THE INCIDENCE AND ASSOCIATED RISK FACTORS OF INJURY IN PROFESSIONAL GOLFERS

A MINOR-DISSERTATION BY JACOBUS A VISAGIE (VSGJAC006) IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE MASTER OF SCIENCE IN EXERCISE AND SPORTS PHYSIOTHERAPY FROM THE UNIVERSITY OF CAPE TOWN

STUDENT: JACOBUS A VISAGIE (VSGJAC006)

SUPERVISOR: DR CANDICE HENDRICKS

CO-SUPERVISOR: A/PROF NIRI NAIDOO

DEPARTMENT OF HEALTH AND REHABILITATION SCIENCES

FACULTY OF HEALTH SCIENCES

UNIVERSITY OF CAPE TOWN

DECLARATION

I, Jacobus A Visagie, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is submitted for another degree at this or any other university.

Signed by candidate

(Signature)

01/02/2021

(Date)

ACKNOWLEDGEMENTS

This research study would have been possible without the guidance, motivation, and support of numerous people. I would like to take the opportunity to extend the sincerest gratitude to all who have contributed to the completion of this dissertation. I would like to give special thanks to the following individuals:

To my supervisor, Candice Hendricks, thank you for your guidance, patience and willingness to always help me solve any problems that arose along the way. I would also like to thank you for being willing to take on the additional workload when I first changed my research proposal and secondly decided to expedite the process of handing in my research study.

To my co-supervisor Niri Naidoo, thank you for sharing your experience and wisdom during the process of completing this research study. Thank you for always pushing me to answer the difficult questions and ensuring that I reach the true potential of my study. Your input was always greatly appreciated.

To Brett Phillips, thank you for always being available and willing to help during your exceptionally busy schedule, even though you had no obligation to do so. Thank you for helping me make sense of the study and helping me see what the end goal should look like.

To Karen Frye, thank you for giving me the platform to launch my research from. Thank you for your guidance, friendship, and the time you spent helping collecting data from the participants. On that note, I would also like to thank Marinda Swanepoel and Celeste Strauss for helping with the data collection process, and for being extremely reliable and always willing to help.

To my wife, Jana, for being the one person to whom I could always turn when things became overwhelming. Thank you for your love and support and for understanding when I could not spend time with you. I love you. To my parents, Kobus and Susan, thank you for always believing in me. Thank you for being there every step of the way, always encouraging, always motivating, and reminding me that there are no limits in life.

Finally, to my saviour, my reason and my brightest light. I thank God for the ability to better myself, not only for my personal goals but to help others.

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BMI: Body mass index

CI: Confidence interval

cm: Centimetre

ER: External rotation

Fig.: Figure

FABER: Flexion, abduction, external rotation

GIRD: Glenohumeral internal rotation deficit

HA: Horizontal adduction

HGT: Hours training components of golf

HOT: Hours spent on other training

HPR: Hours playing rounds of golf

hrs: Hours

ICC: Intraclass Correlation Coefficient

IQR: Interquartile ranges

IR: Internal rotation

km: Kilometre

$km.h^{-1}$: Kilometre per hour

LL: Lower limb

m: Metre

Max.: Maximum

min: Minutes

Min.: Minimum

p: Probability

PGA: Professional Golf Association

ROM: Range of motion

s: Seconds

SD: Standard deviation

SS: Summer swing

TotHrs: Total hours spent training

UCT: University of Cape Town

UL: Upper limb

WS: Winter swing

GLOSSARY OF TERMS

Amateur: An individual who has never competed for a money prize, with or against a professional player, or who has never taught, pursued or assisted in practice of exercise as a means of contributing to a person's livelihood (Morrow, 1986).

Driving: The first shot taken on a hole is a long-game shot known as a drive (GolfBox, 2018). The aim of a drive is to hit the ball as far as possible in the direction of the green (Hume, Keogh, & Reid, 2005).

Extrinsic factors: Factors that are independent of the injured person and are related to the type of activity at the time of the injury (Meeuwisse, Tyreman, Hagel, & Emery, 2007).

Incidence of injury: The incidence of injury in this study is defined as the number of new injuries sustained during the testing period by the total number of participants (Bronner, Ojofeitimi, & Mayers, 2006).

Index injury: The index injury is the first injury that was reported by the participant during the testing period (Hamilton, Meeuwisse, Emery, & Shrier, 2011).

Intrinsic factors: Factors are individual biological and psychosocial characteristic predisposing the player to musculoskeletal injury (Meeuwisse et al., 2007).

Leading side: The side facing the front when standing in position to take a golf swing. In right-handed players, this would be the left shoulder and -hip; and in the left-handed players, this would be the right shoulder and -hip (Marta, Silva, Castro, Pezarat-Correia, & Cabri, 2012).

Overuse injury: An overuse injury is caused by repetitive microtrauma, in the absence of a single identifiable event (Fuller et al., 2006).

Professional: Touring professional players play golf for their livelihood (GolfBox, 2018).

Putting: Playing the ball along the ground towards the hole, using a putter (GolfBox, 2018).

Recurrence of injury: A recurring injury is defined as an injury at the same site and the same type of injury as the index injury (Hamilton et al., 2011).

Region-specific area: A specific region of the body, i.e. the shoulder, the hip, the lower back, knee etc. (Dane, Can, Gursoy, & Ezirmik, 2004).

Round of golf: A round of golf generally refers to a person playing 18 holes of golf (GolfBox, 2018).

Short game: The short game is generally considered the strokes played from within 100 yards from the hole (GolfBox, 2018).

Summer swing: Season ranging from December to March.

Trailing side: When a player is standing in position to play a stroke, the side facing away from the direction to which the ball will be hit is called the trailing side. In right-handed golfer this would be the right side of the body and in a left side it would be on the left side (McHardy, Pollard, & Luo, 2006).

Training load: Load is described as sport burden as a stimulus that is applied to the human biological system over varying periods with varying magnitude (Schwellnus et al., 2016). Total duration has been deemed as the preferred method of measurement of the load while investigating a golfing population (Williams, Gastin, Saw, & Robertson, 2018).

Traumatic injury: A traumatic injury would then be a result of an identifiable mechanism or event (Fuller et al., 2006).

Winter swing: The golfing season in South Africa ranging between April and November.

ABSTRACT

Title: **The incidence and associated risk factors of injury in professional golfers**

Author: **Jaco Visagie**

Date: **26 October 2021**

Background

Golf has become an immensely popular sport around the globe. The competitiveness of golf and the livelihood it provides to the professional players has led to copious amounts of training and individuals pushing the physiological limits of their bodies to play the perfect stroke. Therefore, this population is prone to injury, with prevalence of injury as high as 60%. Literature has shown the lower back to be the most frequently injured anatomical region. There is still a lack of evidence regarding the cause of these high injury rates amongst the professional golfers. Furthermore, investigation of the incidence or associated risk factors of injury has not been conducted amongst the professional players from South Africa. The importance of identifying associated risk factors of injury in this population is of vital importance as this could potentially influence their livelihood directly.

Aim

The aim of this study was to investigate the incidence of overall and region-specific injury in professional South African golfers. The potential risk factors contributing to these injuries have also been investigated.

Results

17 participants (60.7%) reported an injury and a total of 23 index injuries were documented. The incidence rate of injury was 3.27/1000hrs of playing golf. The most frequently injured anatomical regions were the lower back and shoulder (26.1%). There were statistically significant differences in the joint range of motion of horizontal adduction of the leading shoulder ($p=0.04$) between the group reporting an injury compared to the group with no injury. Furthermore, statistically significant differences were found in decreased range of motion of internal rotation of the trailing shoulder ($p=0.04$) in the group with a shoulder injury compared to the group without a shoulder injury, and as well as in the group with hip pain compared to the group without hip pain ($p=0.048$). The group with hip injuries also showed a decreased range of motion of external rotation of the leading hip ($p=0.048$). Furthermore, a decreased range of motion of external rotation of the leading shoulder had a statistically significant difference ($p=0.026$) between the group that reported a wrist injury and the group that did not.

The group that reported lumbar spine injuries had significant decreased range of motion of external rotation in the trailing shoulder (p=0.031), horizontal adduction of the trailing shoulder (p=0.015), horizontal adduction of leading shoulder (p=0.029), and internal rotation of the leading hip (p=0.003).

Furthermore, the uninjured group spent more hours on total training in the eleventh week, which also presented a statistically significant difference (p=0.03).

Conclusion

Injuries amongst professional golfers are common and the anatomical regions most affected are the lower back and the shoulder. Improving the range of motion of the leading and trailing shoulder horizontal adduction, trailing shoulder internal and external rotation, and internal rotation of the leading hip range of motion by means of mobility exercises could potentially minimize the risk of sustaining injury amongst professional golfers. Training volume did not present a statistically significant difference between the injured and uninjured groups in overall or region-specific injuries.

CHAPTER 1: INTRODUCTION

1.1. Background and significance of study

Golf is a vastly popular activity around the globe with 206 countries participating in the sport at different levels (Farrally et al., 2003). It is played by people of all ages, skill levels and whom have different socioeconomic backgrounds (Cabri, Sousa, Kots, & Barreiros, 2009; McHardy et al., 2006). It is a sport played on an outside course, where the goal is to strike a ball using a club with the lowest possible number of shots, before getting the ball into a hole at the other end of the field. There is a variety of club shapes and forms and the club used depends on the area the shot would be played from in relation to the hole. One round of golf usually consists of 18 holes. Its popularity in participation is most likely due to the nature of the sport being limitless in age, gender, and skill.

Amongst novice players it is particularly popular in the older population, due to it being a lower impact sport but still contributes as an aerobic component to exercise for health purposes (McHardy et al., 2006). It has also been reported that participation in this sport may lead to an increase in longevity and improve mental wellbeing. Golf was also been reintroduced into the Olympic Games in 2016, due to popular demand (Murray et al., 2017).

The professional era in golf has also developed from a player earning $43,600 after winning a tournament organized by the Professional Golf Association of America (PGA), to earning $1,820,000 at the 2020 World Championship in Mexico, according to the associations website (PGA, 2020) (Marple, 1983). The South African men's golf tour was rebranded in 2000 as the Sunshine Tour, which now includes events not only in South Africa, but in countries like Namibia, Zambia, Zimbabwe and Swaziland (Fraser, Botha, & Fraser, 2015). Players usually ranked lower on the global ranking system, register for the Sunshine Tour. It is a more accessible tour due to the smaller profitability it can offer. However, the Sunshine Tour is still very popular, with players from all around the world and players from South Africa with the potential to join the globally higher ranked tournaments, competing on this tour (Fraser et al., 2015). During a tournament the players usually start on the Thursday and plays their first round of 18 holes. Thereafter, they play a second round on the following day and after these two rounds the player either qualifies to play the next two rounds or they do not. To be able to qualify, the player must obtain a score low enough to place them within the top 70 players of the specific tournament. If they fail to place within the top 70, they are eliminated from the tournament and do not receive financial compensation for their efforts.

Therefore, the players spend excessive time training with the aim to perfect their golf swing (Gosheger, Liem, Ludwig, Greshake, & Winkelmann, 2003). It has been reported that the average professional player executes more than 2000 swings per week, and with such a large quantity of repetitive movements the players are bound to be at risk of musculoskeletal injuries (Pink, Perry, & Jobe, 1993). A correct diagnosis followed by immediate and effective management serve as crucial components to minimize their recovery period and, ultimately, protect their livelihood (Smith & Hillman, 2012). Therefore, golf injuries should not be undervalued when affecting either the player's time loss during training or competition, but also if the player continues playing and it affects the quality of his game (Cabri et al., 2009).

Prevalence of injury has been reported as high as 60% amongst professional golfers over a period of two seasons (Gosheger et al., 2003). The lower back seems to be the most frequently injured anatomical region and its nature has been identified as an overuse injury as high as 92% of time (Gosheger et al., 2003; Sugaya, Tsuchiya, Moriya, & Morgan, 1999; Hadden, Kelly, & Pumford, 1992). There was also a strong association between mechanical lower back pain and sacroiliac dysfunction amongst a group of club level South African golfers (Munro et al., 2018). In another study, the researchers reported that faulty swing techniques and biomechanical errors during the swing led to a higher risk of lower back pain in the golfing population (Edwards, Dickin, & Wang, 2020). With a prevalence of injury as high as it is, one would suspect that the literature would be focussed on the identification of the associated risk factors to these injuries, with special attention placed on the professional sector. The main contributor to injury in professional golf has been reported to be excessive training, leading to strain on the physiological structures in use during a golf swing (Cabri et al., 2009; McHardy et al., 2006). In another study, the researchers concluded that age and body mass have been associated with lower back pain in golfers (Smith, Hawkins, Grant-Beuttler, Beuttler, & Lee, 2018).

To the researcher's knowledge, there are no studies investigating the incidence of injury in professional South African golfers. In fact, prospective epidemiological studies of professional golfers in general appear to be lacking in the literature (Robinson et al., 2019). However, a prospective longitudinal cohort study design produces a stronger conclusion (Dawson & Trapp, 2004). It is important to identify these common injuries and their possible associated risk factors, because of the high frequency of injury among professional golfers. There also appears to be a lack of literature investigating the intrinsic and extrinsic risk factors of injury in this specific population. The importance of shoulder mobility in the prevention of injury, especially lower back pain, in golfers is highlighted and strongly recommended to include in rehabilitation- and preventative programs (Finn, 2013). Due to the 'supramaximal' ranges the spine has to endure during the swing, trunk mobility has been identified as being a crucial component of preventing injury (Lindsay & Horton, 2002). If the objectives used in this study are met and potentially identify certain associated risk factors contributing to the incidence of injury, specific intervention strategies could be utilized to manage and potentially prevent or minimize the risk of sustaining these injuries in professional golfers. By identifying these underlying factors, this study could inform the design and development of future interventions.

1.2. Aim and objectives

1.2.1. Aim

The aim of this study was to investigate the incidence of overall and region-specific injury in professional South African golfers. Furthermore, the potential risk factors leading to these injuries were investigated.

1.2.2. Objectives

The specific objects of the study were:

1. To determine the incidence of overall and region-specific injury in professional golfers, over a single season.
2. To determine whether decreased shoulder mobility (internal rotation, external rotation; and horizontal adduction) is an intrinsic factor for overall and region-specific injury in professional golfers
3. To determine whether decreased thoracic rotation is an intrinsic risk factor for overall injury and region-specific injury in professional golfers.
4. To determine whether decreased lumbar extension is an intrinsic factor for overall injury and region-specific injury in professional golfers.
5. To determine whether decreased hip mobility (internal- and external rotation) is an intrinsic factor for overall and region-specific injury in professional golfers.
6. To determine whether training load is an extrinsic risk factor for overall injury and region-specific injury in professional golfers.

Following chapter one, chapter two will present the literature found on the relevant topic, chapter three presents the methodology used during data collection, chapter four presents the results found during the conduction of the study, chapter five will discuss the result found during the data collection process, and chapter six will refer to the summary and the conclusion of the study.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

2.1.1. Background

Golf is played in over 206 countries with a population of 60 million golfers participating around the globe (Murray et al., 2020; Royal & Ancient, 2015; Farrally et al., 2003). However, updated literature on the current overall golfing population figures in South Africa were unable to be found.

Golf has been linked to better physical health, mental wellbeing, and a longer life expectancy; with these benefits overshadowing the potential risk factors of illness and injury (Murray et al., 2017). However, the modern swing does challenge the physiological limits of the human body and could result in an injury (Gluck, Bendo, & Spivak, 2008). This literature review will be discussing the epidemiology, more specifically the incidence of injury, and potential associated risk factors in a professional golfing population. The review will focus on the intrinsic characteristics and extrinsic factors, which could potentially predispose a player either to an acute- or an overuse injury. In addition, not only will the frequency of injury amongst professional golfers be highlighted but also the most common anatomical affected by injury due to the physical demands of the golf swing.

There will be a brief discussion of the literature found on the biomechanics of golf (Cole & Grimshaw, 2016; Gluck et al., 2008). When considering the outcomes of this research study, it is important to have a baseline understanding of the mechanics of the golf swing, the relevance of the various joints' movement during the golf swing, and what the repetitive physical demands are for these players. However, this study does not investigate the biomechanics of the golf swing and its correlation to injury.

2.1.2. Search Strategy

This study utilized a conceptual framework to select the most relevant literature to its' own outcomes (Fàbregues et al., 2020). The literature reviewed were sourced from sport, sports science, health science, medicine, orthopaedics, human kinetics, chiropractic, sports physical therapy, athletic training, kinesiology, and osteopathic literature. The search engines that were used include "Google Scholar", "Pubmed", "Primo" and "PEDro". The key terminology used during the searches were: "golf", "injury", "incidence", "prevalence", "epidemiology", "risk factors", "range of motion", "universal goniometer", "training load", "professional", "prevention", "prevalence", "intrinsic", "extrinsic", "pain" and "Sunshine Tour". When the terms "golf" and "injury" were used in combination and a total 110 results were found while utilizing Pubmed. After interchanging the terms "incidence", "prevalence" and "epidemiology" in combination with "golf", 30 articles were found which are relevant to this study. When utilizing the term "risk factor", an additional 3 articles that were considered for literature review. The rest of the references were made up out of searches using "prevention", "universal goniometer", "training load", "range of motion", etc. No results for the search of "Sunshine Tour" resulted in anything relevant to this study. After the inclusion and exclusion, process to find the literature most relevant to this, a total of 50 articles that we used.

2.2. The Game of Golf

2.2.1. Professional vs Amateur Golfers

An amateur golfer is a player who participates in the sport recreationally (Crews & Lutz, 2007). Professional golfers participate in the sport with the aim to receive compensation for their efforts during tournament time and to support their livelihood (Robinson et al., 2019). Therefore, professional players spend significantly more time perfecting their technique of their golf swing compared to the amateur group (McHardy et al., 2006). When competing in a tournament, professionals could potentially play 4 rounds of 18 holes a day, four consecutive days, on a weekly basis for an entire season. Amateur tournaments are less frequent and in most cases only two rounds of 18 holes, played over the weekend. The correlation between the increased volume, in hours, by the professional group and golf-related injuries will be discussed at a later stage in this review.

There is, as with most sporting codes, a very distinct difference between the amateur and professional players when it comes to the nature, anatomical region and frequency of their injuries (McHardy, Pollard, & Luo, 2007b; Gosheger et al., 2003; McCarroll, 1996). The differences in frequency have been linked to technique variations and time spent on the golf course when comparing the two groups, with professionals having a higher injury rate (Robinson et al., 2019; Gosheger et al., 2003). It is a difficult task to attribute an injury to golf when investigating amateur players (players not earning an income by playing golf) because they might have physically demanding occupations or take part in other forms of exercise contributing to their pathology (Gosheger et al., 2003). However, it is believed that in the modern era of professional golf, there has been a major mind shift regarding the importance of strength and conditioning and its benefits to performance (Lephart, Smoliga, Myers, Sell, & Tsai, 2007). Therefore, it is important to consider the training loads of professional players, additionally to their golf training, when investigating associated risk factors.

2.2.2. Sunshine Tour

During an extensive search, no search engine could provide any form of literature on golfing injuries of players competing in the Sunshine Tour. The only literature found on the Sunshine Tour fell under an economics scope and the transition made by South African golfers competing on the European and United States' tours (Fraser et al., 2015). However, this study was irrelevant to the review as it did not provide any information about injuries.

