THE CORRELATION BETWEEN PASSIVE AND DYNAMIC ROTATION IN BOTH THE LEAD AND TRAIL HIPS OF HEALTHY YOUNG ADULT MALE GOLFERS DURING A GOLF SWING

By

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ABSTRACT

Introduction

The golf swing is a complex, sequenced movement of body segments. This movement is smooth and well timed and is referred to as the kinematic golf sequence. This kinematic sequence illustrates the rotational speed, which occurs between the upper and lower body segments.

Hip rotation plays an integral part to a sound kinematic sequence by providing a pivotal point between the upper and lower body segments, ensuring a synchronised golf swing. Hip rotation kinematics during a golf swing has received relatively little attention compared to other body segments' movements. However, clinicians need to have a clear understanding of the rotational contribution that each hip make during golf swing in order to enhance the athlete's performance and reduce the risk of injury.

The aim of this descriptive research project was to obtain and investigate the total passive and total dynamic rotation range of movement in both the lead and trail hips of healthy, young adult, male golfers.

Methodology

Seven, low handicapped, male golfers between the ages of 18 and 40 years were randomly selected in the Western Cape region from areas surrounding Stellenbosch University's Tygerberg campus. A questionnaire gathered participant demographics that determined participatory eligibility.

A preliminary reliability study established a baseline measurement for passive total articular hip rotation. Seat-adjusted total passive hip rotation ranges of motion (ROM) measurements were collected with a hand-held inclinometer.

Dynamic total hip rotation kinematic data was captured during a golf swing with an 8-camera video analysis system (VICON). Data analyses were performed with Statistica version 10. Hand-held inclinometer intra-rater reliability was determined with a two-way interclass correlation, standard error of measurement and a 95% confidence interval level. A Spearman correlation coefficient determined correlation between the total passive and total dynamic rotation range of movement in both the lead and trail hips.

Results

Passive intra-rater reliability was reported as 0.81 (95% CI: 0.46-0.96). The total average passive articular range between the lead (62.1° ±6.4°) and trail hip (61.4° ±3.8°) did not report any significant difference (p=0.8). The total average dynamic golf swing articular range between the lead (29° ± 6.5°) and trail hip (35.° ±7.8°), was reported as significantly (*p=0.04)* asymmetric. The findings also demonstrated a positive correlation between the passive and dynamic total articular range in a lead hip, whereas a negative correlation was reported in a trail hip. During the golf swing the lead hip utilised 46.4%(± 8) of the total passive available hip rotation, whereas the trail hip utilised 58.8% (±13.2).

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Discussion and Conclusions

The findings of this study show that, the passive rotation ROM in a hip (LH=62°; TH=61°) of a golf player does not exceed the available range it has during a golf swing. The golfer's hip utilises 46% of the available passive range of movement in the lead hip and 59% in the trail hip. In the clinical field careful consideration should be given to the motivation behind mobilizing, treating or stretching the hips of a golf player. These findings can be incorporated in future research on the relationship between hip-rotation ROM and reduction in the incidence of injuries amongst golfers.

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OPSOMMING

Inleiding

Die gholfswaai is n komplekse, opeenvolgende beweging van verskeie liggaamsegmente. Hierdie gladde opeenvolgende bewegings word die kinematiese gholfpatron genoem. Hierdie kinematiese opeenvolgende bewegings bied 'n illustrastrasie van die rotasiespoed waarteen die beweging tussen die boonste en onderste liggaamsegmente plaasvind.

Heuprotasie speel 'n deurslaggewende rol in hierdie glad verlopende kinematiese proses. Dit dien as 'n spilpunt tussend die boonste en onderste kwadrant, wat op sy beurt weer 'n gesinkroniseerde gholfswaai verseker. Die heuprotasie kinamtieka tydens n gholfswaai het relatief minder aandag ontvang in vergelyking met ander liggaamsegmente. Klinici moet instaat gestel word om 'n duidelike begrip aangaande die bydrae wat heuprotasie tydens 'n golfswaai lewer, te ontwikkel. Die atleet se prestasie kan sodoende verbeter word, en die risiko tot beserings kan ook sodoende voorkom word.

Die doel van hierdie beskrywende navorsingsprojek was om te bepaal wat die totale passiewe en die totale dinamies rotasie omvang van die leidende en volgende heupe van gesonde jong mans wat gholf speel, te ondersoek.

Metodologie

Sewe gholf-geskoolde manlike gholf spelers met 'n lae voorgee en tussen die ouderdom van 18 en 40 jaar is ewekansig gekies. Hierdie kandidate is gekies uit die omliggende gebiede van die Stellenbosch Tygerberg kampus in die Wes-Kaap waar hulle relatief naby woonagtig was. 'n Vraelys is aangewend om demografiese eienskappe van elke deelnemer in te samel.

Hierdie inligting wat deur die vraelys bekom is, is gebruik om te bepaal of die deelnemers in aanmerking is vir die studie. 'n Voorlopige, intra-meter betroubaarheidstudie is gedoen vir passiewe, totale artikulêre heuprotasie-metings wat met 'n hand hanteerbare hoek meter geneem is. 'n Algemene fisiese ondersoek is in die biomeganiese labaratorium afgehandel om te bepaal of die deelnemers geskik is vir die toetse. Sit-aangepaste passiewe totale hip rotasie beweging metings was ingesamel met 'n hand hanteerbare hoek meter.

Intra-meter betroubaarheid is bepaal met 'n twee-rigting interklas korrelasie, standaard foutmeting en 'n 95% vertroue interval vlak.

Dinamiese totale heup kinematiese rotasiedata is afgeneem met 'n hoë-spoed 3-D videografiestelsel (VICON) tydens 'n gholfswaai. Data-ontleding is bereken met 'n Statistica weergawe 10. Die gemiddelde en Spearman korrelasie koëffisiënt is gebruik as aanwysers van verspreiding.

Resultate

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Passiewe inter-meter betroubaarheid word geraporteer as 0.81 (95% KI: 0.46-0.96). Die resultate dui op ’n onbeduidende totale passiewe artikulêre reeks verskille tussen die leidende (voorste) (62.1 ± 6.4 °) en volgende (agterste) heupe (61.4 ° ± 3.8 °). ’n Beduidende totale dinamiese artikulêre reeks van die leidende (29 ° ± 6.5 °) en volgende heupe (35.9 ° ± 7.8 °) is tydens die gholfswaai bereik.

Verdere resultate toon ’n positiewe korrelasie tussen die passiewe en dinamiese totale artikulêre reeks in die leidende heup, terwyl ’n negatiewe korrelasie gerapporteer word vir die volgende (agterste) heup. Tydens ’n gholfswaai gebruik die leidende heup 46.4% (± 8%) van die totale passiewe beskikbaar heuprotasie, terwyl die opvolgende (agterste) heup 58.8% (± 13.2%) aanwend.

Bespreking en gevolgtrekking

Die bevindinge van hierdie studie toon dat tydens ’n gholfswaai, ’n gesonde gholfspeler nie die beskikbare passiewe beweging wat in sy heup bestaan oorskry nie. Slegs 46.4% van die beskikbare passiewe beweging in sy leidende heup word gebruik, en 58.8% van sy agterste heup. Die klinisie moet deeglike oorweging gegee word aan die motivering agter die mobilisering, strekke en die behandeling van die heupe van ’n gholfspeler. Hierdie bevindings kan in toekomstige navorsing geimplimenteer word om die verhouding wat tussen die omvange vand heuprotasie bestaan te ondersoek. Die voorkoming van moontlike toekomstige beserings in gholfspelers kan ook verhoed word.

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LIST OF ACRONYMS AND ABBREVIATIONS

A.A.O.S	American Academy Of Orthopaedic And Surgery
DA	Data Analyst
ER	External Rotation Of The Hip Joint
FAI	Femoral Acetabular Impingement
H.E.R.C	Health Ethical Research Council
HC	Handicap
IR	Internal Rotation Of The Hip Joint
LBP	Low Back Pain
LH	Lead Hip/ Front Hip/ Dominant Hip
LR/ER	Lateral Rotation /External Rotation
M.R.C	Medical Research Council
MR/IR	Medial Rotation/Internal Rotation
APGA	American Professional Golf Association
PI	Primary Investigator
PM	Principal Marker
ROM	Range Of Movement
S.A.G.A	South African Golf Association
S.U.	Stellenbosch University
TAR	Total Articular Range
TH	Trail Hip/ Back Hip/ Non-Dominant Hip
VICON	Video Confirmation 3-D-System
W.G.S.A	Women's Golf South Africa
WB	Weight Bearing Section

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DEFINITIONS AND GLOSSARY

Address posture	A posture a golfer adopts when he is going to hit a ball on the green.
Anthropometric	Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle and adipose (fat) tissue.
Down-the-line view	The direction of ball flight seen when standing behind a golfer
Golf Club	The apparatus used to hit a specialised ball. There are many kinds and style
Lead hip	The hip facing the down-the –line direction of the golf address posture, thus the left hip of a right-handed golfer, and the right hip of a left-handed golfer.
Phases of a golf-swing	Address; take away; backswing; top of back swing; transition; down swing; ball impact; early follow through; finish.
Primary golf spine angle	Address posture 45° hip forward flexion
Prone	Lying facedown
Secondary spine angle	Address posture at 16° upper trunk side bend to accommodate the lower hand on the club depending on the club being used
Supine	Lying face down
Trail hip	The unilateral hip, thus the hip on the same side of the dominant swing hand of the golfer.

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CHAPTER 1: INTRODUCTION

Golf is a pleasurable popular outdoor sport, which can be played with a diverse profile of athletic ability and may be enjoyed for a number of years (Cabri, Sousa, Kots, & Barreiros, 2009). The favourable South African climate encourages its current 164 000-registered golf players to train throughout the year (SAGA, 2007). This relatively small country with a population of 50 million residents produces 1% of the global professional players. In October 2009, Golf was accepted as an Olympic sport for 2016 (Wikipedia foundation inc, June 2013). This has encouraged a growing trend of young adolescent golfers to take up golf with a parent or family member. The young enthusiastic golfer is then coached by the member and subsequently may develop poor swing mechanics or injuries due to incorrect neuromuscular training (LTAD, 2012; Youth Sport Performance, 2012; Sportcentric, 2012).

The golf swing is a sequence of complex biomechanical movements. This relatively smooth and well-timed movement of body segments occurring during a golf swing is referred to as a kinematic sequence. The primary movement plane, in which these kinematic sequences occur, is called the transverse plane or rotational plane. This is due to the relative position of the body facing the ball at the start of the swing, and is named after the address posture. From an address posture the next phase, the backswing, follows in order to reach the top of the swing. The downswing phase then follows so that the ball is propelled towards the green. This kinematic sequence demonstrates the rotational speed which occurs between the arms, thorax and lumbo-pelvic unit, and therefore reflects the high level of skill that a golf swing demands.

Hip rotation is integral to a sound overall kinematic sequence (Hume, Keogh, & Reid, 2005; Healy et al., 2011). The sequence is divided into two sections. A slow passive backswing (0.8-1 second) in one direction followed by a very dynamic and ballistic faster downswing (0.1-1.3 seconds) in the opposite direction. The hip joint acts as the pivot point between the upper and lower body segments ensuring the synchronized movement between the two directions.

Reduced hip rotation may be related to the high prevalence of low back pain (LBP), which affects one in three golfers. It has been proposed that a reduced hip ROM may place an increased strain on the lower back (Gulgin, 2012b; Harris-Hayes, Sahrmann, & Van Dillen, 2009; Murray, Birley, Twycross-Lewis, & Morrissey, 2009). Murray (2009) illustrated that golfers with back pain have reduced passive and active front hip (lead hip/LH) medial rotation (MR). Asymmetrical hip rotation range is also associated with golfers with low back pain, and could possibly be due to repeated rotational exposure during rotational sports (Gulgin, 2005; Van Dillen, Bloom, Gombatto, & Susco, 2008).

Athletes who regularly partake in a sport that demands repetitive rotation between the trunk and pelvis have limited lead hip (LH) total rotation compared to that of the back hip (trail hip/TH) (Van Dillen et al., 2008). To explore the relationship between hip rotation and LBP it is necessary to understand the regular amount of hip rotation that occurs during a golf swing. A significantly reduced hip internal and total articular range (TAR) was found in both the active and passive hip range of movement of non-golfing-athletes' dominant limb (Almeida,

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de Souza, Sano, Saccol & Cohen, 2012). Therefore, in order to understand the hip kinematics during a golf swing, a normative range of movement in the hip of a golfer has to be established.

Although not yet reported in studies on male golfers, repetitive hip rotation related movement-demands have been investigated in other rotation-related strenuous sports types e.g. judo, racket ball, tennis and squash (Van Dillen, Gombatto, Collins, Engsberg, & Sahrmann, 2007; Van Dillen et al., 2008).

The incidence of low back pain in professional male golfers is reported to be as high as 34% of the total golf-related injuries (Almeida, de Souza, Sano, Saccol, & Cohen, 2012; Cabri et al., 2009; Gosheger, Greshake, Liem, Ludwig, & Winkelmann, 2003; H. R. Gulgin, 2012b; McHardy, 2006). Attention has been given to American Ladies Professional Golfers (ALPG) with an average age of 32 (±6) years (H. R. Gulgin & Armstrong, 2008) with back pain. Passive rotational side-to-side difference of 5° or more was present in this back pain population. To our knowledge specific information regarding hip rotation in a male golfing population has not been studied.

Hip joint kinematics in golf has received relatively little attention compared to that of other body segments such as the shoulder, thorax and pelvis. However, there is a need for clinicians and sports scientists to have a clear understanding of the relative contribution of the hip rotation during the golf swing. This information should be useful in the rehabilitation of a golfer, to either enhance their performance or reduce the risk of injury. In addition this should allow the determination of a baseline hip rotation ROM for use in future studies on the prevention of lower back pain. Lower back pain is the most common injury presently identified in professional golfers (Gosheger et al., 2003).

Clinically, total passive and active non-weight bearing hip rotation range of movement is often utilised to estimate if a golfer has adequate hip range for proper execution of the golf swing. Traditional methods to measure hip range in sitting, supine or prone positions are reliable between test occasions and measurers. However, to date it is unknown whether this clinical method for hip range assessment is also a valid assessment of the amount of rotation during the actual golf swing.

Coaches and clinicians should have knowledge of the typical range of hip rotation required during the golf swing. It should also be of value to understand the correlation between clinical hip rotation assessments of the lead and trail hip and the amount of dynamic hip movement displayed during the swing. To our knowledge, this issue has not previously been addressed adequately and therefore the aim of this study was to investigate the difference between the passive and dynamic rotation range of both the lead and trail hip of healthy young adult male golfers.

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1.1 HYPOTHESIS

1.1.1 The null hypothesis (H0)

There is no difference when the passive and dynamic hip rotation of both the lead and trail hip is compared in a healthy young adult golfer, measured when seated and during a golf swing.

1.1.2 The alternative hypothesis (H1)

There is a clinically applicable outcome when comparing the total motion measured during a passive and a dynamic hip rotation in young adult golfers during a seat-adjusted inclinometer measurement to a Vicon swing analysis measurement.

The thesis is presented according to the faculty's article format guidelines.

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CHAPTER 2: THE LITERATURE REVIEW

2.1 INTRODUCTION

A comprehensive search of the literature was conducted using the following databases: CINAHL (Cumulative Index to Nursing and Allied Health Literature), EBSCO-host, Google Scholar, MD Consult, ProQuest, PubMed, Web of Science and ScienceDirect. The search terms used were: hip kinematics, hip rotations, golf, injury*, swing faults, complexities of golf movements, pelvic rotations, rotational sport and low back pain. Search term limitations applied were: humans; the English language; age groups of children, adolescents, young adults and adults; and a 1982 to current literature time frame was specified.

Golf is considered a rotation-related sport and the literature confirms that the hip rotation range of motion is limited in subjects who participate in rotation-related sport, which may be associated with pain in the lower back (Almeida et al., 2012; Gluck, Bendo, & Spivak, 2008; Harris-Hayes et al., 2009; Murray et al., 2009; Van Dillen et al., 2008). In this chapter the biomechanics of the hip during a golf swing is discussed while the anatomy of the hip is briefly described. The available literature revealed that hip rotation in golfers has been limited. An understanding of hip rotation in a golf swing should give direction for future research projects.

2.2 INCIDENCE OF GOLF INJURIES

Golf is a non-contact sport, yet injuries occur. The incidence of golf injuries has not yet received the attention it deserves, and the cause of these injuries has been poorly researched (Cabri et al., 2009; Fradkin, 2005; Gosheger et al., 2003). The injuries have been described according to the anatomical site of the lesion, and mainly conducted on amateur and/or professional golf players (McHardy & Pollard, 2005b: 135; McHardy, 2006: 171; McHardy, Pollard & Luo, 2007: 1354) leaving injuries sustained by the young lower limit handicap golfers unexplored.

A professional golfer could lose up to 69 days of play per annum due to LPB. Epidemiological reviews of Australian golfers (Age: 18-30 years; handicap: 14) concluded that the incidence of LBP in a normal male golfing population was between 25% and 36%, with 23.7% indicating it was most likely the result of the way they swing (McHardy, Pollard & Luo, 2006: 171). Therefore once a young golf player reaches amateur level, he may have already sustained a LBP syndrome (Gulgin & Armstrong, 2008; Gulgin, 2012b). However information concerning any relationships between LBP and possible hip-related injuries, is currently lacking.

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* is used to describe the various search terms of a word

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A retrospective study has identified the most prominent anatomical locations of injuries as being the back (36%), wrist (16%), elbow (11%), knee (10%) and shoulder (7%) (Batt, 1992). Similarly, McCarroll (1982) reported main injury sites as the lower back (35%), elbow (33%), hand and wrist (20%), shoulder (12%) and knee (9%). These injured players sought the services of physiotherapists as their initial choice of treatment (Fradkin, 2005), which leaves the physiotherapist as a first contact point for managing the injuries. Interestingly, hip injuries listed in studies between 1998 and 2003 (Gosheger et al., 2003; McCarroll & Gioe, 1982; Theriault & Lachance, 1998) did not discuss the aetiology of any hip injuries. McCarroll (1982) mentioned that female golfers experienced hip trochanteric bursitis when they walked on uneven surfaces regularly, but no specific possible causes were discussed. A case study published on two older professional golfers who recently underwent acetabular labral tear surgery, discussed the possibility of repetitive strain forces on the hip joint (H. R. Gulgin, 2012b), while Vad (2004) concluded that lumbar spine extension and lead hip internal and external rotation correlated to repetitive LBP in professional golfers. According to the literature reviewed, only five authors have studied the influence that hip rotation could have on the lower back of golfers (McHardy & Pollard, 2005; Murray et al., 2009; Gluck et al., 2008; H. R. Gulgin & Armstrong, 2008; Vad et al., 2004), although the total passive or dynamic ROM norm in a golfer's hip has not been discussed.

