact Zone)	Mean (SD)	-1.29 (5.79)	1.84 (6.98)	3.52 (8.11)
	p-value		0.12	*0.03
	CI (º)**	33.49º<μ<41.40º		40.81º<μ<47.19º
	CI (º)**	32.56º<μ<43.09º		36.80º<μ<45.20º
Change in Downswing Hip tilt Lateral Flexion	Mean (SD)	-1.61 (4.47)	-0.44 (2.73)	-0.76 (4.32)
	p-value		0.38	0.83
Change in Downswing Hip bend Flexion	Mean (SD)	0.43 (13.19)	1.00 (11.71)	6.93 (13.58)
	p-value		0.56	0.38
Change in Downswing Hip Sway (Address to Impact)	Mean (SD)	0.41 (1.75)	-0.11 (2.05)	0.32 (2.09)
	p-value		0.39	0.61
Change in Downswing Hip Thrust	Mean (SD)	-0.11 (1.22)	-0.04 (1.29)	0.13 (1.45)
	p-value		0.88	0.39
Change in Downswing Hip Speed	Mean (SD)	-10.54 (49.76)	3.76 (158.37)	8.28 (84.17)
	p-value		0.94	0.62

Table 4.10. Negative values indicated an increase in the variable measured. Positive values indicated decrease in the variable measured. P value was determined by ANCOVA (adjusted for baseline). ** Confidence set at 95%

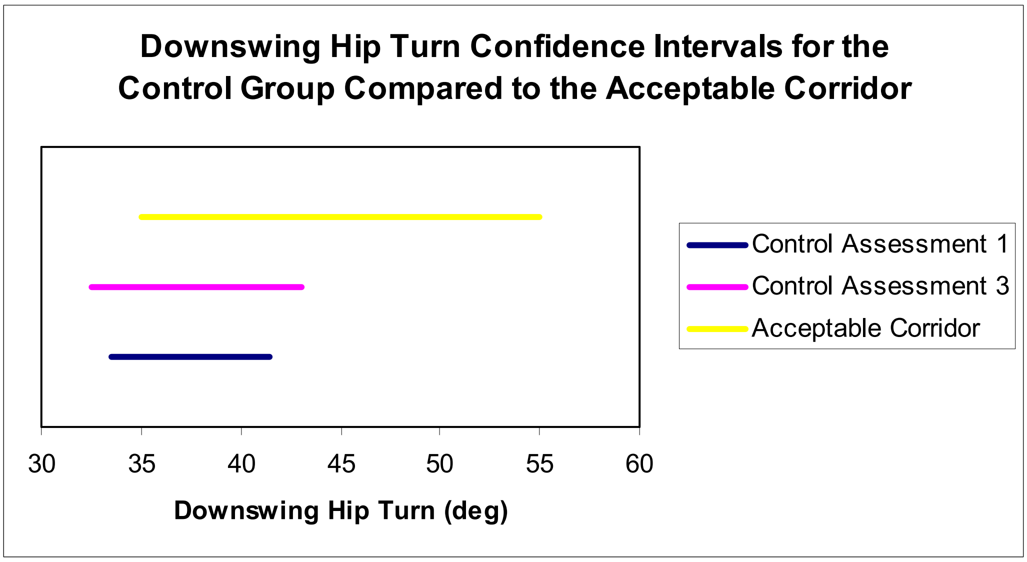

Figure 4.4: Downswing hip turn confidence intervals for the control group (Group3) at Assessment 1 and Assessment 3 compared to the acceptable corridor

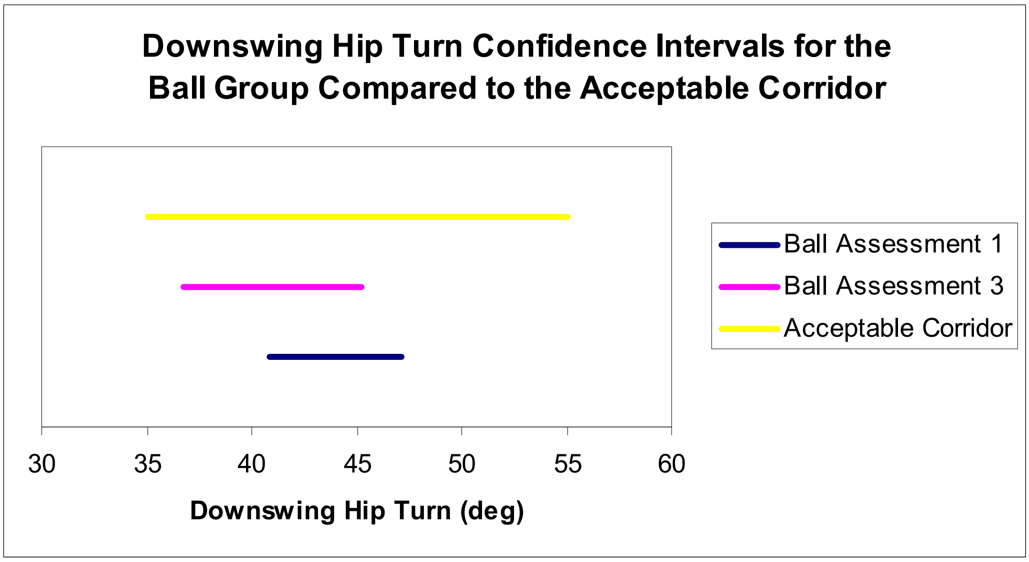

Figure 4.5: Downswing hip turn intervals for the ball group (Group2) at Assessment 1 and Assessment 3 compared to the acceptable corridor

The trigger point therapy followed by a week of ball exercises affected downswing hip turn in the ball group. Downswing hip turn decreased in the ball group relative to the control. The corridor for acceptable downswing hip turn is 35º to 55º. The confidence interval for the control group at Assessment 1 was 33.49º<μ<41.40º. The lower end of the confidence interval for Assessment 1 for the control was very slightly out of the acceptable range. The confidence interval for the control group at Assessment 3 was 32.56º<μ<43.087º. This is slightly outside of the acceptable range for downswing hip turn. Therefore the control group's lower end of the confidence level went slightly more into the unacceptable range. The confidence interval for the ball group at Assessment 1 was 40.81º<μ<47.19º. This is within the accepted range for downswing hip turn. The confidence interval for the ball group at Assessment 3 was 36.80º<μ<45.20º. This too is within the accepted range. This therefore revealed that the ball group remained in the acceptable range (see Figure 4.4; pg.80, and Figure 4.5; pg.81). Based on this, from a clinical perspective the ball group's 3D biomechanics did not improve, but rather stayed good. The control group worsened slightly over the week. Therefore the ball exercises may improve downswing hip turn biomechanics relative to the control; but the clinical significance of this appears to be small.

There was no significant change in the following variables: hip alignment at address (sp=0.66; bop=0.49), pelvic bending (sp=0.23; bp=0.32), pelvic tilting (sp=0.40; bp=0.70), backswing hip turn (sp=0.70; bp=0.30), x-factor (sp=0.65; bp=0.28), x-factor stretch (sp=0.87; bp=0.20), backswing hip drop (sp=0.64; bp=0.89), backswing hip sway (sp=0.99; bp=0.52), downswing hip tilt (sp=0.38; bp=0.83), downswing hip bend (sp=0.56; bp=0.38), downswing hip sway (sp=0.39; bp=0.61), downswing hip thrust (sp=0.88; bp=0.39), and downswing hip speed (sp=0.94; bp=0.62).

Table 4.11: Between-group changes in downswing transition sequence from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

Downswing transition sequence		Control (Group3)	Stretch (Group1)	Ball (Group2)	Total
Improved or stayed good (-1)	No. participants	10	8	13	31
	Percentage of group (%)	35.71	32.00	44.83	37.80
Worsened or stayed bad (+1)	No. participants	18	17	16	51
	Percentage of group (%)	64.29	68.00	55.17	62.20
Total	No. participants	28	25	29	82
	Percentage of group (%)	100	100	100	100

Fishers exact=0.63

There is no relationship between the trigger point therapy followed by a week of home exercises on the downswing transition sequence.

4.9 BETWEEN-GROUP CHANGES IN DOWNSWING TIMING SEQUENCE FROM ASSESSMENT 1 TO ASSESSMENT 3 (STRETCH VERUS CONTROL; BALL VERSUS CONTROL)

Table 4.12: Between-group changes in downswing timing sequence from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

Downswing Timing Sequence		Control (Group3)	Stretch (Group1)	Ball (Group2)	Total
Improved or stayed good from Assessment 1 to Assessment 3 (-1)	No. participants	6	8	6	20
	Percentage of group (%)	21.43	32.00	20.69	24.39
Worsened or stayed bad from Assessment 1 to Assessment 3(+1)	No. participants	22	17	23	62
	Percentage of group (%)	78.57	68.00	79.31	75.61
Total	No. participants	28	25	29	82
	Percentage of group (%)	100	100	100	100

Fishers exact=0.62

There is no relationship between trigger point therapy followed by a week of home exercises on the downswing timing sequence from Assessment 1 to Assessment 3.

4.10 BETWEEN-GROUP CHANGES IN CLUB PERFORMANCE AND BALL FLIGHT FROM ASSESSMENT 1 TO ASSESSMENT 3 (STRETCH VERSUS CONTROL; BALL VERSUS CONTROL)

Table 4.13: Between-group changes in club performance and distance from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Change in Distance	Mean (SD) (m)	4.75 (12.16)	1.36 (12.04)	3.41 (12.52)
	p-value		0.99	0.98
Change in Club Head Speed	Mean (SD) (km/h)	0.25 (6.61)	2.04 (5.07)	0.14 (7.31)
	p-value		0.14	0.81.
Change in Smash Ratio	Mean (SD)	0.01 (0.06)	-0.02 (0.05)	0.01 (0.05)
	p-value		0.26	0.87

Negative values indicated an increase in the variable measured. Positive values indicated decrease in the variable measured. P value was determined by ANCOVA (adjusted for baseline)

The trigger point therapy followed by a week of home stretch exercises did not have any effect on the following club performance and ball flight variables when compared to the control group: distance (p=0.99), club head speed (p=0.14), and smash ratio (p=0.26). The trigger point therapy followed by a week of home ball exercises did not have any effect on the following club performance and ball flight variables when compared to the control group: distance (p=0.98), club head speed (p=0.81), and smash ratio (p=0.87).

Table 4.14: Between-group changes in accuracy from Assessment 1 to Assessment 3 (stretch versus control; ball versus control)

Accuracy		Control (Group	Stretch (Group	Ball (Group	Total
Improved or stayed good from Assessment 1 - Assessment 2 (-1)	No. participants	20	22	25	67
	Percentage of group (%)	71.43	88.00	86.21	81.71
Worsened or stayed bad from Assessment 1 - Assessment 3 (+1)	No. participants	8	3	4	15
	Percentage of group (%)	28.57	12.00	13.79	18.29
Total	No. participants	28	25	29	82
	Percentage of group (%)	100	100	100	100

Fishers exact=0.23

There is no relationship between the week of exercise (ball or stretch) and accuracy from Assessment 1 to Assessment 3.

4.11 BETWEEN-GROUP CHANGES IN ROM WHEN ANCOVA ADJUSTED FOR BASELINE AND DIFFERENCES IN WEIGHT TRAINING, FLEXIBILITY TRAINING AND TOTAL TRAINING FROM ASESSMENT 1 TO ASSESSMENT 3 (CONTROL VERSUS STRETCH, CONTROL VERSUS BALL)

Table 4.15: Between-group changes in ROM when ANCOVA adjusted for baseline and differences in weight training, flexibility training and total training from Assessment 1 to Assessment 3 (control versus stretch, control versus ball)

Variable	Statistic	Control n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Change in Left hip extension	Mean (SD)	2.96(7.10)	0.64(6.78)	1.86(5.59)
	P value		0.26	0.69
Change in Right hip extension	Mean (SD)	5.00(8.03)	5.48(5.28)	3.86(6.42)
	P value		0.76	0.42
Change in Right Lumbar spine Rotation	Mean (SD)	-0.61(2.77)	-1.48(3.32)	-0.52(3.23)
	P value		0.48	0.84
Change in Left Lumbar spine rotation	Mean (SD)	0.43(3.26)	-0.40(2.90)	0.30(2.94)
	P value		0.34	0.91
Change in Right Lumbar Spine Lateral Flexion	Mean (SD)	0.00(4.73)	-0.32(4.84)	0.72(4.23)
	P value		0.58	0.96
Change in Left Lumbar Spine Lateral Flexion	Mean (SD)	-0.43(3.95)	-1.44(5.56)	1.52(5.85)
	P value		0.33	0.44

When differences in training and differences in baseline where adjusted for there was no statistically significant change in ROM (change in left hip extension, change in right hip extension, change in left lumbar spine rotation, change in right lumbar spine rotation, change in left lumbar spine lateral flexion, change in right lumbar spine lateral flexion) in the ball or stretch group from Assessment 1 to Assessment 3. This is statistically the same result that the comparison between the two groups yielded when ANCOVA only adjusted for differences in baseline (see Chapter 4 Section 4.7: Between-group differences in ROM from Assessment 1 to Assessment 3; pg.78), therefore differences in training did not obscure the results of the study pertaining to change in ROM.