Furthermore, other studies have been highlighted golf-related injuries in Australian amateur golfers as well as German and Japanese professional golfers (McHardy et al., 2007b; Gosheger et al., 2003; Sugaya et al., 1999). There were also studies conducted on the Professional Golf Association (PGA) tour, which is predominantly a United States tour but not exclusive to American players, at the 'The Open' tournament, which is a British tournament, and on the European Tour (Smith & Hillman, 2012; Vad et al., 2004; Hadden et al., 1992; McCarroll & Gioe, 1982). The findings of these studies are discussed in the sections to follow.

2.3. Biomechanics of Golf

The golf swing can be described as five components: the backswing, the downswing, the acceleration, the early- and late follow-through (Zouzias, Hendra, Stodelle, & Limpisvasti, 2018).

The technique of the swing has changed over the modern era to allow players to gain more distance and increase their accuracy. This technique is called the "X-factor", where the player keeps their hips as still as possible during the backswing and maximizes their shoulder and thoracic spine rotation (Cole & Grimshaw, 2016; Gluck et al., 2008). The additional separation between shoulders and hips allows a further stretch in the viscoelastic structures in the torso and enhances the storage of potential energy before the forward swing phase; it increases the player's rotational velocity and acceleration of the clubhead up to $250km.h^{-1}$ (Cole & Grimshaw, 2016; Gluck et al., 2008). The modern age swing has not only modified the amount of thoracic rotation, but it also increased the amount of hyperextension in the lumbar spine during the follow-through phase (Gluck et al., 2008). This has been hypothesized as being a contributing factor to injury and more specifically lower back injury. However, there is no substantial evidence that can prove this theory.

The rotator cuff complex and the scapular muscles work together to protect the glenohumeral joint (Zouzias et al., 2018). During the follow-through phase, there is a high eccentric workload (especially on the rotator cuff muscles) due to the need for deceleration after the ball strike (McHardy & Pollard, 2005). Therefore, a lack of eccentric control by these muscle groups may lead to injury. In the trunk, it was found that the muscles are most active during the acceleration phase and the oblique muscles play an important role in trunk rotation (Watkins, Uppal, Perry, Pink, & Dinsay, 1996). However, this was evaluated on a small sample of only 13 professional golfers which could indicate that the study may be underpowered leading to possible false positive results.

Muscle activity in the hips and lower limbs have been recorded as the initiator of the downward swing, even before the shoulders and torso; with the leading hip experiencing a great amount of internal rotation during the follow-through (Gulgin, Armstrong, & Gribble, 2009). The investigator did mention in their limitations of their study that they used the same golf club, despite the anthropometric differences of the subjects, which might have influenced the amount of force generated.

The breakdown of the golf swing can be seen in **Figure 1.**

a) Initial stance

b) Backswing

c) End of backswing

d) Downswing

e) Acceleration

f) Follow-through

Figure 1: The Breakdown of the Golf Swing

(b) Backswing: trailing shoulder abducts and externally rotates, leading shoulder adducts and internally rotates; (c) thoracic spine rotates maximally (90˚-100˚), hips are kept as still as possible (45˚-50˚) (Cole and Grimshaw, 2017).

(d) Downswing: trailing hip and knee extensors contracts, bodyweight shifts to leading foot, torso starts to unwind and leading hip translates laterally (Cole and Grimshaw, 2017).

(e) Acceleration: leading forearm from pronation to supination, trailing forearm from supination to pronation, wrists from extension to flexion and weight still translating forward (Cole and Grimshaw, 2017).

(f) Follow-through: upper torso rotates 120˚, trailing shoulder faces target and lumbar spine hyperextends (Cole and Grimshaw, 2017).

2.4. Injuries in Professional Golfers

2.4.1. Incidence and Prevalence of Injury

There have been epidemiological studies in golfers, however, the professional sector has not been investigated to the same extent as the amateur sector (Robinson et al., 2019). Current literature is lacking a clear and concise definition of injury, with some researchers defining it as 'time loss during injury' (Gosheger et al., 2003), some as 'an event or incident that happened during training or match play' (Smith & Hillman, 2012) and some have failed to provide a definition at all (Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982). For this study, the injury will be defined as an injury that leads to a loss in time of training or competing. An injury to any golfer, whether it be an amateur or professional, affects their lifestyle (Robinson et al., 2019). However, when it comes to the professional group, an injury has a major impact on their performance, career and ultimately their livelihood (Robinson et al., 2019). Therefore, one would expect the literature to be focused on investigating the potential causes, contributing to this phenomenon, but there seems to be lack of comparable published research regarding injuries in professional golfers (Robinson et al., 2019).

Only a few published articles have investigated the epidemiology of golfers over the past 40 years (Smith & Hillman, 2012; Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982). In the most recently published article, the researchers collected data from 36 tournaments over two seasons on the professional European tour (Smith & Hillman, 2012). The data were collected at the service units stationed at the various tournaments. This retrospective cohort study recorded a total of 2328 injuries over two seasons. The authors mentioned the number of approaches to the units was 7430, but there was no mention of the overall number of players from which the sample was gathered. There were also no baseline measurements taken to differentiate between new and existing injuries, which may have led to biased results.

Another retrospective cohort study, with a level III evidence, included 703 professional and amateur golfers, of which 54 were male professional players (Gosheger et al., 2003). The authors reported that the professional group sustained a higher rate of injuries, 3.06 injuries per player, compared to the amateur group, which were 2.06 per player. A six-page questionnaire, consisting of anthropometric details and training history, was utilized by the researchers. However, the methodology of how they selected their players and collected this data from their subjects is unclear and therefore, the results are questionable.

Similarly, in the oldest study in epidemiology in golfers by McCarroll and Gioe (1982), questionnaires were posted to a group of professional players, of which 127 were male. The data were collected retrospectively from over the participants' career span. There was no definition for a golf-related injury in the study and they did not describe their methodology used during their collection of data. In a study by Sugaya and his colleagues (1999), the authors also failed to clarify as to what definition of injury they used during their study while investigating a group of professional golfers in Japan.

A group of investigators conducted a study where they used an online survey to collect information regarding the frequency of injury in professional golfers (Barclay, West, Shoaib, Morrissey, & Langdown, 2011). Data were secured from 526 participants. In this retrospective study, they concluded that 31% of their sample size have sustained an injury within the last year and 66% have sustained an injury throughout their lifetime. However, these professional players were in a mixed group of both males and females; and were either playing on the tour for a living or were professional coaches. Even though they specified that there was no significant difference in frequency when comparing male- and female golfers, it is unclear what the ratio was between the genders participating in the study. Furthermore, this study reported that only 5% of their 526 participants were touring players which means they had the data of 26 golfers, males and females, playing on the tour professionally related to injury. This leaves a relatively small sample for their prevalence study that could introduce some bias to the results.

2.4.2. Overuse Compared to Traumatic Injuries

It is important to distinguish between an overuse- and a traumatic injury, due to their different causative factors. An overuse injury is caused by repetitive microtrauma, in the absence of a single identifiable event (Fuller et al., 2006). A traumatic injury is a result of an identifiable mechanism or event (Fuller et al., 2006). It has been identified in the literature that professional golfers tend to suffer from overuse injuries more frequently compared to traumatic injuries (McHardy & Pollard, 2005; Gosheger et al., 2003).

Overuse injuries have been reported to be as high as 83% in a group of professional players (Gosheger et al., 2003). Certain anatomical regions were more prone to overuse injuries than others, with lower back injuries being the most prevalent (92%) overuse injury reported compared to the ankle (38%) (Gosheger et al., 2003). The authors gave a well-defined description of what constitutes a traumatic injury and what would be described as an overuse injury. Traumatic injuries in golfers are very seldom avoidable and are classified as 'accidents' during play. In another study, 69% of injuries were caused by structure overload and 21% were of traumatic nature, caused by striking an object during the swing (McCarroll & Gioe, 1982). However, poor definition of injury and poor differentiation of overuse- and traumatic injuries was highlighted in this study which could lead to possible biased results. A summary of the demographic description, methods used to collect the data, and the results of the key research studies of golf-related injuries (studies from1982 to 2012) can be found in **Table 1.**

Table 1: A summary of the demographics and results of golf injury-related studies

Author		Study design & methods	Country of study	Results
Smith & Hillman, 2012	"A retrospective service audit of a mobile physiotherapy unit on the PGA European Golf Tour."	A retrospective audit of 7430 approaches to the physiotherapy units from 36 different professional tournaments played on the "European Tour" over two years.	Europe	2328 injuries were reported.
Gosheger et al., 2003	"Injuries and overuse syndromes in golf."	A retrospective questionnaire of 703 selected professional (n=60) and amateur (n=643) golfers, with the data collected over two seasons.	Germany	291 (41%) players reported a total of 637 injuries. Amateur: 255 (39.7%) players- 527 injuries. Professional: 36 (60%) players- 110 injuries.
Sugaya et al., 1999	"Low back injury in elite and professional golfers : an epidemiologic and radiographic study."	A retrospective questionnaire that was completed during four professional tournaments in Japan, 283 (115 males; 55 senior tour males; 113 females) players reported the injuries they have sustained over their entire career.	Japan	248 (72%) players reported an injury with a total of 458 injuries.
Hadden et al., 1992	"Medical cover for 'The Open' golf championship."	Collecting data, of 88 players, retrospectively from the medical reports by the on-call doctor of "The Open Championship" tournament over seven consecutive years.	United Kingdom	101 injuries reported.
McCarroll & Gioe, 1982	"Professional golfers and the price they pay."	A retrospective questionnaire of 226 (127 males; 99 females) players participating on the PGA and Ladies-PGA tours, who were mailed the questionnaire and asked to report injuries they have sustained over their life time, and then mail the answers back to the investigator.	United States	190 (84%) players (103 males; 87 females) reported 393 injuries.

2.4.3. Anatomical Distribution of Injuries

The next section will highlight the golf-related injuries at the various anatomical regions of the body. The order of discussion follows from upper to lower quadrant.

2.4.3.1. Cervical Spine

Cervical spine injuries have been found to range between 3-25% of total injuries sustained by professional golfers (Smith & Hillman, 2012; McCarroll & Gioe, 1982). The study reporting the lowest percentage of cervical spine injuries (3%) was also the oldest study found (McCarroll & Gioe, 1982). The participants had to recall any injury they had sustained throughout their career and responded to the investigator by mail. However, the period for recall of injuries seem to be problematic as it has been found that only 61% of injuries that are recalled within the last 12 months, is accurate (Gabbe, Finch, Bennell, & Wajswelner, 2003). Therefore, the percentage of cervical injuries in the latter study could be inaccurate, as participants had to recall number of injuries sustained during their entire golfing career.

The highest prevalence of cervical injuries (25%), had a male only cohort sample during the European Tour (Smith & Hillman, 2012). Although this was also a retrospective study design over a two-year period, the data were collected after each tournament by a healthcare professional. In addition, the prevalence of cervical injuries included headaches as one anatomical area, which could have inflated the prevalence of injuries specific to the cervical spine and surrounding structures.

2.4.3.2. Shoulder

The shoulder joint (13%) has been reported as the third most common site of injury in professional golfers (Gosheger et al., 2003). However, a study reviewed the medical records of players who participated in 'The Open' championship from 1984 to 1990 (7-year period), and reported 0 injuries of the shoulder, with the majority of injuries being allocated to the spine (Hadden et al., 1992). This study had used similar methods to that used by Smith and Hillman (2012), where a prevalence of 6% of shoulder injuries were found (Smith & Hillman, 2012). The reason for the differences found could be due to the latter study having used the medical records of 36 tournaments over a two year period; whereas the study by Hadden (1992) used medical records of only one tournament over seven years. The current research study relates more to the German group, as it did not exclusively focus on injuries during a tournament, but rather throughout a season (Gosheger et al., 2003)

Other studies have also found the shoulder to be in the top three most frequently injured joints in professional golfers (Sugaya et al., 1999; McCarroll & Gioe, 1982). The high incidence of shoulder injury is still somewhat of a mystery, as golf is not an overhead sport and the shoulder joint is not placed in unstable positions as often as with sports like swimming and tennis (McHardy & Pollard, 2005).

Furthermore, it has been reported that the leading shoulder was injured more frequently than the trailing side (McCarroll & Gioe, 1982), while Gosheger and his colleagues failed to specify whether it was an injury to the leading or trailing shoulder (Gosheger et al., 2003). The cause of the leading shoulder being injured has been attributed to posterior shoulder instability (Hovis, Dean, Mallon, & Hawkins, 2002). In a group of elite golfers with a history of leading shoulder pain, the investigators diagnosed 100% of their subjects with posterior shoulder instability. However, these findings were obtained from a small sample of only eight subjects and therefore the results should be considered with caution (Hovis et al., 2002).

2.4.3.3. Elbow

Elbow injuries are more common under amateur players compared to professionals (McHardy & Pollard, 2005). Ironically, even though an injury to the medial aspect of the elbow is named the 'Golfer's Elbow', it is less prevalent than an injury to the lateral aspect of the elbow, usually referred to as 'Tennis Elbow' (McCarroll, Rettig, & Shelbourne, 1990). Following thoracic spine injuries, players with elbow injuries have recorded the second-highest amount of time lost due to injury, with an average of 74 days (Gosheger et al., 2003). However, the authors did not differentiate these results between amateur and professional golfers.

The retrospective investigation of the German golfers found that 10% of the golfers' injuries were related to the elbow (Gosheger et al., 2003). However, two other studies found a lower prevalence of 1% of elbow injuries, but both of these studies were conducted during professional tournaments and are less likely to capture the data of overuse injuries (Smith & Hillman, 2012; Hadden et al., 1992). In the study of the Japanese golfers, the authors reported an injury rate of 10% to the elbow joint (Sugaya et al., 1999). The trailing elbow (8%) is injured more often than the leading elbow (6%) and the cause is either overuse or by accidentally striking the ground with the head of the golf club (Stockard, 2001). The author gave an overview of elbow injuries in professional golfers, but it is unclear how the conclusions were drawn and what methods were used to gather this data.

Although elbow injuries are considered to be one of the most commonly injured anatomical regions, it is an area that has been poorly researched and therefore highlights the need for further research in professional golfers.

2.4.3.4. Wrist & Hand

The wrist and hand are also areas commonly injured amongst professional golfers. The studies that conducted their investigation during tournaments alone, found that the hand and wrist region made up 6-15% of all the injuries (Smith & Hillman, 2012; Hadden et al., 1992). In some retrospective studies, the prevalence of hand and wrist injuries ranged between 11-37% of all injuries sustained by professional golfers (Gosheger et al., 2003; Sugaya et al., 1999; McCarroll & Gioe, 1982). There were only three studies that reported the hand and wrist as two separate anatomical regions of injury, where 2-10% of the injuries were contributed to the hand and 6-27% to the wrist (Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982).

It has been speculated that hand and wrist injuries most commonly occur due to a traumatic event of striking either an obscure object or by playing a ball from thick grass, which causes a sudden deceleration of the clubhead during the downswing phase (McHardy & Pollard, 2005). However, certain hypotheses claiming that hand and wrist injuries are attributed to traumatic mechanisms, have been challenged. The 'Hook of Hamate' fracture is a relatively frequent occurrence in hand injuries of golfers and the common belief is that the injury is caused by a traumatic event of striking the ground during the swing (Zouzias et al., 2018). However, a contradicting study reports that it is caused by repetitive microtrauma, leading to a stress fracture, rather than a traumatic fracture (Aldridge & Mallon, 2003).

2.4.3.5. Thoracic Spine

Thoracic spine injuries are the least prevalent of all the spinal injuries in professional golfers. According to the literature, thoracic spine injuries range between 0-21% (Smith & Hillman, 2012; Sugaya et al., 1999). Interestingly, the studies that found a higher rate of injury to the thoracic spine were both during tournament data collection (Smith & Hillman, 2012; Hadden et al., 1992). None of the investigations that were conducted outside of tournament time had a thoracic injury percentage of more than 3%, which leads to question whether the mechanism of thoracic spine injuries in golfers, tend to be more of an acute nature rather than overuse (Gosheger et al., 2003; Sugaya et al., 1999; McCarroll & Gioe, 1982). Although the thoracic spine is not the most prevalent site of injuries, it has been reported to lead to the most time off from golf (Gosheger et al., 2003).

2.4.3.6. Lumbar Spine

Lower back pain is the most common musculoskeletal condition worldwide, and affects 84% of the population at some stage during their lifetime (Balagué, Mannion, Pellisé, & Cedraschi, 2012). These statistics seem to be consistent with the literature regarding professional golfers and lower back injuries. In a study that investigated associated risk factors of lower back pain in professional golfers, the researchers used a group of 42 players without any current symptoms of back pain. They collected data retrospectively regarding previous lower back injury, presenting in the absence of radiculopathy symptoms and that lasted longer than 2 weeks. Of the 42 players, 33% had a history of lower back pain, limiting them from participation (Vad et al., 2004). The data were collected over the span of a career and as mentioned previously, this could lead to biased results, as data from memory recollection over such a long period might have an unfavourable validity (Gabbe et al., 2003).

The lower back was the most frequently injured anatomical region found in the majority of the epidemiological literature in professional golfers, except for two studies which reported that the cervical spine and hand/wrist injuries were the most prevalent sites, respectively (Smith & Hillman, 2012; McCarroll & Gioe, 1982). Furthermore, the Japanese study had the highest reported injury rate for lower back pain in professional golfers at 34% (Sugaya et al., 1999). In addition, 51% of the players reported right-sided pain, 28% reported left-sided pain and 21% had central or generalised pain in the spine (Sugaya et al., 1999).

2.4.3.7. Hip

When considering the biomechanics of a golf swing and the amount of rotational force that needs to be endured by the hips, it is difficult to understand that the hip joint has the lowest prevalence of injury reported in the literature. Sugaya et al (1999) reported 0 cases of hip injuries during his investigation (Sugaya et al., 1999). Furthermore, some studies found merely 1% of their cases were attributed to hip conditions (Hadden et al., 1992; McCarroll & Gioe, 1982). The highest injury rate (3%) of the hip in professional golfers was reported in the German group (Gosheger et al., 2003).

In a study investigating acetabular tears in athletes, a group of 41 participants were selected from a population of 111 that underwent an arthroscopic procedure of the hip. Of these 41 patients, golfers were the second highest number of participants (n=5), with Taekwondo having the highest (n=12) (Kang, Hwang, & Cha, 2009). Even though the purpose of the study was not to investigate the epidemiology of labral tears in the sporting population, it is still interesting that with the literature presenting such a low prevalence of hip injuries in golfers, 12% of their sample size still consisted of golfers. However, it should be said that it is unclear how the 41 participants were selected.

2.4.3.8. Knee

It has been reported that the ball-impact and follow-through phases are the points during the swing where the most knee injuries occur (McCarroll & Gioe, 1982). None of the studies found knee injuries to be common amongst their subject groups and according to the findings, knee injury prevalence ranged between 3-8% amongst male professional golfers(Smith & Hillman, 2012; Sugaya et al., 1999; Hadden et al., 1992). Knee injuries were also classified as less serious by the authors after they concluded that took an average of 22 days for a player to return to full force; and only the hip, at 21 days, had a shorter return to play period (Gosheger et al., 2003).