In general, factors of overuse and poor swing mechanics appear to be the cause of golf injuries (Gosheger et al., 2003)Understanding the biomechanics of a golf swing should shed light on possible causes of these golf injuries.

2.3 BIOMECHANICS OF THE GOLF SWING

Golf biomechanics concerns the understanding of the principles and techniques of the structure and function of the movement of the golf swing. The purpose of the assessment of the kinesiology of a golf swing is to improve a subject's performance, and for this particular study, it is to identify the relationships that exist between the passive and dynamic hip rotation.

The golf swing, due to the evolvement of technology in equipment, underwent changes in the 1960s under the legendary leadership of professional golfer Jack Nicklaus, resulting in what was known as the "classic" swing, changing it to that which is now referred to as the "modern" swing. During a modern swing a stiffer metal or graphite club-shaft is utilised, rather than the older flexible hickory club-shaft, which was previously swung with the larger-pelvic-rotation-classic-style backswing. The stiffer shaft has its own implications, but they are outside the scope of this study. For the modern golf swing, Professional Golf Association (PGA) instructors and swing researchers emphasize the importance of a rotational separation between the pelvis and thorax, especially at the top of the backswing, where it creates a rotational angle between the hips and shoulders called the X-factor (Bechler, Jobe, Pink, Perry, & Ruwe, 1995; Cochran & Stobbs, 1968; Gluck et al., 2008; Healy et al., 2011; Hume et al., 2005; Joyce, Burnett, & Ball, 2010; Meister et al., 2011; McTeigue, Lamb, Mottram, & Pirozzolo, 1994; Myers et al., 2008; Zheng, Barrentine, Fleisig, & Andrews, 2008). The X-factor strives to improve the accuracy, power and distance behind the modern golf swing. Therefore it is essential to understand the contribution of each individual hip's rotation during the golf swing.

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The kinematics of the modern golf swing are divided into distinct phases. A consistent starting position, an upward phase when getting into a ready-to-hit-the-ball position, a brief pause period at the top of the backswing named the transition phase or period, a downward phase destined to propel the ball forward, and ending the swing with a finishing position. A short description of each phase is now discussed.

The starting or set-up position is described as the initial *address* phase; no movement occurs in this phase and the body faces the ball. The *backswing* phase follows, where the club is brought from the set-up position on a continuum pathway until the clubface is brought to the back of the head and the shaft is swung behind the ear parallel to the ground. The *downswing* phase is then initiated by the lead hip, in an attempt to transfer the energy created during the backswing to the club and eventually propel the ball towards the hole. The moment where the club impacts the ball is described as "ball-impact." Once impact has occurred, the club continues its swing path towards the *follow through* phase, which is reached once the club shaft is beyond the parallel behind the golfer's ear of the lead hip.

In the *modern swing* a large torque occurs between the moving upper-body and the relatively stationary lower-body whilst heading for the backswing, and again after movement is initiated in the downswing. The swing sequence is initiated by the movement of the legs and hips, followed by the upper body and arms. The importance of the hip mechanics lies within the initiation of the kinematic-sequence, which is led by the *front hip facing the target (lead hip)* during the downswing (McHardy, 2006). Amateurs reached 10% more peak muscle activity, 80% more lateral spine bending, and 50% more torque during their golf swing than their professional counterparts. Peak comprehensive joint load towards the lead hip during a golf swing is known to be 8 times that of bodyweight (Hume et al., 2005). During the address posture 50-60% of the body weight is transferred onto the trail hip. The trunk will be flexed in line with a 45° angle of hip flexion, whilst the knees are comfortably flexed between 20-25°. From a sagittal view, this angle between the thighs and trunk will be called the primary spine angle. Whilst preparing for the backswing, the limited pelvic rotation (47-55°) towards the trail hip is preferably left as centred as possible while the weight distributed is in favour of the trail hip at a rate of 60-40%. The kinetic forces in the pelvis create internal rotation of the femur in a weight-bearing position of the trail hip, and external rotation of the femur on the pelvis in the lead hip. McHardy (2005) supported the findings of Hume (2005: 429) in that the kinetic forces which occur in the golfers hip joint is a direct result of the novice's swing mechanics.

A secondary spine angle is created as a result of a slight lateral side bending in the spine along with scapular depression and inferior rotation (16°) of the hand holding the club lower than the other hand. According to Hume (2005: 429) the secondary spine angle is thought to be the position generating the optimal power to maintain control over a swing. Mathematical models have identified increased lateral flexion and torsional forces on L3 and L4 segments, suggesting that it could be a source of injury (Parziale & Mallon, 2006). If, for example, the rotation of the trail hip was inadequate, the pelvis would tilt posteriorly from the described horizontal position and the knee would extend, resulting in spine angle changes that would change the mechanical forces of the hip-lumbar-spine-complex. For the purpose of this study, the golf swing ranges from the address posture to the end of the follow through phase. The total articular range (TAR) of both the lead and trail hips will be represented by the full golf swing.

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Gulgin (2012a)reported that there was asymmetry between the lead hip and trail hip rotation ROM when measuring the hip rotation in a weight bearing position. A slight decrease in lead hip weight bearing internal rotation was noted, which could have an impact on the lower back structures, although the hip doesn't exceed the available hip rotation ROM. If an amateur golfer is predisposed to injuries due to poor swing mechanics, the young and upcoming golfer is even more likely to sustain injuries, as their swings are more inconsistent and they have a higher frequency training rate (H. Gulgin, Armstrong, & Gribble, 2010).

2.3.1 Arthrokinematics of the hip joint

The hip joint consists of bony articular surfaces shaped in a deeply recessed ball-and-socket joint (Roy, 2009). It is also known as the coxa-femoral joint, which comprises the pelvic acetabulum and the head of the femoral bone (Netter, 2010). The joint is surrounded by a collagen structure comprising a thick joint capsule, ligaments and muscles. The muscles have a neuromuscular tone, which is mainly achieved as a result of exercise and training, and could influence the range of hip rotation (Bohannon, Vigneault, & Rizzo, 2008; Gannon & Bird, 1999). The synovial ball and socket joint has three-degrees of freedom allowing movement about three axis. The acetabulum is deepened by a fibro-cartilaginous labrum.

Motion permitted at the joint are flexion-extension in the sagittal plane occurring around a medial-lateral axis, abduction-adduction in the frontal plane occurring around an anterior-posterior axis, and internal-external rotation in the transverse plane occurring around a longitudinal axis. In this study hip rotation is described as the number of degrees a lower limb rotates along its long-axis. The primary function of the hip is to support the weight of the head, arms and trunk, although the structural adaptations are extensive in support of the functional relevance (Kapandji, 1974). During open kinematic chain movement the convex femoral head glides on a concave acetabulum in direct opposition to movement of the shaft of the femur (Kapandji, 1974). For example, during external rotation the femoral head glides anteriorly, while during internal rotation the femoral head glides posteriorly. During a golf swing the feet are fixed on the ground and the hip functions as a closed kinetic-chain during the side-to-side weight transfer motion. The closed chain transfers the forces up the trunk in order to transfer the energy gained to the club head to propel the ball forward towards the target.

2.3.2 Anatomical abnormalities in a hip joint.

Intra-articular hip joint abnormalities exist in humans. These are distinguished as labral tears, loose bodies, chondral lesions, ligamentum teres tears and femoral acetabular impingement syndrome (FAI) (Roy, 2009). The FAI-syndrome is divided into acetabular labral tear subtypes that are dependent on the femoral-head-neck offset and named the 'pincer-FAI' or 'cam-FAI'. The hip, spine and pelvis also functions as a kinetic-unit, and if a dysfunction is present in one of these units, for example a rotational lack of motion in the hip-joint, it could increase the risk of injury in these segments.

2.4 NORMAL HIP ROTATION RANGE OF MOTION

2.4.1 Passive hip rotation ROM in children.

In order to define the hip rotation in adults, the child's hip ROM and the effect that age has on hip joints need to be considered. As there is currently a lack of information on standardised adult hip rotation, understanding the

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changes that an adolescent hip undergoes during growth will ultimately influence the understanding of adult hip rotation.

In a cohort-study standardising the norm value for hip rotation ROM in children (Sankar, Laird, & Baldwin, 2012) measured 504 hips of boys and girls. Abnormal range of motion, defined as the ROM difference between an affected joint compared to the non-affected joint, is a common indicator of underlying pathology. Therefore, a norm ROM for a population is of great value in early detection of possible underlying musculoskeletal dysfunctions.

While underlying musculoskeletal conditions, systemic condition, and lower extremity injuries were excluded from the Sankar (2012) subject group, goniometer passive supine and prone hip measurements were reported to be 75 ° of rotation. In the male subjects a decline in hip rotation was specifically noted with age (Sankar et al., 2012). Roach (1991) studied the relationship that exists between age and active hip ROM, also reporting a direct correlation. Rotation ROM decreased by 15° to 20° per decade in the first two decades, and 5° per decade thereafter. However, research on children's' hip ROM gathered by Boone (1979) revealed that the hip rotation differed ±10° more than the Sankar (2012) study. The total hip rotation in Sankar (2012) was reported as 100.8°. In the current literature no evidence for active ROM measurements in children could be found.

2.4.2 Passive and active hip rotation ROM in adults.

In the early eighties there were limited clinical data for adult joint range of motion, and the source of reliable information at the time was the 1965 edition of the American Academy of Orthopaedic Surgeons. The accepted norm for adult passive hip rotation was IR=35° and ER=48° (Roaas, 1982), leaving passive total rotation range at 83°. Boone (1979), considered all mechanical and recreation activities imposing on the daily hip activities of 109 male participants (20-50 yrs.), while analysing the effect of age on active adult hip joint ROM and recorded both hips passive rotation ROM as 88.6° (goniometer). In a study by Roaas (1982), passive hip, knee and ankle joint ROM was measured in 210 Swedish male subjects, establishing reliable information on the passive total hip rotation as 66°. Furthermore, in an inter-tool reliability study (electronic inclinometer and the goniometer) by Bierma-Zeinstra (1998), a seated passive rotation ROM of 76.4° was recorded in nine healthy subjects aged 21 to 43 years. An active goniometer ROM in supine (69.1°) and in prone (93.3°) was also recorded, but active WB ROM was not studied.

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A study investigating the hip rotator muscle strength in 18 voluntary male subjects aged 27 ± 10.6 years (Cibulka et al., 2010), reported prone hip goniometer rotation measurements as 105.7°. Prather (2010) investigated passive hip ROM and reported prone measurements to be 69.4° and supine measurements to be 76°. Kouyoumdjian (2012) utilised a photographic method, to assess 120 healthy caucasian adults between the ages of 20 to 60 years, and reported the passive seated hip rotation to be 78.5°.

Form the literature reviewed, it is evident that adults' passive total hip rotation varies widely. It is strongly influenced by the choice of instrument as well as the placement choice of the measured joint. Little evidence is available on the standard passive measurement in a golfer's hip rotation.

2.5 THE RELATIONSHIP BETWEEN THE HIP ROTATION AND LOWER BACK PAIN

Most golfers are exposed to long hours of training to improve their golf swing, and many do so from a young age. In this section the relationship between the lower spine and the range limitations in the hip, as well as the asymmetry that develops between a golfer's left and right hip will be discussed. Studies since the early eighties have ranged from the effect that hip ROM had on lumbar spine kinetics, to investigations in hip joint soft tissue structures, hip flexion contractures and osteoarthritis (Thurston, 1985). Only later was a relationship established which identified possible factors in the hip joint rotation that would influence the lower lumbar spine.

Moreside (2012) investigated three different exercise interventions (core muscle stabilisation, myofascial stretching and motor training), analysing the effect that exercise would have on the soft tissue structures influencing the hip ROM. These results indicated that improving either hip muscle flexibility, or the endurance of the core strength muscles doesn't transfer into functional movement pattern changes. Kujala (1992) studied the effect that shortened soft tissue components had on a hip and spine and discovered that young adolescent athletes (aged 10-13 years) exposed to long hours of training (> 493 minutes per week) would be predisposed to LBP.

Long hours of training are often a factor when young golfers are establishing their swing techniques. Offierski's investigation (1983), using a two-way analysis of variance, indicated that muscle stretches aimed at the upper body components in addition to hip joint components, had as much as a 56% improvement on hip joint range of motion in young men. A study by Lee (1997) supported this finding, concluding from their investigation that associated hip flexor muscle tightness in subjects with a history of LBP, had a 28% accumulative incidence to pain. These findings became important as the influence of the upper body on the lower body became apparent.

In more recent studies, a relationship was established between LBP and hip-rotation asymmetry as the left and right-sided hip rotation measurements were compared with each other in amateur and professional golfers (Almeida et al., 2012; Evans, Refshauge, Adams, & Aliprandi, 2005; Gulgin, 2005; Gulgin, 2012b; H. R. Gulgin & Armstrong, 2008; Murray et al., 2009; Vad et al., 2004; Van Dillen et al., 2007). There is a possibility that the effect of the asymmetry between the lead and trail hip range may lead to low magnitude loading of the surrounding soft tissue structures in the hip and spine, and that this could alter movement patterns in a golfer resulting in the chronic LBP (Ellison, Rose, & Sahrmann, 1990; Gulgin & Armstrong, 2008; Gulgin, Armstrong, & Gribble, 2009; Harris-Hayes et al., 2009). Unfortunately, neither the cause of this hip-joint

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motion asymmetry nor the value of the range is yet established. In a preliminary study that was conducted on young elite golfers, it was established that a golfer needed a larger muscle mass or a heavier build to protect their lumbar spine from injury (Evans et al., 2005).

Since 2009, investigations have focused on the relationship between the hip rotation and LBP, although sport-specific research on golfers was limited. In a study by Ellison (1990: 537) the importance of the function of the hip on normal lumbar spine kinetics was investigated. A group of normal, healthy individuals were examined with regards to their ability to rotate their hips. Three patterns of hip rotation were identified after physical examination. These hip rotation patterns were divided into three groups of [ER=IR], [ER>IR], [ER<IR] and as expected, only 27% of the subjects reported to have equal hip rotation [ER=IR] (Ellison et al., 1990). The total hip rotation ROM was reported being less than 45° in the test subjects. In the subject group with LBP, there was a higher prevalence for a smaller hip internal rotation [IR<ER].

LBP was studied in athletes who partook in rotation-related sport (racquetball, squash, tennis and golf) and a special interest was taken in the relationship between the hip rotation and lower back pain (Van Dillen et al., 2008). When examining whether passive hip rotation was different between athletes with a history of LBP and those who do not experience pain, a significant total diminished value in hip rotation (p=0.35) was present in the pain group. In comparing the left hip to the right hip (side-to-side) more range asymmetry was present in the LBP athletes and in particular, the left total-hip ROM. These finding suggest that sport-specific directional demand may impose on the hip and trunk during regular activities.

Most studies have not distinguished between different kinds of low back pain. Van Dillen (2008) did classify LBP in this study. The classification consisted of four types: a) lumbar strain b) disk herniation c) sacroiliac joint dysfunction and d) avulsion fractures. This was an important guideline for future studies into the cause of the relationship between the relevant structures of the hip and spine. Further research proved that limited hip rotation ROM would increase low magnitude force on the hip-spine-pelvis-complex, specifically if the movement has to compensate for repetitive activities where the full range of motion is required in that unit. Similarly, passive hip-ER was significantly greater than the hip-IR on the unilateral side associated with lumbar pain symptoms in particularly signs associated with the sacral joint pain.

To our knowledge there are no published investigations available regarding active weight-bearing hip rotation other than that of Gulgin (2010). Prone goniometer measurements for passive hip rotation and standing VICON active hip rotation, as well as hip rotation velocities were investigated (Gulgin, 2005). Fifteen elite female golfers (19.6 ± 1.4 years) were examined. The anatomical limitation of hip rotation in 15 female age-matched controls (20.5 ± 1.7 years) was compared. Unfortunately the study did not specify if the control group played golf or any other sport. Hip velocities examined during the golf swing were collected with a video analysis system.

A clear understanding of the hip rotation action in the golf mechanics is a prerequisite for the interpretation of the results investigating hip rotation during a golf swing. The golf swing was divided into two main sections, the back swing and the downswing. In the backswing the lead hip experiences internal rotational forces while the trail hip experiences external forces, and this reverses in the downswing.

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The results of the passive ROM measurements demonstrated that the internal range of the right hip (trail hip) in a right-handed golfer is significantly (p=0.05) greater than that of the control group. The value of internal rotation was found to be 50.8° (± 8.4°) (H. R. Gulgin, 2005). It was further found that when comparing the side-to-side range of movement, the internal rotation of the trail hip is more than that of the lead hip, but that trail hip external rotation is less than that of the lead hip. Interestingly, when weight bearing active rotation was investigated, the external rotation on the trail hip also had a greater range measured at 59.9° (± 13.6°) in the female golfers. When active internal hip rotation (42.3° ± 8.4°) of a female golfer with low back pain is compared to the golf player without back pain, no difference in the internal rotation is noted between the two groups (Gulgin & Armstrong, 2008).

Kinematic data collection with the 3-D video analysis reported that the total active weight bearing (WB) hip joint range for the backswing and downswing collectively, was reported as 23.8° in the trail-hip, compared to the 42.7° measured in the left lead hip (Gulgin et al., 2009). The lead hip thus undergoes a higher velocity and utilises a larger range of motion than the trail hip. The results of the velocities measured for the hip during the swing demonstrate that during the down swing the lead hip utilises 87% of the available active WB internal rotation. The trail hip only utilises 25% of the available active WB external rotation range. The peak velocity for ER in the trail hip is reached at 85.2% of the downswing at a speed of -145.3° per second (± 68.0°), and the peak velocity for IR in the lead hip is reached at 89.1% of downswing at a speed of -227.8 (± 96.6°) per second.

A possible limitation to the Gulgin (2012) study was that a single custom-built driver was used for all the participants. This limits the natural swing of the golfer, who is more accustomed to his/her own driver. Further reports written by Gulgin found that female golfers had a lead-to trail hip degree difference of more than 5° for IR; as well as a lead-to trail hip differential of 5° or more for ER. These subjects were questioned prior to the data collection regarding back pain, hip pain, stretching routines and strength training routines at the time of the study. Seven of the subjects who reported to have a 5° lead-to trail hip range difference also reported to have back pain.

The prevalence of lower back pain in golfers and the relationship between the hip rotation and back pain was observed by Murray (2009). Passive and active hip rotation measurements were taken with an inclinometer in a supine position, rather than with a goniometer as in the study discussed by Gulgin (2005). The passive and active medial rotation in the lead-hip (LH) was significantly reduced by ±10° in the back pain group, compared to the control pain group. Measurements of the trail hip as well as external rotations measured in the lead hip were both found to be insignificant. These measurements were not taken during a golf swing but will be of great value for future projects.