4.12 BETWEEN GROUP CHANGES IN BIOMECHANICS WHEN ANCOVA ADJUSTED FOR BASELINE AND DIFFERENCES IN WEIGHT TRAINING, FLEXIBILITY TRAINING AND TOTAL TRAINING FROM ASSESSMENT 1 TO ASSESSMENT 3 (CONTROL VERSUS STRETCH, CONTROL VERSUS BALL) – PARAMETRIC DATA ONLY

Table 4.16: Between-group changes in biomechanics when ANCOVA adjusted for baseline and differences in weight training, flexibility training and total training (control versus stretch, control versus ball) – parametric data only

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Change in Hip Alignment at Address	Mean (SD)	0.00(4.23)	1.32(6.05)	0.45(6.57)
	P value		0.31	0.36
Change in ‘Pelvic bending’ (AP)	Mean (SD)	-1.46(12.76)	0.96(11.70)	6.97(12.33)
	P value		0.48	0.34
Change in Pelvic tilting’ (Lateral Flexion at Address)	Mean (SD)	-0.79(3.80)	-0.72(3.13)	-0.66(4.10)
	P value		0.55	0.61
Change in Backswing hip turn	Mean (SD)	-0.04(6.27)	-0.52(7.34)	-2.45(7.60)
	P value		1.00	0.32
Change in X-Factor	Mean (SD)	0.00(9.42)	-2.12(5.60)	-0.21(9.42)
	P value		0.47	0.23
Change in X-Factor Stretch	Mean (SD)	0.64(3.17)	0.96(3.93)	-3.00(6.76)
	P value		0.73	0.25
Change in Backswing Hip Drop	Mean (SD)	-0.07(0.71)	-0.01(0.90)	-0.04(0.90)
	P value		0.90	0.93
Change in Backswing Hip Sway	Mean (SD)	0.43(1.81)	0.66(2.47)	0.30(2.07)
	P value		0.90	0.53
Change in Downswing Hip Turn (Impact Zone)	Mean (SD)	-1.29(5.79)	1.84(6.98)	3.52(8.11)
	P value		0.14	*0.04
Change in Downswing Hip tilt Lateral Flexion	Mean (SD)	-1.61(4.47)	-0.44(2.73)	-0.76(4.32)
	P value		0.64	0.97
Change in Downswing Hip bend Flexion	Mean (SD)	0.43(13.19)	1.00(11.71)	6.93(13.58)
	P value		0.88	0.42
Change in Downswing Hip Sway (Address to Impact)	Mean (SD)	0.41(1.75)	-0.11(2.05)	0.32(2.09)
	P value		0.34	0.79
Change in Downswing Hip Thrust	Mean (SD)	-0.11(1.22)	-0.04(1.29)	0.13(1.45)
	P value		0.69	0.34
Change in Downswing Hip Speed	Mean (SD)	-10.54(49.76)	3.76(158.37)	8.28(84.17)
	P value		0.90	0.69

When differences in flexibility training, weight training, total training and differences in baseline were adjusted for, the ball group's downswing hip turn showed statistically significant improvement (p=0.0328) relative to the control group from Assessment 1 to Assessment 3. This is a slightly higher p-value than the one obtained when comparing the change in downswing hip turn between the ball group and the control group from Assessment 1 to Assessment 3 when only baseline was adjusted for (p= 0.0328).

The ball groups' other biomechanical variables (change in hip alignment at address, change in hip bending at address, change in hip "tilting" at address:, change in backswing hip turn, change in x-factor, change in x-factor stretch, change in hip drop during the backswing, change in hip sway during the backswing, change in hip tilt during the downswing, change in hip bend during the downswing, change in hip sway during the downswing, change in hip thrust, change in hip speed) did not show any significant change relative to the control group from Assessment 1 to Assessment 3 when flexibility training, weight training, total training and differences in baseline were adjusted for using ANCOVA.

The stretch groups' biomechanical variables (change in hip alignment at address, change in hip bending at address, change in hip "tilting" at address:, change in backswing hip turn, change in x-factor, change in x-factor stretch, change in hip drop during the backswing, change in hip sway during the backswing, change in hip turn during the downswing, change in hip tilt during the downswing, change in hip bend during the downswing, change in hip sway during the downswing, change in hip thrust, change in hip speed) did not show any significant change relative to the control group from Assessment 1 to Assessment 3 when flexibility training, weight training, total training and differences in baseline where adjusted for using ANCOVA

This is statistically the same result that the comparison between the control and the stretch and the control and the ball groups from Assessment 1 to Assessment 3 yielded when ANCOVA only adjusted for differences in baseline (see Chapter 4, Section 4.8. Between-group differences in Biomechanics from Assessment 1 to Assessment 3; pg.79), therefore differences in training did not obscure the results of the study pertaining to change in biomechanics.

4.13 BETWEEN-GROUP CHANGES IN CLUB PERFORMANCE (CLUB HEAD SPEED AND SMASH RATIO) AND BALL FLIGHT (DISTANCE) WHEN ANCOVA ADJUSTED FOR BASELINE AND DIFFERENCES IN WEIGHT TRAINING, FLEXIBILITY TRAINING AND TOTAL TRAINING FROM ASSESSMENT 1 TO ASSESSMENT 3 (CONTROL VERSUS STRETCH, CONTROL VERSUS BALL) – PARAMETRIC DATA ONLY

Table 4.17: Between-group changes in club Performance (club head speed and smash ratio) and ball flight (distance) when ANCOVA adjusted for baseline and differences in weight training, flexibility training and total training from Assessment 1 to Assessment 3 (control versus stretch, control versus ball) – parametric data only

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Change in Distance	Mean (SD)	4.75 (12.16)	1.36(12.04)	3.41(12.52)
	P value		0.93	0.91
Change in Club head speed	Mean (SD)	0.25(6.61)	2.04(5.07)	0.14(7.31)
	P value		0.13	0.71
Change in Smash ratio	Mean (SD)	0.01(0.06)	-0.02(0.05)	0.01(0.05)
	P value		0.30	0.97

When differences in training and differences in baseline where adjusted for there was no statistically significant change in club performance (change in club head speed and change in smash ratio) or ball flight (distance) in the ball or stretch group from Assessment 1 to Assessment 3. This is statistically the same result that the comparison between the two groups yielded when ANCOVA only adjusted for differences in baseline (see Chapter 4, Section 4.10: Between-group differences in club performance and ball flight from Assessment 1 to Assessment 3; pg.83). Therefore differences in training did not obscure this section of the results of the study pertaining to change in club performance or ball flight.

4.14 COMPLIANCE TO HOME EXERCISES

Table 4.18: Compliance to home exercises

Variable	Statistic	Stretch (Group1) n=25	Ball (Group2) n=28
Exercise compliance	Mean (SD) (%)	58.89(20.91)	54.18(24.08)

The mean compliance of both the ball and stretch groups is low (stretch compliance=58.89%; ball compliance=54.18%).

4.15 REASONS FOR NON COMPLIANCE TO HOME EXERCISE PROGRAMMES

Table 4.19: Reasons for non-Compliance to home exercise programmes

	Stretch (Group1) *n_2=450	Ball (Group2) n_2=522
% of exercises discontinued due to pain	15.66%	5.00%
% of exercises discontinued due to non-compliance	84.32%	95.00%

* n_2 is the number of exercises the group was requested to perform.

In both the Ball and Stretch group the primary reason for poor Compliance was non-compliance (stretch exercise discontinued due to non-compliance = 84.32%; ball exercise discontinued due to non-compliance = 95%) and not pain (stretch exercise discontinued due to pain = 15.66%, ball exercise discontinued due to pain = 5%).

4.16 SUMMARY OF RESULTS FROM ASSESSMENT 1 TO ASSESSMENT 2

The stretch group's accuracy improved (76.47% improvement/stayed good) relative to the control group (48.48% improvement/stayed good) (Fisher's Exact=0.016). In the stretch group trigger point therapy of the iliopsoas followed by a 60 second hip flexor stretch may have had a negative effect on downswing timing sequence (Fisher's Exact=0.057). Although this is 'technically' not statistically significant, it was nearly a statistically significant change and worth commenting on from a clinical perspective. The stretch group's downswing timing sequence (85.29% worsening/stayed bad) worsened relative to the control group (60.61%

worsening/stayed bad) and relative to the ball group (78.79% worsening/stayed bad). The ball group’s backswing hip turn improved relative to the control group (this was both statistically and clinically relevant). The ball group’s accuracy (78.79% improvement/ stayed good) improved relative to the control group (48.48% improvement/stayed good) and relative to the stretch group (76.47% improvement/stayed good) (Fisher’s Exact=0.016). The ball group’s downswing timing sequence (78.79% worsening/stayed bad) worsened relative to the control group (60.61% worsening/stayed bad), but improved relative to the stretch group (85.29% worsening/stayed bad) (Fisher’s Exact=0.057). Although this is ‘technically’ not statistically significant, it was nearly a statistically significant change and downswing timing sequence is clinically relevant.

4.17 SUMMARY OF RESULTS FROM ASSESSMENT 1 TO ASSESSMENT 3

In the stretch group trigger point therapy followed by a week of home stretch exercises had no significant effect on ROM, biomechanics, club performance or ball flight relative to the control group. In the ball group trigger point therapy followed by a week of ball exercises positively affected downswing hip turn. The ball group’s 3D biomechanics did not improve, but rather stayed good. The control group worsened slightly over the week. Therefore the ball exercises improved downswing hip turn biomechanics in the ball group relative to the control group. Differences in training had no significant effect on the results showing change in ROM, ball flight and biomechanics from Assessment 1 to Assessment 3. Both groups had low compliance to their exercise programmes. This was primarily due to non-compliance and not pain.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

The aim of this study was to compare the effect of myofascial trigger point therapy with stretching to myofascial trigger point therapy followed by medicine ball exercises on elite golfers' range of motion (ROM), biomechanics, club performance, and ball flight. A secondary aim was to establish the degree of compliance to the home programmes and to assess if differences in training had an effect on the outcomes of treatment.

The purpose of this chapter is to discuss the results of the study and this discussion will be presented under the following subheadings:

- The effect of trigger point therapy on ROM
- The effect of trigger point therapy combined with ball exercise on ROM
- The effect of trigger point therapy on biomechanics
- The effect of trigger point therapy combined with ball exercise on biomechanics
- The effect of trigger point therapy on club performance and ball flight
- The effect of trigger point therapy combined with ball exercise on club performance and ball flight
- The effect of trigger point therapy followed by a week of stretching and a week of ball exercise on ROM
- The effect of trigger point therapy followed by a week of stretching on biomechanics
- The effect of trigger point therapy followed by a week of ball exercise on biomechanics
- The effect of trigger point therapy followed by a week of stretching on club performance and ball flight

- The effect of trigger point therapy followed by a week of ball exercise on club performance and ball flight
- The effect of differences in training on the results of the study.
- The compliance of the subjects to their home exercise programmes.
- Compliance
- Reason for poor compliance
- Motor planning
- Generalisability of the Study
- Conclusion
- Recommendations

5.2 THE EFFECT OF TRIGGER POINT THERAPY ON ROM

It is interesting to note that throughout the study no change in hip extension ROM or lumbar spine (lumbar spine rotation or lumbar spine lateral flexion) ROM was noted. The trigger point therapy combined with the 60 second stretch exercise (first intervention) had no effect on ROM (hip extension, lumbar spine rotation or lumbar spine lateral flexion). This is contrary to literature on static stretch which states that "static stretch held for 15 seconds was adequate to achieve increased muscle length" (Wilkinson, 1992). The main reason that static stretch increases ROM is that it has an effect on the musculotendinous units' stiffness and muscle length (Behm and Chaouachi, 2011). The primary effect in muscle length should be seen after the first stretch (Wilson and Sherwood, 2008). As the stretch in this study was held for 60 seconds the hip flexor should have increased in length and this should have resulted in increased hip extension as measured by the second modified Thomas test (Assessment 2). This was not the case.