2.4.3.9. Ankle & Foot

In certain studies, as with the hand and wrist, the ankle and foot are classified as a single anatomical area of injury (Smith & Hillman, 2012; Gosheger et al., 2003). These particular studies have found that the prevalence of this combined anatomical region is between 1-6% (Smith & Hillman, 2012; Gosheger et al., 2003). In the literature that separated the ankle and foot, the ankle had a higher frequency of injury in two of the studies at 6% and 4%; and the foot with a prevalence of injury of 1% and 3%, respectively (Sugaya et al., 1999; Hadden et al., 1992). The only study that found a higher rate of injury in the foot compared to the ankle, found the foot attributing to 3% and the ankle was 2% of the total injuries sustained by their participants (McCarroll & Gioe, 1982). Due to the inconsistencies of the reported injuries either to the combined anatomical area or to the separated ankle and foot regions, it is challenging to compare findings across similar studies. It is, therefore, recommended that a standard classification of these regions should be developed for research in order to be able to compare findings in more detail.

2.4.3.10. Other Injuries

Injuries sustained by golfers that did not fit the anatomical description of the “joints” category were classified as “other” injuries. These injuries would usually include the head, rib, shin, hamstring, calf, forearm, or thigh regions (Smith & Hillman, 2012; Gosheger et al., 2003; Hadden et al., 1992).

Most of the studies have determined that the lumbar spine is the anatomical region most injured (22-34%) in professional golfers (Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992). Another study found that the cervical spine was injured most frequently (25%) (Smith & Hillman, 2012).

Finally, one study found the hand and wrist region as the most prevalent injured anatomical region (McCarroll & Gioe, 1982). A summary of the prevalence of injuries in professional golfers is presented in **Table 2** below.

Table 2: The prevalence of golf injuries (%) according to anatomical regions

Author	Cervical spine (%)	Shoulder (%)	Elbow (%)	Hand/wrist (%)	Thoracic spine (%)	Lumbar spine (%)	Hip (%)	Knee (%)	Ankle/foot (%)	Other (%)
Smith & Hillman (2012)	**25**	6	1	6	21	21	2	3	6	9
Gosheger et al (2003)	10	13	10	20	3	**22**	3	6	1	12
Sugaya et al (1999)	20	10	10	11	0	**34**	0	6	7	2
Hadden et al (1992)	22	0	1	15	12	**31**	1	5	7	6
McCarroll & Gioe (1982)	3	9	7	**37**	2	24	1	7	5	5

2.4.4. Associated Risk Factors

There have been studies that investigated associated risk factors for injury in golfers (Baker et al., 2017; Cohn, Lee, & Strauss, 2013; McHardy et al., 2007b; Vad et al., 2004; Gosheger et al., 2003). These risk factors can be divided into either intrinsic- or extrinsic factors.

2.4.4.1. Intrinsic factors

These type of risk factors are based on the individual's biological and psychosocial characteristics, which might potentially predispose them to a musculoskeletal injury (Meeuwisse et al., 2007).

2.4.4.1.1. Joint Range of Motion

There has been a strong association found between the lack of lumbar spine extension and a decreased internal rotation of the leading hip in players complaining of lower back pain; both presenting with a statistically significant difference ($p<0.05$) (Vad et al., 2004). The same study found a statistically significant difference in the measurement of the FABER's test in the leading hips of their group with a history of lower back pain compared to the group without previous complaints of the injury (Vad et al., 2004). The FABER's test is conducted by the subject being in a supine position, their hip is then placed in a flexed, abducted and externally rotated position while the knee is flexed at a 90° angle and the ankle rests on the contralateral knee. The distance from the lateral side of the knee to the horizontal surface is then be measured (Trindade, Briggs, Fagotti, Fukui, & Philippon, 2019). The same investigators did not find a significant relationship between lower back pain and lumbar spine flexion or trailing hip range of motion measurements (Vad et al., 2004).

Another study suggested that even though golf is regarded as a less strenuous exercise compared to jogging and tennis, it exerts similar forces through the tibiofemoral joint, especially in the leading knee (D'Lima, Steklov, Patil, & Colwell, 2008). Contradicting to that of the German group's findings regarding return to play time and knee injuries, as previously mentioned (Gosheger et al., 2003). However, if there is a high torsional load on the knee during the golf swing. This information could be valuable in the return to play protocol after injury or surgery. These high torsional loads through the knees during the swing may lead to overuse- and degenerative pathology. Furthermore, laxity in the knee joint as well as previous knee trauma have been identified as contributing factors to this phenomenon (Marshall & McNair, 2013).

Excessive shoulder rotation has been hypothesised to contribute to shoulder injury in golfers (Thériault & Lachance, 1998). The lack of thoracic rotation increases the workload of the smaller rotators of the shoulder and could lead to shoulder dysfunction (McHardy & Pollard, 2005). This might be due to one of two reasons: decreased kinetic energy available due to a decrease in the storage of potential energy and therefore the musculature of the rotator cuff complex has to exert a larger amount of force to create the same distance of a stroke; or the demand to increase the range that helps with an elastic recoil has to be met and the rotator cuff muscles are then responsible to reach those ranges during the backswing phase (Zouzias et al., 2018).

2.4.4.1.2. Demographic Factors

The investigators found no statistically significant difference in age between the injured and uninjured groups of professional golfers, with ages ranging between 22 and 63 years-old (Gosheger et al., 2003). Similarly, another study that investigated a group of amateur golfers, with a male cohort of 1316 and an average age of 54.25 (SD $\pm$ 15.34) years, found no statistically significant difference in the age of the group reporting lower back pain and the group without lower back pain (McHardy, Pollard, & Luo, 2007a).

The investigators determined the body mass index (BMI) of the participants by using a standardized calculation (weight in kilograms/ height in meters squared) (Gosheger et al., 2003). There were no statistically significant differences in the BMI's of the injured and uninjured group of professional golfers (Gosheger et al., 2003). However, a BMI of lower than 25.7kg/m^2 was found to be a predictor of lower back pain in golfers (Evans, Refshauge, Adams, & Aliprandi, 2005).

Therefore, decreased range of motion of lumbar spine extension, internal rotation of the leading hip, and the FABER's test distance have been highlighted in golfers reporting lower back pain (Vad et al., 2004). The lack of shoulder rotation potentially contributes to shoulder injury in golfers (Thériault & Lachance, 1998).

2.4.4.2. Extrinsic factors

Extrinsic risk factors are independent of the individual player's characteristics and are rather related to the type of activity being exercised during the incident of injury (Meeuwisse et al., 2007).

2.4.4.2.1. Training Load

Training load has been identified as a risk factor among amateur golfers (McHardy et al., 2007b). Golfers who have played three or more rounds per week, where a single round of golf consists of 18 holes, were at higher risk to sustain an injury compared to a group who played two or fewer rounds (OR = 3.73 with 95% CI 1.29-10.75) (McHardy et al., 2007b).Professional golfers therefore have an even higher prevalence of injury compared to amateur golfers, with training load and time spent playing potentially contributing to increased training load as a risk factor to injury in professional golfers (Gosheger et al., 2003). The investigators found that there were significantly more injuries in the group who played four or more rounds of golf in a week and in those who hit 200 or more balls in a single week (Gosheger et al., 2003). In the professional group, 73.3% hit at least 200 balls per week and 30% played four or more rounds of golf per week (Gosheger et al., 2003). In the group that hit more than 200 balls per week, 40% of the players sustained a spine injury, 24% sustained a shoulder injury, and 20% sustained a hand/wrist injury (Gosheger et al., 2003). In the group who played four or more rounds of golf per week, 40% sustained a spine injury, 23% sustained a shoulder injury, 17% sustained a hand/wrist injury, and 11% sustained an ankle/foot injury (Gosheger et al., 2003). This contributes to the idea of this associated risk factor; 98% of professional golfers believe that they train too much (Cabri et al., 2009).

2.4.4.2.2. Technique

The modern-swing or the "X-factor"-swing has been found to contribute to lower back pain in golfers (Gluck et al., 2008). This could be due to the excessive strain on the lower back, as the player rotates the thoracic spine on a relatively neutral lumbar spine, forcing the viscoelastic structures to exceed their physiologic capabilities (Gluck et al., 2008). In another study the investigators found that the injured group tend to address the ball with more spinal flexion compared to the uninjured group and they also have an increased side-flexion component to their leading side during the backswing phase (Lindsay & Horton, 2002). However, their findings show no statistically significant difference between the injured and uninjured groups when investigating the spinal rotational motion during the golf swing.

2.4.4.2.3. Warm-up Routine

An inadequate warm-up of less than 10 minutes has also been correlated with injuries amongst golfers (Lindsay & Vandervoort, 2014; Gosheger et al., 2003). The group (n=570) of players that had a warm-up routine of 10 minutes or less reported an average of 1.02 injuries per player, while the group (n=133) that exceeded a 10 minute warm-up period reported 0.41 injuries per player (Gosheger et al., 2003). However, there were no specifications of what the warm-up entailed.

2.4.4.2.4. Type of Golf Course

The golf course difficulty and surface also play an important role as an extrinsic risk factor, as acute wrist injuries in professional golfers are commonly caused by either hitting out of a thick or heavy turf, or if they strike an unseen object, for example, tree roots or a rock (Zouzias et al., 2018; Cohn et al., 2013). However, as mentioned before, not all wrist and hand injuries should be categorized as traumatic injuries (Aldridge & Mallon, 2003). Fatigue could be another possible factor due to walking long distances on the course as it exposes the knees to decrease stability during the stroke (Baker et al., 2017). Generally, professional golfers walk the entire course, without making use of the golf carts.

Training load and warm-up routines have been proven to be important contributors in either causing or preventing injury in professional golfers (McHardy et al., 2007b; Gosheger et al., 2003). It has been hypothesized that certain swinging techniques might contribute to injuries in golfers, but substantial evidence is still lacking (Gluck et al., 2008). The current literature presents studies investigating the associated risk factors of injuries in professional golfers, however, there is a lack of evidence regarding determining the relationship between these risk factors and injury in this population. The following section will discuss studies that have investigated preventative strategies to address these risk factors.

2.5. Preventative strategies

There have not been many studies investigating preventative strategies for golfing injuries in general. The recommendation for injury prevention strategies tends to rely on the information gathered from the literature that investigated associated risk factors, rather than from studies that have implemented an intervention to prevent these injuries. Literature regarding injury prevention in the form of either equipment or adaption to techniques have not received supporting evidence.

When considering the golf club length in preventing knee injuries, it has been suggested that a shorter length club might aid in a decrease of load on the leading knee (Marshall & McNair, 2013; Parziale & Mallon, 2006). However, there is conflicting evidence reported as there is no significant difference in compressive loads in the knee, when using different length clubs (D'Lima et al., 2008). Golfing shoes have spikes underneath to help avoid the player from slipping during the swing. Therefore, it was hypothesized that the gripping of the shoe spikes into the ground might contribute to a torsional load in the knee after the ball strike phase (Guten, 1996). However, similarly to the length of the golf clubs, a group of investigators found no significant difference in the mean peak forces on the leading knee between the group who were wearing spiked golfing shoes compared to the group not wearing spiked shoes, during a golf swing (Gatt, Pavol, Parker, & Grabiner, 1998).

In a study that investigating the causative factors and prevention strategies of lower back pain in golfers, the authors concluded with a list of recommendations to decrease the risk of developing lower back pain (Lindsay & Vandervoort, 2014). Their preventative strategies included avoiding excessive play, improving trunk rotation flexibility, improving hip mobility, including a warm-up regime of at least 10 minutes, and improving spinal endurance and strength (Lindsay & Vandervoort, 2014). Another suggestion to combat asymmetry caused by the sport itself, was to take practice swings left- and right-handed (Lindsay & Vandervoort, 2014). However, with fine motor control and imagery being highly important components to the outcome of the stroke, the professional players use their practice swings to "fine-tune" their proprioception and thoughts before they have to strike the ball on the tee (Ploszay, Gentner, Skinner, & Wrisberg, 2006). These suggested preventative strategies should be taken with caution as the recommendations were based on the study about the risk factors leading to injury and not from the effect of an intervention study to prevent injury.

Another study conducted an intervention to determine the effectiveness of a brace in preventing medial epicondylitis in golfers (Glazebrook, Curwin, Islam, Kozey, & Stanish, 1994). Considering the mechanism and pathophysiology of the condition, the researchers investigated the amount of force production in the muscle group associated with medial epicondylitis, with and without the brace. No significant difference was found in muscle activity of the symptomatic group when the brace was applied (Glazebrook et al., 1994). The same group changed grip sizes of the golf clubs, to determine if any change in muscle activity in the muscle group. However, similarly to the brace, no significant difference was found (Glazebrook et al., 1994).

Excessive supination, due to a change in putting grip position, resulted in pain in the palmar aspect of the wrist (McHardy & Pollard, 2004). An intervention study by authors, using a combination of returning to the player's previous grip position and manual therapy, resolved the symptoms (McHardy & Pollard, 2004). However, the authors did not specify the exact type of modalities or treatment techniques used during the manual therapy treatments.

2.6. Summary

Overall, there is a paucity of quality of literature regarding injuries in golfers, especially professional golfers. A lack of a concise and standardised terminology leads to results of studies being incomparable. Starting with the term 'injury', the authors had different classifications and reporting of an injury in professional golfers. Investigators used the terms 'incidence' and 'prevalence' interchangeably, without differentiating the meaning or results of each of them (Sugaya et al., 1999). There was no epidemiological literature in golfers found with a level of evidence higher than three (Robinson et al., 2019). Generally, it was found that professional players are injured more frequently compared to amateur players, with overuse injuries being a major attribution to this statistic (Gosheger et al., 2003).

No literature could be found that investigated a cohort prospectively, with all the data collected by the investigators being of retrospective study design (Smith & Hillman, 2012; Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982). Lower back injuries were found to be most prevalent in most of the research, followed by the hand and wrist. The anatomical region which seemed to have the lowest prevalence of injury across the board was the hip (Smith & Hillman, 2012; Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982). Regarding associated risk factors, decreased leading hip internal rotation and lumbar extension were found to be significant intrinsic attributions to lower back pain in golfers (Vad et al., 2004). Excessive training loads, inadequate warm-up routines and striking an obscure object were amongst the most common extrinsic risk factors in this population (Cabri et al., 2009; McHardy et al., 2006).

Preventative strategies in golfers have been commonly reported in the literature. Most of the recommendations were based on the findings of studies about risk factors (Lindsay & Vandervoort, 2014; Ploszay et al., 2006). Very little evidence is based on the implementation of an intervention and the studies that have attempted to intervene have not produced any significant findings. The results of this study will influence the intervention modalities used to prevent injury in this population.

Currently, there is no literature investigating the incidence of injury or associated risk factors in the South African professional golfing population. The popularity of golf in South Africa highlights the importance of determining these associated risk factors.

Chapter 3: Methodology

3.1. Introduction

As discussed in Chapter 2, the incidence of injury in professional golfers has not been investigated to the same extent as that of amateur golfers. There were a few studies, of retrospective study design, investigating the prevalence of injury amongst professional golfers (Smith & Hillman, 2012; Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982). A questionnaire was used in most cases to collect the data from the participants (Gosheger et al., 2003; Sugaya et al., 1999; McCarroll & Gioe, 1982). Two of the studies collected their data from medical reports of the units stationed at the respective tournaments (Smith & Hillman, 2012; Hadden et al., 1992).

This research study aimed to determine whether the range of motion of the shoulder, hip, thoracic spine, or lumbar spine is an intrinsic risk factor to predispose to injury in this specific group. It also determined whether external training load, measured in hours of playing golf, has an influence on the incidence of injury in these golfers over the span of a season. Investigation of all possible risk factors for injury in professional golfers is beyond the scope of this study, however, the findings of this study will allow researchers to investigate other potential intrinsic- and extrinsic associated risk factors.

In this chapter, the process of the sample collection, the testing procedure, and data analysis of the findings are outlined.

3.2. Study design

The study used is a prospective, longitudinal cohort study design.

3.3. Participants

3.3.1. Inclusion criteria

There were three important inclusion criteria: The participant had to be a healthy, uninjured male professional South African golfer. An injured and healthy participant is defined as a player free from symptoms which prevents them from competing or training. The minimum age was 18 years old. Finally, the informed consent form had to be signed by the participant himself. None of our participants selected for the study, did not meet the inclusion criteria.

3.3.2. Exclusion criteria

Players who has had surgery in either the hip, lumbar spine, thoracic spine or shoulder within the last 12 months were excluded from the study. This was to minimize the risk of aggravating the area, by measuring the ranges, prior to the start of the tournament.

3.3.3. Sample size

The sample size was calculated by determining the lowest expected incidence of injury in a population. This was calculated suing by the number of South African players with direct entry in the Alfred Dunhill Championship 2019, at an accepted confidence interval of 5%, a minimum sample size of 36 participants were required to achieve a 95% confidence level, 33 participants for a 90% confidence level and 28 participants for an 80% confidence level in statistics (Open Epi™ Version 3). Investigating similar variables to identify associated risk factors in injury of swimmers, we expected that the lowest incidence of injury would be 11% for our study (Walker, Gabbe, Wajswelner, Blanch, & Bennell, 2012). ***Table 3*** below presents the calculation of the sample size.

Table 3: Calculation of sample size

Population size	46
Expected Frequency	11%
Confidence Limits	5%
Design Effect	1.0
Cluster Size for Confidence Level of 80%	**28**

3.4. Instrumentation

The instrumentation used during the data collection process included goniometry, a self-developed questionnaire and a log book for each participant to track their weekly injuries and training loads.

3.4.1. Goniometry

A standard goniometer was used to measure the range of internal rotation, external rotation and horizontal adduction of both the shoulders. Goniometer measurement is used universally with good reliability outcomes. However, for accurate, reliable and valid results- one should be specific with the methods used (Gajdosik & Bohannon, 1987).

During the swing, the shoulder joint has to move through large ranges; which includes horizontal adduction of the player's leading arm and external rotation of his trailing shoulder during the backswing; and then the trailing arm moves into horizontal adduction and the leading arm into external rotation during the follow-through phase (Mitchell, Banks, Morgan, & Sugaya, 2003). Glenohumeral internal rotation deficit (GIRD) has also been linked to shoulder pathology and is often a sign of rotator cuff and posterior capsule tightness due to repetitive cocking (Rose & Noonan, 2018).

Investigators found the use of a goniometer to be reliable when measuring internal-(ICC: 0.94; CI(95%): 0.89-0.96) and external rotation (ICC: 0.97; CI (95%): 0.94-0.99) of the shoulder (Salamh & Kolber, 2012; Laudner, Stanek, & Meister, 2006); while the intrarater (ICC: 0.93) and interrater (ICC: 0.91) reliability were high when using a goniometer to measure horizontal shoulder adduction (Laudner et al., 2006).

Thoracic spine rotation was also measured with the goniometer. The lack of thoracic rotation increases the workload of the smaller rotators of the shoulder and could lead to shoulder dysfunction (McHardy & Pollard, 2005). Thoracic rotation in a seated position with the bar in front of the participant had good intrarater (ICC: 0.91, CI: 95%) and interrater (ICC: 0.87; CI: 95%) reliability scores and low standard error of measurements during intertester reliability of 1.72˚ to the right and 1.82˚ to the left respectively (Johnson, Kim, Yu, Saliba, & Grindstaff, 2012). The authors do admit that even though they are unable to confirm that the motion was occurring exclusively at the thoracic spine, their measurements were consistent with previously reported normative values of thoracic spine movements when measured by the three space Fastrak system.