A cross-sectional study was undertaken in athletes who partook in rotation-related sport (Harris-Hayes et al., 2009). The relationship between the hip and lower back pain was investigated for three possible influencing factors (activity demand, lower back pain classification and gender), which could be accountable for a hip-lower-back-pain relationship. The findings of this study were consistent with findings of other studies conducted on professional golfers in that there is a hip-rotation asymmetry present in LH-to-TH measurements in athletes who partook in rotation-related sport even on a recreational level (Almeida et al., 2012; Evans et al., 2005; Gulgin, 2005; Van Dillen et al., 2008). No specific reasoning as to the causes was discussed, but it is worth considering that Mellin (1988) noted that hip and lumbar spine mobility was mostly affected by hip flexion and extension when the lumbar spine is rotated. Future consideration should be given to the spine mobility and the relationship a hip would have in the spine function.

2.6 HIP ROTATION RANGE IN ROTATION-RELATED SPORTS

2.6.1 Hip rotation in adults who partake in other rotation-related sport

A rotation-related sport is defined as a sport that requires a repetitive rotational demand in the hip and lumbo-pelvic area to perform the related sport skill. Due to the higher demand on the hip and lumbo-pelvic complex, rotation-related sport participating individuals with LBP were examined (Harris-Hayes et al., 2009; Hoffman, Johnson, Zou, Harris-Hayes, & Van Dillen, 2011; Van Dillen et al., 2008). The results showed a hip rotation ROM deficit would be compensated by hypermobility in the lumbar spine, thereby generating overload and compensatory mechanisms in the surrounding musculoskeletal system (Van Dillen et al., 2007).

It was hypothesised by Van Dillen (2008) that individuals participating in rotation-related sport with LBP would have less total hip articular range (TAR) and more hip asymmetry (L≠R) than a control group. The results were conclusive. The subject group with a history of LBP had significantly less TAR and more asymmetry between the lead and the trail hip (left being more limited than right) than the control group. The mean total passive articular range for the subject group without pain was reported as 62.2° (±1.2°) in the lead hip and 60.3° (±2°) in the trail hip, reporting a significant asymmetry between the hip of the painful subjects as 4.99° (±0.18°). This value coincided with the results from the study by Gulgin (2005). Of the 48 participants only one played golf. Asymmetry in hip rotation ROM results in asymmetrical forces on the lumbo-pelvic region, and these forces have been identified as a risk factor for low back pain (Adams, 2004).

In a study regarding Judo athletes who suffer from non-specific LBP, a limitation in non-weight bearing active and passive hip internal rotation was recorded (Almeida, De Souza, Sano, Saccol & Cohen, 2012: 231). These measurements were interpreted using a postural assessment software program (V.0.67). There were no statistically significant gender differences. The passive TAR of the pain-free subject group in the lead hip was 105.1° (±12.1°) and 105.1° (±11°) in the trail hip. Active total dynamic hip rotation in the pain free subjects was given as 87.9° (±12.6°) in the lead hip and 87.4° (±7.9°) in the trail hip. If the non-weight bearing dynamic range is expressed as a percentage of the passive range, the dominant hip of the control group utilises 82.9% of the passive range when not standing on it, and non-dominant hip utilises 83.2% of the available range. In comparison, the pain group utilises 85.1% of the dominant hip's passive range, whilst the non-dominant hip utilises 84.8% of the available passive range. This hip will utilise over 80% of the passive rotation range available when actively moving in a non-weight bearing environment.

2.6.2 Hip range in an adult golfing population.

In a golfer, the lead-hip faces the direction of the ball flight and experiences a rotational force asymmetrical to that of the trail hip. Due to this asymmetrical rotational torque forces, the golf swing requires a high force demand on the lower extremities (Meister et al., 2011).

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In examining passive hip rotation ROM in 31 healthy elite female golfers (19 years), Gulgin (2005; 2008) concluded that subjects without LBP had an insignificant side-to-side total passive rotational hip ROM difference, while subjects with LBP had a measurable difference of five degrees or more between the hips. The passive goniometer prone ROM measurements taken in healthy subjects, were 88.4° (±14.4°) in the lead hip, and 87.9° (±13.5°) in the trail hip.

Further investigations into the relationship between the passive and dynamic hip rotation of golfers with lower back pain, concluded that there were insignificant differences in healthy subjects (Murray et al., 2009). However, subjects with medial rotation pain of the lead hip did show a significant difference. An insignificant difference was reported for the passive and dynamic medial rotation in the trail hip. Both the passive and dynamic measurements were taken with an inclinometer and the subjects were in a prone position. The passive and active rotation of the lead hip was reported as 73° and 69°, while the trail hip passive and active rotation ROM was given as 78° and 70°. Findings in MR deficit from both the Gulgin et al. (2010) and Murray et al. (2009) studies were similar in golfers. In LBP-subjects the lead hip has a deficit in medial rotation compared to the trail hip.

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2.7 CHAPTER SUMMARY

In summary, a variety of joint measuring instruments are clinically available. Clinicians have a variety of joint positions to choose from when examining the hip joint in a subject. Therefore, a wide variety of normal hip rotation ROM is reported for healthy subjects who participate in a rotation-related sport, which includes golf. According to the literature evaluated for this study, the value for total hip rotation varies between 60 ° and 88 ° if the influencing factors of instruments, measurement position and techniques are not taken into account.

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CHAPTER 3: THE MANUSCRIPT

PASSIVE AND DYNAMIC HIP ROTATION RANGE OF MOVEMENT IN LEAD AND TRAIL HIPS OF ADULT MALES DURING A GOLF SWING

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ABSTRACT

The purpose of this research project was to obtain and investigate the total passive and dynamic rotation range of movement (ROM), in both the lead and trail hips of healthy young adult male golfers. Seven skilled, male golfers between the ages of 18 and 40 years were randomly selected. Seat-adjusted passive hip rotation ROM measurements were collected with a hand-held inclinometer. Dynamic hip rotation kinematic data were captured with a high-speed 3-D videography system during a golf swing. The results indicated insignificant differences in total passive articular range between the lead (62° ± 6.5°) and trail hip (61.5° ± 4°). For the total dynamic articular range measured during the golf swing, a significant asymmetry between the lead (29°± 6.5°) and trail hip (36° ± 9°) was reported. Further results indicated a positive correlation between the passive and dynamic total articular range in the lead hip, whereas a negative correlation was reported for the trail hip. During the golf swing the lead hip utilised 46% of the total passive hip rotation available, whereas the trail hip utilised 59%. Clinical application of the outcome is applicable in possibly reducing the incidence of high-end injuries in the professional golfer. Research into the understanding in the dynamic range of a golfer's hip rotation is encouraged.

Keywords

Lower limb rotation, golf swing biomechanics, hip kinematics, lower back pain.

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1. INTRODUCTION

The golf swing is a sequence of complex biomechanical movements. This relative smooth and well-timed movement of body segments occurring during a golf swing is referred to as a kinematic sequence. The primary movement plane, in which these kinematic sequences occur, is called the transverse plane or rotational plane. This is due to the relative position of the body facing the ball at the start of the swing, and is named after the address posture. From an address posture the next phase, the backswing, follows in order to reach the top of the swing. The downswing phase then follows so that the ball is propelled forward. This kinematic sequence demonstrates the rotational speed that occurs between the arms, thorax and lumbo-pelvic unit and therefore reflects the high level of skill that a golf swing demands.

Hip kinematics is integral to a sound overall kinematic sequence (Healy et al., 2011; Hume et al., 2005). The hip joint acts as the pivot between the upper and lower body segments and thereby ensures a synchronized swing. Reduced hip rotation may be related to the high prevalence of lower back pain (LBP), which affects one in three golfers. It has been proposed that reduced hip ROM may place an increased strain on the lower back (Gulgin, 2012; Murray et al., 2009)

Murray et al. (2009) illustrated that golfers with back pain have reduced passive and active lead hip (LH) medial rotation (MR/IR). Asymmetrical hip rotation range is also associated with golfers with LBP, and could possibly be due to repeated rotational exposure during rotational sports (Gulgin, 2005; Van Dillen et al., 2008) Athletes who regularly partake in a sport that requires repetitive rotation between the trunk and pelvis have limited LH total rotation compared to that of the trail hip (TH) (Van Dillen et al., 2008)

To explore the relationship between hip rotation and LBP, it is necessary to understand the regular amount of hip rotation that occurs during the golf swing. A significantly reduced hip internal and total articular range (TAR) was found in both the active and passive hip range of movement of non-golfing-athletes' dominant limb (Almeida, De Souza, Sano, Saccol, & Cohen,

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2012). Therefore, in order to understand the hip's kinematics during a golf swing, a normative range of movement in the hip of a golfer has to be identified.

Hip kinematics in golf has received relatively less attention compared to that of body segments such as the pelvis, shoulder and thorax. However, there is a need for clinicians and sports scientists to have a clear understanding of the relative contribution of the hip rotation during the golf swing. This information should be useful in the rehabilitation of a golfer to either enhance their performance or reduce the risk of injury.

Clinically, non-weight bearing total passive and active hip range of movement, total articular range (TAR), is often utilised to estimate whether a golfer has adequate hip range for proper execution of the golf swing. Traditional methods to measure hip range in sitting, supine or prone positions are reliable between test occasions and measurers. However, to date it is unknown whether this clinical method for hip range assessment is also a valid assessment of the amount of rotation during the actual golf swing. Coaches and clinicians should have knowledge of the typical hip rotation range required during the golf swing. It should also be of value to understand the correlation between clinical hip rotation assessments of the individual hip and the amount of real performance a hip movement displays during a golf swing. To our knowledge, this issue has not previously been addressed and therefore, the aim of this study was to determine the difference between the passive and dynamic rotation range of both the lead and trail hips of healthy young adult male golfers.

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2. METHODOLOGY

The study received approval from the Health Research Ethical Committee at Stellenbosch University (no. S12/11/272). Informed consent was obtained and signed for each participant

Study design

This descriptive study was conducted for total passive hip rotation range of motion in relation to the degree of dynamic hip rotation range of motion utilised during a golf swing. A preliminary, reliability study was conducted to ascertain total articular range of hip passive movement measured with an inclinometer.

Sample recruitment, size and description

An acquired candidate list form from the Western Cape (WC) region of golf academies and clubs was randomized. Candidates from the list were contacted telephonically in a descending order. This established eligibility while answering the first section of the questionnaire. A sample size of seven participants was recruited. The sample size was limited by resources and the exploratory nature of the study. A sample size calculation was neglected due to the unavailability of similar studies.

A study by Gulgin et al. (2010) who compared standing weight-bearing hip rotation ROM to an actual golf swing, was the closest-related to this study, with 15 female golfers participated in the Gulgin et al. study. Male golfers aged between 18 and 40 years, with a handicap (HC) of 16 or lower were eligible. Participants had to have played golf for at least two years, and play an 18 hole-round of golf per week and continue practicing three or more hours per week on the golf range or greens. Candidates were excluded if any musculoskeletal injury, pain, surgery or fractures to the spine, upper or lower extremities were present. Participant with hip abduction less than a normal 30° and hip flexion less than a normal 105° were also excluded. None of the participants had abnormal hip ROM.

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Instrumentation

Total passive hip rotation range of motion

Total passive hip rotation range of motion was measured with a plastic Baseline® Bubble hand-held inclinometer. The inclinometer reliability was better than that of a digital inclinometer or goniometer. A hand-held inclinometer is user-friendly for clinical utility. A low error of measurement (0.54º and 1.22º), a low minimal detectable change value of 3º, and low variability has been reported while measuring passive hip rotation ROM with the (Boyd, 2012). The validity and reliability of a hand-held was also found to be excellent while measuring hip range of movement (Boyd, 2012).

Total dynamic hip rotation range of motion

Total dynamic hip rotation range of motion during a golf swing was measured using an eight camera T-10 Vicon (Ltd) (Oxford, UK) system with integrated software, Nexus 1.8. The Vicon motion analysis system is a three-dimensional (3-D) digital video system, which is widely used in a variety of ergonomics and human factor applications. 3-D motion analysis technology is regarded as the gold standard for 3-D analysis of movement due to the good reliability and validity (Kadaba, Ramakrishnan, & Wootten, 1990; Tsushima, Morris, & McGinley, 2003)

Preliminary reliability study

A preliminary reliability study was completed to determine the investigator intra-rater reliability for total inclinometer passive hip articular range measurements. Eight golfers, aged 17 and 40years, who met the inclusion criteria of the study, participated in the reliability study. Measurements were taken at the end of a practice day. Prior to the measuring procedure, each participant performed two chosen supervised hip rotation stretches (a standing stork stretch and standing sit-squat stretch), chosen to enhance the surrounding soft tissue for hip flexibility (Evans et al., 2005; Kurihashi et al., 2006; Tamai, Kurokawa, & Matsubara, 1989)**.** Seated measurement positions, as described in the study methods, were followed. Three measurements of each hip (lead

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hip, trail hip) were measured two minutes apart for each participant. The hip joint was returned to neutral before the following ROM was recorded.

Procedures

Questionnaire and data collection sheet

After eligibility was obtained telephonically the data sheet of the continuum sections in the questionnaire was filled out during an interview prior to the passive procedures. The questionnaire included questions regarding the participant's personal details and demographics, as well as their medical, golf, family, physical conditioning and sport participation history.

The study was conducted at the Biomechanical Laboratory, Stellenbosch University. Participants were familiarized with the laboratory environment and equipment, and then debriefed regarding the testing procedure. The main biomechanical outcomes were passive hip range during a seat-adjusted position and dynamic hip range measurement during a golf swing

Passive hip rotation range of motion measured in sitting.

Participants were dressed in knee-exposing, non-restrictive clothing without shoes. Prior to the passive range of movement assessment, a 10-minute stationary bicycle warm-up was completed. Participants sat across on the firm medical plinth, set at an 85cm height. A 45° angled plastic-covered wedge was added as back support and a pelvic belt was placed over the anterior iliac spinea and strapped to the plinth to prevent any pelvic movement during passive hip rotation (see Figure 1). The contralateral foot was placed on the plinth, leaving the hip in full flexion, thereby isolating the hip and pelvis, which is being tested. The hip being measured was placed at an angle of 135° hip extension, replicating a hip's position during a golf address posture (Hume et al., 2005). The fibular head was marked with a skin marker, as this point was used for the inclinometer placement (see Figure 2).

The investigator sat on a 25cm high gym step, in front of the participant, facing the knee at eye level. Passive hip total-rotation was performed until a firm end-feel was felt, or any pelvic

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compensatory movement was noted. The hip was returned to the mid-position before external rotation and the total rotation range was recorded separately. Each movement was performed in the same order for all participants.

Figure 1: Seated position for inclinometer hip rotation measurements

Figure 2: Inclinometer placement for hip rotation measurements

Anthropometric measurements

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Anthropometric measurements required for the VICON-analysis were recorded. The participant's height, weight, leg length, shoulder offset, hip circumference, hand thickness as well as the width of the wrist, elbow, knee and ankle were recorded.

Dynamic hip rotation range of motion measured during a golf swing

All reflecting clothing or objects were either removed or covered to prevent interference with the 3-D video-system. A half body retro-reflective marker set was placed on bony landmarks by a physiotherapist experienced in marker placement and who had training for this according to the conventions of the Plug-in-Gait model (see Figure 3). System calibration was achieved according to standard Vicon procedures. Model calibration was captured with the participants assuming a standard standing T-position. Soft golf balls were used for ball-impact purposes protecting the laboratory equipment. Each participant used his own seven iron and golf shoes. Five to ten practice swings were allowed prior to the testing procedure. A series of ten swing-trials were performed for data collection purposes. Verbal instructions (see Table 1) were given to each participant prior to each of the ten captured golf swings. Total range of hip rotation was calculated using the Plug-in-Gait model and filtered with a 4th-order Butterworth filter at a 10Hz cut-off frequency.

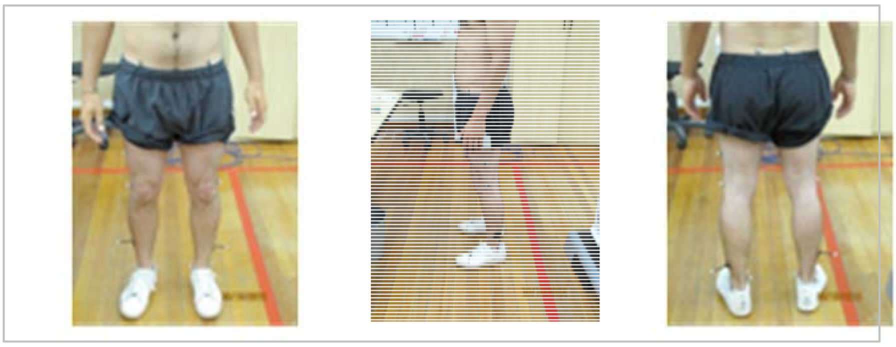

Figure 3: Lower body retro-reflector marker placements. Anterior, lateral and posterior views

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Table 1: Golf swing Instruction to participants.

Description of swing movement	**Instructions**
Face down the line holding their own 7-iron club; each subject wearing his own golf shoes	"Address your ball in the manner most common to the start of your swing."
Three golf swings (full back swing to full final phase) is practiced to instil a normal practice swing while the soft ball is in place	"take a few practice swings to familiarise yourself with the lab environment and get a feel for the soft ball."
A full swing will be captured 10 times (from the address to the finish phase). The Bio-statistician will establish a starting nod for each participant.	"get ready to take a full swing, aim for the centre of the wall at the back of the lab."
Encourage the participants to walk away and re-address the ball each time he swings ensuring the most natural swing he could mimic in the lab setup.	"relax, and walk away from the starting point, take care not to bump any equipment please" "repeat the swing again" (until 10 trails is reached)

Data analysis

For data capturing purposes, Microsoft Excel was chosen and STATISTICA version 10 (StatSoft Inc., 2012) was chosen to analyse the data.

For determining inclinometer intra-rater reliability, a two-way interclass correlation coefficient (ICC), standard error of measurement (SEM) and a 95% confidence interval level was calculated. ICC values of between 0.85-1.0 were accepted. For the descriptive statistics, the mean was used as a measure of central location and standard deviations as indicators of spread. Spearman correlation coefficients (r) were calculated for the study results. Scatterplots were used to express the correlation between total passive and dynamic articular ranges. A p-value of $p < 0.05$ represents statistical significance in hypothesis testing and 95% confidence intervals were used to describe the estimation of unknown parameters.

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3. RESULTS

Reliability of passive ROM measurements

The ICC for TAR was 0.81 (95% CI: 0.46-0.96) and the SEM was 3° for the intra-rater reliability.

Participant demographics

The descriptive data of the participants (n=7) is summarised in Table 2. All participants were right-handed players. The mean age at which the participants started playing golf was 9.7 (±4.1) years. None of the participants had upper limb, lower limb or musculoskeletal complaints of the spine during the past 12 months. The waist-hip ratio (WHR) measurements were within normal limits (0.86 ± 0.06).

Table 2: Participant demographics.