This ‘resistance’ to stretch has been seen in the literature with regards to another muscle, namely the hamstring. In the study performed by McHugh et al (2012) it was found that neural tension in the hamstring limited passive stretch of the hamstring. In a similar study performed by Halbertsma and Goeken (1994) it was also found that passive stretching of the hamstring over four weeks at home did not improve hamstring muscle length or stiffness. It only improved tolerance to stretch.. The hamstring has a large neural interface with the sciatic nerve and this may be why it is so sensitive to neural tension (University of the Witwatersrand, 2012). The iliopsoas also has a large neural interface with the femoral nerve and part of the femoral nerve plexus passes through the psoas major (3D4Medical, 2012, van de Graaf, 1998). This may mean that the iliopsoas is particularly sensitive to neural compression. Neural structures may be compressed as they travel through the psoas major thereby increasing neural tension (University of the Witwatersrand, 2012). The interface between the iliopsaos and the femoral nerve may also cause neural tension (University of the Witwatersrand, 2012). The iliopsoas was mobilised using trigger point therapy and static stretch and this may have mobilised the neural tissue as well, but neural tissue is postulated to respond better to gliding and strumming techniques (Ellis and Hing, 2008). This may be the reason that ROM did not increase throughout the study.

The trigger point therapy was intended to augment the first static stretch. Trigger points have been associated with increased muscle stiffness (Fernandez-de-las-Penas et al., 2006). Ischaemic pressure combined with stretching (trigger point therapy) has been shown to improve pain in patients with trigger points (Hanten et al., 2000). The clinical rationale behind using trigger point therapy was that if trigger point therapy could deactivate trigger points then the stiffness associated with the trigger points may also decrease. This, however, was not the case. ROM (hip extension, lumbar spine rotation and lumbar spine lateral flexion) did not improve after the trigger point therapy. A possible explanation for this (based on the previous proposed pathogenesis: see Chapter 2, Section 2.13: Trigger point therapy; pg.32) is that treating trigger points has an effect on the nociceptors of the pathology, but not on the sustained muscle contracture caused by the excess calcium.

The fact that the trigger point therapy combined with the 60 second stretch of both iliopsoas had no effect on ROM of hip extension in 34 elite golfers is an important clinical finding. Trigger point therapy combined with static stretching is used extensively by physiotherapists in an attempt to increase ROM (Borg-Stein and Simons, 2002, Hanten et al., 2000, Smith and Hillman, 2012). This study shows that trigger point therapy combined with static stretching on the iliopsoas had no effect on ROM (hip extension, lumbar spine rotation and lumbar spine lateral flexion).

5.3 THE EFFECT OF TRIGGER POINT THERAPY COMBINED WITH BALL EXERCISE ON ROM

As mentioned in the above section no significant change in ROM was noted throughout the study. The ball exercise was designed to have an impact on ROM by including in it a dynamic stretch of the hip flexor which was repeated 50 times each side in the first intervention. This ball exercise was used to increase ROM (Wilkinson, 1992) by reciprocal inhibition of antagonist muscles (gluteus activation when the participant extends the hip while lifting the ball across the body), and by providing a short stretch at the end of extension on the iliopsaos (McHugh et al., 2012). The ball exercise had no effect on ROM. A possible reason for this may be that the psoas is similar to the hamstring in its resistance to stretch and that it may have responded better to techniques aimed specifically at the neural structures. It is true that a dynamic stretch may produce a similar movement to neural gliding, but going to end of range at the first treatment session would be excessive if the aim was to treat neural structures (University of the Witwatersrand, 2012) (see Section 5.2; pg.99 above)

Trigger point therapy was used in this study to augment the dynamic stretch. Trigger point therapy has been postulated to increase ROM, but only a very weak link has been established by the literature. There are no published studies (to the researchers' knowledge) showing that trigger point therapy improves ROM (see Section 5.2; pg.99 above for more detailed discussion on trigger point therapy).

5.4 THE EFFECT OF TRIGGER POINT THERAPY ON BIOMECHANICS

The trigger point therapy combined with a stretch exercise had no effect on hip alignment at address, hip bending at address, hip "tilting" at address, backswing hip turn, x-factor, x-factor stretch, hip drop during the backswing, hip sway during the backswing, hip turn during the downswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, and transition sequence.

The trigger point therapy combined with stretch exercise had an almost statistically significant[8] effect on timing sequence. It is important to point out that although the 3D analysis 'classified' this as a "negative effect" because the downswing timing sequence was not maximising power through the use of "summation of speed"; this change in timing sequence was accompanied by a positive effect on ball flight (accuracy) while at the same time no significant change was seen in other variables that measure power (such as club head speed and distance). This is most likely due to an improvement in club position during the downswing. In a highly efficient swing the hips outrace the club and the club gets 'stuck' behind the golfer. This is a common swing fault in good golfers (Leadbetter, 2003). This swing fault results in decreased accuracy (Leadbetter, 2003). It can be corrected either by speeding up the upper body or by tending towards a "Classical Swing Timing Sequence". The participants in this study appear to have altered their timing sequence to that of a more classical approach. As performance has more to do with ball flight than with biomechanics the researcher has re-classified this change from a "negative effect on timing sequence" to a "timing sequence deviating from the modern golf swing towards a classical swing approach" (please see Section 5.6; pg.105 for an in depth discussion on the link between the change in timing sequence and the improvement in accuracy).

The researcher proposes that the mechanism for this change in biomechanics was related primarily to the trigger point therapy and not the stretch. The reason for this

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[8] "These cut-offs are arbitrary and have no specific importance. It is ridiculous to interpret the results of a study differently according to weather the P value obtained was, say, 0.055 or 0.045. These P values should lead to very similar conclusions, not diametrically opposed ones." Altman (1999)

was that both groups that received trigger point therapy saw an almost statistically significant change in downswing timing sequence, but the week of stretch exercises had no effect on downswing timing sequence. Trigger points have been associated with motor dysfunction, disturbed motor function, and muscle weakness as a result of motor inhibition (Dommerholt et al., 2006). The researcher postulates that the trigger point therapy improved motor function thereby altering the golfers' proprioception which resulted in more control during the downswing so that their hips did not outrace their club. This resulted in their downswing timing sequence tending towards a more classical swing approach.

In summary the trigger point therapy combined with stretch exercise may have resulted in a change in downswing timing sequence. This may have had a positive effect on ball flight.

5.5 THE EFFECT OF TRIGGER POINT THERAPY COMBINED WITH BALL EXERCISES ON BIOMECHANICS

The trigger point therapy combined with the ball exercises had no effect on hip alignment at address, hip bending at address, hip "tilting" at address, x-factor, x-factor stretch, hip drop during the backswing, hip sway during the backswing, hip turn during the downswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, and transition sequence.

The trigger point therapy combined with the ball exercise had an almost significant change in downswing timing sequence. The researcher once again postulates this was primarily due to the trigger point therapy and not due to the exercise. This is seen in the fact that both groups that received trigger point therapy experienced a significant change in downswing timing sequence, but after the week of ball exercise no effect on downswing timing sequence was observed.

The group that received trigger point therapy combined with ball exercises experienced a significant change in backswing hip turn. Backswing hip turn is a measure of rotational biomechanics. The researcher postulates that the change in rotational biomechanics may have been linked to the ball exercises and not the trigger point therapy. The reason for this is that the group that received the trigger point therapy combined with stretching showed no change in rotational biomechanics, whereas the ball group experienced improvements in rotational biomechanics after the trigger point therapy combined with ball exercises (backswing hip turn) and the week of home ball exercises (downswing hip turn).

The proposed mechanism for the improved rotational biomechanics was improved muscle control in the pelvic area. This is postulated to have occurred through neural reorganisation and not through improved tensile muscle strength (see Chapter 2, Section 2.15: Medicine Ball Exercises; pg.37). In order to perform the ball exercise correctly the golfer would have to control concentric and eccentric loading of the iliopsoas. This would have encouraged hip rotational biomechanics. In order for a golfer to achieve good backswing hip rotational biomechanics he must eccentrically lengthen the right iliopsoas (controlling hip internal rotation) and concentrically contract the left iliopsoas (produce hip external rotation). In order to achieve good follow-through hip rotational biomechanics he must eccentrically lengthen the left iliopsoas (controlling hip internal rotation) and concentrically contract the right iliopsoas (so as to produce hip external rotation and hip extension) (Gladys et al., 1994, 3D4Medical, 2012, Titlest Performance Institute, 2006, Jensen et al., 2003, van de Graaf, 1998). Good rotational biomechanics at the hips are essential for developing power (Hume et al., 2005). Another power source in the swing is that of ground reaction forces (Jensen et al., 2003). Ideally a golfer wants good rotational biomechanics with controlled ground reaction forces. If a golfer was unable to utilise good hip rotational biomechanics it is postulated that he will try to gain power by use of excessive ground reaction forces (seen in the swing as a “sway” or “slide” swing fault). Poor hip rotational biomechanics and excessive lateral movement during the golf swing have been associated with lumbar spine injury. (Sherman and Finch, 2000, Lindsay et al., 2009, Titlest Performance Institute, 2006). As the ball exercises improved hip rotational biomechanics it is possible to hypothesise that if the golfer had poor rotational biomechanics and he continued to do the ball exercises he could potentially increase power and decrease his injury risk.

5.6 THE EFFECT OF TRIGGER POINT THERAPY ON CLUB PERFORMANCE AND BALL FLIGHT

The trigger point therapy had no effect on club head speed, distance or smash ratio. It did, however, improve accuracy relative to the control group (Assessment 1 to Assessment 2). The proposed mechanism of improved accuracy is linked to the "almost statistically significant" worsening in timing sequence. Accuracy improved (statistically significantly) yet there was nearly a significant change in timing sequence. Four swing experts Michael Balderstone, Dave Roodt, Douglas Wood and Garth Milne were consulted. They all agreed that timing is essential for the development of power during the swing. This is supported by the "summation of speed" principle. In order to achieve high velocity at the distal segment the proximal segments must transfer energy efficiently in the correct sequence (proximal to distal) at the correct time (measured by timing sequence) (Hume et al., 2005). This is essential for the development of power during the golf swing. But Michael Balderstone also said that in a highly efficient swing the upper body needs to have speed to catch up with the lower body segment in order for the club not to get "caught behind the golfer" (Leadbetter, 2003). When a player has this swing fault the club head speed is high, but the club head angle is wrong and accuracy worsens. In order to solve this problem the golfer has two choices: improve upper body speed or adopt a "classical swing" sequence (see Appendix A, pg.124); i.e. the upper body moves with the torso. Either of these would solve the accuracy problem. The classical approach could potentially result in a "worsened timing sequence" on the 3D analysis. Michael Balderstone is of the opinion that this group of elite golfers were within this development period. This is in line with David Leadbetter's theory of synchronising the golf swing. He is also of the opinion that the better golfer (those trying to break eighty in a round of golf) usually have an athletic golf swing that is very "torqued up" but that their lower body becomes over-active and outraces their hands resulting in the club being stuck behind the body. He says this results in both hooks and slices (poor accuracy) (Leadbetter, 2003). David Leadbetter is an internationally respected golf coach who has coached many top professional golfers including Tiger Woods.

Another possible reason for the improvement in accuracy is the multi-factoral aspects that surround ball flight. The best biomechanics do not always translate into the best ball striking ability (Please see section 2.7: Club performance and ball flight variables; Pg 22)

5.7 THE EFFECT OF TRIGGER POINT THERAPY COMBINED WITH BALL EXERCISE ON CLUB PERFORMANCE AND BALL FLIGHT

The group that had trigger point therapy combined with ball exercises showed improvement in accuracy relative to both the stretch group and the control group. This was based on two findings. The first being the same as that of the stretch group. The ball group also saw a change in downswing timing sequence towards a more classical swing approach (see Section 5.6; pg.105 for the link between downswing timing sequence and accuracy). The ball group, however, had an additional benefit of improved rotational biomechanics. The ball groups' backswing hip turn improved. Good rotational biomechanics about the hip is associated with improved accuracy (Hume et al., 2005). This is because when rotational biomechanics improves there is less need to use large ground reaction forces to produce power in the golf swing. Large ground reaction forces are produced by excessive lateral weight shift. Excessive lateral weight shift moves the centre of mass towards the outside of the base of support thereby making the shot more difficult to control and accuracy worsens (Hume et al., 2005).

In summary the trigger point therapy combined with ball exercises resulted in an improvement in accuracy relative to the control and stretch group. The reason for the improvement relative to the stretch group was that both downswing timing sequence and backswing hip turn experienced changes, as opposed to the stretch group that only experienced a change to downswing timing sequence.