There was a strong association between the lack of leading hip internal rotation and players complaining of lower back pain (Vad et al., 2004). The goniometer was used to measure both internal- and external rotation of the participants' hips. Hip internal- and external rotation is deemed to have an excellent test-retest (ICC: 0.9, CI: 95%) reliability when measured with a goniometer for both movements (Nussbaumer et al., 2010).

Decreased lumbar extension has been documented as a risk factor for lower back pain in golfers (Vad et al., 2004). Therefore, the participants' range of lumbar extension was measured with the goniometer. The modern age swing has not only modified the amount of thoracic rotation, but it also increased the amount of hyperextension in the lumbar spine during the follow-through phase (Gluck et al., 2008). Using a goniometer in testing lumbar spine extension has been found to have a good interrater (ICC: 0.88, CI: 95%) reliability when testing a group of male participants (Fitzgerald, Wynveen, Rheault, & Rothschild, 1983).

3.4.2. Self-developed Questionnaire

The Golfer's questionnaire is a self-developed questionnaire that gains demographic, training-load and history of injury information. This was a once-off questionnaire, completed at the beginning of the study (**Appendix D- Questionnaire**). The basis of the questionnaire correlates with the most recent recommendations by the international consensus statement for reporting golf injuries (Murray et al., 2020). The tool recommended by the consensus includes questions regarding the onset, the mechanism, history of the injury, the type of setting where the injury was sustained, and the performance level of the player (Murray et al., 2020).

3.4.2.1. Pilot Questionnaire

The investigator obtained content validity for the questionnaire by a panel of four experts in the field of sports physiotherapy for review. After feedback was obtained from the experts, the questionnaire was adapted according to their suggestions and queries. The suggestions included: Collecting detailed information regarding the participants' injury and training history. Furthermore, there was suggested that the answering process was made more time efficient by changing the 'fill in answers' to 'ticking a box'. After these changes were made, the questionnaire was sent back to the panel of experts. There were no further suggestions from the panel of experts after the second draft of the questionnaire was sent to them.

After final approval was obtained from the experts, the questionnaire was introduced as a pilot questionnaire to local club-level golfers to determine face validity of the self-developed questionnaire. Feedback from eight club-level golfers from Hermanus Golf Club was obtained. The feedback received from the golfers included: Which box to tick if they spend no time on a specific training component and what the timeframe for the Winter Swing and Summer Swing is. After addressing their suggestions and queries, the questionnaire was finalized.

3.4.3. Logbook

The logbook was presented to a panel of four experts in the field of sports physiotherapy. Feedback from the experts included: Allowing the participants the option of responding via 'Whatsapp' and to add a clear definition of 'injury' on the actual logbook. After the amendment of the logbook as suggested by the experts, it was presented to eight local club-level players from Hermanus Golf Club. There were no suggestions or queries regarding the logbook from the players. Therefore, the logbook was finalized before presented to the participants.

Each participant in this study received a digital (Word format) 'logbook' on a weekly basis via email. The logbook required details about time spent on the golf course or doing other type of training and if the participant has sustained any new injuries or still carrying a previous one during this week (**Appendix F- Players' logbook**.

3.5. Procedure

The study was able to commence after ethical approval was obtained from the Human Research Ethics Committee (HREC) of the University of Cape Town (reference number HREC:731/2019). The tournament organisers also granted permission for the data to be collected at the tournament and the head of the physiotherapy unit permitted the use of the unit facilities for the physical testing. All the necessary forms were completed by the participants to provide informed and signed consent, before testing commenced. The participants also reported their own weight, height, age, which hand they use to write, and if they are a left- or right-handed golfer.

3.6. Recruitment

Once ethical approval was obtained, golf players who were registered with the Sunshine Tour were eligible to participate in the study. The Sunshine Tour is the professional male golf tour of Southern Africa. For a player to be eligible to compete on the Sunshine Tour, he must have an active player's card. To obtain a player's card, a person must attend "Q-school". This requires him to compete against other hopeful candidates through a four-stage process. If a player finishes within the top 60 players of the group at the conclusion of this process, he receives a player's card; and is now allowed to compete on the tour. He is also automatically registered with the Sunshine Tour Players' Council Association, which serves as a link between the players and the tour organizers. The association is led by the chairman, who communicates on a regular basis with the players and the tournament organizers, presenting any concerns or queries from either party to the other.

The Alfred Dunhill Championship is a tournament that annually forms part of the Sunshine Tour schedule. There are eight major tournaments played from November to February during a season. During 2019 the tournament was from 28 November to 1 December. The players are required to physically report at the tournament office for registration at least one day prior to the start of the tournament. This is to ensure the playing field is saturated and that there are no vacant positions before they commence. If a player fails to register on time or cannot make the tournament for some reason, a player from the "reserve list" will be allowed to take the absent player's position in the tournament. To qualify for participation in one of these major tournaments, a player should either be ranked high enough on the national rankings list to be directly entered into the tournament or he has to play qualifying rounds; to compete for one of 10 possible qualifier spots in the tournament. Even though our study is conducted in South African players only, there are multiple nationalities competing on the Sunshine Tour, including the European-, the American-, the Asian- and the rest of African countries.

Three methods of recruitment were used to inform participants about the study:
Firstly, the Chairman of the players' council was contacted, and permission was obtained to send the players information regarding the study. An email to the players followed prior to the start of the tournament. The email contained information regarding the reason for the study, the procedure to follow, what will be expected from the participants, the potential risks and the potential benefits if they choose to participate (Appendix A- **Informed consent and consent form**. The investigator's personal phone number was added to the email and players were invited to make contact if they had any questions or concerns, or if they wanted to confirm interest in participating.

Secondly, the Chairman sent two broadcast messages to the players' cellular communication group. The messages had the same content but were sent on separate occasions. The first message was sent one week prior to the players' registration date of the tournament, and the second was sent two days prior to the players' registration date. The messages were sent on 18 and 23 November 2019. The cellular message contained less information than the email. The aim of the broadcast message was to introduce the investigator, to remind the players about the email that was distributed to them, and to inform them where the investigator will be stationed if they wish to volunteer for the study. The investigator's private cellular number was added to the group again and players were invited to make contact regarding queries.

Finally, players that arrived at the physiotherapy unit from the Monday to the Wednesday were informed about the study. Participants were only included in the study if they volunteered to participate. The recruitment of participants had to be done from the Monday to the Wednesday, because Thursday was the official starting day of the tournament. The reasons the recruitment had to be done prior to the start of the tournament were to ensure that the participants' performance and focus would not be affected by the investigator during tournament time, and to ensure that the baseline testing was done on a healthy and uninjured sample, to allow for longitudinal monitoring of study parameters throughout the season.

3.7. Testing Personnel

The Alfred Dunhill Championship had a total of 4 senior physiotherapists, who assisted with the initial data collection during the tournament. All physiotherapists were skilled in the methods used for measurements, and a consensus regarding landmarks and scoring criteria was discussed and practiced prior to the tournament. Each physiotherapist managed approximately 10 players a day, but not all of these were South Africans, and, in most cases, they were returning players.

Testing began at the Alfred Dunhill Championship, 25 November 2019 at Leopard Creek. The final data collection was done 12 weeks later; after the Di-Data tournament at Fancourt, 17 February 2020, in George. The tournaments each spanned over a period of seven days. The players started with their practice rounds on the Monday through to the Wednesday, thereafter, they started with the tournament on the Thursday and finished on the Sunday. None of the players, that came to the physiotherapy unit from the Monday to the Wednesday, had any pre-tournament injuries and were only visiting the unit for maintenance and preventative reasons before the tournament started.

The informed consent form was verbally read with the participant, by the physiotherapist upon arrival at the unit and any questions or queries were answered by the investigator. The participant completed and signed the informed consent form prior to the start of the testing. The participant also completed a questionnaire before the start of the consultation. Finally, they completed a logbook of hours spent training and/or competing on a weekly basis. The completion of the questionnaires was assisted by the researcher and the three assisting physiotherapists. Range of motion measurements were done once and recorded once, only.
The physical tests were done in the following order:

3.7.1. Lumbar Spine

Lumbar spine extension was measured with a universal goniometer. The participant stood with his feet approximately shoulder width apart and the investigator stood at the side of the participant. The axis of the goniometer was placed on the most superior aspect of the iliac crest, aligned with the midaxillary line. The stationary arm was positioned perpendicular to the floor, while the moving arm will be aligned with the midaxillary line. The participant was instructed to maintain full extension of the knees throughout the movement. He was then instructed to bend directly backwards, as far as possible. When he had reached his maximum range, the movement was recorded in degrees (Fitzgerald et al., 1983).

3.7.2. Thoracic Spine

For the measurement of thoracic spine rotation, the participant was seated with his hips and knees at 90˚ of flexion, feet on the ground and a ball (21cm diameter) were placed between the knees to limit lower extremity movement during the thoracic motion. A 105cm bar, which was marked at the midpoint, was placed horizontally across the chest and the arms crossed over it. The goniometer was placed parallel to the ground and the axis between the T1 and T2 spinous processes. The stationary arm faced the contralateral side to which the rotation was tested, and the moving arm followed the motion of rotation up to the end range. The angle was recorded in degrees and was repeated to the other side (Johnson et al., 2012).

3.7.3. Shoulder

For shoulder internal and external rotation, the participant was placed in a supine position, the shoulder abducted to 90˚, the elbow in 90˚ flexion and the forearm in a neutral position. The axis of the goniometer was placed on the olecranon process, with the stationary arm directed vertically and the moving arm aligned with the ulna. Starting from a neutral shoulder position, the physiotherapist passively rotated the shoulder either externally or internally and the measurement was made accordingly (Brumitt, Meria, Nee, & Davidson, 2008). The tests were performed on both shoulders.

When we tested for horizontal adduction of the shoulder, the participant was positioned in supine, the physiotherapist stood at the head of the table and faced towards the head of the participant, on the side of the shoulder to be tested. The shoulder was abducted to 90˚ and the elbow was flexed at 90˚. The scapula was stabilized by the one hand of the physiotherapist and the other handheld onto the proximal aspect of the participant's forearm. The shoulder was then passively moved into horizontal adduction. A second physiotherapist measured the degrees of adduction, with the axis of the goniometer placed on the acromion, the stationary arm perpendicular to the plinth and the moving arm in line with the lateral aspect of the humerus (Laudner et al., 2006). The test was performed on both shoulders.

3.7.4. Hip

While the patient stayed in the supine position and the hip and knee flexed at 90˚, internal and external hip rotation was measured with the goniometer. The axis of the goniometer was positioned over the apex of the patella, the stationary arm was parallel to the transverse line across the anterior superior iliac spine of the pelvis and the moving arm fixed to the tibial line. The participant's hip was passively rotated internally or externally, and the measurement was taken. The initial reading was 90˚, so the difference between 90˚ and the reading after the end of range of rotation is reached, was the angle documented (Nussbaumer et al., 2010). The test was performed on both hips.

3.7.5. Logbook

After the completion of the above measurements, the participants received the logbook in which they documented the time they spent practicing golf, training away from the golf course, injuries they might have picked up during the week and its anatomical area. The "new" logbook was sent to them on the Sunday for the following week's information and to remind them to submit the results of the week that has passed, back to the investigator. The questions were simple and straightforward; with numerical answers, yes/no answers and identifying the body part. There was a glossary of terms added to each sheet, so they understood what was asked of them. They were also given the option of responding via “WhatsApp” at the end of the week, answering the questions presented on the logbook. Most of the participants opted for the “WhatsApp”-option. The international consensus of reporting golf injuries recommends that weekly reports of health complaints and exposure to golf as an appropriate method of data collection (Murray et al., 2020).

3.8. Data analysis

3.8.1. Injury

In this research study, an injury is defined as time loss, due to pain or discomfort, either in competition or in any form of training. Competition and training time consist of playing rounds, component training, and other exercise. Playing rounds include time spent either during a tournament or during training, where the participant keeps score during this period. The training components include training putting, training short game, or training driving. Other exercise includes cardiovascular exercise, upper limb and lower limb resistance training, flexibility exercise, plyometric training, or core training.

The index injury is the first injury that was reported by the participant during the testing period (Hamilton et al., 2011). A recurring injury is defined as an injury at the same site and the same type of injury as the index injury. A subsequent injury is defined as a new injury, but at a different site than the index injury (Hamilton et al., 2011). Injuries were reported either as an injury on the leading side, the left side for a right-handed golfer, an injury on the trailing side, the right side for a right-handed golfer, or a spinal injury. A participant who has sustained an index injury was documented as “injured” and if the participant had zero injuries during the testing period he was documented as “uninjured”.

3.8.2. Training Load

Total duration has been deemed as the preferred method of measurement of the load while investigating a golfing population (Williams et al., 2018). It allows for consistency when measuring training components and playing rounds, although it might lack a degree of sensitivity (Williams et al., 2018). In this study we have used hours spent playing rounds, including practice and tournament participation, hours spent training components of golf, and hours spent on other exercises as the total load of training by a participant.

3.8.3. Statistical Analysis

IBM SPSS Statistic Subscription (version 1.0.0.1347) was the software program used to analyse the data. One-way ANOVA's were conducted to compare injury with uninjured groups. Normal probability plots were inspected for deviations from normality and were judged to be acceptable.

The descriptive statistics were used to describe the anthropometric (height, weight, and age) and demographic data of the participants. The mean and standard deviation were calculated according to their age, height, weight, and BMI. The means of the injured and uninjured groups' age, height, weight, and BMI were calculated respectively. An independent-sample t-test was used to determine whether there was a statistically significant difference between the two groups. The frequency distribution and proportions of the trailing-, leading side, or spinal injuries were calculated.

The data obtained from the questionnaire regarding time spent on specific components of golf training were converted to the average of the selected estimated time spent on the specific component. Therefore, if a participant selected '2 to 3 hours', the figure used for analysis was '2.5 hours'. The means and standard deviations of each of the components were calculated and an ANOVA test was used to determine whether there was a statistically significant difference when comparing the injured to the uninjured group.

When the effect of range of motion measurements were tested, the means and standard deviations of the variables were calculated. The means were tested by an independent t-test to determine whether there was a statistically significant difference of the respective range of motion measurements between the injured and uninjured groups.

The incidence of injury in this study is defined as the number of new injuries sustained during the 11-week follow-up period divided by the total number of participants (Bronner et al., 2006). However, the injury incidence rate was calculated by converting the total number of new injuries sustained during the season, to the number of injuries per 1000 hours of exposure to golf. Exposure to golf includes playing rounds and training the components of golf. The frequency distribution and proportions of injury by anatomical region were determined. An independent t-test for parametric variables was used to challenge the null hypothesis and determine if there was a significant difference in any of the range of motion measurements when comparing the injured and uninjured groups for injury to a specific anatomical region. The 95% confidence intervals for the prevalence and incidence of injury were determined by using VassarStats website for statistical computation software.

The means and standard deviations of the total hours spent training and hours spent playing rounds of golf were calculated. The means were used by an independent t-test to determine the statistically significant difference between the injured and uninjured groups for each section of training. Furthermore, the effect of each training section was tested between the injured and uninjured groups of each anatomical region. Mixed model ANOVA was used to compare measurements over time (weeks). Participants were entered into the model as random effect. Group (injury, non-injury) and time (weeks) were entered as fixed effects. Post hoc analyses were conducted using Fisher least Significant Difference (LSD).

3.8.4. Ethical considerations

This study was conducted once ethical approval from the UCT Human Research Ethics Committee was obtained. The study was conducted under the principles of the Declaration of Helsinki (Association, 2013).

For a participant to be included in the study an informed consent form was signed, giving permission to participate in the study. Before the start of the tournament, the informed consent form was emailed to the players to read at their own pace before initial contact with the physiotherapist was made. At the initial appointment, the participant and physiotherapist read through the informed consent form together to ensure the participant understood the procedure and what was expected of him. The emails were sent from the investigator's email account and questions were directed to the investigator via a response to the email or to the investigator's cell phone.

The participant was informed that they could withdraw from the study at any time they wanted to do so. They were also allowed to refuse to be part of the study with no repercussions.

Full confidentiality of the participant's personal information was ensured and is not part of the publication. The consent forms were kept separate from the data collection forms and were stored in a safe space with an electronic passcode. The study results were kept in a separate safe, also with an electronic password.

Electronic results were kept on the researcher's personal computer, which is password protected, known only to the researcher. Sensitive information was encrypted, and the password was only known to the researcher and the supervisor. Data will be stored up to five years after the completion of the research study.

3.8.5. Potential risks to participants

All participants, that met the inclusion criteria of the study, were healthy, uninjured players. Therefore, they did not have any acute injuries, that would have been exacerbated by the physical testing, at that stage of the investigation. However, during physical testing, the participant had the potential risk of discomfort at the end ranges of mobility testing. If they had a chronic injury, from which they had no loss of time during play, they would have the potential risk of symptom reproduction. If the participant was injured during testing in anyway, the participant would be referred for physiotherapy immediately for assessment and treatment. The risks were explained to the participant prior to the testing. All potential risks were considered, and an open communication relationship was established for the participant to inform the investigator if he was uncomfortable or if he felt that he would rather not continue with the test. The participant could withdraw from the study at any time they wanted to. The researcher was also covered by the University of Cape Town's insurance, if for some unforeseen circumstance, something went wrong.

3.8.6. Potential benefits

The participants did not benefit directly from this research, because it was an observational research study. However, at the end of the research study, the investigator was able to identify some of the potential risk factors of injury in professional golfers. The participant therefore potentially benefitted from the study by receiving information regarding the prevention of injury. Physical limitations were discussed with the participant and its potential contribution to injury, which can be addressed by them during their training or rehabilitation sessions. They also benefitted from the information gained by the investigator regarding the training load. This could potentially serve as a guide to their training and competition load, which can assist with injury prevention and performance maximization. All information regarding potential risk factors was only discussed with the participant once the study was concluded. All participants in this study received feedback regarding the findings of the investigation via email, together with advice as how to manage these potential intrinsic- or extrinsic risk factors. The information from this study would also aid future studies investigating preventative methods in professional golfers.

Chapter 4: Results

4.1. Participants

4.1.1. Sample size

Initially, a group of 30 players were included in the study. After the data collection period, we were able to use the information gathered from 28 participants of our original group. Two of the participants that were part of the initial group were unresponsive during the follow-up data collection period, which led to an attrition rate of 6.7%. Considering that at the beginning of the data collection period, there were 46 South Africans with direct entry into the 2019 Alfred Dunhill Championship, and we were able to conclude our study with a confidence level of 80%. The summary of the study sampling process can be seen in **Figure 2** below.