Variables	*Mean*	*SD*
Age (years)	26.50	±8.1
Height (cm)	176.9	±5.1
Mass (kg)	79.14	±13.5
HRT/7*	13.2	±5.9
HC**	+1	±0.8
WHR***	0.86	±0.9

*** HRT/7 = hours training per week **HC = Handy-cap system ***WHR = Waist-hip-ratio**

Total Articular Range (TAR)

Passive TAR of the lead and trail hip

A statistical insignificance (*p=0.8)* was reported (see Table 3) between the mean lead and trail hip passive TAR. Four of the participants had a passive TAR asymmetry of 10 degrees or more between the two hips.

Dynamic TAR of the lead and trail hip.

A statistical significance (*p*=0.04) was reported (see Table 3) between the mean dynamic TAR of the lead and trail hip. Three of the participants reported a dynamic TAR asymmetry of 10 degrees or more between of the two hips.

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Range difference between passive and dynamic TAR.

A male golfer utilises 46.4% of the mean passive lead hip TAR while in the trail hip, he utilises 58.8%. The median (LH=49.5%; TH=58.6%) was closely related to the mean values (see Table 3). The difference between passive TAR and dynamic TAR is reported in Table 3, while the difference between the passive and dynamic TAR ranged from 27.7°- 40.5° in the lead hip and 16.4° - 42.5° in the trail hip. In the trail hip, a greater variability was noted when the ROM difference was compared to the lead hip.

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Table 3: The Lead and trail hip mean passive and dynamic ROM in degrees and the percentage that each hip utilise from the available passive range while hitting a golf ball

	Passive TAR*	Dynamic TAR*	Difference*	% Utilised
LEAD HIP				
P1	60.0°	30.9°	29.1°	51.6%
P2	55.0°	27.2°	27.8°	49.5%
P3	70.0°	36.5°	33.5°	52.1%
P4	65.0°	36.7°	28.3°	56.4%
P5	70.0°	29.5°	40.5°	42.2%
P6	55.0°	19.9°	35.1°	36.1%
P7	60.0°	22.3°	37.7°	37.1%
Mean	**62.1 ° ±6.4°**	**29.0° ±6.5°**	**33.1° ±5.0°**	**46.4% ±8%**
TRAIL HIP				
P1	60.0°	43.6°	16.4°	72.7%
P2	66.0°	23.5°	42.5°	35.7%
P3	60.0°	35.2°	24.8°	58.6%
P4	64.0°	43.1°	20.9°	67.3%
P5	60.0°	43.1°	16.9°	71.8%
P6	65.0°	33.4°	31.6°	51.5%
P7	55.0°	29.6°	25.4°	53.8%
Mean	**61.4° ±3.8°**	**35.9° ±7.8°**	**25.5° ±9.2°**	**58.8% ±13.3%**

P=Participant; TAR*=Total articular range. ** Difference between passive and dynamic total rotational range

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Movement correlations

1. *The correlation between passive and dynamic TAR of the lead hip*

There was a positive correlation (r=0.7) between the passive TAR and dynamic TAR of the lead hip (see Figure 4).

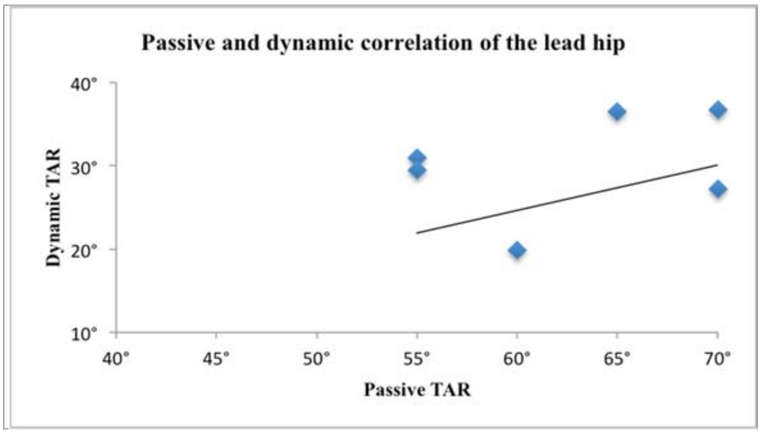

Figure 4: The lead hip passive and dynamic total articular range depicted as a scatterplot correlation

2. *The correlation between passive and dynamic TAR of the trail hip*

There was a negative correlation (r=0.14) between the passive TAR and dynamic TAR of the trail hip.

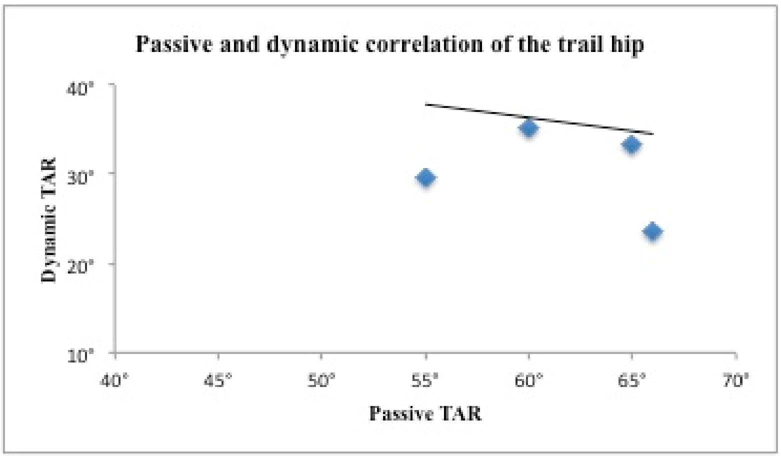

Figure 5: The trail hip passive and dynamic total articular range depicted as a scatterplot correlation

3. *The correlation between the lead and trail hip passive TAR*

A negative correlation (*r*=0.12) was found between the lead and trail hip total passive ROM.

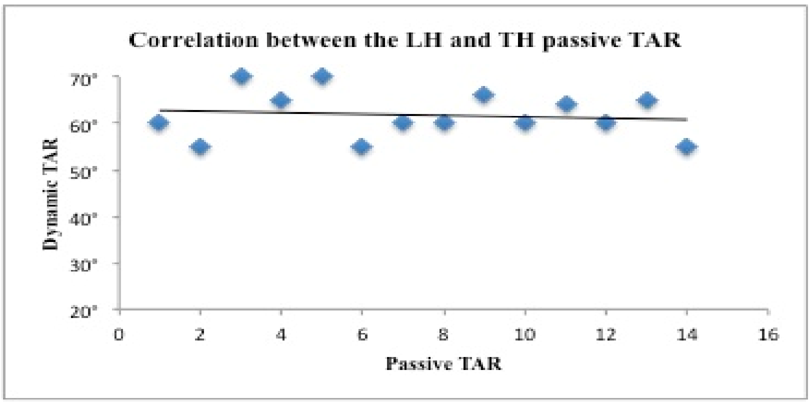

Figure 6: The lead to trail hip passive correlation

4. *The correlation between the lead and trail hip dynamic TAR*

A positive correlation (*r*=0.3) was established between the lead and trail hip total dynamic ROM.

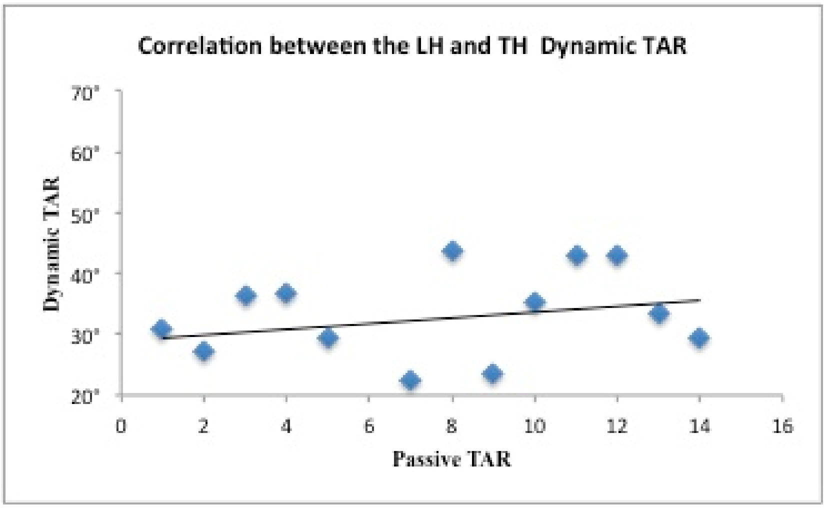

Figure 7: The lead and trail hip dynamic correlation

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Graphic illustration of the golf swing

The following graphics present an illustration of the kinematic pattern of the group mean as reported in the lead hip (see figure 8) and trail hip (see figure 9).

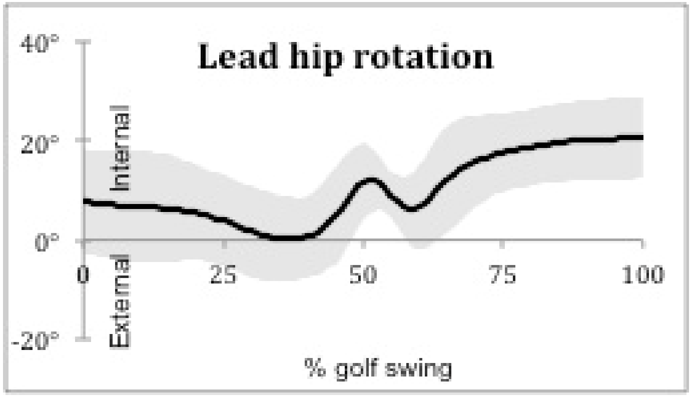

Figure 8: A lead hip rotation representation during a swing

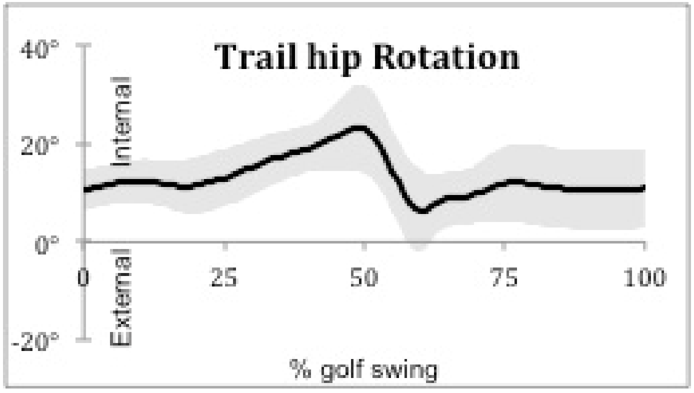

Figure 9: A trail hip rotation representation during a swing

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4. DISCUSSION

The main purpose of the current study was to investigate the passive and dynamic rotation ROM difference (passive in sitting and dynamic during the swing) of both the lead and trail hip of healthy, young, adult male golfers. The hip joint rotation in a golf swing synchronises the kinematic sequence as it serves as a pivotal point to the backswing, and as an initiator in the downswing (Enoka, 1994). Although there are several studies addressing the kinematics of the golf swing, research correlating the available passive range, which exists in the hip of a golfer to the dynamic rotation during a golf swing, is unavailable according to the current search.

Participant demographics

Relationship between hip rotation and the waist-hip-ratio (WHR)

The relationship between hip rotation and the waist-hip ratio was investigated (Kouyoumdjian et al., 2012). WHR measures central adiposity in participants. A hip loses 0.98° of rotation (p<0.0006) for each fat percentage-unit that increases. Therefore, the WHR-method was considered as part of the participant eligibility criteria as it provides an indication of the body fat percentage. Participants with a high obesity index would have been excluded from this study sample, as it would have influenced the degree of hip rotation. No participants were excluded.

The golfer's handicap as eligibility criteria for the study

Handicapping a golfer is an effective equalizer among golfers with different abilities. A golf handicap (HC) system (see Table 4) is based on the assumption that in every 9-hole and 18-hole stroke played by a golf a player, he/she will endeavour to achieve the best score at each hole played and will report this score to the South African golf association within a 24 hour period, regardless where the round of golf was played. The current study group has an average HC of one (±0.8), which means they partook in regular play, making them eligible participants.

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The median age for the study group was 27 (±8.2) years. On average, the participants have been participating in a rotation-related sport for 17 (±3) years. Gosheger (2003) reported in their study regarding injuries and overuse syndromes in golfers that the average age of golfers was 46 years, and they have been playing golf for 10 (±7.8) years. Gosheger et al. (2003:438) studied a larger group of 703 golfers and represent a population of golfers better.

Table 4: The purpose of the Handicap (HC) system.

The Handicap system:
• Provides all golfers with a fair HC • Reflects the player's inherent ability and trends to his recent score • Has the ability to adjust an HC to a player's ability • Disregards freak high scores that bear no relation to the player's normal ability • Establishes handicaps for all golfers, from informal play to championships • Assists a handicapper to identify a player whose handicap does not reflect a playing ability.

Total articular range (TAR)

Excellent inclinometer reliability measurement was established, with low measurements of error (0.54°-1.22°) and a low minimal detectable change value of 3° have been reported (Boyd, 2012). This author also reported a low variability and excellent validity for a hand-held inclinometer. Hip flexion during a straight leg raise movement was used during the assessment position. This established and supported the lower limb outcome measurements.

The average passive TAR of the lead and trail hip

The average passive TAR of the lead and trail hip in young, male golfers was reported as 62°(±6.5°) in the lead hip, while the trail hip it was reported as 61.5° (±4°).

Murray et al. (2009) reported the prone passive inclinometer TAR in golfers as 73° in the lead hip and 78° in the trail hip. The larger rotation range of ±15° could be explained by the fact that the reported ROM included males and females in the study group. It has been reported that female subjects, irrespective of age, had between 16°-26° more rotational mobility than their male counterparts (Soucie et al., 2011). This became a motivation for this study to utilise a male-only population, as a female study had already been conducted. That latter study reported that female

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golfers' passive inclinometer TAR in a lead hip was 93° (±17°) and the trail hip was 92° (±19°). Both of these studies reported larger ranges than our male study group.

Regardless of gender or side, total seated articular passive range of a normal, non-golfing population, was reported to be 78.5° ±11° (Kouyoumdjian et al., 2012) and 76.5 ° (Bierma-Zeinstra et al., 1998). These ranges fell within the range measured for the golfers in our study, but possible differences could be attributed to measurement techniques, joint positions or measuring instrumentation. One other possibility could be that seated hip extension (135° flexion), as chosen in our study to represent a seated starting posture, could lead to a slight tightening of the strong and dense hip capsule, which would usually reach maximal tightening and coiling once a hip reaches full extension (Norkin, 1992). The usual seated measurement position is 90° of hip flexion.

Dynamic hip rotation

In published reports the angle measured between the hip axis (pelvis) and the shoulders axis is sometimes described as the amount of hip rotation taking place during a golf swing (Burden, Grimshaw, & Wallace, 1998; Hume et al., 2005; Myers et al., 2008). This measurement of hip rotation is a measurement of pelvic rotation in relation to shoulder axial rotation. The present study measures dynamic hip rotation, femoral acetabular hip rotation, with the VICON plug-in-gait model. This model measures hip rotation as the relative angle between the hip and the pelvis.

The mean dynamic TAR in male golfers in the current study showed the lead hip rotation as 29° (± 6.5°) and the trail hip as 36° (± 7.8°) during a golf swing (see Table 3). The active weight bearing hip range in a rotation-related sport such as golf occurs in a closed kinetic sequence. Gulgin et al. (2010) discovered that the weight-bearing rotation ROM measured was 64.5° in the lead hip and 24° in the trail hip range. These measurements were taken by a VICON on a group of female golfers in a standing closed kinetic chain position. These results indicated that hip rotation ROM in a golfer adapts to the demand that is placed on it.

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The hip TAR results from the present study on the lead hip in the male group are in close proximity to those of the female group in Gulgin et al. (2010) study, and once again could be influenced by the gender or the technique. The larger difference in the trail hip's ROM is not yet clear, but could be due to the negative TAR-correlation found by our study. To our knowledge, data documenting weight-bearing hip rotation in golfers or data illustrating the actual amount of dynamic hip rotation ROM, which occur during a full golf swing, is not currently publicly available.

In this study, two of the golfers had less than the mean dynamic articular range in the lead hip than the group average, while two golfers reported 10° more. Two of participants had less dynamic ROM in the trail hip than the group average, while three participants had 5 degrees more than the average (see Table 3). This indicates a reasonable performance variation in young golfers of the same profile.

Movement correlation

A positive correlation was found (see Figure 4) between the passive rotation ROM and dynamic rotation utilisation of the lead hip. The interpretation of this correlation is clinically significant for physiotherapist, biokineticists and sports trainers who engage in the rehabilitation and treatment of golfers. With the present data at hand, it seems that the golfer will benefit from a total rotation range of 62° (see Table 3) in the lead hip. While the hip will only utilise 46% (see Table 3) of this passive available range during a full swing, it can be expected that the golfer would utilise less rotation range if the hip joint has an underlying pathology. Reduced passive rotation range may place strain on other segments such as the lower back and thorax (Tsai, 2005) consequently, resulting in injury and pain.

In the trail hip we found this correlation (see Figure 5) between the passive and dynamic rotation utilisation to be negative. The clinical application of these findings is that improving the passive hip ROM of the trail hip may not be beneficial to the golfer's swing. Although the trail hip utilises a larger portion of the available passive ROM during a swing than the lead, the trail hip may not respond in the same manner as the lead hip during the golf swing.

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However, we need to consider the findings regarding the correlations between the trail and lead hip and passive range with caution, due to the small dataset currently available. A larger study group should be investigated to provide further insight for coaches and clinicians treating golfers.

Limitations and recommendations

Although the results provide valuable information and insight into the relationship that exists between the passive and dynamic hip rotation, there are several limitations. A larger sample size could validate the statistical significance. Sample size calculations can now be conducted based on the preliminary findings of this study. The inclinometer reliability study did not use a blinded measurer, and inter-tester reliability was not performed and should be considered for future studies.

Due to limited resources, the hip joint integrity was not investigated e.g. MRI, x-rays and sonars, but could be considered. Possible kinematic influences from the knee and foot were not assessed, but could play a role in influencing the kinematic chain of the lower limb. Comparisons between groups of golfers and non-golfers were not investigated but could help to establish a normative value for dynamic ROM in golfers.

In addition to addressing the limitations as outlined, the influence that the hip joint flexibility has on hip mobility in a golfer would be of great clinical value. Comparing low handicap golfers to higher handicap golfers could be valuable in exploring the effect a golfer could expect on his lumbar spine after long periods of intense exposure to a rotation related sport. A normative database for dynamic hip rotation ROM in a golfer's hip joint should be established, which can assist in classifying the golfer according to their degree of rotation and subsequent risk of injury. Investigation into golfers with pathologies, injury or pain in the lower back should be conducted. This could provide insight into rotational factors associated with musculoskeletal problems that golfers may experience.