5.8 THE EFFECT OF TRIGGER POINT THERAPY FOLLOWED BY A WEEK OF STRETCHING AND A WEEK OF BALL EXERCISE ON ROM

No effect on ROM (hip extension, lumbar spine rotation or lumbar spine lateral flexion) was seen in the stretch group or the ball group after a week of home exercise. This may be due to iliopsoas resisting stretch due to neural components (see Section 5.2., pg.99). Another possible reason for the stretch group and ball group not experiencing any significant change in ROM may have been the poor Compliance to their exercise regime.

5.9 THE EFFECT OF TRIGGER POINT THERAPY FOLLOWED BY A WEEK OF STRETCHING ON BIOMECHANICS

No effect on biomechanics (hip alignment at address, hip bending at address, hip "tilting" at address, backswing hip turn, x-factor, x-factor stretch, hip drop during the backswing, hip sway during the backswing, hip turn during the downswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, transition sequence, timing sequence) was seen in the stretch group after a week of home exercise. This may be as a result of the stretch exercises not achieving the desired therapeutic outcome; i.e. improved ROM hip extension. Although this seems to indicate that from a consistency perspective stretching is not a concern, the researcher would like to caution that this result may be obscured by the fact that the primary therapeutic outcome of stretching (increased ROM) was not achieved either. More research needs to be done to ascertain if stretching that does produce a change in ROM would affect biomechanics.

5.10 THE EFFECT OFTRIGGER POINT THERAPY FOLLOWED BY A WEEK OF BALL EXERCISE PROGRAMME ON BIOMECHANICS

No effect was seen in the following biomechanical variables in the ball group after a week of home exercise: hip alignment at address, hip bending at address, hip "tilting" at address, backswing hip turn, x-factor, x-factor stretch, hip drop during the backswing, hip sway during the backswing, hip tilt during the downswing, hip bend during the downswing, hip sway during the downswing, hip thrust, hip speed, transition sequence, and timing sequence.

The week of ball exercises resulted in an improvement in downswing hip turn. This indicates an improvement in rotational biomechanics during the follow through. Improved rotational biomechanics could potentially result in decreased injury risk and improved performance (see Section 5.5; pg.103 for a more detailed explanation) The ball exercise may therefore be associated with decreased injury risk and improved performance.

5.11 THE EFFECT OF TRIGGER POINT THERAPY FOLLOWED BY A WEEK OF STRETCHING ON CLUB PERFORMANCE AND BALL FLIGHT

The trigger point therapy combined with stretching followed by a week of home stretching had no effect on club performance or ball flight (assessment 1 to assessment 3). This may be as a result of the stretch exercises not achieving the desired therapeutic outcome; i.e. improved ROM hip extension (The researcher postulates that had the stretch increased hip flexor ROM, the lever length would have increased thereby increasing the torque produced by the golfer, and this may have increased club head speed.). Although this seems to indicate that from a performance consistency perspective stretching is not a concern, the researcher would like to caution that this result may be obscured by the fact that the primary therapeutic outcome of stretching (increased ROM) was not achieved. More research needs to be done to ascertain if stretching that does produce a change in ROM would affect club performance or ball flight.

5.12 THE EFFECT OF TRIGGER POINT THERAPY FOLLOWED BY A WEEK OF BALL EXERCISE ON CLUB PERFORMANCE AND BALL FLIGHT

The trigger point therapy combined with ball exercises followed by a week of home ball exercises had no effect on club performance or ball flight. This may be due to the fact that the therapeutic outcome of the dynamic stretch contained in the ball exercise did not increase hip extension ROM (the desired therapeutic outcome).

Another possible reason for the improved rotational biomechanics not affecting ball flight was the fact that the confidence intervals for the change in downswing hip turn after intervention 2 (trigger point therapy combined with ball exercises followed by a week of home exercise), which did not result in a change in club performance or ball flight, was relatively small (from a clinical perspective) compared to the confidence intervals for the change in backswing hip turn, which did result in a change in accuracy, after intervention 1 (trigger point therapy combined with the ball exercise).

In summary the trigger point therapy combined with the ball exercises followed by a week of ball exercises had no effect on club performance or ball flight.

5.13 EFFECT OF DIFFERENCES IN TRAINING ON THE RESULTS OF THE STUDY

Differences in flexibility training, weight training and total training had no effect on the significance of the results obtained (i.e. the statistically significant results stayed significant even when differences in training were adjusted for). It was important to control for this, because the results of the group that performed the week of stretch exercises may have been obscured by one group doing more general flexibility training than another group. Changes in weight training and flexibility may also have obscured the ball groups' results which were relying primarily on muscle facilitation and dynamic stretches. Total training may also have obscured the results as generally the more an athlete trains the better they perform. This may have obscured the biomechanical analysis, the club performance analysis or the ball flight analysis.

5.14 COMPLIANCE

The mean compliance of both the ball and stretch groups was fairly low (stretch compliance=58.89%; ball compliance=54.18%). The poor compliance to stretch and ball exercises may be a possible reason for why no effect was seen on ROM from Assessment 1 to Assessment 3.

The fact that the desired therapeutic outcome of increased muscle ROM of the hip extension was not achieved may be as a result of the poor compliance of the ball and stretch groups to their home programmes. The fact that ROM did not alter may have been the reason that the stretch group saw no change in biomechanics, club performance or ball flight; and the ball group only saw no improvement in biomechanics (other than in downswing hip turn), club performance and ball flight.

Despite this the ball group's low compliance they did experience an improvement in rotational biomechanics (downswing hip turn). This indicates just how effective the ball exercise was in improving rotational biomechanics. Even with a mean Compliance of 54.18% to the medicine ball exercises the golfers experienced an improvement in downswing hip turn after only one week of training.

5.15 REASON FOR POOR COMPLIANCE

In both the ball and stretch group the primary reason for poor compliance was non-compliance (stretch exercise discontinued due to non-compliance=84.32%; ball exercise discontinued due to non-compliance=95%) and not pain (stretch exercise discontinued due to pain=15.66%, ball exercise discontinued due to pain=5%).

In order to address the issue of non-compliance the researchers could have adopted the "directly observed exercise approach". The limitation to this is the fact that golf is an individual sport and as such they do not have "group training sessions" (common to team sports such as rugby). To have a "directly observed exercise approach" would have mimicked an unrealistic training environment. The researcher felt that there was little point in mimicking an unrealistic environment, when the purpose of this research was to provide clinicians with evidence regarding the prescription of home exercise on ROM, biomechanics, club performance and ball flight so that they can apply this evidence practically when weighing the risks and benefits of these techniques to their patients.

Poor compliance primarily due to non-compliance and not pain highlights the importance of educating patients to gain their ‘buy in’. Poor compliance to exercise regimes is a well documented problem (Milroy and O'Niel, 2000). It is common to all age groups and usually occurs early in the exercise programme (Milroy and O'Niel, 2000).

The following factors help improve compliance: (i) setting the exercise at the appropriate skill level (if an exercise is too hard the participant will become disheartened and if the exercise is too easy the participant will lose interest), (ii) the exercise should be enjoyable, (iii) verbal encouragement , (iv) clear communication about the benefits of doing a particular exercise, (v) appropriate cost effective exercise, (vi) support from social network and accountability, (vii) ability to remember the exercise (Milroy and O'Niel, 2000).

The researcher did address some of these issues by: (i) providing the golfers with clear information regarding the benefits of the interventions they would receive and the exercise programme. This was relayed to them in two ways: an informed consent document and a short briefing to the entire group before the study session; (ii) the cost effectiveness of the exercise was addressed: the stretch could be performed without the use of any external device (e.g. a plinth or a table) and the participants in the ball group were given a 4kg medicine ball to take home with them for the week of the study; (iii) helping participants to remember the exercise: the physiotherapist prescribing the exercise demonstrated the exercise and then she observed the participant performing the exercise and corrected any faults, the Compliance tool provided them with a picture and instructions as to the number of repetitions; (iv) providing a tool that helped encourage accountability: the Compliance tool provided a visual self-accountability tool (much like a checklist) for the participant to encourage accountability and the participant was requested to mark if they did or did not perform an exercise.

5.16 MOTOR PLANNING

As previously discussed the physiotherapy interventions were able to positively influence ball flight and biomechanics. The trigger point therapy effected downswing timing sequence and positively effected accuracy. The ball exercises improved rotational hip biomechanics (backswing hip turn and downswing hip turn). These are all good changes. The concern, however, with elite athletes, is the fact that that they rely on consistency to maximise performance (Marek et al., 2005, Newell, 2003). Consistency prior to a major event is almost always preferable to good changes in biomechanics and ball flight. (Please see Section 2.16 Motor Learning, Pg 41). This study highlights the need to carefully periodise physiotherapy techniques with elite players and to warn patients who undergo physiotherapy just prior to a major event that their biomechanics and/or club performance may be affected by the physiotherapy treatment.

5.17 GENERALISABILITY OF THE STUDY

The researcher and all those involved in assessment of the participants were blinded as to the group allocation and participants were randomly allocated. There were a fairly large number of participants in the study (100). This study could be generalised to the golfers between the ages of 16-25 with handicaps lower than 6.

Although the study's results could be used in a broader sense to alert physiotherapists to the potential risks of physiotherapy interventions affecting biomechanics and ball flight in all golfers; the researcher would advocate caution when generalising the results to: female golfers, children, older golfers, and higher handicap golfers.

The researcher would advise caution when applying these results to females, as females experience different responses to stretch (Thompson and Wayne, 2004). Female golfers also have different golf swing biomechanics when compared to men (Egret et al., 2006). In the study done by Egret et al 2006 it was shown that women produce a wide swing that has larger hip and shoulder rotations than men (Egret et al., 2006).

The researcher would advise caution when applying these results to older male golfers. The first reason being that older men have different swing biomechanics to that of younger men (Lathey et al., 2009). Older golfers have a tendency to have strong coupling between the hip and lumbar spine during the golf swing. The second reason is that people experience different responses to stretch as they age. The reason that the effect of stretching alters with age has physiological explanation. As people age their soft tissue (collagen and elastin), bone and body fat undergo significant changes (Hollard et al., 2002). It is interesting to note that the largest age-related loss in ROM in the hip region is that of hip extension. This further supports the caution in applying these results to older men.

The researcher would also advise caution when applying these results to golfer with handicaps of six and above, the reason being that amateur and higher handicap players have different swing biomechanics to those of elite players. (Zheng et al., 2008). High handicap players also have a more inconsistent swing and as such do not have a deep groove of motor learning (Hume et al., 2005). This may mean that the change brought about by the physiotherapy intervention could be less than the normal variance they experience in their swing.

5.18 LIMITATIONS OF THE STUDY

This study was only done over one week. As such the effects of intensive long term trigger point therapy and long term ball or stretch exercise on ROM, biomechanics club performance and ball flight was not seen.

This was study was also limited in its lack of generalisability to female golfers, children, older golfers, and higher handicap golfers (Please see section 5.16: Generalisability of the Study, Pg 112).

This study was also limited in that although the findings indicated a change in ball flight and rotational biomechanics (which may alter tournament performance); it has not been determined whether these findings would definitely be associated with altered tournament performance.

This study was also limited in that there may have been contamination of the results as a result of the stretch group being shown the ball exercise, the ball group being shown the stretch exercise and the control group being shown the stretch and the ball exercise. The reason that the respective groups were shown the exercises that the other group was doing and was requested not to do the other group's exercises was that many of the participants use the same facilities to train at. It was the researchers intention to prevent a participant from seeing their colleague performing an exercise and copying the exercise (without prior knowledge that this may interfere with the results of the study). There is no way to ensure that the participant did not follow the researchers instruction. This is always the dilemma of clinical trails. A researcher may request when doing a trial on blood pressure that the participant not take any other medication that may interfere with the results of the study, but there is no way to ensure absolute compliance. As this study was only a week long and did not take place during a crucial tournament phase, the temptation not to be compliant may have been lessened (the participant could try the exercise in one week's time). The participants were also allowed to withdraw from the study at any time. If they felt strongly that they wished to perform an exercise not allocated to their group they were able to do so. No participants withdrew as a result of such a desire.

This study was also limited in that it only included two different home exercise programmes, namely the hip flexor stretch programme and the medicine ball exercise programme. The effects of home programmes that address posture or daily ergonomics is therefore unknown.