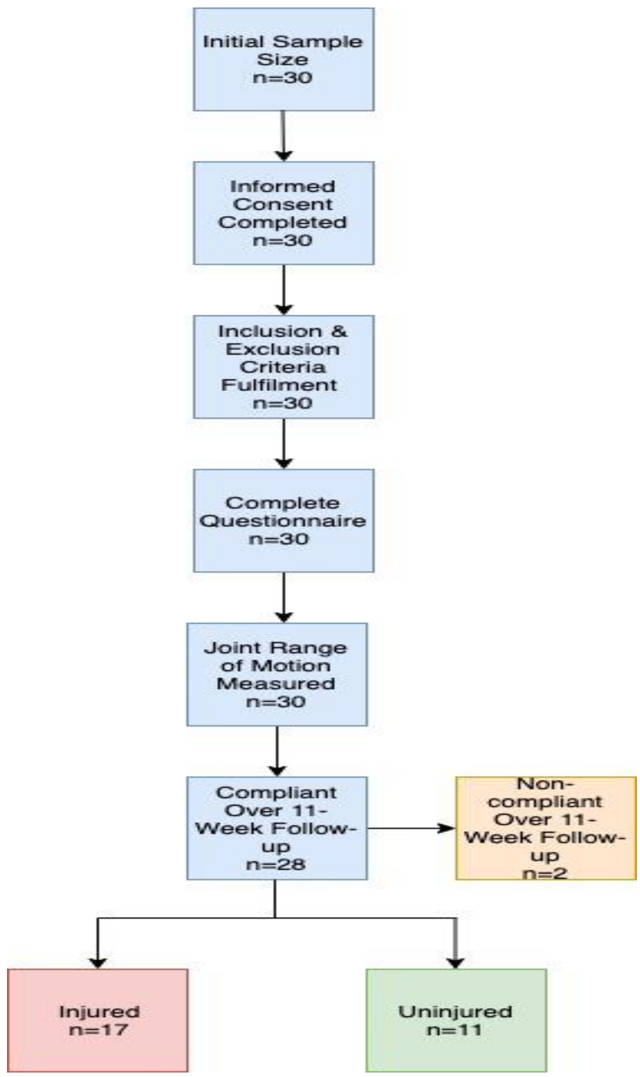

Figure 2: Summary of Study Sample

4.1.2. Demographic and Anthropometric Data

The oldest participant was 51 years old and the youngest was 21 years old. There was a normal distribution of data, with the mean age of 31.6 years (SD=7.7) of the participants. There were no statistically significant differences between the ages of the injured and uninjured groups (t=–1.32; p= 0.199).

The tallest participant was 206cm and the shortest participant was 168cm. The mean height of the total group was 182.11cm (SD= 8.25cm). There were no statistically significant differences in height between the injured and uninjured groups (t=0.71; p= 0.487).

The heaviest participant weighed 113kg and the lightest was 67kg. The mean weight of the total group of participants was 84.32kg. There were no statistically significant differences between the injured and uninjured groups (t=–1.02; p= 0.318).

The mean of the total group for BMI was 25.42 (SD= 2.79). The lowest BMI was 20.94 and the highest was 33.38. According to the WHO, 12 of our participants were classified as “overweight” and 3 falls under the “obese I” category. The mean BMI of the uninjured group was higher than the injured group. The difference between the two groups were of statistical significance (t=–2.084; p=0.047*).*

In the sample that was selected for this study, there was only one (3.6%) player that was a left-handed golfer. This is relevant because when documenting the location of the injury it is important to know whether it was the player’s leading or trailing side that was affected.
Table 4 presents the mean values, t-values, and p-values for the demographic data of the total group, injured group, uninjured groups.

Table 4: Mean and SD of anthropometric measurements for the total, injured, and uninjured groups

	Total group mean (n=28)	**Injured mean (n=17)**	**Uninjured mean (n=11)**	**t-value**	**p-value**
Age (years)	31.57 ± 7.65	30.06 ± 5.19	33.91 ± 10.25	-1.318	0.199
Height (cm)	182.11 ± 8.25	183.00 ± 8.75	180.73 ± 7.59	0.705	0.487
Weight (kg)	84.32 ± 11.59	82.53 ± 11.33	87.09 ± 11.99	– 1.018	0.318
BMI (kg.m²)	25.42 ± 2.79	24.58 ± 2.22	26.71 ± 3.19	– 2.084	**0.047***

*Statistically significant differences (p<0.05) are indicated with *.*

4.2. Training History

When considering the ordinal categorical data that was collected from the participants regarding their training history, the "Summer Swing" (SS) from the "Winter Swing" (WS) were separated. No component of training showed a statistically significant difference between groups in the WS or the SS. The estimation of training history for WS is seen in **Table 5** and for SS in **Table 6**.**Table 6**

Table 5: Estimation of Training History During Winter Swing (WS)

	Total Group (n=28)	Injured Group (n=17)	Uninjured Group (n=11)	F-value	p-value
Driving	6.46 ± 2.12	6.47 ± 2.34	6.45 ± 1.82	0.00	0.98
Short Game	5.82 ± 2.12	5.68 ± 2.22	6.05 ± 2.04	0.20	0.66
Putting	5.88 ± 2.41	6.35 ± 2.18	5.16 ± 2.67	0.85	0.21
UL Resistance	2.46 ± 1.98	2.66 ± 2.23	2.16 ± 1.59	0.42	0.52
LL Resistance	2.29 ± 2.00	2.38 ± 2.24	2.16 ± 1.65	0.08	0.78
Core	2.30 ± 1.81	2.35 ± 2.01	2.23 ± 1.54	0.03	0.86
Plyometric	1.51 ± 1.44	1.51± 1.59	1.5 ± 1.26	0.00	0.98
Cardiovascular	2.56 ± 1.78	2.88 ± 2.02	2.07 ± 1.27	1.42	0.24
UL Stretching	1.79 ± 1.72	1.87 ± 2.02	1.66 ± 1.21	0.09	0.76
LL Stretching	2.04 ± 1.75	2.03 ± 2.09	2.05 ± 1.13	0.00	0.98
Neck Stretching	0.71 ± 0.83	0.49 ± 0.61	1.05 ± 1.02	3.32	0.08
Back Stretching	1.96 ± 1.91	2.01 ± 2.07	1.86 ± 1.70	0.04	0.84
Other	0.76 ± 1.04	0.79 ± 1.09	0.70 ± 1.00	0.05	0.83

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Table 6: Estimation of Training History During Summer Swing (SS)

	Total Group (n=28)	Injured Group (n=17)	Uninjured Group (n=11)	F-value	p-value
Driving	5.57 ± 2.57	5.46 ± 2.79	5.75 ± 2.29	1.68	0.66
Short Game	5.79 ± 2.14	5.94 ± 2.21	5.55 ± 2.09	0.22	0.64
Putting	5.40 ± 2.54	5.57 ± 2.79	5.14 ± 2.19	0.19	0.66
UL Resistance	2.04 ± 1.92	2.28 ± 2.18	1.66 ± 1.45	0.70	0.41
LL Resistance	1.9 ± 1.92	2.07 ± 2.22	1.64 ± 1.39	0.34	0.57
Core	1.95 ± 1.74	2.03 ± 1.95	1.82 ± 1.43	0.10	0.76
Plyometric	1.3 ± 1.37	1.34 ± 1.56	1.25 ± 1.08	0.03	0.87
Cardiovascular	2.04 ± 1.79	2.41 ± 2.10	1.48 ± 0.99	1.89	0.18
UL Stretching	1.54 ± 1.70	1.59 ± 2.06	1.48 ± 0.99	0.03	0.87
LL Stretching	1.64 ± 1.66	1.68 ± 2.02	1.59 ± 0.96	0.02	0.90
Neck Stretching	0.70 ± 0.76	0.56 ± 0.83	0.91 ± 0.63	1.44	0.24
Back Stretching	1.75 ± 1.84	1.74 ± 1.95	1.77 ± 1.75	0.00	0.96
Other	0.71 ± 0.99	0.78 ± 1.1	0.61 ± 0.85	0.18	0.67

4.3. Injury History

Data collected from the questionnaire suggests that 14 (50%) of our selected sample have sustained at least one injury over the past 12-months prior to the start of this season, forcing them to spend less time training or competing than what they usually do or had planned to do. One participant reported four injuries over the past 12-months, while three other participants had suffered three different injuries each, over this period. There was a cumulative count of 27 injuries from all the participants. Lower back injuries had the highest frequency at 25%, followed by the shoulder at 14.3%. There were zero reports of knee injuries. **Figure 3** illustrates the injuries sustained by these professional golfers over the last 12-months, prior to the start of the season.

Of the 27 injuries reported by the participants, 66.7% cases were of gradual onset. All the participants were diagnosed by a healthcare professional, where 40.7% of the injuries were diagnosed by multiple practitioners. Physiotherapists diagnosed 25.9% of the injuries, doctors 22.2%, and chiropractors 11.1%.

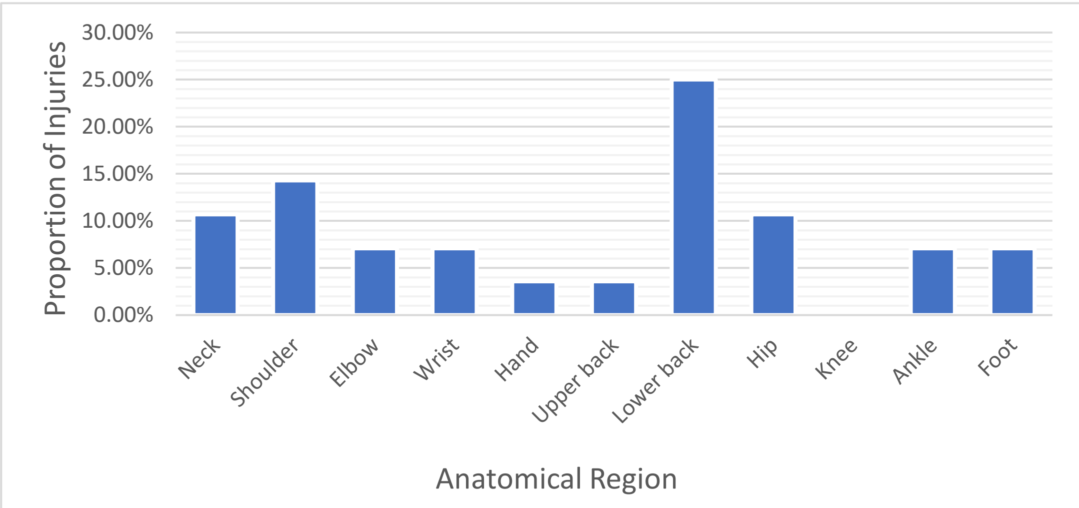


Figure 3: Proportion (%) of injuries sustained over the previous 12-months, retrospectively.

4.4. Range of Motion Measurements

When comparing the joint range of motion measurements of the injured and the uninjured groups, the only variable with a statistically significant difference between the two groups was horizontal adduction (HA) of the leading shoulder ($t = -2.17$; $p = 0.04$). HA of the trailing shoulder has also shown a noticeable difference when comparing the groups, however, the difference is not of statistical significance. **Table 7** presents the mean differences of the leading and trailing shoulder internal and external rotation, the leading and trailing shoulder horizontal adduction, the thoracic spine rotation towards the backswing and follow through, the internal and external rotation of the leading and trailing hip, and lumbar spine extension range of motion measurements when comparing the total group, the injured group, and the uninjured group.

Table 7: Mean range of motion measurements of the total, injured, and uninjured groups.

	Total group mean (n=28)	Injured mean (n=17)	Uninjured mean (n=11)	t-value	p-value
Trailing Shoulder IR (°)	69.43 ± 15.82	66.65 ± 18.39	73.73 ± 10.06	– 1.164	0.255
Leading Shoulder IR (°)	77.43 ± 13.42	77.00 ± 15.00	78.09 ± 11.20	– 0.206	0.838
Trailing Shoulder ER (°)	97.86 ± 9.32	98.94 ± 10.72	96.18 ± 6.74	0.759	0.454
Leading Shoulder ER (°)	90.75 ± 8.91	91.47 ± 7.99	89.64 ± 10.48	0.525	0.604
Trailing Shoulder HA (°)	45.89 ± 10.02	43.00 ± 9.47	50.36 ± 9.55	– 2.002	0.056
Leading Shoulder HA (°)	48.14 ± 11.32	44.65 ± 11.21	53.55 ± 9.61	– 2.165	**0.040***
Thoracic spine backswing Rot (°)	79.86 ± 13.27	78.65 ± 16.33	81.73 ± 6.5	– 0.593	0.558
Thoracic spine follow through Rot (°)	78.18 ± 9.46	76.76 ± 10.55	80.36 ± 7.42	– 0.982	0.335
Trailing Hip IR (°)	36.11 ± 9.39	35.88 ± 7.33	36.45 ± 12.32	– 0.155	0.878
Leading Hip IR (°)	35.61 ± 7.92	34.71 ± 8.24	37.00 ± 7.58	– 0.742	0.465
Trailing Hip ER (°)	33.18 ± 7.37	33.18 ± 6.86	33.18 ± 8.46	–0.002	0.999
Leading Hip ER (°)	31.50 ± 7.28	31.53 ± 8.18	31.45 ± 5.99	0.026	0.979
Lumbar extension (°)	30.82 ± 8.08	31.71 ± 6.94	29.45 ± 9.79	0.714	0.482

*Statistically significant differences (p<0.05) between the groups are indicated with **

4.5. Incidence of Injury

At the conclusion of an 11-week follow up, 17 (60.7%) (CI (95%): 0.42–0.76) players reported an injury during this period. Of these 17 participants, a total of 23 (CI (95%): 0.64-0.92) index injuries were recorded. The group of participants accumulated a total of 7039 hours(hrs) of playing golf. Therefore, the incidence of injury in professional golfers, over a single season, was 3.27/1000hrs of play. The week with the highest frequency of injuries was 16-22 December 2019 (week three). Of the 23 new injuries sustained, 17.4% were of traumatic onset and 82.6% of an overuse nature. **Figure 4** illustrated the distribution of the frequency of the injuries over the 11-week period and a comparison between overuse- and traumatic injuries.

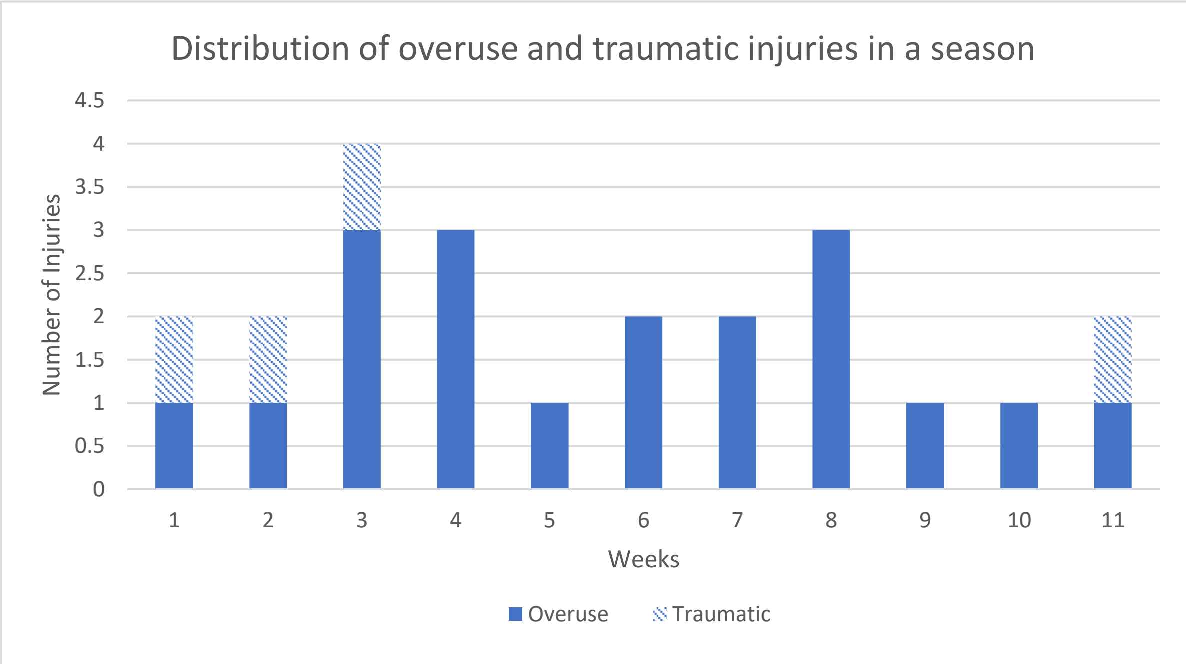


Figure 4 Distribution of the frequency and mechanism of injury, over 11-week period

4.6. Anatomical Distribution

Table 8 presents the proportion of leading- and trailing side injuries of the total injury count. It also presents anatomical regions injured for each of these two categories. The remainder of the injuries consisted of spinal injuries (30.44%), to the cervical and lumbar regions.

Table 8: Data presenting the side of injury and anatomical area affected.

	Lead	Trail
Shoulder injury	5	1
Elbow injury	0	0
Wrist injury	2	0
Hand injury	0	0
Thoracic spine injury	0	0
Hip injury	1	2
Knee injury	0	1
Ankle injury	1	0
Foot injury	1	0
Other	1	1
Total	11 (47.82%)	5 (21.74%)

The participants were asked to record their injuries according to anatomical area. They would report the specific joint that was injured or the area on the spine. If the injury was not directly related to a specific joint, the injury was classified as "other". These injuries typically included soft tissue injuries of the calf or thigh region. **Table 9** present the anatomical distribution of injuries.

Table 9: Anatomical Distribution of Injuries

Anatomical Region	Frequency of injury	Percentage of injury (%)
Cervical spine	1	4.3
Shoulder	6	26.1
Elbow	0	0
Wrist	2	8.7
Hand	0	0
Thoracic spine	0	0
Lumbar spine	6	26.1
Hip	3	13.0
Knee	1	4.3
Ankle	1	4.3
Foot	1	4.3
Other	2	8.7

4.6.1. Shoulder injury

Table 10 presents the mean and standard deviation of the joint range of motion measurements and the hours spent on training sections of participants reporting a shoulder injury compared to participants with no shoulder injury. There was a statistically significant difference for trailing shoulder internal rotation (t=–2.158; p= 0.040). There were no statistically significant findings between the two groups when comparing the training hour sections.

Table 10: Relationship of shoulder injury, range of motion and hours spent training

	Shoulder Injury (n=6)	**No Shoulder Injury (n=22)**	**t-value**	**p-value**
Trailing Shoulder IR (°)	57.83 ± 13.85	72.59 ± 15.07	– 2.158	**0.040***
Leading Shoulder IR (°)	70.00 ± 16.15	79.45 ± 12.22	– 1.571	0.128
Trailing Shoulder ER (°)	93.25 ± 6.50	98.63 ± 9.60	– 0.299	0.768
Leading Shoulder ER (°)	91.5 ± 3.11	90.63 ± 9.58	– 0.691	0.496
Trailing Shoulder HA (°)	46.17 ± 11.04	45.82 ± 10.00	0.074	0.941
Leading Shoulder HA (°)	49.83 ± 12.77	47.68 ± 11.18	0.406	0.688
Trailing Hip IR (°)	38.50 ± 8.04	35.45 ± 9.79	0.697	0.492
Leading Hip IR (°)	39.83 ± 6.05	34.45 ± 8.09	1.509	0.143
Trailing Hip ER (°)	32.17 ± 7.73	33.45 ± 7.44	– 0.373	0.712
Leading Hip ER (°)	31.67 ± 8.48	31.45 ± 7.14	0.062	0.951
Thoracic spine rotation backswing (°)	77.50 ± 8.89	80.25 ± 13.97	– 1.232	0.229
Thoracic spine rotation follow-through (°)	72.33 ± 6.80	79.77 ± 9.58	–1.773	0.088
Lumbar extension (°)	29.17 ± 3.66	31.27 ± 8.93	–0.559	0.581
Playing golf rounds (hrs)	183.08 ± 64.31	176.45 ± 46.10	0.287	0.776
Training golf components (hrs)	76.92 ± 49.70	88.57 ± 59.22	–0.440	0.664
Other training (hrs)	44.50 ± 24.38	39.06 ± 22.16	0.523	0.605
Total training (hrs)	304.50 ± 95.35	304.13 ± 106.16	0.008	0.994

4.6.2. Wrist injury

Error! Reference source not found.Table 11 presents the data for the joint range of motion measurements and the hours spent on training sections of participants reporting a wrist injury compared to subjects with no wrist injury. There was a statistically significant difference (t=–2.360; p= 0.026) of the leading shoulder external rotation (ER) between the two groups. There were no statistically significant findings in the training hour sections between the two groups.