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5. CONCLUSION

Hip rotation during a golf swing is important. The findings of this study show that, a healthy hip of a golfer does not exceed the available passive rotation ROM (LH=62°; TH=61°) that exists in his hip joint during a dynamic golf swing. A negative correlation was found between the available trail hip passive rotation ROM and the dynamic rotation ROM that his hip utilise during the golf swing. In the lead hip, a positive correlation was found between the passive and dynamic rotation ROM. These findings imply that in the clinical field careful consideration should be given to the motivation behind mobilizing or treating the hip of a golf player. Future research should be conducted to help establish a normative dynamic and passive total articular range of hips in a larger golfing population.

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CHAPTER 4: RESULTS AND DISCUSSION

The aim of the study was to investigate the passive and dynamic rotation ROM difference (passive in sitting and dynamic during the swing) of both lead and trail hips of healthy young skilled male golfers. The hip joint rotation in a golf swing synchronizes the kinematic sequence as it serves as a pivotal point to the backswing, and as an initiator in the downswing (Enoka, 1994). Although several studies (Angle, Gillette, & Weimar, 2012; Gonzálezjurado, Moreno, & Floría Martín, 2011; Hellström & Tinnmark, 2008; Hume et al., 2005; Zheng et al., 2008) address the kinematics of the golf swing, research investigating passive and dynamic rotation range which exist in the hip of a golf player was limited in the databases that were used for this study. Each participant had individual characteristics, which influenced the eligibility criteria and is discussed in the following paragraph. The participants' characteristics are summarized in Table 5.

Table 5: Participant characteristics.

Variables	*Mean*	*SD*
Age (years)	26.50	±8.1
Height (cm)	176.9	±5.1
Mass (kg)	79.14	±13.5
HRT/7*	13.2	±5.9
HC**	+1	±0.8
WHR***	0.86	±0.9

*** HRT/7 = hours training per week **HC = Handycap system ***WHR = Waist-hip-ratio**

4.1 PARTICIPANT'S DEMOGRAPHICS

4.1.1 The relationship between hip rotation and the waist-hip-ratio (WHR)

The relationship between hip rotation and the waist-hip-ratio (WHR) has been previously investigated (Kouyoumdjian et al., 2012). WHR measures central adiposity in participants. For each fat percentage-unit which increase in a body the hip joint would looses 0.98° of rotation ($p<0.0006$). Therefore, the waist-hip-ratio-method was considered as part of the participant eligibility criteria in order to provide an indication of the participant's obesity index. Participants with a high obesity index would have been excluded from this study sample, as it would have influenced the degree of passive hip rotation ROM. No participants were excluded.

4.1.2 The eligibility criteria for the study considered the golfers handicap

Handicapping a golf player is an effective equaliser among golfers with differing abilities. A golf handicap (HC) system (see Table 4) is based on the assumption that in every 9-hole and 18-hole stroke play of golf a player will endeavour to make the best score at each hole played and report such score to the South African Golf Association within a 24 hour period, regardless where the round of golf was played. The current study group has an average HC of one (±0.8), which

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meant they partake in regular play, making them eligible participants. The group's average age at which the participants started playing golf was 9.7 (±4) years. The median age for the study group was 26.6 (±8.2) years. On average, the participants have been participating in a rotation related sport for 16.9 (±2.9) years. Gosheger et al. (2003) reported in their study regarding injuries and overuse syndromes in golfers that the average age of golfers was 46 years, and they have mostly been playing golf for 9.8 (±7.8) yrs. Gosheger et al (2003) larger study group of 703 golfers represents the population of golfers better.

Table 6: The guidelines of a Handicap (HC) system.

	A Handicap system guidelines:
1	Provide all golfers with a fair HC
2	Reflect the players inherent ability and trends to his recent score
3	Have the ability to adjust a HC to a players ability
4	Disregard freak high scores that bear no relation the players normal ability
5	Establish handicaps for all golfers, from informal play to championships
6	Assist a handicapper to identify a player whose handicap does not reflect a playing ability.

4.2 Total articular range (TAR)

During inclinometer measurement studies, excellent reliability was established. Low measurements of error (0.54°-1.22°) and a low minimal detectable change value of 3.41° was reported (Boyd, 2012). Boyd (2012) also reported a low variability and excellent validity for hand held inclinometer measurements. Hip flexion during straight leg raise movements was used as an assessment position, which established and supported the lower limb outcome measurements in this study reliable.

4.2.1 The average passive TAR of the lead and trail hip

The average passive TAR of the lead and trail hip in young male golf players were reported as 62.14°(±6.4°) in the lead hip, while in the trail hip it was reported as 61.43° (±3.8°).

Murray et al. (2009) reported the prone passive inclinometer TAR in golf players as 73° in the lead hip and 78° in the trail hip. The larger rotation range of ±15° could be explained by the fact that the reported ROM included males and females in the study group. It is reported that female subjects, irrespective of age, had between 16°-26° more rotational mobility than their male counterparts (Soucie et al., 2011). This was a study motivation to utilise a male only population, as a female study has been conducted. That study reported that female golfers' passive inclinometer TAR in a lead hip was 93.3° (±16.9°) and the trail hip was 91.7° (±19°). Both these studies that included female golfers reported larger ranges than our male study group.

Regardless of gender or side, total seated articular passive range of a normal French non-golfing population, was reported to be 78.5° ±11.3° (Kouyoumdjian et al., 2012) and 76.4 ° (Bierma-Zeinstra et al., 1998). These ranges falls within the range measured for golfers in our study, but possible difference could be attributed to measurement techniques, joint positions or measuring instrumentation. One other possibility could be that seated hip extension (135° flexion), as chosen in our study to represent a seated starting posture, could lead to a slight tightening of the strong and dense hip capsule, which would usually reach maximal tightening and coiling once a hip reaches full extension (Norkin, 1992). The usual seated measurement position is 90° of hip flexion.

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4.2.2 Dynamic hip rotation

In published reports (Burden et al., 1998; Hume et al., 2005; Myers et al., 2008) the angle measured between the hip axis (pelvis) and the shoulders axis is sometimes describe as the amount of hip rotation which is taking place during a golf swing. This measurement of hip rotation is not a true representation of the degree of hip rotation, which occurs between the femoral head, and the acetabulum as described by this study. The present study measures dynamic hip rotation with the VICON plug-in-gait model. This model measures hip rotation as the relative angle between the hip and the pelvis.

The mean dynamic TAR in male golfers in this the current study reported the lead hip rotation as 29° (±6.5°) and the trail hip as 35.9 (±7.8°) during a golf swing (see Table 7). The active weight bearing hip range in a rotation related sport such as golf, occur in a closed kinetic sequence. Gulgin (2010) discovered that the weight-bearing rotation ROM measured was 64.5° in the lead hip and 23.8° in the trail hip range. These measures were taken by a VICON on a female group of golfers, in a standing closed kinetic chain position. These results indicated that hip rotation ROM in a golfer adapts to the demand that is placed on it. The results from the current study on the lead hip in the male group are in close proximity to that of the female group in Gulgin et al. (2010) study, and once again could be influenced by the gender or the technique. The larger difference in the trail hip's ROM is not yet clear, but I could be due to the negative TAR-correlation found by our study. To our knowledge, data documenting weight bearing hip rotation in golfers or data illustrating the actual amount of dynamic hip rotation ROM, which occur during a full golf swing, was not currently available.

In this study, two of the golfers had less than the mean dynamic articular range in the lead hip than the group average, while two golfers reported 10° more. Two of participants had less dynamic ROM in the trail hip than the group average, while three participants had 5 degrees more than the average (see Table 3). This indicates a reasonable performance variation in young golfers of the same profile.

4.3 MOVEMENT CORRELATION

We found a positive correlation (see Figure 4) between the passive rotation ROM and dynamic rotation utilization of the lead hip. The interpretation of this comparison is clinically significant for physiotherapist, biokinetesist and sports trainers who engage in the rehabilitation and treatment of golfers. With the present data at hand, it seems that the golfer will benefit from a total rotation range of 62° (see Table 7) in the lead hip. While the hip will only utilise 46% (see Table 7) of this passive available range during a full swing, it can be expected that the golfer would utilise even less rotation range if the hip joint has underlying pathology. Reduced passive rotation range may place strain on other segments such as the lower back and thorax (Tsai, 2005), consequently resulting in injury and pain.

In the trail hip we found a negative correlation (see Figure 5) between the passive and dynamic rotation utilisation. The clinical application of these findings is that improving the passive hip ROM of a trail hip may not be beneficial to the golfers swing. Although the trail hip utilises a larger portion (see Table 7) of the available passive ROM during a swing than the lead, the trail hip may not respond in the same manner as the lead hip during the golf swing.

However we need to consider the findings regarding the correlations between the trail and lead hip and passive range with caution, due to the small dataset currently available. A larger study group should be investigated to provide further insight for coaches and clinicians treating golfers.

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Table 7: The mean degrees passive and dynamic ROM in the lead and trail hip, as well as the percentage ROM that a hip utilise of the available passive hip ROM, during a golf swing.

	Passive TAR*	Dynamic TAR*	Difference**	% Utilised
LEAD HIP				
P1	**60°**	**30.9°**	29.1°	51.6%
P2	**55°**	**27.2°**	**27.8°**	**49.5%**
P3	**70°**	**36.5°**	33.5°	52.1%
P4	**65°**	**36.7°**	28.3°	56.4%
P5	**70°**	**29.5°**	40.5°	42.2%
P6	**55°**	**19.9°**	35.1°	36.1%
P7	**60°**	**22.3°**	37.7°	37.1%
Mean	**62.1 ° ±6.4°**	**29.0° ±6.5°**	**33.1° ±5.0°**	**46.4% ±8%**
TRAIL HIP				
P1	**60°**	**43.6°**	16.4°	72.7%
P2	**66°**	**23.5°**	42.5°	35.7%
P3	**60°**	**35.2°**	24.8°	58.6%
P4	**64°**	**43.1°**	20.9°	67.3%
P5	**60°**	**43.1°**	16.9°	71.8%
P6	**65°**	**33.4°**	31.6°	51.5%
P7	**55°**	**29.6°**	25.4°	53.8%
Mean	**61.4° ±3.8°**	**35.9° ±7.8°**	**25.5° ±9.2°**	**58.8% ±13.3%**

P=Participant; TAR*=Total articular range. ** Difference between passive and dynamic total rotational range

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CHAPTER 5: LIMITATION AND RECOMMENDATIONS

Although the results provide valuable information and insight into the relationship that exists between the passive and dynamic hip rotation, there are several limitations. A larger sample size would validate the statistical significance. Sample size calculations can now be conducted based on the preliminary findings of this study.

The inclinometer reliability study didn't use a blinded measurer, and inter-tester reliability was not performed and should be considered for future studies. Due to limited resources, the hip joint integrity was not investigated e.g. MRI, x-rays and sonars, but could be considered. Possible kinematic influences from the knee and foot were not assessed, but could play a role in influencing the kinematic chain of the lower limb. Comparisons between groups of golfers and non-golfers were not investigated but could help to establish a normative value for dynamic ROM in golfers.

The future recommendation, in addition to addressing the limitations as outlined, of the influence that the hip joint flexibility has on hip mobility in a golfer would be of great clinical value. Comparing low-handicapped golfers to higher handicapped golfers could be valuable in exploring the effect a golfer could expect on his lumbar spine after long periods of intense exposure to a rotation-related sport. A normative database for dynamic hip rotation ROM in a golfer's hip joint should be established, which can assist in classifying the golfer according to their degree of rotation and subsequent risk of injury. Investigation into golfers with pathologies, injury or pain in the lower back should be conducted. This could provide insight into rotational factors associated with musculoskeletal problems golfers may experience

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CHAPTER 6: CONCLUSION

Hip rotation during a golf swing is important. The findings of this study indicate that, a healthy, skilled golf player does not exceed the available passive rotation ROM that exists in his hip joint during a dynamic golf swing. A young male golf players hip utilise 46% of the available passive lead hip ROM, while the trail utilise 59% of the passive ROM during the swing. A negative correlation was reported between the available trail hip passive rotation ROM and the dynamic rotation ROM that he utilises during a golf swing. However, a golf player does utilise more of the passive range in the trail hip than the lead hip during the swing. In the lead hip, a positive correlation was found between the passive and dynamic rotation ROM of the project. These findings imply that in the clinical field careful consideration should be given to the motivation regarding mobilising, treating, stretching and the rehabilitation of the specific hip of a golf player. Future research should be considered to establish a normative dynamic and passive total articular range of hips in a larger golfing population.

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APPENDICES

Appendix 1: Health Research Ethics council approval letter

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Approval Notice
New Application

03-Dec-2012
ALDERSLADE, Villene

Ethics Refernce #: **S12/11/272**

Title: **Investigating the range of movement degree -difference between passive and dynamic rotation of both the lead hip and trail hip in healthy young adult golfers when performing a golf swing**

Dear Ms Villene ALDERSLADE,

The **New Application** received on **01-Nov-2012**, was reviewed by Health Research Ethics Committee 1 via Committee Review procedures on **28-Nov-2012** and has been approved.
Please note the following information about your approved research protocol:

Protocol Approval Period: **28-Nov-2012 -28-Nov-2013**

Present Committee Members:
Kinnear, Craig CJ
Seedat, Soraya S
Mukosi, M
Theunissen, Marie ME
Kearns, E
Meintjes, WAJ Jack
Mohammed, Nazli
Weber, Franklin CFS
Nel, Etienne EDLR
Sprenkels, Marie-Louise MHE
Rohland, Elvira EL
Theron, Gerhardus GB
Els, Petrus PJJS
Hendricks, Melany ML
Welzel, Tyson B
Barsdorf, Nicola

Please remember to use your **protocol number** (**S12/11/272**) on any documents or correspondence with the HREC concerning your research protocol.

Please note that the HREC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

After Ethical Review:
Please note a template of the progress report is obtainable on www.sun.ac.za/rds and should be submitted to the Committee before the year has expired.
The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.
Translation of the consent document to the language applicable to the study participants should be submitted.

Federal Wide Assurance Number: 00001372
Institutional Review Board (IRB) Number: IRB0005239

The Health Research Ethics Committee complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel: +27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

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Appendix 2: Demographic questionnaire for young golfers

Demographic!questionnaire!

This questionnaire is designed to assist the research study on hip rotation rom in collecting information from a group of golf player between the ages of 18-40 yrs.

The aim of the study is to find the degree range of passive hip-rotation and dynamic hip-rotation in both the lead and trail hip of healthy young adult male golf players.

Section!A!!

Personal!information!

1. *Name*
2. *Surname*
3. *How old are you?*
4. *With which hand do you lead your golf swing?*
5. *At which golf club are you currently registered?*
6. *What is your current handicap?*
7. *What is your occupation?*
8. *Do you lift heavy objects repetitively daily?*

Section!B!

Medical!history!

These questions are designed to find any previous personal injury or harm to your body and takes of note any self-reported pain that influence your golf swing currently.

1. *Did you endure any injuries in the past 12 months? Yes/N0*
2. *Have you ever experienced or been diagnosed with any of the following injuries?*

	Body part	Surgery	Fracture	Self-reported pain in the past 6 months	Does that pain influence your golf game?	NOTES	
Upper limb	Wrist	Y/N	Y/N	Y/N	Y/N		
	Elbow	Y/N	Y/N	Y/N	Y/N		
	Shoulder	Y/N	Y/N	Y/N	Y/N		
Lower limb	Ankle	Y/N	Y/N	Y/N	Y/N		
	Knee	Y/N	Y/N	Y/N	Y/N		
	Hip	Y/N	Y/N	Y/N	Y/N		
Spine	Neck	Y/N	Y/N	Y/N	Y/N		
	Thoracic spine	Y/N	Y/N	Y/N	Y/N		
	Lower back	Y/N	T/N	Y/N	Y/N		
	Sacrum/ pelvis	Y/N	Y/N	Y/N	Y/N		

3. *Have you ever been diagnosed with any other medical conditions or diseases?*

YES	NO

If the answer is yes, what were your diagnoses?

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Section C

Family history

1. *Does any member of your family play golf regularly?* Y/N
2. *Who is the member and what sport do they play?*
3. *Do they experience any pain during golf?* Y/N

Member	***Sport***	***Area of pain***	***For how long have they had pain?***	***sport***	***Area of pain***	***For how long have they had pain?***	***sport***	***Area of pain***	***For how long have they had pain?***	
			Y/N						Y/N	
									Y/N	
									Y/N	
									Y/N	
									Y/N	
									Y/N	

Section D

Golfing career

1. *How many hours do you spend practicing on the golf range per week?*
2. *How many hours do you spend practice on the green per week?*
3. *Do you play any golf rounds per week?*
4. *How many golf rounds do you play per week?*

5. *How many of those golf rounds are 9 holes?*
6. *How many of those golf rounds are 18 holes?*
7. *How old were you when you started hitting golf ball on the driving range?*
8. *At what age did you start competing at club level?*

U/12	*U/14*	*U/16*	*U/18*

9. *At which level are you currently competing in golf?*

SOCIAL	*CLUB*	*PROVINCIAL*	*NATIONAL*	*INTERNATIONAL*

10. *In which category are you competing?*

JUNIORS	*OPEN AMATEURS*	*MID AMATEURS*

Sections E

Physical conditioning and experience

1. *Do you partake in any other sport currently?*

Tennis	***Hockey***	***Soccer***	***Rugby***	***Cricket***	***Dance***	***Martial -art***	***Water -ski***	***Snow-ski***

2. *At what level are you participating in this sport? SOCIAL/PROVINCIAL*

Tennis	***Hockey***	***Soccer***	***Rugby***	***Cricket***	***Dance***	***Martial -art***	***Water -ski***	***Snow-ski***

3. *How often do you partake in this sport?* *Frequency*

YEARLY	*MONTHLY*	*WEEKLY*

4. *Do you make use of any of the following therapies/treatments or coaching?*

	Swing couch	Gym ac-cess	Gym train-er	Bio-kinetic s	Stretc hing plan	Pilates	Yoga	Physio therap ist	Mas sag e the rap ist	Chiro Prac-tor	Osteo-path	Podia-trist
	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
HZ *												

*(Frequency: how many times per week or per month)

SECTION!F!

RESEARCHER!

DATE

NAME

SIGNITURE

Appendix 3: Demographic data info sheet for golfers

Demographic Information sheet for young male golfers

Researcher
Name
Surname
Date
Signature

Section A
Personal information

Name			
Surname			
Age			
Handed player	right		left
Registred club			
Handicap			
Occupation		heavy lifting involvement	Y N

Section B
Medical history

Injuries in the previous 12 months? Y N

		surgery	previous fractures	self reported pain in the past 6 /12	performance influenced by injury?
Upper limb	wrist	Y N	Y N	Y N	Y N
	elbow	Y N	Y N	Y N	Y N
	shoulder	Y N	Y N	Y N	Y N
Lower limb	ankle	Y N	Y N	Y N	Y N
	knee	Y N	Y N	Y N	Y N
	hip	Y N	Y N	Y N	Y N
Spine	neck	Y N	Y N	Y N	Y N
	chest	Y N	Y N	Y N	Y N
	lower back	Y N	Y N	Y N	Y N
	sacrum	Y N	Y N	Y N	Y N

Other medical conditions/ diseases Y N Describe

Demografic Information sheet for young male golfers

Section C

Family History

Does any other family member play golf regularly? Y / N

Do they experience any pain during golf ? Y / N

Member	sport	area of pyn	for how long have they experienced pain?