The researcher did not anticipate that the hip flexor length would not change with the interventions. There is extensive literature supporting the use of static stretch and dynamic stretch to increase range of motion (Wilkinson, 1992). In hindsight it would have been beneficial to test these participants femoral neural tension as this may have been what caused the resistance to stretch. Although the techniques used in the study (trigger point therapy, stretching and ball exercises) would have had some effect on neural tissue mobilisation, a more targeted neural tissue mobilisation may have worked better in increasing ROM (such as neural gliding, neural flossing, neural stretches, or neural strumming). The iliopsoas has lots of neural interface passing over and through it (3D4Medical, 2012) as such it may be similar to the hamstring in resisting stretch (McHugh et al., 2012). There are no published works on iliopsoas resisting stretch and very little research exists on the effects of neural techniques in restoring ROM and function (Ellis and Hing, 2008). Perhaps if the trigger point therapy and static stretching had been combined with specific neural tension treatment techniques such as strumming, gliding or neural flossing, changes in ROM would have been seen. The reason that these techniques were not initially chosen is that support for neural mobilisation remains primarily anecdotal (Ellis and Hing, 2008)

5.19 CONCLUSION

The ball exercise was able to produce significant improvements in rotational biomechanics (backswing hip turn and downswing hip turn). As poor rotational biomechanics is associated with back pain, improved rotational biomechanics caused by the ball exercise could potentially result in decreased lumbar spine injury incidence. The trigger point therapy resulted in an improvement in accuracy, which may have occurred partly as a result of an almost statistically significant change in downswing timing sequence. The week of home stretching resulted in no significant changes in ROM, biomechanics or ball flight. From a therapeutic perspective this study advocates the use of trigger point therapy followed by movement preparation type exercises (such as the medicine ball exercise) over the use of trigger point therapy combined with a week of stretching in the treatment of elite male golfers with shortened hip flexors. The use of these modalities, however, needs to be careful periodised as elite golfers rely on consistency to maximise performance (Marek et al., 2005, Newell, 2003). Consistency prior to a major event is almost always preferable to good changes in biomechanics or ball flight (Please see Section 2.16 Motor Learning, Pg 41). This study highlights the need to carefully periodise physiotherapy techniques with elite players and to warn patients who undergo physiotherapy just prior to a major event that their biomechanics and/or ball flight may be affected by the physiotherapy treatment.

5.20 RECOMMENDATIONS

5.20.1 CLINICAL RECOMMENDATIONS

This study showed that manual physiotherapy techniques combined with medicine ball exercises are able to improve swing biomechanics in elite golfers with shortened hip flexors. These improvements in swing biomechanics would help reduce injury rate as this intervention encouraged rotational movement in the golf swing as opposed to lateral movement in the golf swing (see Chapter 2, Section 2.4: Swing faults; pg.16)

At initial glance it looks like this study would uniformly advocate the use of manual techniques combined with medicine ball exercises in elite golfers. The issue, however, is that the performance variables also changed. Accuracy improved. As with all change, the question is, ‘when to make the change?’ A player may have a faulty grip, but the swing coach is unlikely to change his grip the morning of a major championship. The reason for this is that change (even good change) just before a tournament increases the degrees of freedom available to an athlete and the athlete runs a risk of losing consistency (see Chapter 2, Section 2.16: Motor Learning; pg.41). It is also important to note that in this study only one tight muscle was released and significant changes were seen in ball flight. The effect of this may be compounded if numerous muscles were treated the morning of a big tournament. This highlights the need for periodisation of physiotherapy techniques, screening and informed consent. Muscle range in elite golfers should be measured during off season times and treated if stiff. Elite golfers should be made aware that the physiotherapy techniques may result in changes in ball flight (this is especially relevant during tournaments). In suggesting periodisation of physiotherapy, the researcher is not advocating ignoring muscle stiffness during tournament season until it causes pain and injury, but rather as far as possible, to treat muscle stiffness during off seasons times; and if treatment is necessary during the tournament season to advise the golfer of the potential performance risks of the intervention.

5.20.2 RECOMMENDATIONS FOR FURTHER RESEARCH

It would be useful to have studies done on the effect of other types of manual therapy on performance (such as massage, manipulation, neural mobilisation). The researcher is not aware of any studies on the effect of these modalities on golf biomechanics and swing performance. In fact, very little research has been done into the clinical effects of myofascial trigger points (de las Penas et al., 2005). This further research would give therapists involved with precision sport a better idea of when to use which modalities and which modalities are able to affect swing biomechanics and performance.

It would also be useful to have studies done on the effect of manual therapy and exercise programmes over time (consistent use) on ROM, golf swing biomechanics and performance. The effects of routine therapy and prolonged exercise programmes may not be the same as those who receive a once off intervention.

Neural tension may be a possible reason that the golfers in this trial did not experience significant changes in ROM. Research into the prevalence of femoral neural tension of elite golfers would be useful. Very little research has been done into prevalence of neural tension and efficacy of neural techniques (Ellis and Hing, 2008). More research is needed into the use of these techniques.

Future studies could include more methods to encourage compliance. There are a few areas in which the researcher could have perhaps improved in encouraging compliance: (i) with regard to setting the skill and enjoyment level perhaps the researcher could have done a survey with some elite golfers between the ages 16-25 years to obtain some qualitative information about the exercise (e.g. perceived level of enjoyment, perceived level of exertion) and some quantitative information (VO2 max, maximum heart rate); (ii) with regard to encouragement perhaps the researcher could have sent messages to or called the participants during the week to encourage them. The only concern with the second point is that it is dissimilar to the golfers' normal practice environment.

CHAPTER 6: REFERENCES

3D4MEDICAL 2012. Muscle System Pro III. *In:* MEDICINE, S. U. S. O. (ed.) *Muscle System Pro III.*

ALVAREZ, M., S., S., G., C. & J.C., R. 2011. Effects of an 18-week strength training program on low-handicap golfers' performance. *Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc.),* 0**,** 1-12.

BAKER, D. & NEWTON, R. U. 2005. Acute effect on power output of alternating an agonist and antagonist muscle exercise during complex training. *Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc.),* 19**,** 202-205.

BARR, K. P., GRIGGS, M. & TODDD, C. 2005. Lumbar stabilization: a review of core concepts and current literature, part 1. *American Journal Physical Medicine Rehabilitation*

BEHM, D. G. & CHAOUACHI, A. 2011. A review of the acute effects of static and dynamic stretching on performance. *European Journal of Applied Physiology,* 111**,** 2633.

BLAZEVICH, A. J. 2012. *Sports Biomechanics the Basics: Optimising Human Performance,* London, A&C Black Publishers.

BOGDUK, N., M., P. & G., H. 1992. Anatomy and Biomechanics of Psoas Major. *Clinical biomechanics***,** 109-119.

BORG-STEIN, J. & SIMONS, D. 2002. Myofascial pain. *Archives of Physical Medicine Rehabilitation,* 83**,** S40-70.

BREUM, J., WILBERG, J. & BOLTON, J. 1995. Reliability and concurrent validity of the BROM II for measuring lumbar mobility. *Journal Manipulative Physiological Therapy* 8**,** 497-502

BURDEN, A. M., P.M., G. & E.S., W. 1998. Hip and shoulder rotations during the golf swing of sub-10 handicap players. *Journal of Sports Sciences***,** 165-176.

CLAPIS, P. A., DAVIS, S. M. & DAVIS, R. O. 2008. Reliability of inclinometer and goniometric measurements of hip extension flexibility using the modified Thomas test. *Physiotherapy Theory and Practice,* 24**,** 135-141.

COOK, G., L., B., KIESEL, K., G., G. R. & M., B. 2010. *Movement: Functional Movement Systems: Screening, Assessment, Corrective Strategies*, On Target Publications.

DE LAS PENAS, C. F., CAMPO, M. S., CARNERO, J. F. & PAGE, J. C. M. 2005. Manual therapies in myofascial trigger point treatment: a systematic review. *Journal of Bodywork & Movement Therapies,* 9**,** 27-34.

DOAN, B. K., R.U., N., KWON Y-H & W.J., K. 2006. Effects of Physical Conditioning on Intercollegiate Golfer Performance. *Journal of Strength and Conditioning Research,* 20**,** 62-72.

DOMMERHOLT, J., BRON, C. & FRANSSEN, J. 2006. Myofascial Trigger Points: An Evidence-Informed Review. *Journal of Manual & Manipulative Therapy (Journal of Manual & Manipulative Therapy),* 14**,** 203-221.

EGRET, C. I., NICOLLE, B., DUJARDIN, F. H., WEBER, J. & CHOLLET, C. 2006. Kinematic Analysis of the Golf Swing in Men and Women Experienced Golfers. *International Journal of Sports Medicine,* 27**,** 463-467.

ELLIS, R. F. & HING, W. A. 2008. Neural mobilization: a systematic review of randomized controlled trials with an analysis of therapeutic efficacy. *Journal of Manual & Manipulative Therapy (Journal of Manual & Manipulative Therapy),* 16**,** 8-22.

ETNYRE, B. R. 1998. Accuracy characteristics of throwing as a result of maximum force effort. *Perceptual & Motor Skills,* 86**,** 1211-1217.

EVANS, K., S.A., H., R.J., N., R.S., B. & P.M., M. 2012. Repeatability of three-dimensional thorax and pelvis kinematics in the golf swing measured using a field-based motion capture system. *Sports Biomechanics***,** 1-11.

FERNANDEZ-DE-LAS-PENAS, C., M.L, C. & J.A., P. 2006. Myofascial Trigger Points, Neck Mobility, and Forward Head Posture in Episodic Tension-Type Headache. *Journal of Head and Face Pain***,** 662-672.

FLETCHER, I. M. & HARTWELL, M. 2004. Effects of an 8-week combined weights and pylometric training programme on golf performance. *Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc.),* 18**,** 59-62.

FLIGHT SCOPE 2011. Flightscope User Manual. *In:* EDH (ed.) *Flight Scope.*

GABBE, B., BENNELL, K., WAJSWELNER, H. & FINCH, C. 2004. Reliability of common lower extremity musculoskeletal screening tests. *Physical Therapy in Sport***,** 90-97.

GERGLEY, J. C. 2010. Latent effect of passive static stretching on driver club head speed, distance, accuracy, and consistent ball contact in young male competitive golfers. *Journal of Strength and Conditioning Research,* 24**,** 3326-3333.

GLADYS, T. M., CERNIGLIARO, P.L, A., P.J., M., V.F, H., S., F. & P.R., R. Iliopsoas Compartment: Normal Anatomy and Pathological Processes. RNSA Scientific Assembly, 1994.

GLUK, G. S., J.A., B. & J.M., S. 2008. The lumbar spine and low back pain in golf: a literature review of swing biomechanics and injury prevention. *The Spine Journal,* 8**,** 778-788.

GRIMALDI, A. 2011. Assessing lateral stability of the hip and pelvis. *Manual Therapy,* 16**,** 26-32.

GROBLER, L., COLLINS, M. & LAMBERT, M. I. 2004. Remodeling of skeletal muscle following exercise-induced muscle damage. *International SportMedicine Journal,* 5**,** 67-83.

HALBERTSMA, J. P. K. & GOEKEN, L. N. H. 1994. Stretching exercises: Effect on Passive Extensibility and Stiffness in Short Hamstrings of Healthy Subjects. *Archives of Physical Medicine Rehabilitation,* 75**,** 976-81.

HANTEN, W. P., OLSON, S. L., BUTTS, N. L. & NOWICKI, A. L. 2000. Effectiveness of a home program of ischemic pressure followed by sustained stretch for treatment of myofascial trigger points. *Physical Therapy,* 80**,** 997-1003.

HARDY, A. M. & POLLARD, H. 2005. Muscle Activity during the golf swing. *British Journal of Sports Medicine,* 39**,** 799-804.

HOLLARD, G. J., TANAKA, K., SHIGEMATSU, R. & NAKAGAICHI, M. 2002. Flexibility and physical functions of older adults: a review. *Journal of Aging & Physical Activity,* 10**,** 169-206.

HOSEA, T. M. & GATT, C. J. 1996. Back pain in golf (Douleur du dos en golf). *Clinics in Sports Medicine,* 15**,** 37-53.

HTTP://GOLFMAJORCHAMPIONSHIPS.COM/BYCOUNTRY. date accessed: December 2012.

HUME, A., KOEG, J. & REID, D. 2005. The Role of Biomechanics in Maximising Distance and Accuracy of Golf Shots. *Journal of Sports Medicine,* 5**,** 429-449

JENSEN, T., WILSON, P. & RICE, A. 2003. Chronic Pain, Clinical Pain Management. *London: Arnold*.

KELLY, B. 2012. *About.comGolf* [Online]. Available: golf.about.com 06 December 2012].

KOSTOPOULOS, D. 2001. *The Manual of Trigger Point and Myofascial Therapy*, Slack Incorporated, US.

LATHEY, C., STRIKE, S. & LEE, R. The Effects of Aging on the Hip and Spinal Motions in the golf Swing. 27 International Conference on Biomechanics in Sport, 2009 limerick, Ireland.