Table 11: Relationship of wrist injury, range of motion and hours spent training

	Wrist Injury (n=6)	**No Wrist Injury (n=22)**	**t-value**	**p-value**
Trailing Shoulder IR (°)	64.50 ± 7.78	69.81 ± 16.30	– 0.450	0.656
Leading Shoulder IR (°)	65.00 ± 7.07	78.38 ± 13.38	– 1.382	0.179
Trailing Shoulder ER (°)	95.00 ± 7.07	98.08 ± 9.54	– 0.443	0.661
Leading Shoulder ER (°)	77.5 ± 17.68	91.77 ± 7.62	– 2.360	**0.026***
Trailing Shoulder HA (°)	43.50 ± 10.61	46.08 ± 10.17	– 0.345	0.733
Leading Shoulder HA (°)	44.50 ± 7.78	48.42 ± 11.61	– 0.465	0.646
Trailing Hip IR (°)	36.50 ± 9.19	36.08 ± 9.58	0.060	0.952
Leading Hip IR (°)	35.00 ± 11.31	35.65 ± 7.91	– 0.110	0.913
Trailing Hip ER (°)	35.00 ± 5.66	33.04 ± 7.56	0.357	0.724
Leading Hip ER (°)	22.50 ± 9.19	32.19 ± 6.84	– 1.901	0.068
Thoracic spine rotation backswing (°)	81.00 ± 5.66	79.77 ± 13.74	0.124	0.902
Thoracic spine rotation follow-through (°)	80.50 ± 9.19	78.00 ± 9.64	0.354	0.726
Lumbar extension (°)	27.50 ± 10.61	31.08 ± 8.06	– 0.596	0.556
Playing golf rounds (hrs)	138.00 ± 52.33	180.94 ± 48.73	–1.197	0.242
Training golf components (hrs)	48.00 ± 15.56	89.00 ± 57.72	–0.986	0.333
Other training (hrs)	18.50 ± 26.16	41.89 ± 21.65	–1.460	0.156
Total training (hrs)	204.50 ± 94.05	311.88 ± 100.37	–1.461	0.156

*Statistically significant difference (p<0.05) is marked with *.*

4.6.3. Lumbar spine injury

Table 12 presents the data for the joint range of motion measurements and the hours spent on training sections of participants reporting a lumbar spine injury compared to participants with no lumbar spine injury. There were statistically significant differences for trailing shoulder external rotation (t=2.227; p=0.031), trailing shoulder horizontal adduction (t=–2.600; p= 0.015), leading shoulder horizontal adduction (t=–2.318; p= 0.029), trailing shoulder external rotation, and leading hip internal rotation (t=–3.308; p= 0.003). There were no statistically significant findings in training hours between the two groups.

Table 12: Relationship of lumbar spine injury, range of motion and hours spent training

	Lumbar spine Injury (n=6)	No Lumbar spine Injury (n=22)	t-value	p-value
Trailing Shoulder IR (°)	66.17 ± 18.26	70.32 ± 15.44	– 0.563	0.579
Leading Shoulder IR (°)	77.00 ± 10.66	77.55 ± 14.30	– 0.087	0.932
Trailing Shoulder ER (°)	105.00 ± 14.72	95.91 ± 6.44	2.277	**0.031***
Leading Shoulder ER (°)	94.00 ± 10.95	89.86 ± 8.35	1.008	0.323
Trailing Shoulder HA (°)	37.33 ± 8.02	48.23 ± 9.34	– 2.600	**0.015***
Leading Shoulder HA (°)	39.33 ± 8.45	50.55 ± 10.94	– 2.318	**0.029***
Trailing Hip IR (°)	33.33 ± 8.62	36.86 ± 9.64	– 0.811	0.425
Leading Hip IR (°)	27.50 ± 6.35	37.82 ± 6.87	– 3.308	**0.003***
Trailing Hip ER (°)	33.50 ± 7.77	33.09 ± 7.45	0.118	0.907
Leading Hip ER (°)	33.00 ± 8.51	31.09 ± 7.07	0.563	0.579
Thoracic spine rotation backswing (°)	73.83 ± 23.34	81.50 ± 9.13	– 1.269	0.216
Thoracic spine rotation follow-through (°)	75.00 ± 14.82	79.05 ± 7.69	– 0.926	0.363
Lumbar extension (°)	36.00 ± 8.34	29.41 ± 7.59	1.849	0.076
Playing golf rounds (hrs)	165.50 ± 26.69	181.25 ± 53.80	–0.687	0.498
Training golf components (hrs)	81.25 ± 26.00	87.39 ± 62.90	–0.231	0.819
Other training (hrs)	40.46 ± 14.65	40.16 ± 24.25	0.029	0.977
Total training (hrs)	165.50 ± 26.69	181.25 ± 53.80	–0.687	0.498

*Statistically significant difference (p<0.05) is marked with *.*

4.6.4. Hip injury

Table 13 presents the data for the joint range of motion measurements and the hours spent on training sections of participants reporting a hip injury compared to participants with no hip injury. There were statistically significant differences for trailing shoulder internal rotation (t=2.075; p= 0.048) and leading hip external rotation (t=3.148; p= 0.004). There were no statistically significant differences in training hours between the two groups.

Table 13: Relationship of hip injury, range of motion and hours spent training

	Hip Injury (n=6)	No Hip Injury (n=22)	t-value	p-value
Trailing Shoulder IR (°)	86.33 ± 16.50	67.40 ± 14.79	2.075	**0.048***
Leading Shoulder IR (°)	86.33 ± 15.82	76.36 ± 13.06	1.228	0.230
Trailing Shoulder ER (°)	89.00 ± 1.73	98.92 ± 9.30	– 1.815	0.081
Leading Shoulder ER (°)	91.33 ± 3.22	90.68 ± 9.40	0.118	0.907
Trailing Shoulder HA (°)	46.67 ± 11.50	45.80 ± 10.09	0.139	0.891
Leading Shoulder HA (°)	43.33 ± 16.80	48.72 ± 10.84	– 0.773	0.447
Trailing Hip IR (°)	40.00 ± 4.36	35.64 ± 9.77	0.754	0.458
Leading Hip IR (°)	37.00 ± 7.00	35.44 ± 8.14	0.317	0.754
Trailing Hip ER (°)	36.33 ± 8.14	32.80 ± 7.57	0.778	0.443
Leading Hip ER (°)	42.33 ± 4.51	30.20 ± 6.44	3.148	**0.004***
Thoracic spine rotation backswing (°)	76.00 ± 7.76	80.32 ± 13.50	– 0.526	0.604
Thoracic spine rotation follow-through (°)	79.33 ± 9.02	78.04 ± 9.69	0.220	0.828
Lumbar extension (°)	33.33 ± 2.89	30.52 ± 8.48	0.563	0.578
Playing golf rounds (hrs)	191.67 ± 39.12	176.22 ± 50.75	0.506	0.617
Training golf components (hrs)	80.17 ± 42.87	86.78 ± 58.75	–0.188	0.853
Other training (hrs)	44.83 ± 11.41	39.67 ± 23.35	0.373	0.712
Total training (hrs)	316.67 ± 90.75	302.71 ± 105.10	0.219	0.828

*Statistically significant difference (p<0.05) is marked with *.*

4.6.5. Other injury

Table 14 presents the mean and standard deviation of joint range of motion measurements and the hours spent on training sections of participants reporting "other" injuries compared to subjects with no "other" injuries. There were no statistically significant differences for any of the measurements nor the time spent training between the two groups.

Table 14: Relationship of 'other' injury, range of motion and hours spent training

	Other Injury (n=6)	No Other Injury (n=22)	t-value	p-value
Trailing Shoulder IR (°)	61.00 ± 9.90	70.08 ± 16.13	− 0.776	0.445
Leading Shoulder IR (°)	79.50 ± 14.85	77.27± 13.61	0.223	0.826
Trailing Shoulder ER (°)	97.50 ± 10.61	97.89 ± 9.45	− 0.055	0.956
Leading Shoulder ER (°)	92.50 ± 3.54	90.62 ± 9.22	0.283	0.779
Trailing Shoulder HA (°)	53.00 ± 7.07	45.35 ± 10.10	1.043	0.307
Leading Shoulder HA (°)	56.50 ± 2.12	47.50 ± 11.50	1.087	0.287
Trailing Hip IR (°)	34.00 ± 5.66	36.27 ± 9.67	− 0.324	0.749
Leading Hip IR (°)	44.50 ± 0.71	34.92 ± 7.81	1.704	0.100
Trailing Hip ER (°)	37.50 ± 3.54	32.85 ± 7.52	0.856	0.400
Leading Hip ER (°)	38.50 ± 12.02	30.96 ± 6.87	1.440	0.162
Thoracic spine rotation backswing (°)	72.50 ± 10.61	80.42 ± 13.45	− 0.809	0.426
Thoracic spine rotation follow-through (°)	72.50 ± 3.54	78.62 ± 9.67	− 0.877	0.389
Lumbar extension (°)	32.50 ± 3.54	30.69 ± 8.35	0.300	0.767
Playing golf rounds (hrs)	199.75 ± 49.85	176.19 ± 49.80	0.645	0.525
Training golf components (hrs)	66.00 ± 9.90	87.62 ± 58.54	−0.513	0.612
Other training (hrs)	61.75 ± 41.37	38.57 ± 20.70	1.445	0.160
Total training (hrs)	316.67 ± 90.75	302.71 ± 105.10	0.219	0.828

4.7. Training Load

4.7.1. Overall Training Hours

When comparing the mean values of the different categories of training, the uninjured participants spent more time on training the components of golf (HGT), other type of training exercise (HOT), and had a higher number of total hours (TotHrs) spent training. However, there were no statistically significant differences between the injured and uninjured groups when comparing the overall time spent on the different categories of training and competing respectively, nor were there a statistically significant difference when comparing the total time spent on training and competing**. Table 15** presents the mean and standard deviation (SD) values of the total hours spent on each component according to injury status and as the total participant group.

Table 15: Mean and SD data for training hours of the total group, injured and uninjured groups

	Total group (n=28)	Injured mean (n=17)	Uninjured mean (n=11)	t-value	p-value
HPR	166.02 ± 65.54	177.91 ± 46.91	177.82 ± 55.05	0.005	0.996
HTG	80.33 ± 58.86	83.77 ± 52.73	89.64 ± 64.76	– 0.263	0.794
HOT	37.54 ± 23.81	39.51 ± 18.28	41.32 ± 28.38	– 0.205	0.839
TotHrs	283.93 ± 125.24	301.25 ± 90.15	308.77 ± 123.17	– 0.187	0.853

4.7.2. Breakdown of Training Load over 11-Weeks

There were no statistically significant differences when comparing the injured and uninjured groups regarding the mean time spent in hours for playing rounds of golf (HPR), training components of golf (HTG), participating in other exercise (HOT), or total time spent on training (TotHrs).

Table 16: Weekly means and SD of each section of training for the total group, injured and uninjured group

	Total group (n=28)	Injured (n=17)	Uninjured (n=11)	F-value	p-value
HPR	16.17 ± 9.79	16.17 ± 9.24	16.17 ± 10.63	0.00	1.00
HTG	8.04 ± 8.20	7.98 ± 8.53	8.15 ± 7.68	0.01	0.94
HOT	3.66 ± 3.12	3.59 ±3.09	3.76 ± 3.17	0.04	0.84
TotHrs	27.65 ± 15.00	27.38 ± 13.55	28.07 ± 17.06	0.04	0.85

4.7.2.1. Hours playing rounds

The hours spent playing rounds has significantly increased over the testing period duration (F=24.01; p<0.01). As presented in **Figure 5Figure 6**, there is a continuous increase in HPR until week seven. The only statistically significant difference between the injured and uninjured groups was in week 11 (p= 0.02), as presented by **Figure 6**.

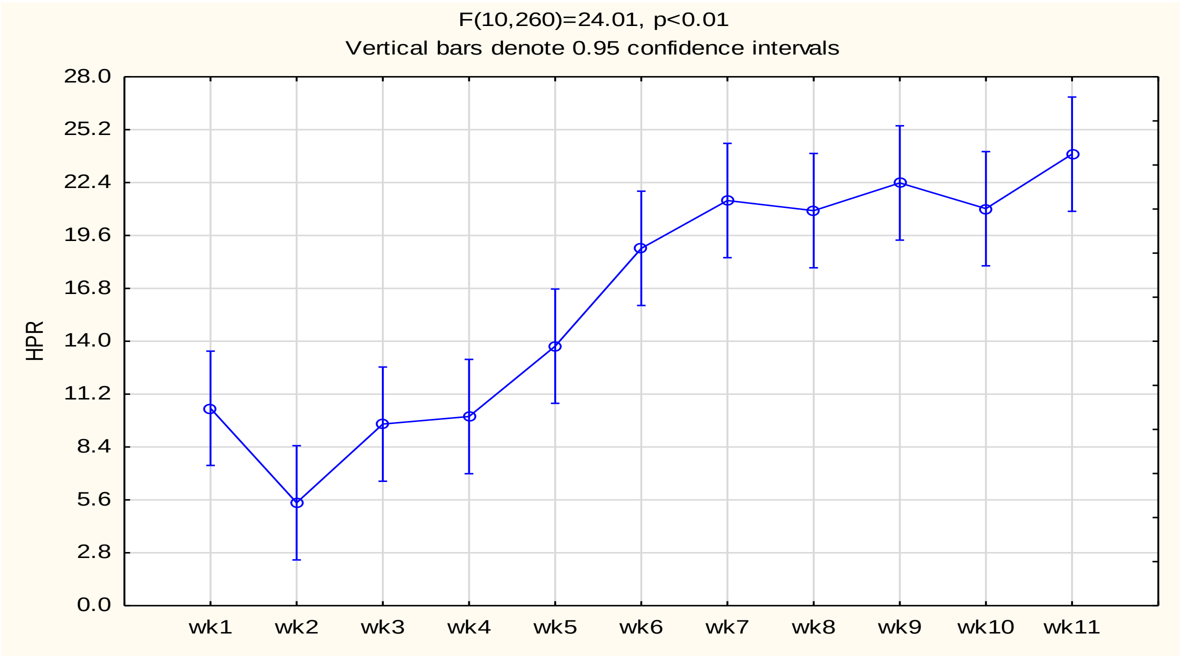


Figure 5: Mean weekly hours spent on playing rounds of golf by the total group over 11-weeks

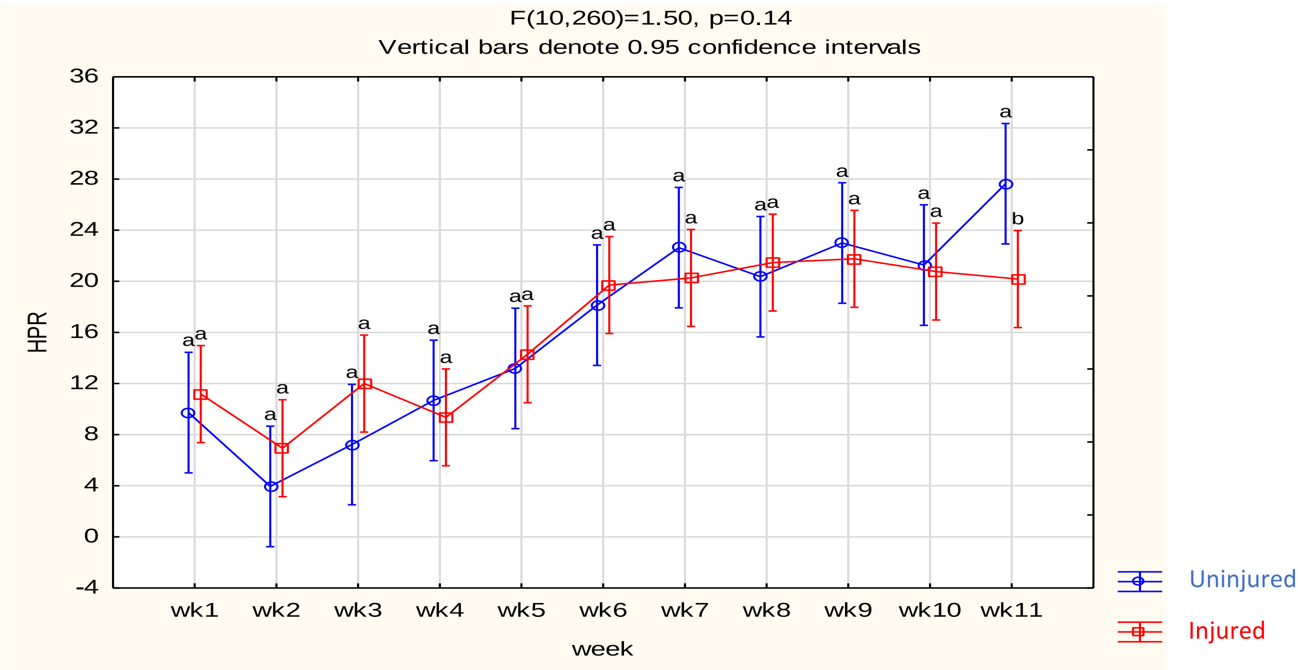


Figure 6: Mean weekly hours spent on playing rounds of golf, injured vs uninjured group

4.7.2.2. Hours spent on training components of golf

There was a gradual increase in HTG from week one to week six and then a decrease in hours spent on this component of training, as presented by **Figure 7.** The only statistically significant difference in HTG between the injured and uninjured groups was in week two (p= 0.02). **Figure 8Error! Reference source not found.** presents the mean weekly hours spent on training the components of golf of the injured compared to the uninjured group.