Section D

Golfing career

1. How many hours do you spend praticing on the golf range per week? 2.Greens?

3. Do you play any golf rounds per week? Y / N

4. How many golf rounds do you play per week? 5. 9 holes 6. 18 holes

7. How old were you when you started hitting golf ball on the driving range?

8. At what age did you start competing at club level?

U/12	U/14	U/16	U/18

9. At what level are you currently competing ?

current level	social	club	provincial	national	international

10. category	juniors	open amateurs	mid amateurs	other

Section E

Physical conditioning experience

Other sport play	tennis	soccer	martial arts	hockey	cricket	dance	water ski	snow ski	rugby
sport	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N	Y N
level	S/P	S/P	S/P	S/P	S/P	S/P	S/P	S/P	S/P
frequency Y/M/W									

key: *Y=yes **N=no S=sosial P=provincial

Do you make use any of the following therapies? yes/no

			Monthly Frequency			
Swing couch	Yes	NO	years	months	week	NAP
Gym access	Yes	NO	years	months	week	NAP
Gym trainer	Yes	NO	years	months	week	NAP
Biokineticist	Yes	NO	years	months	week	NAP
Stretching plan	Yes	NO	years	months	week	NAP
Pilates	Yes	NO	years	months	week	NAP
Yoga	Yes	NO	years	months	week	NAP
Physiotherapist	Yes	NO	years	months	week	NAP
Massage therapist	Yes	NO	years	months	week	NAP
Chiropractor	Yes	NO	years	months	week	NAP
Osteopath	Yes	NO	years	months	week	NAP
Podiatrist	Yes	NO	years	months	week	NAP

key: NAP=not at present

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Appendix 4: Participant consent form

TITLE OF THE RESEARCH PROJECT

Investigating the correlation between the passive and dynamic rotation both the lead hip and trail hip joint of healthy young adult golfers during a golf swing

REFERENCE NUMBER:S12/11/272

PRINCIPAL INVESTIGATOR:

Villene Alderslade, BPHYST.UP

ADDRESS:

Faculty Health Sciences, Physiotherapy Division, Box 19063 Tygerberg, 7503.

CONTACT NUMBER:

villenealderslade@gmail.com or +27 21 938 9300

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff or PRINCIPLE INVESTICATOR any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. In addition, your participation is **voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Health Research Ethics Committee at Stellenbosch University and will be conducted according to the ethical guidelines and principles of the International Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is this research study all about?

This study is testing if there is a difference in your hip rotation ranges of your lead hip and trail hip when comparing the range of the hip rotation during sitting and during your golf swing.

The study will be done at the Stellenbosch University, Faculty to Health Sciences at the Tygerberg campus. The Vicon lab is the only setting used for both the passive and dynamic hip rotation measurements. A total number of 7 randomly selected participants will be tested.

The aim of this study is to investigate the passive range of hip rotation and the dynamic range of hip rotation of motion that a lead and trail hip needs during a golf swing.

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When you arrive at the laboratory, the following will take place:

A short warm-up on a stationary bicycle will be followed by passive measurements taken by the primary investigator

This will include a physical examination on your hip, knee and ankle muscle length and joints movements as well as the length and thickness of your bones using callipers.

All tests are non-invasive and none of these tests will hurt.

A dynamic hip rotation measurement test with the 3-D analysis system will follow the physical examination:

A physiotherapist will then apply little special skin markers on body points around your hip and leg area. You will be without a shirt and will be dressed in tight gym shorts and your golf shoes, as the special cameras cannot see the markers under clothing.

You will then be asked to hit a few air balls into space

The movements your body makes will then be captured by the cameras and a computer system will make the measurements we need for the study

This should not take longer than 2, 5 hrs.

This current research study aims to better explain hip related injuries sustained during golf. As you are a male golfer with a low handicap, between the age of 18 and 40 years, and play golf regularly. Your participation will be very meaningful in the prevention of possible future golf injuries to the lower back or hip. This topic is poorly researched and not enough information is known regarding the role of hip rotation in lower back pain.

What will your responsibilities be?

If you agree to participate, your responsibilities are merely to turn up in your golf kit, bring along your clubs to the Motion Analysis Laboratory on the agreed testing date.

Will you benefit from taking part in this research?

You will not be benefitting from this study directly at present. There are currently only two studies known to be investigation the golfing hip in the international community. This research study will be the first study conducted in SA. This information is considered important for future studies regarding the prevention of lower back. If any joint problems are identified during your evaluation, this will be assessed and treated free of charge

There are no risks involved in participating in this study. If you do not want to participate, it is entirely your choice, but there are no alternatives to this study at present.

Who will have access to your medical records?

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Any information regarding you or your health status will not be available to any outside parties. Your personal information is only known to the Primary investigator. The information gathered about you, will be available for your personal gain.

What will happen in the unlikely event of some form injury occurring as a direct result of your taking part in this research study?

Injuries are unlikely.

Will you be paid to take part in this study and are there any costs involved?

You will not be paid or be asked to pay for any tests conducted. You will be reimbursed for expenses that you may incur unnecessary.

Communication arrangements:

All communication must be confirmed via email or text. You are welcome to ask any questions at anytime. You can contact my supervisor or co- supervisor at 021 938 9300 (Mrs. L. Crouse or Prof. Q. Louw) at the physiotherapy department or the Health Research Ethics Committee at 021-938 9207 if you have any concerns or complaints that may have not been adequately addressed by your Primary investigator**.**

You will receive a copy of this information and consent form for your own records.

Declaration by participant

By signing below, I agree to take part in a research study entitled: Investigating the ROM degree-difference in both the lead hip and trail hip joint during passive and dynamic rotation of healthy young adult golfers when performing a golf swing

I declare that:

- I have read or had read to consent form and me this information and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurized to take part.
- I may choose to leave the study at any time and will not be penalized or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the study doctor or researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ....…………….. On (*date*) …………....……….. 2012

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Signature of participant Signature of witness

Declaration by investigator

I Villene Alderslade declare that:

I explained the information in this document to …………………………………..

I encouraged him to ask questions and took adequate time to answer them.

I am satisfied that he adequately understands all aspects of the research, as discussed above

I did not use an interpreter.

Signed at (*place*) ....…........…….. On (*date*) …………...……….. 2012

Signature of investigator

……………………………………………..

Signature of witness

………………………………………….

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Appendix 5: Preliminary study check list

Addendum""

A. Check'list'for'pilot'study"

Name and surname Of participant	
Date of test	
Primary investigator	
Research assistant / Marker placer	
Research bio- engineer	
Time in	
Time out	
Investigator	

B. Participant""

"	Sms reminder
"	Choice to participation
"	Introduction to study and lab
"	Golf shoes
"	Golf iron 7
"	Consent form signed Addendum
"	10 min Warmed – up on bicycle
"	Reason for participating
"	Do you want the results?
"	Did you receive lunch?
"	Did you receive a drink?

C. Dynamic'list"

"	Golf shoes Golf iron 7
"	Grass surface
"	Air balls
"	Golf net

"

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D. Anthropometric"measurements"

"	Warmed- up
"	Calipers
"	Anthropometric measuring form Addendum
"	Consent form
"	Measuring tape

E. Physical"examination"

"	Physical exam Form Addendum
"	Measuring Tape
"	Skin Marker
" "	Goniometer
"	Blue double section split plinth

F. Passive"R.O.M"tests"

"	2 x 85 cm ribbons
"	45 deg plastic Wedge
"	Inclinometer
"	Pelvic belt
"	Skin marker
"	Gym step, 25cm high
"	Leg support step

"

"

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Appendix 6: Intra-rater reliability test

Intra-rater (tester) reliability			
(check if tester measure the same each time)			
Name/tester:……………………………………..		Date:……………………………………..	
	Left hip rotation range		
PARTICIPANT	IR	ER	TAR
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

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Appendix 7: Anthropometric information sheet.

Anthropometric measurements information sheet

Name and Surname		
Measurement date		
Waist to hip ratio		
Hip circumference		
Waist circumference		
Height		
Weight		
	Left	Right
Hand thickness		
Wrist width		
Elbow width		
Shoulder offset		
Leg Length		
Knee width		
Ankle width		

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Appendix 8: physical examination collectio form.

PHYSICAL EXAMINATION DATA COLLECTION FORM

NAME AND SURNAME		
DATE		AGE
GOLF HANDED	RIGHT	LEFT

JOINT Movement	**PT Position**	**Joint position**	**ROM** (degrees) Inclinometer	
Hips			Left	Right
Flexion (knee to chest)	Supine			
Extension	Side	Knee Ext		
Abduction	Supine	Hips Ext		
Adduction	Supine			
External rotation	Seated			
Internal rotation	Seated			
Total articular range	Seated			
Femoral ante version	Prone	N=15-25°		
Modified Thomas test	Supine	Hip flex? (Psoas)		
		Knee ext? (Rec Fem)		
Stiff hips	Supine	Abd <30° flex <110°		
Forefoot position	Prone			

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Appendix 9: Passive hip rotation data collection form

PASSIVE DATA COLLECTION FORM

SEATED AT 135° HIP FLEXION	INCLINOMETER MEASUREMENTS OF THE HIP JOINT		
LEAD HIP	RIGHT	LEFT	
	PASSIVE HIP INTERNAL ROTATION	PASSIVE HIP EXTERNAL ROTAION	TOTAL HIP ROTATION
1			
2			
3			

SEATED AT 135° HIP FLEXION	INCLINOMETER MEASUREMENTS OF THE HIP JOINT		
TRAIL HIP	RIGHT	LEFT	
	PASSIVE HIP INTERNAL ROTATION	PASSIVE HIP EXTERNAL ROTAION	TOTAL HIP ROTATION
1			
2			
3			

Investigator name……………………………. date……………………………………….

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Appendix 10: Investigators declaration form

	STELLENBOSCH UNIVERSITY **FACULTY OF HEALTH SCIENCES**	

HEALTH RESEARCH ETHICS COMMITTEE 1 & 2

INVESTIGATOR'S DECLARATION

(To be completed in typescript)

The principal investigator, as well as all sub- & co-investigators must each sign a separate declaration.

A. RESEARCHER

Surname	ALDERSLADE			**Initials**	V		**Title**	MRS
Capacity	**Principal investigator**	X	**Sub-investigator**			**Co-investigator**		
Department	PHYSIOTHERAPY							
Present position	CLINICAL PRACTICE			**E-mail**	VILLENE@TISCALI.CO.ZA			
Telephone no.	**(w)**	0218764234	**Cell**	0832821379		**Fax**	0214131290	

B. PROJECT TITLE (MAXIMUM OF 250 CHARACTERS FOR DATABASE PURPOSES)

What is the difference between passive hip-rotation R.O.M and dynamic hip-rotation R.O.M in both the lead and trail hip of healthy young adult golfers when performing a golf swing?

I, MRS VILLENE ALDERSLADE declare that

- **I have read through the submitted version of the research protocol and all supporting documents and am satisfied with their contents**
- I am **suitably qualified and experienced** to perform and/or supervise the above research study.
- I agree to conduct or supervise the described study **personally** in accordance with the relevant, current protocol and will only change the protocol after approval by the **HREC**, except when urgently necessary to protect the safety, rights, or welfare of subjects. In such a case, I am aware that I should notify the HREC without delay.
- I agree to timeously report to the HREC **serious adverse events** that may occur in the course of the investigation.
- I agree to maintain **adequate and accurate records** and to make those records available for inspection by the appropriate authorised agents when and if necessary.
- I agree to comply with all other requirements regarding the obligations of clinical investigators and all other pertinent requirements in the Declaration of Helsinki, as well as South African and ICH GCP Guidelines and the Ethical Guidelines of the Department of Health as well as applicable regulations pertaining to health research.
- I agree to comply with all regulatory and monitoring requirements of the HREC.
- I agree that I am conversant with the above **guidelines**.
- I will ensure that every patient (or other involved persons, such as relatives), shall at all times be **treated in a dignified manner and with respect**.
- I will submit all required reports within the stipulated **time frames**.

Principal / Sub- / Co-investigator / Supervisor **: Mrs L CROUS**

Signature : . .

Co-Supervisor **: Prof Q Louw**

Signature : . .

Date : . .

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CONFLICT OF INTEREST DECLARATION (OBLIGATORY)

I MRS VILLENE ALDERSLADE Declare that

- [X] I have no **financial or non-financial interests**, which may inappropriately influence me in the conduct of this research study.

OR

- [ ] I do have the following financial or other competing interests with respect to this project, which may present a potential conflict of interest: (Please attach a separate detailed statement)

Signature: **Date**

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Appendix 11: Guidelines to the Journal: Sports Biomechanics

Publisher International Society for the Biomechanics of Sport, Taylor & Francis.

Description

Sports Biomechanics is the scientific journal of the International Society of Biomechanics in Sports (ISBS), the only international society dedicated to biomechanics in sports. The journal sets out to generate knowledge to improve sports performance and reduce the incidence of injury, and to communicate this knowledge to sports scientists, coaches, and sports participants. Sports Biomechanics is unique in its emphasis on sports techniques and sports injuries. As well as maintaining scientific rigor, there is a strong editorial emphasis on 'reader friendliness' by emphasizing the practical implications and applications of research in sports biomechanics; the journal seeks to benefit sports practitioners directly. Sports Biomechanics publishes papers in four sections: Original Research, Reviews, Teaching, and New Methods and Theoretical Perspectives.

Peer Review Statement

All manuscript submissions are subject to initial appraisal by the Editor, and, if found suitable for further consideration, to peer review by independent, anonymous expert referees.

All peer review is single blind and submission is online via ScholarOne Manuscripts.

Instructions for authors

This journal uses ScholarOne Manuscripts (previously Manuscript Central) to peer review manuscript submissions. Please read the guide for ScholarOne authors before making

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a submission. Complete guidelines for preparing and submitting your manuscript to this journal are provided below.

Sports Biomechanics considers all manuscripts on the strict condition that they have been submitted only to Sports Biomechanics, that they have not been published already, nor are they under consideration for publication or in press elsewhere. Authors who fail to adhere to this condition will be charged with all costs, which Sports Biomechanics incurs and their papers will not be published.

Contributions to *Sports Biomechanics* must report original research and will be subjected to review by referees at the discretion of the Editorial Office.

Manuscript preparation

For authors whose native language is not English, it is strongly recommended they use a professional editing service to improve the quality of writing and screen out grammatical errors prior to manuscript submission. Manuscripts can be rejected on the basis of quality of writing. During the course of manuscript review, the Editor-in-Chief or the Associate Editor may require authors to provide proof that such an editing service was used when it was recommended through the review process. Use of such an editing service, however, does not guarantee manuscript acceptance and the quality will be judged by the Editor-in-Chief and the Associate Editor.

Authors should endeavor to write in a style that is 'reader friendly' and, in particular, 'coach friendly'. Achieving this while maintaining scientific rigor is obviously a major challenge for authors, reviewers and the editorial team. The avoidance of non-standard abbreviations and mnemonics greatly enhances a paper's readability, as does writing in plain idiomatic English. Keeping the paragraphs in reasonable lengths with clear key points will also help improving the manuscript's readability.

General guidelines

1. 1. Manuscripts should be written in UK English, double-spaced in 12 Font with normal character spacing.
2. Double-space the entire manuscript. Double space between lines of body text and titles, headings and block quotations.
3. Double-space the reference list and figure captions.
4. Use a serif typeface, such as Times New Roman, for the text of your manuscript. Use a sans serif typeface, such as Arial for figures and labels.
5. Indent the first line of every paragraph one- half inch.
6. Align the text to the left-hand margin, leaving a "ragged" right margin.
7. Format the headings according to the five level format guidelines in the APA journals. (http://flash1r.apa.org/apastyle/basics/index.htm?__utma=185732729.380255240.1380493216.1380493216.1380493216.1&__utmb=185732729.20.10.1380493216&__utmc=185732729&__utmx=&__utmz=185732729.1380493216.1.1.utmcsr=(direct)|utmccn=(direct)|utmcmd=(none)&__utmv=-&__utmk=258544906)
8. Add continuous line numbers to the main document (abstract to appendices), as reviewers will use only the line numbers to specify locations in the manuscript. Do not restart line numbers on each page.
9. Allow at least 25 mm borders at top, bottom, left and right of each page, lay out as if to be printed on A4 or Letter-size paper.
10. Unless otherwise specified in these Guidelines, the formatting and referencing style should conform to the guidelines in the Fifth Edition of the Publication Manual of the American Psychological Association (2002).

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Structure □

Authors are required to adhere to the following structure for 'Original Research' papers; some of these sections may not be relevant for other types of paper.

Title: □

The title should reflect the practical importance of the research as well as indicate its scientific basis.

Abstract: □

The abstract should be not more than 200 words. Include the word count at the end of the abstract. The abstract should summarize the main findings and should conclude with clear statements off the research questions of the study. Refrain from including generic or explanatory statements in the abstract. Construct the abstract in a single paragraph with no subheading.

Introduction: □

The introduction should clearly elaborate the potential benefits of the research and its findings for sport practitioners. The purposes (aims and objectives) should be stated so as to capture both the contribution to knowledge and the practical benefits of the study. All hypotheses should be clearly formulated based on a sound theoretical framework. Plain descriptive studies with no systematic research focus or underlying theoretical framework won't be accepted. Authors should elaborate on explaining the mechanisms, not on simply describing the phenomena. The research questions and hypotheses should be justified fully within the introduction and the rest of the manuscript must be tightly organized around the research questions/hypotheses.

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Methods:

The methods section should document the overall procedures and the participants involved, provide sufficient detail to allow replication of the study, and give relevant technical information to establish clearly the scientific merit of the study. However, authors should seek to make this material comprehensible to a non-specialist reader and provide guidance when technical information is presented. Material that is difficult for a non-specialist reader, such as complex mathematical models, should be included as an appendix and referred to in the methods section.

Using an appropriate sample size is essential in generalizing the study findings. Studies using a small sample without proper justification may be returned to the authors immediately with no further consideration. A section should be dedicated to the statistical methods/procedures used and it should explicitly include the independent and dependent variables used in the analysis.

The methods may also incorporate the following:

- Definitions of technical terms.
- If appropriate, and if not already incorporated into the introduction, a description of the rationale for selecting particular variables for analysis and their relationship to performance or injury should be included.
- Where appropriate, information to establish the validity and reliability of the methods, and the magnitude of errors, should be provided, except in review papers. A statement that approval for the study was obtained from the appropriate research ethics committee must be included.

Results:

Sport practitioners should not be prevented from grasping the results because of a lack of knowledge of statistical procedures and terminology. However, no claims should be made without citing the relevant statistical results. Avoid using redundant numerical data in the text that are already presented in the tables and/or figures. Avoid using generic and

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narrative statements. Refer to relevant tables and figures parenthetically whenever possible and refrain from using expressions such as "Figure/Table x shows…." excessively.