LEADBETTER, D. 2003. Get Your Swing in Sync. *Golfers Digest.*

LINDSAY, D. M., VERSTEEGH, T. H. & VANDERVOORT, A. A. 2009. Injury Prevention: Avoiding One of Golf's More Painful Hazards. *International Journal of Sports Science & Coaching,* 4**,** 129-148.

LYLE, M. A., MANES, S., MCGUINNESS, M., ZIAEI, S. & IVERSEN, M. D. 2005. Relationship of physical examination findings and self-reported symptom severity and physical function in patients with degenerative lumbar conditions. *Physical Therapy,* 85**,** 120-133.

MAGNUS, G. 1852. On the derivation of projectiles; and on a remarkable phenomenon of rotating bodies. *Journal Tyndall & W. Francis (eds)*

MAGNUSSON, S. P. 1998. Passive properties of human skeletal muscle during stretch maneuvers. A review. *Scand J Med Sci Sports,* 8**,** 65-77.

MAREK, S., CRAMER, J., FINCHER, L., MASSEY, L., DANGELMAIER, S., PURKAYASTHA, S., FITZ, K. & CULBERTSON, J. 2005. Acute Effects of Static and Proprioceptive Neuromuscular Facilitation Stretching on Muscle Strength and Power Output. . *Journal of Athletic Training.,* 40**,** 94-103.

MCGILL, S., JUNKER, D. & KROPF 1996. Quantitative Intramuscular Myoelectric activity of Quadratus Lumborum during a wide variety of tasks. *Clinical biomechanics* 11**,** 170-172.

MCHUGH, M. P., JOHNSON, C. D. & MORRISON, R. H. 2012. The role of neural tension in hamstring flexibility. *Scandinavian Journal of Medicine & Science in Sports,* 22**,** 164-169.

MILROY, P. & O'NIEL, G. 2000. Factors affecting compliance to chiropractic prescribed home exercise: a review of the literature. *Journal of the Canadian Chiropractic Association,* 44**,** 141-148.

MORAN, K. A., MCGRATH, T., MARSHALL, B. M. & WALLACE, E. S. 2009. Dynamic stretching and golf swing performance. *International Journal of Sports Medicine,* 30**,** 113-118.

MORLING, G. 2009. Understanding iliopsoas: clinical implications for the massage therapist. *Journal of the Australian Traditional-Medicine Society,* 15**,** 7-12.

MYERS, J., LEPHART, S., TSAI, Y.-S., SELL, T., SMOLIGA, J. & JOLLY, J. 2008. The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences,* 26**,** 181-188.

NACHEMSON, A. 1966. Electromyographic Studies on the Vertebral Portion of the Psoas Muscle: With Special reference to its stabilizing Function of the Lumbar Spine. *Acta Orthopaedic Scandinavia,* 37**,** 177-190.

NAKAJIMA, Y. 2006. *Golf Club Shaft*. United States of America patent application 11/362806.

NATIONAL DEPARTMENT OF SPORT AND RECREATION 1998. National Department of Sport and Recreation White Paper. *In:* RECREATION, N. D. O. S. A. (ed.).

NESBIT, S. & SERRANO, M. 2005. Work and Power Analysis of the Golf Swing. *Journal of Sports Science and Medicine* 520-533

NEWELL, K. M. 2003. Change in motor learning: a co-ordination and Control Perspective. *Motriz, Rio Claro,* 9**,** 1-6.

PERFORMANCE ATTAINMENT ASSOCIATES 2012. Procedure for Measuring Back Motion with the BROM II. *In:* ASSOCIATES, P. A. (ed.) *Spine products.* Instruction manual: Performance Attainment Associates.

PETERSON, M. D., ALVAR, B. A. & RHEA, M. R. 2006. The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc.),* 20**,** 867-873.

PETROFSKY, J. S., PROWSE, M., LEMOINE, M., BARTELINK, T., BATT, J., SUH, H. J., FURR, A., JAUREGUI, A., DICK, A., RETZER, G., HARPER, R. A., BOUTERIE, R., BROWN, J., LEYVA, S., CHARBONNET, M., STACEY, L. & BAINS, G. S. 2008. Muscle use during exercise with a mini medicine ball compared to other abdominal exercise modalities. *Journal of Applied Research,* 8**,** 95-115.

RADFORD, J. A., BURNS, J., BUCHBINDER, R., LANDORF, K. B. & COOK, C. 2006. Does stretching increase ankle dorsiflexion range of motion? A systematic review. *British Journal of Sports Medicine,* 40**,** 870-875.

ROSENBAUM, D. A. 2009. *Human Motor Control 2nd Ed*, Academic Press.

SAJKO, S. & STUBER, K. 2009. Psoas major: a case report and review of its anatomy, biomechanics, and clinical implications. *Journal of the Canadian Chiropractic Association,* 53**,** 311-318.

SHERMAN, C. & FINCH, C. 2000. Preventing injuries to competitive and recreational Adult Golfers: What is the Evidence? *Journal of Science and Medicine in Sport* 1**,** 65-78.

SHRIER, I. & GOSSAL, K. 2000. Myths and truths of stretching: individualized recommendations for healthy muscles. *Physical Sports Medicine,* 28**,** 57-63.

SMITH, M. & HILLMAN, R. 2012. A retrospective service audit of a mobile physiotherapy unit on the PGA European Golf Tour. *Physical Therapy in Sports,* 13**,** 41-44.

SWANSON, J. R. 2006. A Functional Approach to Warm-up and Flexibility. *Strength & Conditioning Journal (Allen Press),* 28**,** 30-36.

TAYLOR, K.-L., SHEPPARD, J. M., LEE, H. & PLUMMER, N. 2009. Negative effect of static stretching restored when combined with a sport specific warm-up component. *Journal of Science & Medicine in Sport,* 12**,** 657-661.

TERIAULT, G. & LACHANCE, P. 1998. Golf Injuries: an overview. *Journal of Sports Med* 1**,** 43-57

THOMPSON, C. & WAYNE, H. 2004. Effects of an 8-week Multimodal Exercise Program on Strength, Flexibility, and Golf Performance in 55- to 79-Year-Old Men. *Journal of Agining and Physical Activity* 12**,** 144-13.

TITLEST PERFORMANCE INSTITUTE 2006. TPI Certified Seminar Manual Level 1. Acushnet Company.

TOUSIGNANT, M., MORISSETTE, J. & MURPHY, M. 2002. Criterion validity study of lumbar goniometers BROM II and EDI-320 for range of motion of lumbar flexion of low back pain patients. *Journal of Back & Musculoskeletal Rehabilitation,* 16**,** 159-167.

UNIVERSITY OF THE WITWATERSRAND 2012. *Neurodynamics notes*.

VAN DE GRAAF, K. M. 1998. *Human Anatomy,* Boston, Massachussets, WCB Mc Graw-Hill.

WILKINSON, A. 1992. Stretching the truth. A review of the Literature on Muscle Stretching. *Australian Journal Physiotherapy* 38**,** 283-287.

WILSON, E. J. & SHERWOOD, D. E. 2008. Do the principles of motor program editing apply to longer sequences of rapid aiming movements? Part II. *International Journal of Exercise Science,* 1**,** 50-61.

WITVROUW, E., N., M., L., D. & P., M. 2004. Stretching and Injury Prevention: An Obscure Relationship. *Journal of Sports Med,* 34**,** 443-449.

WWW.CALGOLFTECH.COM. date accessed: December 2012.

WWW.EHOW.COM/HOW-DOES_4655444_ANGLE-GOLF-CLUB-AFFECCT-SHOT.HTML. date accessed: December 2012.

WWW.ENGINEERINGNEWS.CO.ZA/ARTICLE/SURVEY-SHOWS-THAT-SA-GREEN-FEES-ARE-FAR-LOWER-THAN-THOSE-IN-EUROPE-THE-MIDDLE-EAST-2007-05-18. date accessed: December 2012.

WWW.EUROPEANTOUR.COM/TOURGROUP/PHYSIOMEDICAL/INDEX.HTML. date accessed: December 2012.

WWW.GOLFDIGEST.COM. date accessed January 2013.

WWW.PHYSIOSA.ORG.ZA/. date accessed: December 2012.

WWW.SUNSHINETOUR.COM/HOME.ASP. date accessed: December 2012.

WWW.THEGOLFACADEMYLA.COM/COACHING/TECHNOLOGY/FLIGHTSCOPE.ASPX. date accessed: December 2012.

WWW.TOTALGOLFANALYSIS.CO.UK. date accessed: December 2012.

ZHENG, N., BARRENTINE, S., FLEISIG, G. & ANDREWS, J. 2008. Kinematic Analysis of swing in pro and amateur golfers. *International Journal of Sports Medicine,* 29**,** 487-93.

APPENDIX A: CLASSICAL GOLF SWING VERSUS MODERN GOLF SWING

[images from (Gluk et al., 2008)]

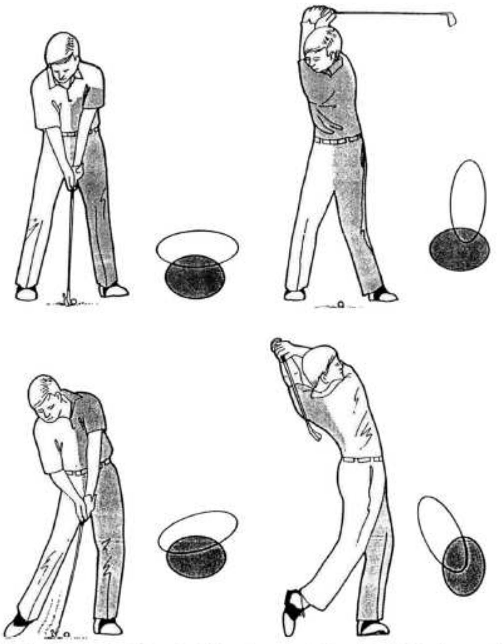


Fig. 2. Modern golf swing. Note the restricted hip turn. (unshaded oval represents shoulder position; shaded oval represents hip position) [12].

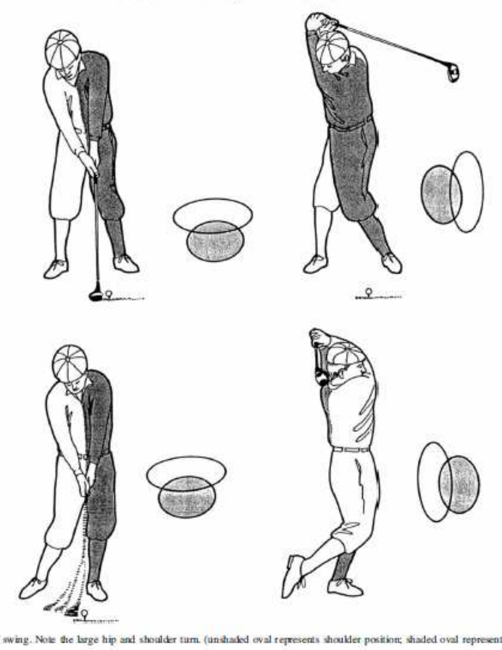


Fig. 3. Classic golf swing. Note the large hip and shoulder turn. (unshaded oval represents shoulder position; shaded oval represents hip position) [12].

APPENDIX B: DEMOGRAPHIC QUESTIONNAIRE

Demographic Questionnaire

Participant Code	

Personal Information

Name	
Age	
Gender	Male
Date of Birth	
ID	
Race	
Telephone number (home)	
Telephone number (work)	
Telephone number (cell)	
Email address	
Golf Handicap	
Amateur or professional golf status	
Full time or social golfer	
Occupation	

Address (Postal)

Residential Address

Medical History
Serious Illness

Training Academy/ coach	
Academy contact person	
Academy email address	
Academy contact person telephone number	

Next of kin (If under 18 years please use parent or guardian)	
Relationship of next of kin	
Telephone number next of kin	
Additional contact number of next of kin	
Email of next of kin	

APPENDIX C: STRETCH COMPLIANCE TOOL

Stretch Compliance Diary

	Date	Morning (Before 10:00)		Mid day (10:00-14:00)		Afternoon (after 14:00)	
Day 1		Yes	No	Yes	No	Yes	No
Day 2		Yes	No	Yes	No	Yes	No
Day 3		Yes	No	Yes	No	Yes	No
Day 4		Yes	No	Yes	No	Yes	No
Day 5		Yes	No	Yes	No	Yes	No
Day 6		Yes	No	Yes	No	Yes	No
Day 7		Yes	No	Yes	No	Yes	No

Image taken from:

http://femmefataleconqueringmarathonwithp90x.files.wordpress.com/2011/03/hipstretch2_graham_mitchell_getty.jpg

Notes

Please circle yes if you performed the exercise or no if you did not..

Please draw a P with a circle around it if you had to discontinue due to pain.

Please hold the stretch for 60 seconds.