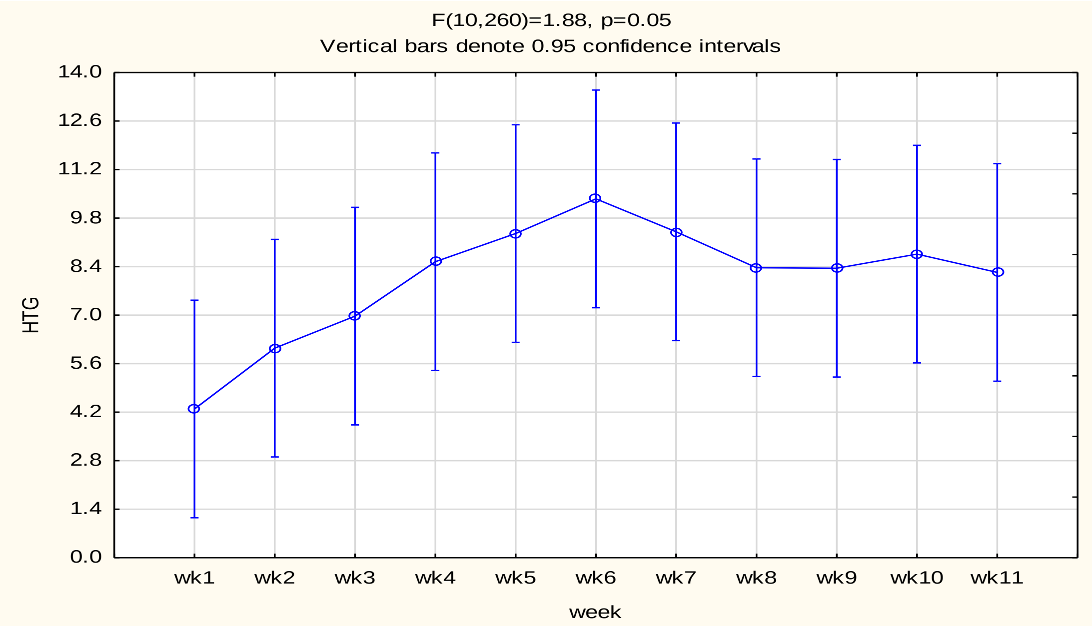


Figure 7: Mean weekly hours spent on training components of golf by the total group over 11-weeks

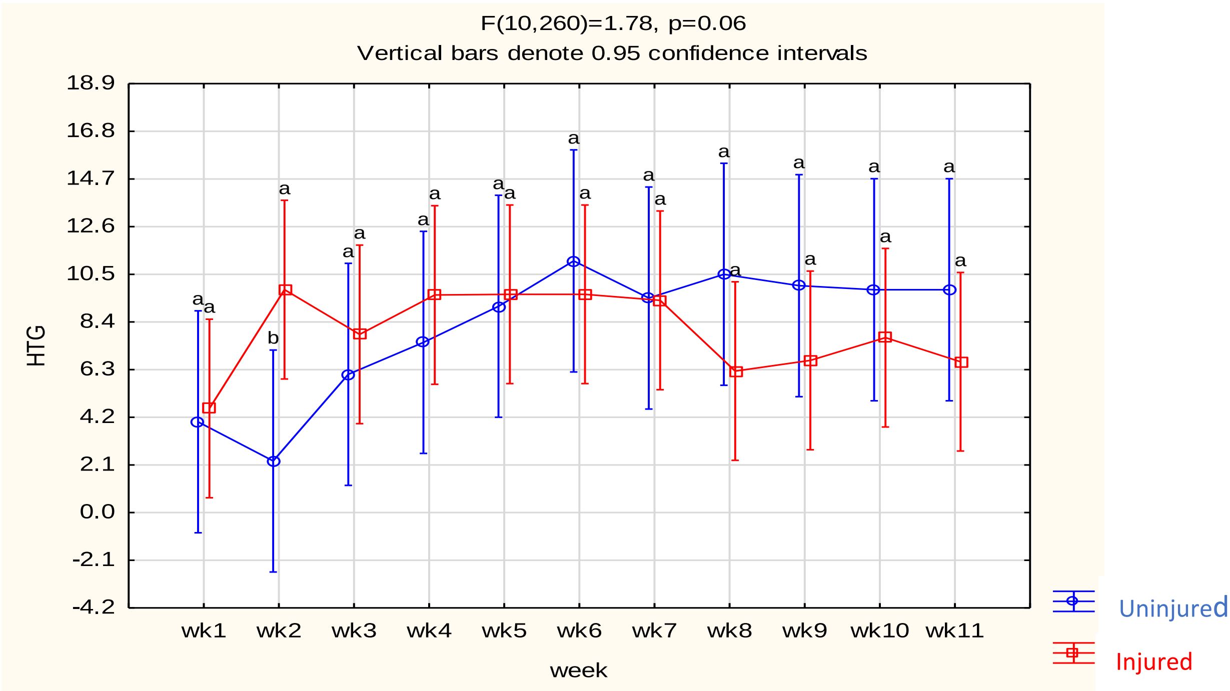


Figure 8: Mean weekly hours spent on training components of golf, injured vs uninjured group

4.7.2.3. Hours spent on other type of exercise

There was statistically significant increase (p= 0.03) in HOT from the fifth to the sixth week and a statistically significant decrease (p=0.02) in HOT from the eighth to the ninth week. **Figure 9** presents the weekly mean hours spent on other type of exercise over the 11-week data collection period. There were no weeks with statistically significant differences when comparing HOT of the injured and uninjured groups. **Figure 10** present hours spent on other exercise, comparing the injured and uninjured groups.

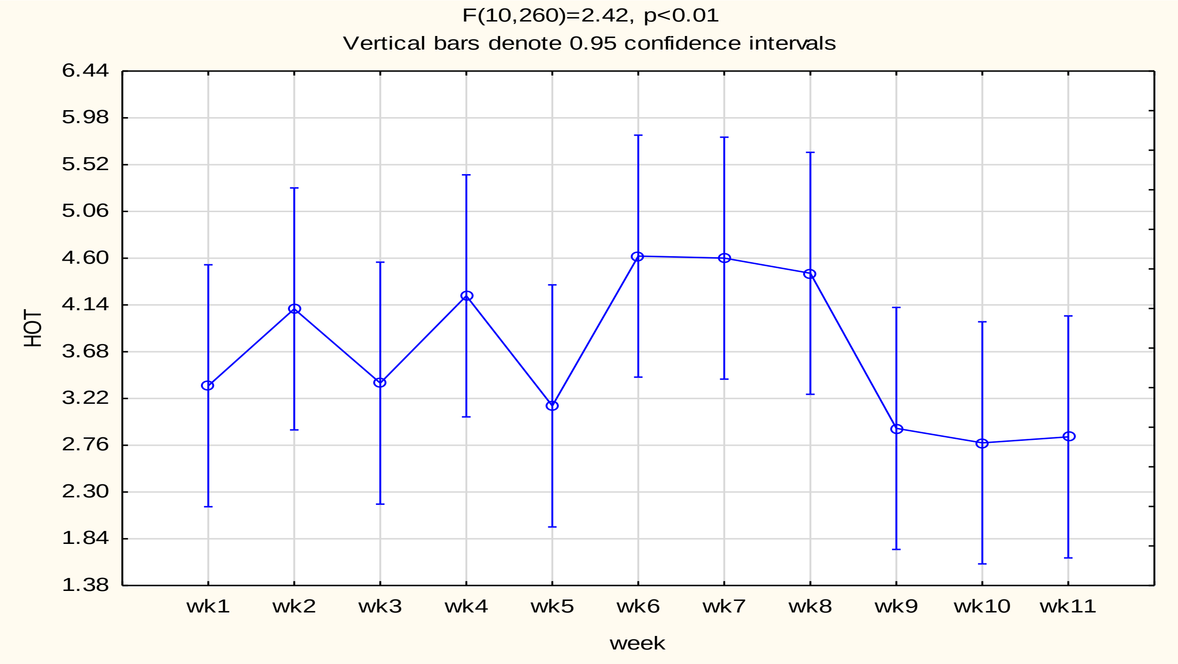


Figure 9: Mean weekly hours spent on other type of exercise by the total group over 11-weeks

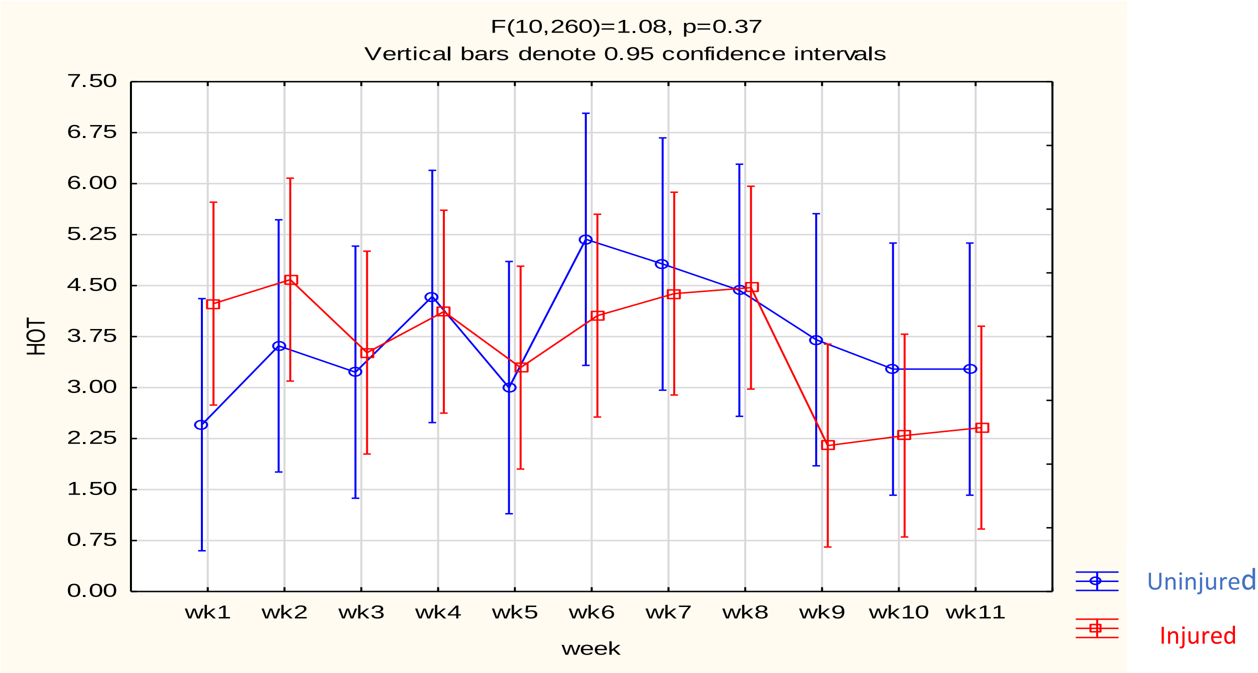


Figure 10: Mean weekly hours spent on other type of exercise, injured vs uninjured group

4.7.2.4. Total hours spent training

There was a statistically significant increase in TotHrs from the second to the third week (p= 0.02) and also from the fifth to the sixth week (p<0.01). The only week presenting with a statistically significant difference in TotHrs between the injured and uninjured was week 11 (p= 0.03). **Figure 11** presents the mean weekly total hours spent on training over the 11-week data collection period. **Figure 12** presents the mean weekly total hours spent on training for the injured compared to the uninjured groups.

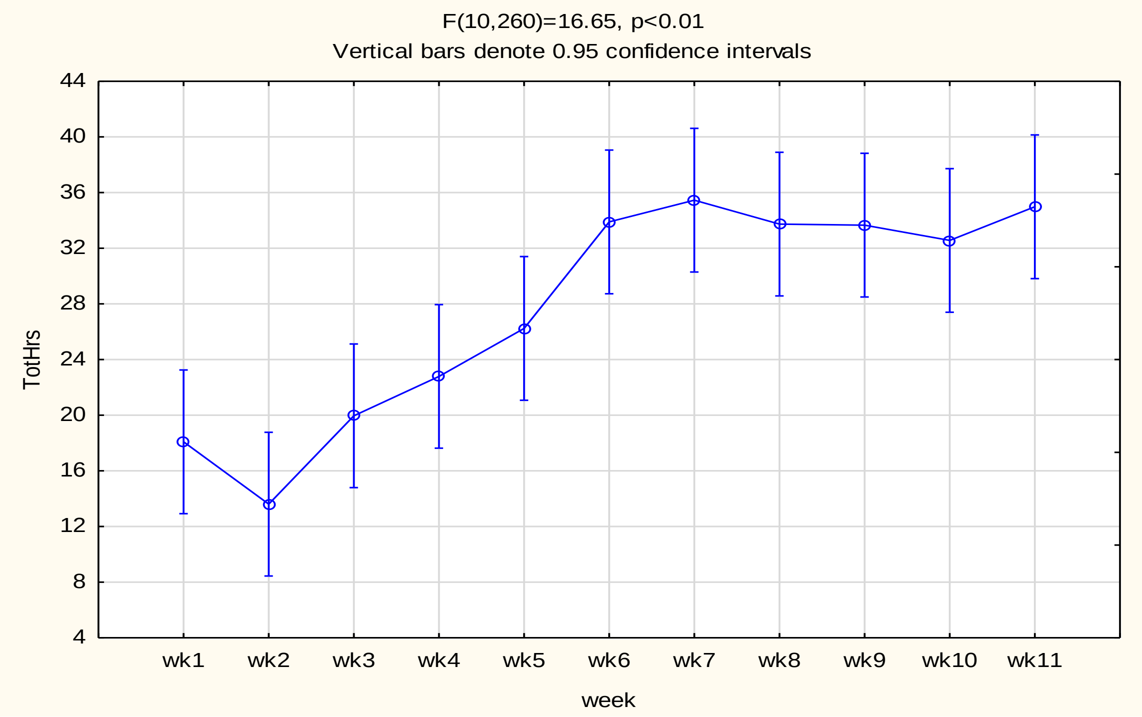


Figure 11: Mean weekly total hours spent training by the total group over 11-weeks

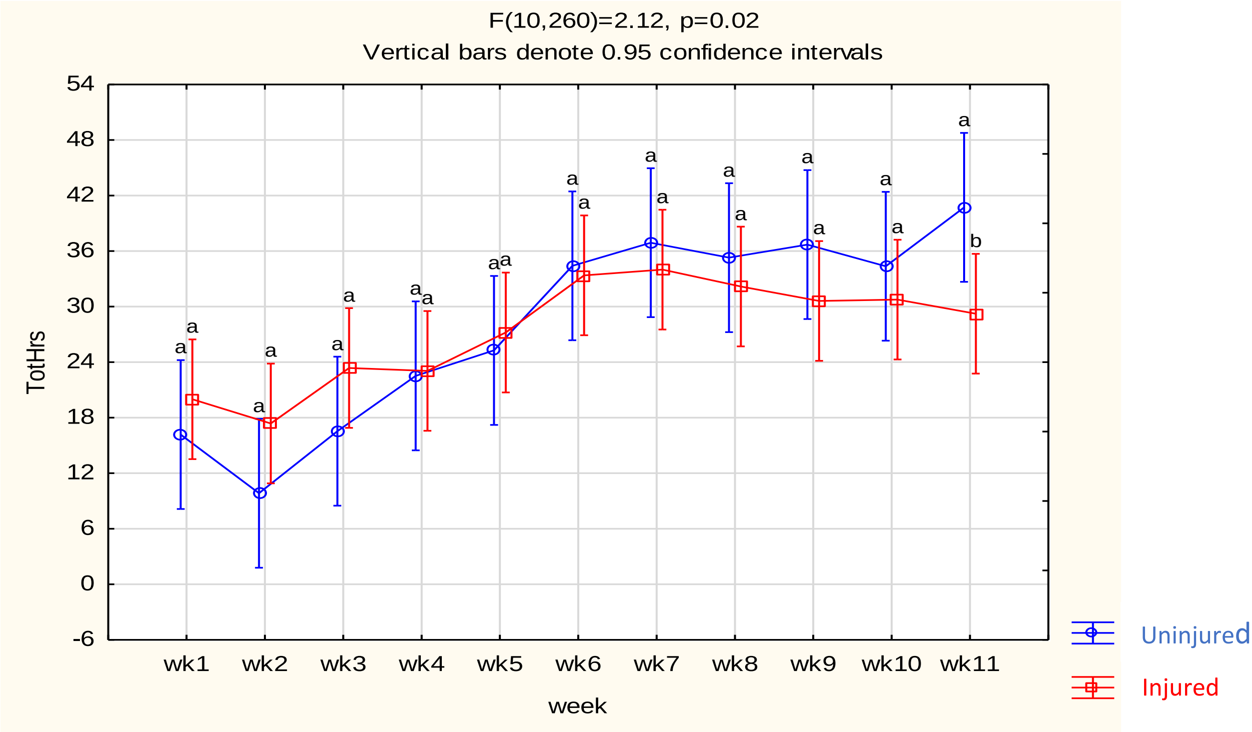


Figure 12: Mean weekly total hours spent training, injured vs uninjured group

4.8. Summary of Results

4.8.1. Demographics

After the statistical analysis of the data in this study, a statistically significant difference (p=0.047) was found when comparing the BMI of the injured and uninjured groups. The injured group presented with a lower BMI than the uninjured group.

4.8.2. Training History

No statistically significant differences between the injured and uninjured groups relating to the training history were found.

4.8.3. Injury History

Half of this study's sample reported that they have sustained an injury over the past 12-months. The highest prevalence of injury was lower back injury (25%).

4.8.4. Range of Motion Measurements

There was a statistically significant difference (p=0.040) found when comparing the leading shoulder horizontal adduction between the injured and uninjured groups.

4.8.5. Incidence of Injury

At the conclusion of the season, this study reported that 60.7% (CI (95%): 0.42–0.76) of the participants sustained an injury. The incidence of injury rate was 3.27/1000hrs of playing golf.

4.8.6. Anatomical Distribution

The lower back and the shoulder were the two most frequently injured anatomical regions, both at 26.1%. The hip followed making up 13% of the injury count.

There was a statistically significant difference (p=0.04) of the trailing shoulder internal rotation when comparing the participants who reported a shoulder injury and the participants who did not. There was also statistically significant difference (p=0.026) in the measurement of the leading shoulder external rotation when comparing the group who sustained a wrist injury and the group who did not. Furthermore, there were statistically significant differences in the measurements of the trailing shoulder external rotation (p=0.03), the leading (p=0.015) and trailing (p=0.029) shoulder horizontal adduction, and the leading hip internal rotation (p=0.003). There were statistically significant differences in the measurements of the trailing shoulder internal rotation (p=0.048) and the leading hip internal rotation (p=0.004) when comparing the groups with and without a hip injury.

4.8.6.1. Training Load

No statistically significant differences were found when comparing the overall training loads of the injured and uninjured groups.

Chapter 5: Discussion

The aim of this study was to determine whether the range of motion of the shoulder, hip, and spine serve as an intrinsic risk factor to injury in professional golfers. Furthermore, this study investigated training load as an extrinsic risk factor to injury in this population. The purpose of this study would be to contribute to preventative strategies, regarding minimizing injuries and ultimately improving performance in professional golfers.

During the first section of this discussion, the participants and their descriptive characteristics will be addressed. Furthermore, the second section will be discussing the retrospective data collected from the participants regarding their training- and injury histories. In the third section, the range of motion measurements and their contribution to injury will be discussed. The fourth and fifth section will address the incidence and anatomical distribution of injury amongst this population. Finally, the last section will be discussing the influence of training load on injury in professional golfers.
A critical analysis of this study's findings and the implication thereof will be discussed as a conclusion of this chapter, including this study's limitations and recommendations. The order will follow as presented in chapter four.

5.1. Participants

5.1.1. Sample Size

This study included 28 male participants, who are all competing as professional golfers on the Sunshine Tour. The participants were divided into either the 'injured' or 'uninjured' group, depending on their status at the end of the 11-week data collection period. In similar studies, the sample sizes ranged between 60 and 127 professional male players (Gosheger et al., 2003; McCarroll & Gioe, 1982). These were substantially higher than the sample size of this study, however, the population sizes from which the samples were drawn from were much higher than our available population of 46 South African golfers, participating at the Alfred Dunhill Championship. Furthermore, the studies did not involve any physical testing of participants, and relied on monitoring of injury during a season, collecting data from a medical unit at the tournament, or via retrospective questioning (Smith & Hillman, 2012; Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982).