Discussion and Implications:

This section should be separate from the results section and should elaborate the implications of the results; it should also make clear the limitations of the study. It should be possible to read this section without recourse to the statistical results or further statistical information and terminology. Practitioners should be able to skip the results section and understand the findings of the study, and their implications for sport performance or injury prevention, from the discussion and implications section alone. Achieving this requires skill from authors to restate findings simply without repeating unnecessarily the information provided in the results section. If appropriate, this section may include coaching practices, training drills and activities that are indicated by, or arise from, the research or review. It is important to keep the discussion within the scope of the study.

Conclusion:

The conclusion should summarise the main scientific findings and their practical implications in the context of the study's aims and objectives.

References:

Please ensure that the paper contains adequate referencing. Be fastidious with checking reference details, ensuring that all references given in the body of the document appear in the reference list and that authors and years of publication correspond. For referencing style, see comments later in these guidelines.

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Tables and figures

1. Tables must be created in Word and not imported from another package.

2. Tables should be laid out with clear row and column headings and units should be included where appropriate. Place the Table caption above the Table. Keep the Table captions as concise as possible and place the peripheral items in the footnotes.

3. Tables and figures must not be imbedded in the text. Add tables to the end of the main document (a separate list of Table captions is not necessary) followed by a list of the figure captions and the figures; the figures must not contain titles or notes. Figures must be submitted as separate image files (JPG, TIFF, etc.).

4. Do **not** send figures in a format that cannot be edited, such as EPS. Do **not** submit illustrations or graphs created in MS Word or Excel, as these cannot be imported into the typesetting programs used. If you do submit figures in such formats, the cost of redrawing may be passed back to you.

5. Pay attention to the relative proportion of the figure and the text used in the figure including the axis scales.

6. All figures must be of camera-ready quality. They can be submitted in black and white or colour.

7. Photographs should be scanned at a minimum of 300 dpi and line illustrations should be scanned at a minimum of 600 dpi. The final size of the scan to be about 250 x 200 mm.

8. On line illustrations, do not use a line weight of less than 1 point.

9. TIFF images should be sent either uncompressed or compressed using lossless compression software packages, such as LZW.

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10. Images downloaded from the internet and JPEGs are usually low resolution (72 dpi) and unsuitable for reproduction.

11. Do not use tints on computer-generated illustrations that are lighter than 15% or darker than 70%. Do not use pattern or colour fills.

12. Copyright permission must be obtained for all figures taken from other sources, including the internet.

Units, Symbols and Numbers

1. Use SI units throughout. The standard unit of time is 's', not 'sec'.

2. Put a space between the number and the unit except for ° and %.

3. To help practitioners to read your data, use the convention m/s rather than m·s -1 . Bracket and use powers to avoid ambiguity: for example use m/s 2 not m/s/s; (kg·m)/s; W/(m·K).

4. Do not give results to too many significant figures; be guided by how accurately you can measure or calculate a variable. Three significant figures is a good rule-of-thumb, but few data acquisition systems used in sports biomechanics can measure to better than 1°, so giving a figure of 13.7° is unrealistic.

5. Scalar variables, including statistical symbols such as *p* , *t* and *r* , should be in italics, vectors in bold typeface, constants and abbreviations, such as sin, that are not variables should be in roman typeface; all should usually be lower case. Greek symbols, and subscripts and superscripts that are identifiers not variables should be in roman typeface; for example, θ not *θ* , *x i* where *i* = 1,2,3… but *r* 1 , *F* max

Submission Categories

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Papers may be submitted for publication in *Sports Biomechanics* in any of the following categories:

- Original Research
- Review
- Method and Theoretical Perspective
- Teaching Biomechanics
- Letter to Editor

Publication charges

- Submission fee

There is no submission fee for *Sports Biomechanics.*

- Page charges

There are no page charges for *Sports Biomechanics.*

- Color charges

Colour figures will be reproduced in colour in the online edition of the journal free of charge. If it is necessary for the figures to be reproduced in colour in the print version, a charge will apply. Charges for colour pages in print are £250 per figure ($395 US Dollars; $385 Australian Dollars; 315 Euros). For more than 4 colour figures, figures 5 and above will be charged at £50 per figure ($80 US Dollars; $75 Australian Dollars; 63 Euros).

Style guidelines

The American Psychological Association reference (APA) style method 6th ed. is used.

www.apastyle.org/

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Supplementary online material

Authors are welcome to submit animations, movie files, sound files or any additional information for online publication.

Information about supplementary online material

Manuscript submission

All submissions should be made online at the Sports Biomechanics ScholarOne Manuscripts site . New users should first create an account. Once logged on to the site, submissions should be made via the Author Centre. Online user guides and access to a helpdesk are available on this website.

For the reviews, manuscripts may be submitted in any standard format, including Word, PostScript and PDF. These files will be automatically converted into a PDF file for the review process. LaTeX files should be converted to PDF prior to submission because ScholarOne Manuscripts is not able to convert LaTeX files into PDFs directly. The final version, however, should be submitted in Word format only.

Authors must also submit a separate scanned cover letter, signed by the contact author with the authority of all of the authors, which establishes the originality of the material submitted, that it has not previously been published (except as an abstract) and is not under consideration for publication elsewhere.

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Authors MUST provide names of at least two preferred reviewers with their contact info including the affiliations and email addresses. The preferred reviewers must be experts in the contents area with track records (publications) and sufficiently fluent in English to perform the review. Authors may also register their non-preferred reviewers/associate editors in the submission process, if any.

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Appendix 12: Report of Protocol

Report of the proposal of the research study 2012 titled:

Investigating the correlation between passive and dynamic rotation of both the lead and trail hips in healthy young adult male golfers when performing a golf swing

The Study design

Research Question

What is the degree difference between passive hip rotation ROM and dynamic hip rotation ROM in both the lead hip and trail hip of healthy young adult golfers when performing a golf swing?

Aim of the Study

The aim of the study is to investigate the passive hip-rotation ROM, measured with a hand held inclinometer and dynamic hip- rotation ROM, measured using a 3D visual confirmation video analysis system during a golf swing, in order to determine if there is a relationship between the passive and dynamic ROM in both the lead hip and trail hip of healthy young adult golfers.

The Objectives

3.1 Primary objectives

The primary objective of this study is to determine what the difference is in passive hip-rotation ROM and dynamic hip-rotation ROM in both the lead hip and trail hip of healthy young adult golfers.

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Hypothesis

4.1 The Null Hypothesis (H0)

There is no degree ROM difference in the passive and dynamic hip rotation ROM in both the lead and trail hip of a healthy young adult golfer during a golf swing.

4.2 The Alternative Hypothesis (H1)

In comparing the degree ROM measured during a passive and dynamic total hip rotation in young adult golfers during sit-adjusted inclinometer measurement to Vicon swing analysis measurements, there is a clinically applicable degree difference.

Research team

5.1 Principle investigator (PI)

The principle investigator (PI) has a physiotherapy degree from the University Of Pretoria (UP). She has gained experience in sport and orthopaedic physiotherapy during the past 20 years. The PI will be responsible for taking the measurements with the inclinometer as well as performing the physical examinations on the subjects during the pre- and post passive testing procedures. The principle investigator will also be present during all the dynamic testing.

5.2 Principal Marker (PM)

The physiotherapist responsible for placing the markers on the subjects has a BSc Physiotherapy degree from the University of the Western Cape; a Post Graduate Orthopaedic Manipulative Therapy Diploma (Curtin University, Perth WA); and is currently completing an MSc Sport Physiotherapy (University of Bath). He is the senior Physiotherapist in the Motion Analysis Clinic at Stellenbosch University. The PM will be the only person to apply the skin reflectors on the subjects.

5.3 Data analyst (DA)

The biomedical engineer present at SUN icon laboratory will operate the Vicon motion analysis system that will be used to collect data.

5.4 Bio-statistician

Data analysis and interpretations will be managed by the bio statistical department of Stellenbosch, Prof. M. Kidd.

5.5 Questionnaire designer

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Dr Joe Barnes, Dept. of Interdisciplinary Health Sciences, Division of Community Health, Faculty of Health Sciences.

The Methodology

Research Design

Descriptive study

A descriptive study will be done to determine the difference between the passive and dynamic rotation ROM of both the lead and trail hips, in healthy adult young golf players during the golf swing. The ROM will be observed, noted, analysed and then statistically calculated for clinical application. The outcome of the study is measured in degrees of ROM.

The study design is descriptive in nature, as far as regarding the trail and lead hip rotation ROM and has an analytical component. The lead and trail hip joint outcome measurement in degrees of range is compared due to the importance of the hip rotation as is discussed in paragraph three of the introduction.

The Population description

There are currently 500 elite young male golfers registered with the South African Golf Association (S.A.G.A).The ages of the male open-amateur group varies between 18 and 35yearsand this category of players usually plays golf three or more times per week (H. R. Gulgin & Armstrong, 2008). They practice daily and their swing pattern is more consistent than the younger age groups, which are categorized into groups of u/12, u/14, u/16 and u/18. Handicapping is a great equalizer among golfers of differing abilities. A golf handicap system is based on the assumption that in every 9-hole and 18-hole stroke play of golf, the player will endeavour to make the best score at each hole played and report such score to the S.A.G.A for handicap purpose, regardless where the round was played.

The purpose a HC system is to:

- provide all golfers with a fair handicap
- reflect the players inherent ability and trends to his recent score
- have the ability to adjust a handicap to a players ability
- disregard freak high scores that bear no relation the players normal ability
- establish handicaps for all golfers, from informal play to championships
- assist a handicapper to identify the player whose handicap does not reflect his playing ability

The amateur group (ages 18-40 yrs) has thus managed to bring their golf handicap score (HC) down to a lower value due to regular play. A research study conducted in 2007, investigating golf handicap values, and found that handicap values varied from a low HC of 0-7 (3±2), to a mid HC of 8-14 (12 ± 2) and a high HC of >15 (21 ±4) (Zheng et al., 2008). This information is important to keep in mind when one considers the chosen group for this research project.

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Sample description and size

A convenient study sample will comprise of male subjects between the ages of 18-40 yrs. The sample size calculation suggested that the measurements of 30subjects will be large enough to detect a difference of 6° (80% power) between passive and dynamic rotation.

The Hypothesis mean of 0.0 and the alternative hypothesis mean of 6.0, with an estimated standard deviation of 11.3 and with a significance level (alpha) of 0.05, were established using a two-sided one-sampled-test.

Sample recruitment method

The chairpersons of the Western Cape regional golf clubs will be contacted via e-mail to inform them of the aim and objectives of the research study as well as of the proposed data collection procedure (Appendix 1). The PI will request a list with contact details for the registered players that are between the ages of 18-40 yrs. The utmost care and sensitivity will be regarded towards member confidentiality and privacy during the random selection of the young golfers. Permission will be asked from the relevant club chairperson to put a notice on the notice board in the cloakroom of the appropriate golf club, to explain the intentions the study to the prospective subjects (Appendix 2).

The bio-statistician will randomly select 30 subjects from the original combined obtained club-list with a computer generated random feature tool. The P.I will contact the first thirty participants from that list via e-mail and or cellular phone text, to inform him of a forthcoming phone call to ask if he would be willing to participate in the study. He will need to answer the questions on the questionnaire (Appendix 3) to be included in the study. The questionnaire can be emailed to them but it will only be used to guide the questions for the information needed for the demographic info sheet (Appendix 4). If the subject decides not to participate, the next number on the list will be contacted until 30 subjects are obtained. The PI will screen eligible participants telephonically.

Sample Inclusion criteria

The following inclusion criteria will be applied to the study sample:

- healthy young male golfers between the ages of 18 and 35 years;
- a handicap of 16 or lower is included;
- practicing for three or more times a week on the driving range and or on the golf greens;
- practice for three or more hours per week on the driving range and or greens;
- playing 1 round of 18 holes of golf per week (H. R. Gulgin & Armstrong, 2008);
- have to be playing golf for two or more years (H. Gulgin et al., 2009; H. R. Gulgin, 2012b);
- currently training actively in a gym or participate in a golf strength and conditioning program.

Sample Exclusion criteria

The following exclusion criteria will be applied to the study sample:

- injuries to the spine, hip, lower extremity or upper extremity (Kouyoumdjian et al., 2012)
- any previous surgery to the hip, lumbar spine, upper or lower extremities

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- a history of fractures of peripheral joints or lumbar spine
- a history of sacro-iliac pain that has influenced golf play
- complaints of “stiff hips”
- participating in other rotation related sport on a provincial level, e.g. soccer, tennis, judo, dance, cricket, martial art and karate.

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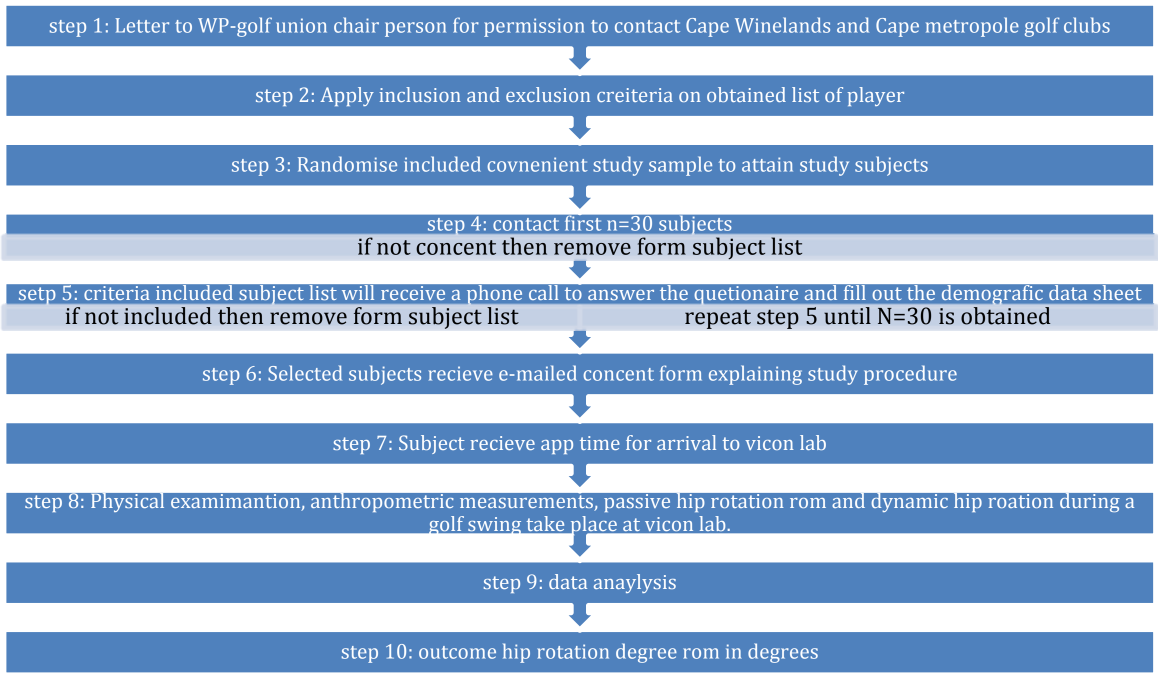
Data Collection

Table 8: Flowchart per description to the study method



8.1 Outcome measurements

The data collection will consist of three steps:

1. A data capture sheet (Appendix 4) and associated questionnaire (Appendix 3) to collect demographic history of the subjects
2. The measurements of passive ROM of both the lead and trail hip with an inclinometer
3. The measurements of dynamic ROM of both the lead and trail hip utilising a 3-D Vicon analysis system.

8.2 Data collection setting

The Vicon laboratory at the University of Stellenbosch at the Tygerberg campus will be used for all the measurement and data collections. The manager of the Vicon laboratory, Prof Quinette Louw, was contacted and consent is obtained for the study to be conducted in the laboratory (Appendix 5). A time schedule will be in place and the exact time of appointment will be confirmed with each subject via an e-mailed. Each participant will be informed of the three-step testing procedure upon arrival. The measurement procedure should take about 1.5 -2hrs per subject, but this will be confirmed with the pilot study.

A well-padded plinth is used to collect passive range measurement and the same PI and RA will record the data. The subjects will be requested to bring their own driver clubs and golf shoes with them as well as to wear non-restrictive

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clothing, preferable knee exposing sport shorts and a sport shirt. The PI will measure passive ROM and record the data in a MS office excel statistically designed spreadsheet.

During dynamic ROM measurement, the research PM will apply all the reflecting skin markers. As the reflective markers will be placed directly on the skin, no shirts may be worn during dynamic testing as it may restrict the cameras ability to detect the reflective markers. A Vicon analysis will be offered after the testing procedures if they participated in the study.

8.3 Data collection instruments

8.3.1 Data collection sheet and questionnaire

The data sheet (Appendix 4) is designed around a questionnaire (Appendix 3) that will collect question answers regarding the demographic information of the registered young healthy golfers, which was randomly selected from the Western Cape region. It is divided into sections from A to E. These sections will collect the subject's personal details, medical history, golfing history, family history and physical conditioning as well as sport participation history. The aim of this data-collecting sheet is to obtain information on the subject for purpose of inclusion and exclusion criteria to the study group. The data collected from section A to E will be imported into a statistically approved designed spreadsheet to have accurate access to correct and reliable data.

8.3.2 Passive measuring tool

8.3.2.1 Inclinometer

For the purpose of this study, a plastic Baseline® Bubble hand held inclinometer is used to measure passive hip rotation ROM in an adjusted seated 135°hip flexion (90°+45°) position in order to mimic the golf address posture (Gluck et al., 2008). In a comparative study where an inclinometer was tested against a goniometer whilst measuring hip joint range, the hand held inclinometer was found to be clinically friendlier and more reliable than the digital inclinometer (Barbee Ellison, Rose, & Sahrmann, 1990; Kouyoumdjian et al., 2012). A hand held inclinometer is a relatively inexpensive alternative measuring tool costing about R500.

Figure 10: Baseline® Bubble hand held inclinometer

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8.3.2.1.1 The reliability of the tool

In measuring ROM in a joint the reliability of an inclinometer was found to be excellent (Boyd, 2012). The inclinometer has a very low measurement of error (0.54º and 1.22º) and has a low minimal detectable change value of 3.41º.

8.3.2.1.2 The validity of the tool

The validity was found to be excellent for a hand held inclinometer-measuring neuro dynamic ROM in a straight leg raise (Boyd, 2012).

8.3.2.1.3 The Variability of the tool

During testing for passive hip-rotation ROM the outcome variability proved low for an inclinometer (Bierma-Zeinstra et al., 1998; Ellison et al., 1990).

8.2.3.2 Inter- rater and intra-rater reliability

These reliability tests will be determined before conduction of the pilot study. Subjects of the same age will be used. 5 subjects will be measured.