Please remember that you should feel the stretch where the hip flexor is. There should be no pain in your back..

APPENDIX D: BALL EXERCISE COMPLIANCE TOOL

Stretch Compliance Diary




	Date	Morning (Before 10:00)	Mid day (10:00-14:00)	Afternoon (after 14:00)
Day 1		Yes No	Yes No	Yes No
Day 2		Yes No	Yes No	Yes No
Day 3		Yes No	Yes No	Yes No
Day 4		Yes No	Yes No	Yes No
Day 5		Yes No	Yes No	Yes No
Day 6		Yes No	Yes No	Yes No
Day 7		Yes No	Yes No	Yes No

Notes

Please circle yes if you performed the exercise or no if you did not.

Pease repeat 50 times each side.

Stop the exercise if it causes pain and try again later.

Please draw a P with a circle around it if you had to discontinue due to pain.

APPENDIX E: LOG BOOK

Training Log Book

	Date	Putting		Short Game		The range (Woods and Irons)		Flexibility training		Postural Training		Weight Training		Cardiovascular training		Rounds of Golf
		Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	No. of holes played
Day 1																
Day 2																
Day 3																
Day 4																
Day 5																
Day 6																
Day 7																

Notes

Please record up to the closest 15 minutes. i.e. 1hour 15 min; 1 hour 30 min

If you forget to record on a day please don’t make it up. Please just put an asterix (*) in the column you are unsure of

Call Cindy on (011)6081387 if you are unsure where to record a particular training.

APPENDIX F: INFORMED CONSENT

INFORMATION DOCUMENT AND INFORMED CONSENT

Study Title:

"The effect of manual therapy and exercise on range of motion, biomechanics, club performance and ball flight- a randomised controlled trial on elite golfers."

Good afternoon. Thank you for taking time out to consider taking part in this study.

I, Samantha-Lynn Quinn (B.Sc. Physiotherapy) and the University of the Witwatersrand (Physiotherapy Department), are doing research on the effects of myofascial trigger point therapy (a type of massage that involves pressing a muscle for approximately 45 seconds at a time) with stretching versus myofascial trigger point therapy and muscle activation on elite golfers' ROM and performance. Research is a process that we use to answer this question.

In this study we want to learn:

- If trigger point therapy and stretching has an effect on elite golfers' ROM and performance.
- If stretching has an effect on an elite golfers' ROM and performance.
- If muscle activation has an effect on an elite golfers' ROM and performance.

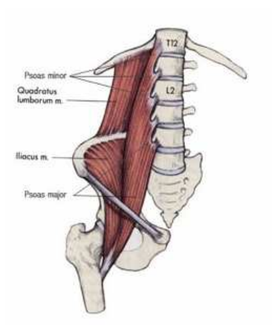
We would like to invite you/your child to take part in this study.

What is involved in the study?

This study is a randomised controlled trial. If you chose to take part in this study you will be randomly assigned to one of three groups. The first group will receive the trigger point therapy combined with stretching followed by two weeks of home stretching. The second group will receive myofascial trigger point therapy and muscle activation followed by two weeks of home muscle activation exercises. Both groups 1 and 2 will be required to fill in a stretch Compliance diary (we will explain how to fill this in). The third group will be a control group. This group will receive no intervention. All three groups will be required to fill in a training logbook for the entire duration (1 week) of the study (we will explain how to fill this in).

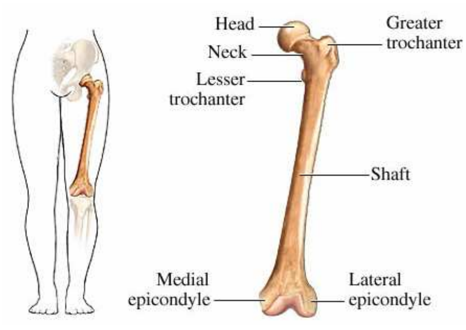
Which muscles will be trigger pointed and/or stretched in this study?

1. Iiopsoas (Hip Flexor): This muscle is one of the muscles used to lift the thigh (e.g. the muscle used to move the hip to kick). It comes from the lower back and ends in the femur (The large bone in the leg – see diagram below). This muscle is used extensively during the golf swing (Please see reference 1 and Golf Swing Diagram).



Iliopsoas Muscle

(Image taken from: www.yogaartandscience.com)



Femur

(Image taken from: www.images.webmd.com

Please take note of how these muscles are used during the Golf swing

Golf Swing

Images taken from Mc Hardy et al (2005)

What involvement will be required from me?

You will need to come to the Serengeti Golf Academy, Serengeti Golf and Wildlife Estate, Kempton Park, South Africa. The researcher will measure your lower back movements, your hip extension, swing movements and driver distance and accuracy. If you are in groups 1 and 2 you will receive the interventions and a home programme. Group 3 will not receive any interventions. All three groups will then be re-measured. Thereafter you will go home. If you are in Group 1 you will fill in the training log book and the stretch Compliance diary. If you are in Group 2 you will fill in the training log book and the muscle activation diary. If you are in Group 3 you will only fill in the training log book.

One week later you will return to Serengeti Golf and Wildlife Estate. We will once again measure your lower back movements, your hip extension, swing movements and driver distance and accuracy. You will hand in your training logbook (Group 1, 2, and 3) and stretch Compliance diary (Group 1) and muscle activation Compliance diary (Group 2).

How much of my time will the study require?

The initial and final assessment will require approximately one hour to complete. The second visit will require 45 min to complete. The total duration of the study is 1 week. During this time if you are in the ball or stretch group you will be required to perform a home exercise programme.

How many physiotherapy assessments/treatments will I/my child receive?

- Groups 1 and 2 will receive one physiotherapy treatment session and three physiotherapy assessments.
- Group 3 will receive three physiotherapy assessments only.

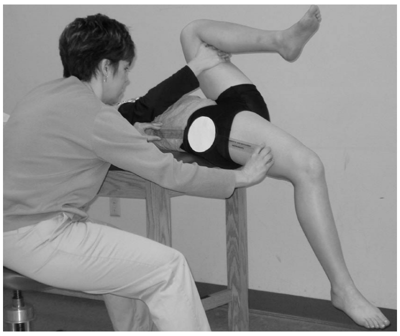
Do I need to pay for these assessments/treatments?

You will not be charged for physiotherapy assessments/treatments that form part of the study.

How do you measure range of motion and performance?

1. For back movement we will use the BROM II. This instrument is not invasive.

2. To measure hip movement we will use a goniometer. This also a non-invasive technique



3. To measure Swing biomechanics: We will use electromagnetic 3D swing analysis system and the Flightscope. Neither of these assessments is invasive.

Please note that all massage, stretch and muscle activation techniques will be performed by qualified physiotherapists registered with the Health Care Professions Council of South Africa. The physiotherapist will measure your hip and lumbar spine spine ROM. A golf coach from Serengeti Golf Academy will measure the swing biomechanics.

Will you change my training?

If you are in Group 1 we will add stretches to your training. If you are in Group 2 we will add muscle activation to your training. If you are not in Group 1 we will ask you not to perform the specific hip stretch for the duration of the study (one week). If you are not in Group 2 we will ask you not to perform the muscle activation for the duration of the study.

Who is taking part in the study?

- Elite golfers (handicap less than 6) in the Johannesburg area.
- People with tightness in certain hip muscles.
- Ages 16-25 years
- Male.
- Currently hitting at least 500 balls per week.
- Not currently receiving physiotherapy interventions
- No known serious back or hip pathologies (including disc herniations, Scheuermans, fractures at the pars)

Please note that you will be excluded from the study if you don't meet all of the above criteria.

WHAT ARE THE RISKS?

- Trigger point therapy can cause mild discomfort.

WHAT ARE THE BENEFITS?

- Your range of motion and performance results will be made known to you. This can assist you in your training.
- The interventions themselves may help decrease the tightness in the hip muscles. This may help with pain, injury prevention and perhaps even your golf performance.

WHAT OTHER ALTERNATIVES DO I HAVE TO ACHIEVE THESE BENEFITS?

- Physiotherapy interventions such as joint mobilisation, nerve mobilisation may also give rise to these benefits.
- A core stability training programme may also give rise to these benefits.

We will give you any pertinent information on the study while involved in the study. We will also make the results of the study known to you.

Will I be disadvantaged in any way if I do not take part in the study?

Participation in the study is totally voluntary and you may withdraw from the study at any time. This will not result in any penalty or loss of benefits to which you are normally entitled.

WILL I GET REIMBURSED FOR "OUT OF POCKET" EXPENSES?

We will reimburse you for travelling costs.

WILL MY DETAILS BE KEPT CONFIDENTIAL?

- Although every effort is made to keep your documentation confidential (through the use of code names instead of your actual name) as with any study there is the risk of it being breached.
- Please note that personal information may be disclosed if required by law.
- Certain organisations such as the Research Ethics Committee may inspect/and or copy the research records.

References

Journals

1. Hume A., Koeg J., ReidD.; The Role of Biomechanics in Maximising Distance and Accuracy of Golf Shots. Journal of Sports Medicine. 2005;35(5):429-449

Images

1. McMardy A., Pollard H.; Golf and Upper Limb injuries: a Summary and review of the literature. Chripopractor Osteopath Journal 2005; 13:7

2. www.easyvigour.net.nz (accessed 07.07.2008)

3. www.fotosearch.com (accessed 07.07.2008)

4. www.golforeless.biz/storetour.html (accessed 23/04/2008)

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7. www.yogaartandscience.com (accessed 07.07.2008)

RESEARCHERS CONTACT DETAILS

Samantha-Lynn Quinn

Office Hours: (011) 608 1387

Cell: 083 226 6529

Research Ethics Committee (REC) Administrator and Chair Details

Please contact the REC should you wish to report complaints or problems.

Tel: (011) 717 1234

Fax: (011) 717 126

I, ______________________________, have read and understood the above information. I am happy that my concerns and questions have been answered satisfactorily. (I will)/(I will allow my child, __________________________,) to take part in this study: “The Effect of Manual Therapy and Exercise on Range of Motion, Biomechanics, Club Performances and Ball Flight- a Randomised Controlled Trial on Elite Golfers.” I understand that I need to notify you in writing should I wish to withdraw (myself)/(my child) from the study.

SIGNED (PARTICIPANT): __________________________

Date: _____________________

SIGNED (WITNESS): _______________________________

Date: _____________________

SIGNED (RESEARCHER):__________________________

Date: ____________________

APPENDIX G: INFORMED ASSENT

INFORMATION DOCUMENT AND INFORMED ASSENT

Study Title:

"The effect of manual therapy and exercise on range of motion, biomechanics, club performance and ball flight- a randomised controlled trial on elite golfers."

Good afternoon. Thank you for taking time out to consider taking part in this study.

We, Samantha-Lynn Quinn (B.Sc. Physiotherapy) and the University of the Witwatersrand (Physiotherapy Department), are doing research on the effects of myofascial trigger point therapy (a type of massage that involves pressing a muscle for approximately 45 seconds at a time) with stretching versus myofascial trigger point therapy and muscle activation on elite golfers' ROM and performance. Research is a process that we use to answer this question.

In this study we want to learn:

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- If stretching has an effect on an elite golfers' ROM and performance.
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We would like to invite you to take part in this study.

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This study is a randomised controlled trial. If you chose to take part in this study you will be randomly assigned to one of three groups. The first group will receive the trigger point therapy combined with stretching followed by two weeks of home stretching. The second group will receive myofascial trigger point therapy and muscle activation followed by two weeks of home muscle activation exercises. Both groups 1 and 2 will be required to fill in a stretch Compliance diary (we will explain how to fill this in). The third group will be a control group. This group will receive no intervention. All three groups will be required to fill in a training logbook for the entire duration (1 week) of the study (we will explain how to fill this in).

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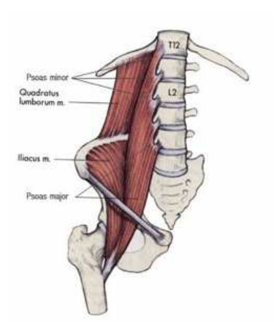
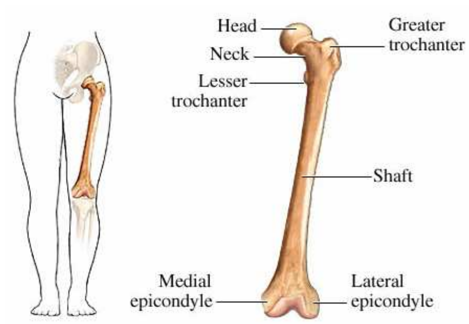


Iliopsoas Muscle

(Image taken from: www.yogaartandscience.com)



Femur

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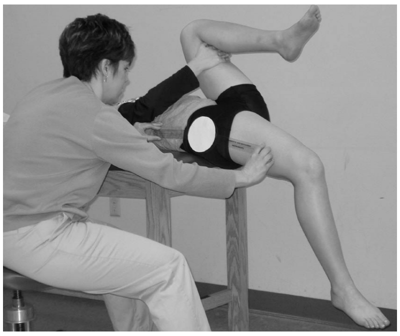

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- Ages 16-25 years
- Male.
- Currently practicing golf for at least 2 hours per week.
- Not currently receiving physiotherapy interventions
- No known serious back or hip pathologies (including disc herniations, Scheuermans, fractures at the pars)

Please note that you will be excluded from the study if you don't meet all of the above criteria.