To determine inter-rater reliability between the primary investigator and the research assistant, three measurements of the total passive hip rotation ROM will be taken of each subject, 2 minutes apart. The information is then recorded on a statistically designed excel spreadsheet for analysis (Appendix 6). This will ensure that the primary investigators measurements are reliable against the next rater. They will be blinded to each other's measurements

Determining intra-rate reliability, passive measurements of the left hip-rotation ROM will be taken by the P.I of 5 subjects will be tested. This information will be recorded on an excel spread sheet (Appendix 7).The analysis will be done by calculating a standard error of measurement (S.E.M) and a interclass correlation coefficient (I.C.C). The I.C.C values of 0.8-1.0 will be accepted. I.C.C values will be classified as follow: 0.00-0.20=poor, 0.21-0.40= slight, 0.41-0.60=fair, 0.61-0.80=moderate, 0.81-0.90=substantial, 0.91-1.00=almost perfect.

8.3.3 Dynamic Measuring Tool

8.3.3.1 Visual confirmation 3D MOTION system

The Vicon Motion System (Ltd) (Oxford, UK) tool is a three-dimensional digital visual confirmation motion analysis system that records dynamic human movement. This has been a popular tool since 1984, and it is used in motion studies that allow the researcher immediate visualization of the investigation and analysis for off-line recorded data. (www.vicon.com, 2003). For the purpose of this study, an eight-camera T-series Vicon MX system with a Bertec (Bertec Ltd) forceplate will be used to capture the kinetic and kinematic variables. The T-10 system has a resolution of 1 megapixel and captures 10-bit grey scale images using 1120 x 896 pixels. It has a high-speed accuracy with speeds of up to 2000 frames per second in full resolution. It is capable of capturing as much as 250 frames per second in a full frame resolution. A custom-designed Vicon Vegas CMOS sensor provides a full frame "true" shutter. The integrated Nexus 1.4 116 software and giganet is used for calculating ROM and angular velocities of the involved segments and joints in all three planes. The analysis of the Vicon software creates a graph looking at a joint angle relative to time. The system extract the peaks and average angles across this information and apply it to statistical analysis, and in the current study is looking for dynamic rotational movement of the hip joint during the golf swing. The Vicon lens itself is custom-built for motion capture, enhancing the performance of the system. The lens has a large red image circle, which ensures even illumination of the image instead of centre illumination.

Figure 11: Vicon camera

Dynamic calibration of the system will be done. This is achieved while the lab technician walks through the capturing volume, while moving the T-wand in scooping movements. The ability of the cameras to detect this movement within the capturing volume will be calculated by the software. System marker orientation is done using a VICON T-wand. Retro reflective markers with a diameter of 9.5millimetres will be used. All trials will be reconstructed to view the graphical image of the subjects and then the labelling of all trials will be checked again the bio-engineer for accuracy of the labelling of the anatomical marker positions.

8.3.3.2 The Reliability and Validity

Tests for both the validity and reliability for the Vicon (Ltd) (Oxford, UK) has been established (Chen, Zhao, Cao, & Zhang, 2011; Standaert, 2008). Good intra-rater reliability was established with tests executed on the same day (Lal & Hoch, 2007). High criterion validity was established for the Vicon (Ltd) (Oxford, UK) in the measurement of upper limb kinematics, compared to inertial tracking sensors.

8.3.3.3 Data processing

After all the trials for the dynamic swing are captured, each trial will be reconstructed and labelled. by the bio-statistician. Possible gaps in the data will be filled using either the Spline- or pattern-fill options ref. If a gap is smaller than or equal to 4 frames the Spline fill will be used, if the gap is bigger than 4 frames the Pattern fill function will be used. For each trial, a sum of two gait strides will be used for data analysis. The two consecutive strides, which fall within the area where the visual field of all the cameras overlap, are selected. The cycle parameters are manually inserted. Once this is completed, the Dynamic Plug-in gait pipeline including the Butterworth filter will be run. Data exported to Matlab to extract the parameters of interest.

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8.4 Measuring procedure

8.4.1 Passive Procedure

8.4.1.1 Clinical evaluation

Each subject will be given a participation and consent form (Appendix 8) to sign upon arrival. To ensure reproducibility, each measurement of the participant is taken on the same day and in the same room. All subjects will be familiarized with the laboratory environment and equipment, as well as debriefed on the testing procedure. To ensure the safety of the subjects and protection of the lab equipment, a standard checklist (Appendix 9) will be performed to ensure that all aspects are covered. Once the subjects are familiarized, each participant will be asked to do a warm-up session on the stationary bike in the gym prior to clinical evaluation for 5 min and the golfers will be dressed in knee exposing non-restrictive clothing without shoes. They will be asked to sit on a medical plinth to take anthropometric measurement and to allow a clinical evaluation to be performed. A standard anthropometric form (Appendix10) will be used to record the physical examination data. The following measurements will then be taken:

- height
- weight
- waist circumference
- hip circumference
- shoulder offset
- elbow width
- hand thickness
- leg length
- knee and ankle width

A physical examination will then be conducted to establish passive joint ranges. The hip, knee and ankle joints will be included.

- hip external rotation
- hip internal rotation
- hip flexion
- hip extension
- Thomas test
- hip abduction and adduction
- femoral ante-version
- knee and ankle joint ROM

A physical examination and passive data collection form (Appendix 11) will be used to capture the data.

8.4.1.2 The Inclinometer

For the purpose of this study, a universal gravity inclinometer will be used. The subjects will be sitting on the firm, well-padded, top and mid-section slide mechanism medical plinth. The plinth will be set on an 85cm height. To make

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this height reliable and practical for each test, two 85cm ribbons will be attached to the edge of the plinth to be re-checked before each measurement. A 45-degree angle plastic covered wedge will be added as back support when passive hip ranges are measured. The subject will be moved forward towards the end of the plinth in order to have the knees hanging free over the bottom edge. The patient will now be a seated in hip flexion of 135°which is a replicated open kinematic chain position in the golf address posture (Hume et al., 2005).A pelvic belt will be placed over the anterior iliac spinea and strapped to the plinth to prevent any pelvic movement during hip rotation.

The testing limb will be free over the bottom edge of the plinth in a 90º knee flexed angle (Hume et al., 2005). A skin marker pencil will be used to mark on the tibial tuberosity and inter-malleoli line as well as the medial and lateral femoral condyle. This anterior line is used as midline marker for recording purposes and the lateral markings is used for inclinometer placing. The contra lateral hip will be placed over the other side of the plinth placed on a supportive step to use as stability control and isolate tester hip ROM and the pelvis. The PI will sit on a 25cm high gym step in front of the subject facing the knee on a comfortable eye level. The inclinometer will be placed on the lateral side of the knee femoral condyle to record the measurements.

The PI will perform a *hip internal -rotation* (this is where the heel is rotated away from the midline of the body) until a firm end-feel is experienced at the hip joint end ROM, or a pelvis compensatory movement is noted. The P.I will accurately record these measurements. The hip will be returned to the mid-position before the external rotation is recorded (Appendix 11).

The same procedure will be applied for the *hip external rotation* (this is where the heel is rotated toward the midline of the body). The total ROM (internal rotation to external rotation) will then be recorded in the same fashion and with the same end feel criteria. Each ROM to the end feel will be repeated three times with the order being: internal rotation, external rotation, total ROM. The best of the three values (Prather et al., 2010) will be use for the purpose of this study and recorded separately as IR and ER and as a unit TAR. Both the trail hip and lead hip passive measurements will be recorded separately.

8.4.2 Dynamic Procedure

8.4.2.1 The Vicon

Each subject will be in the movement laboratory, warmed-up and familiar with the procedure has been debriefed during the passive procedure. All the anthropometric measurements have been performed during the physical examination and entered by the bio-statistician into the Vicon system. All subjects will be dressed in their own golf shoes and their upper bodies will be exposed for the placement of the reflector markers in order to allow the cameras to see all placed markers. An upper and lower body multi set (42) of bilateral retro-reflective markers will be applied with double-sided tape on the upper body segment, pelvic segment and the femoral segment of the body.

The pelvic segments are defined as:

- the bilateral anterior spine of the iliac crest (2)
- the bilateral posterior iliac spine (2)

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The bilateral femoral and lower limb segments are:

- greater trochanter (2)
- anterior thigh (2)
- lateral aspect of the thigh (2)
- lateral knee on the lateral femoral epicondyles (2)
- medial and lateral ankle malleoli (4)
- lateral aspect of the shin (2)
- second metatarsal head (2)
- posterior aspect of the calcaneus (2)

The upper body segments are:

- spinous process of T10 and C7 (2)
- supra sternal notch (1)
- xiphi sternum (1)
- right scapular(1)
- the acromio-clavicalur joint(2)
- lateral epicondyles of the elbow (2)
- radial and ulnar styloid processes of the wrist(4)
- Distal second metacarpal(2)
- front and back head (4)

The PM will be the only person to place all the skin reflector markers on the subjects. A quick unfold golf-net will be erected for these procedures in order to create a space for the balls to be collected. Reflective air balls will be used for golf-club-ball-impact purposes. With each subject utilising his own driver and golf shoes, it will encourage the golfer to swing from a more comfortable natural familiar address-posture. Testing subject can practice 10-15 tests swings beforehand to put them at ease with the unfamiliar swing environment. There after they will have to perform a series of 5 to 10 golf swings for data collecting purposes. The joint centres and joint axis markers of the three femoral segments are used for the calculations. Rotation (movement around the long axis of the femur) will be calculated from the transverse plane motion of the femur relative to the pelvis (H. R. Gulgin & Armstrong, 2008; Zheng et al., 2008).

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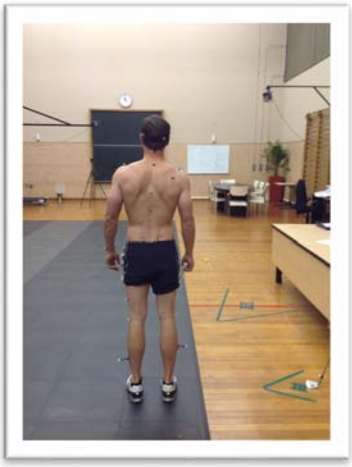

Figure 12: Reflective skin marker

The golf swing will then be captured. A full set of instruction will be given to the subject regarding the swing phase (see Table 1).

8.4.3 Intra-rater reliability

To ensure intra-rater reliability, the PM has received local and international training on marker placement and follows a precise marker placement protocol developed for the S.U.N movement laboratory. The markers will not be removed during any of the test movements and even if data is lost during a movement; the precise position of the marker will easily be located by the data analyst. Therefore, marker placement should not introduce bias into the study findings.

Pilot study

A pilot study, including a physical examination, passive ROM measurements and dynamic testing, will be conducted to ensure that all the measurements are reproducible and that the research team is familiar with the project procedures. Data collection time will then be calculated and tested to be able to set-up a time schedule or the participants. A conventional gait analysis will be tested for each subject prior to each golf swing testing cycle. Data collected will be checked by the bio-statistician and corrected for the outcome of the project. One subject will be used for the pilot testing. This is planned for October 2012 or as soon as approval from the H.E.R.C is received.

Data analysis

For data capturing purposes, Micro Soft Excel and STATISTICA version 10 (Stat Soft Inc. 2012) a data analysis software system, was chosen to analyse the data. Statistical summaries will be used to describe the variables. Distributions of variables will be presented with histograms and or frequency tables. Medians and means will be used as the measures of central location for ordinal and continuous responses and standard deviations and quartiles as indicators of spread (Machin, Campbell, Frayers, & Pinol, 1997; Zar, 1984).

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Relationships between two continuous variables will be analysed with regression analysis and the strength of the relationship measured with the Pearson correlation, if the continuous variables are not normally distributed. If one continuous response variable is to be related to several other continuous input variables, multiple regression analysis will be used and the strength of the relationship measured with multiple correlation. The relation between two nominal variables, the degree outcome of passive hip-rot ROM and dynamic hip rot ROM will be investigated with contingency tables and likelihood ratio chi-square tests.

A p-value of $p < 0.05$ will represent statistical significance in hypothesis testing and 95% confidence intervals will be used to describe the estimation of unknown parameters.

10.1 Statistical values

A power analysis was performed to detect a minimum difference of 6 degrees between passive hip rotation and dynamic hip rotation ROM. The result indicates that 30 subjects would be necessary to achieve 80% power with an mean of 0.0 and the alternative mean of 6.0 with an with an estimated standard deviation of 11.3 and a significance level (alpha) of 0.05000 using a two-sided one-sample t-test. The subject size was altered as the funding to accommodate such a large study group was lacking. Due to the restricted funding of the project, 7 subjects will be utilised.

Table 9: Sample calculation

	N	Alpha	Beta	Mean0	Mean1	S	Size
0.80775	43	0.05000	0.19225	0.0	5.0	11.3	0.442
0.80118	30	0.05000	0.19882	0.0	6.0	11.3	0.530
0.80897	23	0.0500	0.19103	0.0	7.0	11.3	0.618
0.80662	18	0.05000	0.19338	0.0	8.0	11.3	0.707

Ethical considerations

The study will be conducted according to the ethical standards and guidelines of the International Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (M.R.C) Ethical Guidelines for Research. The study will only be conducted after the approval from the Health Research Ethic Committee (H.R.E.C.) at Stellenbosch University. Each subject will be given a consent form designed by the H.R.E.C. to sign before the study is conducted. Withdrawal of the subject may be done at any point if so chosen. No harmful tests are done on any subjects and no invasive procedures are conducted at any time. The exclusion criteria will ensure that no subjects with injures will be exposed to any testing. All testing will be done away from the club premises and in complete confidentiality. The information obtained may contribute to improved training strategies for coaches and physiotherapist alike. The information from the testing procedures will be made available to the individual participant if requested from the participant. The study findings will be published.

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Study Timeframe

Table 10: Timeframe

Protocol draft	**January 2012 to September 2012**
Submit for Ethics approval and protocol	October 2012
Running of pilot study	November 2012
Data capturing	November 2012 to February 2013
Submit to Statistical department	March 2013
Writing of thesis	March 2013 to August 2013
Submit for language approval	September 2013
Submit of Thesis	November 2013

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Budget planning

Table 11: Budget planning

Budget		
		Period:
Personnel Compensation		
	vicon lab per subject	R 10500.00
	assisant researcher	4000
Participant Compensation		
Consulting Services		
	expert engineer	4000
	Database Programmer	
	Statistical Services	
Travel, participants		
	snacks and cool drinks	175
	Travel to golf clubs	550
Equipment & Furniture		
	golf net (swingfit sponser)	R 0.00
	inclinometer	R 500
	golf air balls (100)	R 500.00
	reflective tape	450
Other Direct Costs		
	Telephone, Cell Phone & fax	
	Editing	
	Office Supplies	R 500.00
	Courier & Postage	R 150.00
	Printing & Copying	R 500
Total Direct Costs		R 21825.00
Indirect Costs(14%)		R 3055.50
Total Expenditure		R 24880.50

The Vicon lab has an estimate charge of R1500 per subject per dynamic test procedure. A total of R45000 will be needed for the Vicon procedure project. A grant from the Harry Crossly foundation was denied.

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Appendix 13: Letter to Western Cape Golf Union chairperson

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

25 July 2012

Dear Eden

I am currently busy with my Master's Degree in Physiotherapy at Stellenbosch University. My research study aims to determine the amount of rotation a golfer needs to rotate his hips while he is swinging. Lower back pain is the injury that influences the amateur golfer the most, and we know from previous studies conducted internationally on golfers, that the hip joint rotation influences and cause low back pain. In order to understand the mechanism of this injury, I need to understand the hip joint rotation that a golfer needs for his swing.

This is the first study of its kind to be conducted in South Africa. Cape Winelands and Cape Metro pole Golf clubs will be approached to take part in the study. I am thus addressing this writing to you to ask permission to conduct this study at the golf clubs. A study sample will be selected from the list of members through a process of random sampling procedure.
This research study is two-fold. Firstly, the selected players will have to complete a questionnaire and secondly the range of hip rotation will be measured passively with an inclinometer and dynamically with 3 D video analysis whiles they swing. Both these measurements will be performed at Stellenbosch Medical Faculty Tygerberg campus. The duration of the evaluation should be approximately two hours for each participant. The study will not influence any golfers swing nor put them at risk of an injury.

If you give permission, I need a list of all the clubs in the Western Cape. From that list I need the names of all the registered members between the ages of 18 and 35 who have a handicap of 16 and lower. The statistician will then randomly select 30 players from that list to use for our study. I will then contact those players to ask if they are willing to participate in this study. It is understood that their information will be handled with the utmost of care and privacy.
I could collect the data for this study from you either via email or directly from your office.
Could I make an appointment to discuss this research with you?

You time is highly appreciated.
Kind regards

Villene Alderslade
BPhysT.UP

Fakulteit Geneeskunde en Gesondheidsweteskappe
Faculty of Medicine and Health Sciences

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Appendix 14: Cloakroom notice for a prospective subject

Notice for prospective young golfers to participate in a research project

WE NEED 10 HEALTHY YOUNG ADULT REGISTRED GOLFERS BETWEEN THE AGES OF 18 AND 40 TO TEST AND SEE WHAT THE AVAILABLE MOVEMENT RANGE IN THEIR HIP ROTATION IS OF BOTH THE LEAD AND THE TRAIL LEG DURING A GOLF SWING

Research project

Investigating the PASSIVE AND DYNAMIC degree range of movement difference of HIP ROTATION in both the LEAD AND TRAIL HIP of the healthy young adult golfer.

WHY SHOULD YOU PARTAKE?

- 34% of professional and amateur golfers struggle with lower back pain, and research has shown that your hip could be an important factor to consider when trying to resolve back problem
- If you are serious about your golf future and intent on continuing a golf career pain free, please help find a solution to the possible dysfunction between the hip and the lower back

ARE YOU WILLING TO PARICIPATE?

- You will be contacted once a random list has been generated from all the clubs in the western cape and your name has been selected by the computer program
- Participation if you've been selected is not compulsory and you may decline if you are contacted and don't want to partake

WHAT YOU DO NEED TO HAVE TO PARTAKE?

- Be selected from the randomization procedure
- Be registered with your golf club
- Be between the ages of 18-35
- Have a H.C of 16 or lower
- Play golf once a week
- Have been playing golf for longer than 2 years
- Regularly practice golf on the range and train in the gym
- Have never broken a bone
- Do not currently suffer from any current lower back ache that influences your golf play
- Do not partake in other rotation related sport e.g. judo on a

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Appendix 15: Permission letter from the VICON laboratory

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

150 Pearl Valley Golf Estate, Paarl, 7646

20 September 2012

Dear Villene

PERMISSION FOR CONDUCTION OF STUDY IN THE VICON LABORATORY.

I hereby grand acceptance for the following study to be performed in the Vicon laboratory during the completion of the degree of Masters in Physiotherapy.

Title of the study

Investigating the range of movement degree-difference between passive and dynamic rotation of both the lead hip and trail hip in healthy young adult golfers when performing a golf swing.

Kind regards

Fakulteit Geneeskunde en Gesondheidsweteskappe
Faculty of Medicine and Health Sciences