WHAT ARE THE RISKS?

- Trigger point therapy can cause mild discomfort.

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I, ____________________________________, have read and understood the above information. I am happy that my concerns and questions have been answered satisfactorily. I have decided to take part in this study: “The Effect of Manual Therapy and Exercise on Range of Motion, Biomechanics, Club Performances and Ball Flight- a Randomised Controlled Trial on Elite Golfers.” I understand that I need to notify you in writing should I wish to withdraw from the study.

SIGNED (PARTICIPANT): ___________________________

Date: ______________________

SIGNED (WITNESS): _________________________________

Date: ______________________

SIGNED (RESEARCHER):___________________________

Date: ______________________

APPENDIX H: ADDITIONAL RESULTS TABLES

Table H.1: Results from the First Assessment of ROM variables

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Left Hip Extension º	Mean (SD)	5.06 (6.91)	4.12 (5.12)	4.52 (3.68)
Right Hip Extension º	Mean (SD)	4.58 (6.21)	5.38 (5.05)	4.85 (3.17)
Right Lumbar Spine Rotationº	Mean (SD)	10.61 (2.38)	10.71 (2.70)	11.06 (3.31)
Left Lumbar Spine Rotation º	Mean (SD)	11.36 (2.04)	11.56 (2.92)	11.18 (3.10)
Right Lumbar Spine Lateral Flexion º	Mean (SD)	29.52 (5.25)	29.24 (5.08)	31.46 (4.80)
Left Lumbar Spine Lateral Flexion º	Mean (SD)	29.33 (5.73)	29.15 (6.26)	31.46 (4.86)

Results not adjusted for statistically significant differences in the baseline

Table H.2: Results from the First Assessment of ball flight variables

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Distance km/h	Mean (SD)	159.55 (13.40)	154.32 (16.65)	156.33 (19.6)
Club Head Speed km/h	Mean (SD)	152.58 (10.12)	151.29 (9.14)	151.55 (10.59)
Smash Ratio	Mean (SD)	1.2 7(0.05)	1.25 (0.07)	1.27 (0.05)

Results not adjusted for statistically significant differences in the baseline

Table H.3: Results from the First Assessment of swing biomechanics variables

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Hip Alignment at Address°	Mean (SD)	0.94 (3.86)	1.94 (4.25)	-0.24 (5.55)
Pelvic bending (AP) °	Mean (SD)	23.30 (12.03)	21.59 (11.63)	31.00 (12.24)
Pelvic Tilting Lateral Flexion at Address °	Mean (SD)	-1.91 (2.85)	-1.21 (2.19)	-1.76 (3.133\)
Backswing Hip Turn °	Mean (SD)	-46.27 (9.40)	-44.97 (7.69)	-48.61 (10.49)
X-Factor °	Mean (SD)	-34.30 (7.73)	-37.56 (7.78)	-31.94 (11.55)
X-Factor Stretch °	Mean (SD)	-15.15 (7.15)	-14.15 (6.25)	-21.46 (8.42)
Backswing Hip Drop cm	Mean (SD)	-2.70 (1.96)	-2.92 (1.70)	-2.52 (1.90)
Backswing Hip Sway cm	Mean (SD)	0.52 (2.75)	1.66 (4.00)	1.96 (3.50)
Downswing Hip Turn °	Mean (SD)	37.42 (11.65)	39.18 (10.47)	44.00 (9.34)
Downswing Hip Tilt Lateral Flexion °	Mean (SD)	9.33 (4.19)	10.00 (4.21)	10.79 (4.05)
Downswing Hip Bend °	Mean (SD)	5.30 (11.35)	4.62 (11.25)	9.85 (12.05)
Downswing Hip Sway (Address to Impact) cm	Mean (SD)	-11.88 (4.30)	-11.89 (3.48)	-11.53 (4.86)
Downswing Hip Thrust cm	Mean (SD)	1.43 (2.78)	1.96 (2.71)	1.12 (1.9)
Downswing Hip Speed deg/sec	Mean (SD)	420.55 (68.00)	431.97 (95.34)	459.09 (84.99)

Results not adjusted for statistically significant differences in the baseline

Table H.4: Results from the Second ROM Assessment.

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Left Hip Extension º	Mean (SD)	2.79 (6.46)	2.12 (4.82)	2.94 (6.06)
Right Hip Extension º	Mean (SD)	2.67 (7.67)	1.68 (5.95)	1.81 (5.49)
Right Lumbar Spine Rotationº	Mean (SD)	11.36 (2.78)	11.84 (3.21)	11.14 (3.23)
Left Lumbar Spine Rotation º	Mean (SD)	11.42 (2.63)	11.88 (3.09)	11.47 (2.77)
Right Lumbar Spine Lateral Flexion º	Mean (SD)	30.70 (5.62)	30.12 (4.77)	31.16 (5.02)
Left Lumbar Spine Lateral Flexion º	Mean (SD)	29.91 (5.76)	30.29 (5.52)	30.94 (6.46)

Results not adjusted for statistically significant differences in the baseline

Table H.5: Results from the Second Ball Flight Assessment.

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Distance km/h	Mean (SD)	159.55 (13.40)	154.32 (16.65)	156.33 (19.68)
Club Head Speed km/h	Mean (SD)	153.85 (8.48)	151.18 (9.60)	150.88 (8.75)
Smash Ratio	Mean (SD)	1.26 (0.05)	1.26 (0.06)	1.27 (0.05)

Results not adjusted for statistically significant differences in the baseline

Table H.6: Results from the Second Biomechaincs Assessment.

Variable	Statistic	Control (Group3) n=33	Stretch (Group1) n=34	Ball (Group2) n=33
Hip Alignment at Address°	Mean (SD)	1.27 (4.16)	1.03 (5.00)	-0.64 (5.96)
Pelvic bending (AP) °	Mean (SD)	26.58 (10.30)	22.71 (12.77)	27.49 (11.11)
Pelvic Tilting Lateral Flexion at Address °	Mean (SD)	-1.09 (2.58)	-1.18 (2.44)	-1.39 (3.82)
Backswing Hip Turn °	Mean (SD)	-48.85 (8.28)	-45.85 (10.09)	-47.03 (10.28)
X-Factor °	Mean (SD)	-33.49 (8.53)	-35.00 (9.71)	-32.94 (10.60)
X-Factor Stretch °	Mean (SD)	-15.97 (6.58)	-15.21 (6.48)	-18.09 (9.62)
Backswing Hip Drop cm	Mean (SD)	-2.67 (2.10)	-3.09 (1.49)	-2.42 (1.90)
Backswing Hip Sway cm	Mean (SD)	0.63 (3.26)	1.45 (3.76)	1.91 (3.77)
Downswing Hip Turn ° (Impact Zone)	Mean (SD)	36.64 (10.89)	37.62 (11.12)	40.70 (10.75)
Downswing Hip Tilt Lateral Flexion °	Mean (SD)	9.88 (4.52)	9.91 (4.55)	10.55 (6.28)
Downswing Hip Bend °	Mean (SD)	7.82 (12.46)	5.03 (11.60)	7.21 (11.49)
Downswing Hip Sway (Address to Impact) cm	Mean (SD)	-11.66 (4.49)	-11.77 (3.37)	-11.47 (5.00)
Downswing Hip Thrust cm	Mean (SD)	1.23 (3.19)	1.98 (2.70)	1.27 (2.24)
Downswing Hip Speed deg/sec	Mean (SD)	431.52 (72.28)	420.82 (71.35)	435.36 (64.47)

Results not adjusted for statistically significant differences in the baseline

Table H.7: Results from the Third ROM Assessment.

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Left Hip Extension °	Mean (SD)	1.54 (6.55)	3.24 (5.97)	2.38 (6.47)
Right Hip Extension °	Mean (SD)	-0.50 (8.16)	-0.28 (5.71)	1.07 (6.60)
Right Lumbar Spine Rotation°	Mean (SD)	11.36 (2.78)	11.84 (3.21)	11.14 (3.23)
Left Lumbar Spine Rotation °	Mean (SD)	11.07 (3.10)	11.80 (3.58)	10.48 (2.98)
Right Lumbar Spine Lateral Flexion °	Mean (SD)	29.04 (4.74)	29.20 (5.91)	30.59 (4.85)
Left Lumbar Spine Lateral Flexion °	Mean (SD)	29.36 (4.31)	30.00 (7.49)	29.93 (5.49)

Results not adjusted for statistically significant differences in the baseline

Table H.8: Results from the Third Assessment of ball flight variables.

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Distance km/h	Mean (SD)	156.25 (10.73)	151.40 (14.53)	154.52 (16.45)
Club Head Speed km/h	Mean (SD)	153.61 (8.28)	149.48 (9.74)	151.86 (10.15)
Smash Ratio	Mean (SD)	1.26 (0.06)	1.26 (0.06)	1.26 (0.04)

Results not adjusted for statistically significant differences in the baseline

Table H.9: Results from the Third Assessment. of Swing Biomechanics

Variable	Statistic	Control (Group3) n=28	Stretch (Group1) n=25	Ball (Group2) n=29
Hip Alignment at Address°	Mean (SD)	1.04 (5.78)	1.12 (5.28)	-0.48 (6.10)
Pelvic bending (AP) °	Mean (SD)	23.61 (13.30)	19.92 (9.03)	24.66 (9.22)
Pelvic Tilting Lateral Flexion at Address °	Mean (SD)	-1.21 (3.29)	-0.36 (2.71)	-0.83 (2.78)
Backswing Hip Turn °	Mean (SD)	-45.93 (8.95)	-44.12 (9.73)	-46.21 (12.20)
X-Factor °	Mean (SD)	-34.04 (8.30)	-34.20 (7.19)	-30.59 (8.33)
X-Factor Stretch °	Mean (SD)	-15.18 (6.77)	-15.08 (6.51)	-18.76 (7.88)
Backswing Hip Drop cm	Mean (SD)	-2.66 (1.80)	-2.96 (1.60)	-2.66 (1.78)
Backswing Hip Sway cm	Mean (SD)	0.16 (3.39)	1.40 (3.66)	1.65 (3.53)
Downswing Hip Turn ° (Impact Zone)	Mean (SD)	37.82 (13.53)	36.32 (12.11)	41.00 (11.04)
Downswing Hip Tilt Lateral Flexion °	Mean (SD)	10.96 (5.45)	10.52 (3.04)	11.90 (4.56)
Downswing Hip Bend °	Mean (SD)	4.25 (13.44)	2.28 (8.58)	3.66 (7.39)
Downswing Hip Sway (Address to Impact) cm	Mean (SD)	-11.97 (4.22)	-11.19 (4.19)	-11.65 (4.89)
Downswing Hip Thrust cm	Mean (SD)	1.99 (2.70)	2.00 (2.99)	1.06 (2.11)
Downswing Hip Speed deg/sec	Mean (SD)	423.57 (59.33)	429.24 (139.76)	454.17 (75.03)

Results not adjusted for statistically significant differences in the baseline

APPENDIX I: ETHICAL CLEARANCE CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Quinn

CLEARANCE CERTIFICATE — **PROTOCOL NUMBER M080636**

PROJECT — A Randomised control trial on elite golfers Comparing the effect of myofascial trigger point release with stretching vs only stretching on range of motion & performance

INVESTIGATORS — Mrs S-L Quinn

DEPARTMENT — Physiotherapy

DATE CONSIDERED — 08.06.27

DECISION OF THE COMMITTEE* — Approved unconditionally

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

DATE 08.10.14 **CHAIRPERSON** ....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Ms W Wood

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 J: RELEASE OF MEDICAL INFORMATION FORM

I, ________________________________ ID(_________________________), hereby consent to the release of my medical details from the study "“The Effect of Manual Therapy and Exercise on Range of Motion, Biomechanics, Club Performances and Ball Flight- a Randomised Controlled Trial on Elite Golfers.” to my golf coach/ golf academy _ _________________________________.

____

SIGNED (Participant)

____

SIGNED (Researcher)