This study sample meets the criteria for a confidence level of 80%. However, the sample was collected from a single tournament at the beginning of the season, which potentially limited the number of participants and ultimately influenced the external validity of this study.

Due to the smaller sample size, the true reflection of certain injuries, which seem to be of higher prevalence in other studies, were not reported as frequently in this study (Sugaya et al., 1999; McCarroll & Gioe, 1982). However, even though the sample size was not as large as similar studies, it reported a low attrition rate of only 6.67%.

5.1.2. Descriptive Characteristics

The mean age of the participants in this study was 31.57 ($\pm$7.65) years. The uninjured group had a slightly higher mean age (33.91 $\pm$ 10.25) when compared to the injured (30.06 $\pm$ 5.19) group but were not of statistical significance. The mean age of this study sample seems to be consistent with similar studies where the mean ages of participants were 30, 37, and 40 years respectively (Gosheger et al., 2003; Sugaya et al., 1999; McCarroll & Gioe, 1982). Similarly to the findings of previous studies, age was not found to be an associated risk factor in professional golfers (Gosheger et al., 2003; Hadden et al., 1992).

Similarly to the findings of this study, there were no other studies reporting height or weight as associated risk factors to injury in professional golfers. The mean height of the participants in this study was 182.11 ($\pm$ 8.25)cm and the mean weight was 84.32 ($\pm$ 11.59)kg. Neither of these could be compared to similar studies because no study could be found reporting the mean values of these variables.

There was a statistically significant difference in the injured (25.58 $\pm$ 2.22 $kg.m^2$) and the uninjured (26.71 $\pm$ 3.19 $kg.m^2$) group when comparing their BMI. The uninjured group presented with a higher BMI than the injured group, with 12 of this study's participants being classified as being 'overweight' and three participants fall under the 'obese I' category according to the World Health Organization (WHO) (Anuurad et al., 2003). The only study reporting on BMI as an associated risk factor to injury in professional golfers found a statistically significant higher prevalence of lower back injuries in participants with a BMI of higher than $25kg.m^{-2}$ (Gosheger et al., 2003). However, these findings were reported as lower back injuries unrelated to golf and therefore cannot be compared to the findings of this study. In another study, the researchers had similar findings compared to this study as the participants who had a BMI lower than $25.7kg.m^{-2}$ were more at risk of sustaining an injury (Evans et al., 2005).

5.2. Training History

The participants of this study reported their training history according to the specific season (Summer Swing or Winter Swing) retrospectively. They would estimate the time they spend on various categories of training golf, strength and conditioning, and flexibility during the two seasons respectively. There were statistically significant differences in any of the categories for training, strength and conditioning, or flexibility.

5.3. Injury History

In this sample, 14 (50%) of the participants presented with an injury over the past year. Lower back pain (25%) was the most common injury sustained over the past year. This does correlate with the findings of this study, where the lower back is one of the two most frequently injured anatomical areas. The shoulder follows the lower back as the second most frequently injured anatomical area over the past 12 months (14.3%). During a study in elite footballers, the authors concluded that previous injury is a strong risk factor for injury amongst this population (Hägglund, Waldén, & Ekstrand, 2006).

5.4. Incidence of Injury

The first objective of this study was met by determining the incidence of injury in professional golfers, Injuries were reported by participants if it affected the time they spent on training or competition. Clarsen and Bahr (2014) reported that this method of injury identification is as easy to report for the general sporting population as it is for health professionals. However, this does leave margin for error in reporting all injuries if the participant decides that his injury is not of significant value or if the participant decides that his time playing is more important than the injury.

When comparing the nature of injury within this sample, most of the injuries were of overuse nature (82.6%). This correlates with previous findings of the German investigators' where 80% of the injuries in participants were of overuse nature (Gosheger et al., 2003). Professional golfers are prone to develop overuse injuries due to the excessive repetitive motions while training, which has been attributed to 79.9% of total injuries in a professional golfing population (Thériault & Lachance, 1998).

At the conclusion of an 11-week follow up, 17 (60.7%) participants reported an injury during the season. This aligns well with the findings of Gosheger et al. (2003), where they had 60% of their professional participants reporting an injury. However, their data was collected over two seasons compared to this study, which was only done over a single season.

Other studies found a much higher prevalence of injury than this study. Sugaya et al. (1999) reported that 72% of their participants sustained an injury. Similarly to Sugaya et al. (1999), another study reporting on injury over a life time, they found a prevalence of injury as high as 84% (McCarroll & Gioe, 1982). However, these results were reported over the span of an entire career and could therefore not be compared to this study.

This study reported a total of 23 index injuries and five participants experienced recurring injuries during the season. This means that there were 0.82 index injuries per participant. In two studies following professional golfers, the authors reported 1.1 and 1.8 injuries per participant respectively (Gosheger et al., 2003; Hadden et al., 1992). Although this study seems to have fewer reported injuries compared to highlighted studies, it is important to note that these studies had failed to report whether the injury was classified as an index- or recurring injury.

The group of participants accumulated a total of 7039 hours(hrs) of playing golf. Therefore, the incidence of injury in professional golfers, over a single season, was 3.27/1000hrs of play. There were no studies found which calculated the incidence of injury of professional golfers over a season or any other period. However, McHardy et al. (2007b) reported an incidence of injury rate of 0.6/1000hrs of play while investigating a group of amateur golfers in Australia. The lower incidence of injury reported by the amateur group correlates with the fact that professional players spend more time playing golf than amateur players and are, therefore, more at risk of injury (McHardy et al., 2006; Gosheger et al., 2003).

It is well documented that overuse injuries are more common in golfers than traumatic injuries (Gosheger et al., 2003; McCarroll & Gioe, 1982). In this study similar findings were reported, with 82.6% of the index injuries being of overuse nature and only 17.4% of traumatic nature. Gosheger et al. (2003) reported that 83% of the injuries sustained by their participants were overuse injuries. A clear definition of traumatic and overuse injury is imperative when documenting the nature of injury. Fuller et al. (2006) reported that a clear description of the mechanism of injury is needed to determine whether an injury is overuse or traumatic in nature. Furthermore, participants should be able to report an identifiable mechanism contributing to a traumatic injury and if there was no identifiable mechanism of their injury they should report it as an overuse injury (Fuller et al., 2006). The participants of this study were informed about these definitions and were able to understand and report prospective injuries accurately.

5.5. Anatomical Distribution of Injury

The lumbar spine (26%) and shoulder (26%) were the two anatomical areas with the highest prevalence of injury in this sample, followed by the hip (13%). Lumbar spine injury in professional golfers ranges between 21-34% of injuries in the current literature which aligns with the findings of this study (Smith & Hillman, 2012; Sugaya et al., 1999). This may be due to high torsional loads and excessive extension of the lumbar spine as a result of the modern-day swing labelled the 'X-factor' (Lindsay & Vandervoort, 2014). However, there has been no conclusive evidence in the literature that the mechanics of the golf swing causes lower back pain in golfers (Smith et al., 2018).

Shoulder injuries were reported by this study's participants and were compared to the participants of a previous study that found a prevalence of 13% of shoulder injuries (Gosheger et al., 2003). Further analyses revealed that of the six reported shoulder injuries during this study, five were on the leading side and only one on the trailing side. There might be an underlying reason for the leading side being more prevalent, which most likely has a biomechanical influence and would fall out of the scope of this study (Cabri et al., 2009).

Injury to the hip region was reported three times and contributed to 13% of the total number of injuries. Previous studies had much lower prevalence of hip injuries, ranging between 0-3% of their injuries (Gosheger et al., 2003; Sugaya et al., 1999). Gulgin et al. (2009) reported that the leading hip experiences high loads of internal rotation during the follow-through phase of the swing, therefore, one would expect a higher prevalence of injury to this region in the previously conducted studies. However, in this study, there were more hip injuries reported on the trailing side than on the leading side. A possible reason for the higher prevalence of hip injuries in this study could be due to two out of the three participants reported a previous hip injury in the last 12 months, both on the trailing side.

There were single (4.3%) injuries of the knee, ankle, foot, and cervical spine. This study regarded the ankle and foot as two anatomical areas, however, in the majority of the literature the two areas were classified as one anatomical area (Smith & Hillman, 2012; Gosheger et al., 2003; Hadden et al., 1992). Therefore, if the foot and ankle are classified as one anatomical area, the findings of this study were similar to the findings of the previous literature with the prevalence of foot and ankle injuries ranging between 1-7% (Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992; McCarroll & Gioe, 1982). Ankle injuries are generally reported after slipping or falling over an object (Zouzias et al., 2018). In this study these types of accidents did not occur during the testing period as frequently.

Furthermore, knee injuries in golfers are more common amongst an elderly population (McHardy et al., 2006). In this study, the majority of the participants were under the age of 50 years and this could explain why knee injuries were less frequent.

The biggest discrepancy between this study and previous literature was seen in the cervical spine. There was only one (4.3%) participant that reported a cervical spine injury, whereas other studies reported higher prevalence of cervical spine injuries (20-25%) which does not correlate with this study's findings (Smith & Hillman, 2012; Sugaya et al., 1999; Hadden et al., 1992). However, two of these studies, collected their data during tournament time only, which might suggest that an injury to the cervical spine could potentially be more prone to traumatic or acute injury (Smith & Hillman, 2012; Hadden et al., 1992). A plausible reason for the low prevalence in cervical spine injuries in this study could be due data being collected over a season as other studies, that collected data over a few seasons or a lifetime, had a lower prevalence of cervical spine injuries too (3% and 10%) (Gosheger et al., 2003; McCarroll & Gioe, 1982).

In this study, two (8.6%) participants reported a 'other' injury, which means the injury did not fall under any of the anatomical regions surrounding the joints or spine. The two 'other' injuries reported were a calf strain and a distal hip adductor injury. These findings fall within the prevalence range of previous studies which found 'other' injuries between 3-12% (Gosheger et al., 2003; Sugaya et al., 1999). These included injury to the ribs, calf, hamstring, and to the shins (Gosheger et al., 2003; Sugaya et al., 1999; Hadden et al., 1992). However, the researchers did not report the diagnosis of the injury.

There were no injuries reported for the hand, thoracic spine, and elbow in this study. According to McHardy and Pollard (2005), elbow injuries are seen more frequently amongst amateur players compared to professional golfers. The prevalence of thoracic spine injuries varied between studies, with the majority reporting lower figures (0-3%) and this would correlate with the findings of this study (Gosheger et al., 2003; Sugaya et al., 1999; McCarroll & Gioe, 1982). The thoracic spine and elbow are the two anatomical regions with the longest 'time-loss' according to Gosheger et al. (2003), therefore, the participants in this study were fortunate to have no injuries at these anatomical regions and avoided a prolonged absence from participation in the tournament.

During this study, the range of motion measurements of the shoulders, thoracic spine, lumbar spine, and hips were investigated as potential risk factors of injury in professional golfers. However, due to the study being underpowered, the risk factors could not be determined by odds ratio or correlation.

The second objective of this study was determining whether decreased shoulder mobility is a risk factor of injury in this population. While investigating the relationship between the overall injury rate and range of motion measurements, the leading shoulder horizontal adduction was the only range of motion measurement which had a statistically significant (p=0.04) difference between the overall injured and the uninjured group. The injured group had a significant decrease in shoulder horizontal adduction in the leading shoulder compared to the uninjured group. The leading shoulder is required to go through great ranges of horizontal adduction during the backswing and failure to do so could potentially expose the shoulder or other anatomical regions to excessive physiological loads (Hovis et al., 2002). The trailing shoulder horizontal adduction had a markable difference with reduced ranged of motion found in the injured group compared to the uninjured group, however, this was not statistically significant (p=0.06).

It has been suggested that an increased mobility of the shoulder joint increases the risk of shoulder injuries in golfers (Thériault & Lachance, 1998). However, this study had contradicting findings. The results of this study found a statistically significant difference (p=0.04) in the trailing shoulder internal rotation between participants presenting with a shoulder injury compared to the group without injury. Decreased external rotation of the leading shoulder has also shown to have a statistically significant (p=0.026) difference between the group who suffered from a wrist injury and the group who has no injury. This could potentially be the result of over-cocking the wrist during the follow-through phase due to a lack of mobility in the leading shoulder (McHardy & Pollard, 2005).

In a study investigating the effect of hip mobility in professional golfers complaining of lower back pain, the authors reported a statistically significant difference in internal rotation of the hip between their injured and uninjured groups (Vad et al., 2004). A strong association (p<0.05) between a decreased range of motion of internal rotation of the leading hip and the participants complaining of lower back pain were found (p=0.003). This finding was supported by another group of researchers, investigating causative factors of lower back pain in amateur golfers (Murray, Birley, Twycross-Lewis, & Morrissey, 2009). The lack of internal rotation of the leading hip plays an important role during the follow-through phase and could potentially lead to the participants increasing lumbar extension at the end of the swing (Gulgin et al., 2009; Gluck et al., 2008). Additionally, this study found that a decrease in horizontal adduction of the leading- (p=0.029) and trailing shoulder (p=0.015) were statistically significant between the groups.

Like the lack of internal hip rotation, if there is a decrease in shoulder range of motion, the lumbar spine has to achieve excessive ranges in order for the participant to be able complete a successful stroke. This meets the criteria in determining whether decreased hip range of motion is a contributing factor to injury in professional golfers.

Decreased external rotation of the leading hip was the only statistically significant (p=0.004) finding, regarding range of motion measurements, when comparing the group complaining of hip pain and the group without hip pain. Leading hip rotation is markedly high in the initial stages of the downswing, therefore, decreased mobility of hip external rotation could cause increased strain on the hip joint (Mun, Suh, Park, & Choi, 2015).

5.6. Training Load

The final objective was to determine whether training load serves as an extrinsic risk factor of injury in professional golfers. The group who reported an 'other' injury had the highest mean value for 'total hours spent training golf' (327.5 $\pm$ 101.12), followed closely by the group complaining of a hip injury (316.67 $\pm$ 90.75). However, during this study's investigation, training load had no statistically significant influence on region specific injuries, which included the lower back, wrist, shoulder, hip, and 'other' injuries. As to be expected, most of the time was spent on 'playing rounds of golf' (166.02 $\pm$ 65.54) and the least time was spent on 'other type of training' (37.54 $\pm$ 23.81).

It has been suggested that amateur players who have a higher training volume are more at risk than those who have a lower training volume (McCarroll, 1996). However, this assumption was made regarding the player's experience and level of play rather than a measurement in training volume, as was done in this study. In another study, the authors determined that players who played more than four rounds of golf per week were exposed to a higher risk to injury compared to the group that played less than this (Gosheger et al., 2003). In this study, there were no statistically significant differences in the total number of hours spent playing rounds of golf when comparing the injured to uninjured groups. However, the injured group spent significantly less time playing rounds of golf in the eleventh week compared to the uninjured group. This might be due to high number of active injuries (five) reported in that week that prevented the injured participants from training this component as frequently as the uninjured group. Similarly, during the eleventh week, there was a statistically significant difference (p=0.03) between the injured and uninjured group in the total hours of training for that week, with the injured group having spent fewer hours.

However, this difference might be attributed to the decrease in the hours spent playing rounds of golf, which does make up the bulk of the total training hours.

Furthermore, it has been suggested that hitting more than 200 balls a week is a potential risk factor for injury in professional golfers (Gosheger et al., 2003). This number does seem relatively low when considering the time professional golfers spent on each of the training components per week, as suggested by this study. It is also unclear whether the authors included the number of balls hit during playing rounds of golf to the 200 strokes. In this study, the injured group presented a statistically significant difference (p=0.02) in hours spent training components of golf during the second week of testing compared to the uninjured group. However, as the 11-week follow-up period continued, the uninjured group gradually increased their hours spent training the components of golf, while the injured group steadily declined.

The participants gradually increased the hours they spent playing golf and the total training hours throughout the 11-week testing period. At the beginning of the testing period, it was over Christmas time and could potentially be the reason why the hours were so low. Furthermore, the participants seemed to have spent less time on other type of exercise towards the later stages of the season, which might be due to time constraint as they increased their hours in the other sections of training. However, there was no association between the number of hours spent on other exercise and injury.

5.7. Limitations to this study and recommendations for future research

There were several limitations to this study. Firstly, even though the sample size of this study does meet the criteria for an 80% confidence interval, it is still relatively small when compared to similar studies. Unfortunately, as a result, specific statistical analyses such as odd ratio analyses to determine associations between some variables (range of motion of the specific joints and training load) and injury could not be executed. Hence, this study could not determine any possible risk factors associated with the injuries reported by the participants. Future studies should consider using a larger sample size to do further statistical analyses to determine such associations, to increase the external validity and the statistical power of such a study.

Secondly, the self-reporting of training loads might have been a limitation to this study. The participants could have under- or over-reported the hours spent training. Participants often lose track of time or forget how long they spend on training when they completed the logbook at the end of the day. There is also the question of how much time they spend on playing a stroke and how much time they spend walking or standing around.

Future studies should consider monitoring the number of strokes the participant plays which is simple to monitor during rounds of golf and training components.

In this study the players were informed to report the region of their injury only. This might have led to the interpretation that when an injury of the same anatomical area was reported within a week, it was a recurring injury and not an index injury. Therefore, potentially, index injuries may have been missed during data collection. Definitions and clarifications of injury types before the start of the testing period would allow for more accurate reporting of injuries.

Furthermore, the baseline measurements were also done at a single tournament. This was a tournament at the beginning of the season, which is an ideal time to capture the baseline information however, it does limit the pool from which participants could be recruited. A suggestion for future studies would be to capture the baseline measurements of the participants prior to the start of the tournament at their training courses. This could potentially lead to an increase in the number of participants, larger sample size, and increase the statistical power of the study. The range of motion measurements were only done once, and it would be suggested that future studies increase the number of times the joint ranges are measured to improve the reliability. The measurements were only done once and it would be advised that future studies measure the joint range of motion more than once an that the average of the measurements are used for data collection.

Due to the longitudinal nature of this study, the training load which was reported might have been affected by the injuries sustained. As per definition of this study, an injury is reported if it caused a decrease time spent on training or competition. Therefore, if a participant sustained an injury he stopped or minimized his playing time, and this would have affected the training load hours reported by this participant. The total hours reported as training load would then not be a true representation of a potential risk factor to injury, as the fluctuation of training hours follows the presence of an injury. A suggestion for future studies would be to consider using the acute chronic workload ratio (ACWR) as a monitoring tool. This would allow the researcher to monitor whether the participant is within the 'sweet spot' when it comes to training load on a weekly basis (Gabbett & Whiteley, 2017).

The mechanical load a participant's body has to endure during a season would potentially be better monitored by the number of strokes he plays, rather than the amount of time spent playing. It would also be beneficial to collect the baseline information not only from a single tournament and using the ACWR as a monitoring tool for training load rather than the hours spent training.

Chapter 6: Summary & Conclusion

6.1. Summary

There is a high prevalence of injury amongst professional golfers. Due to the mechanical stressors on the musculoskeletal system caused by the repetitive motion of the swing, two factors play an important role in determining the outcome of injury. The manner in which the player swings the club, determined by the range of motion of the joints involved and the number of times that the player swings the club, determined by the training load (Gosheger et al., 2003).

The aim of this study was to investigate the incidence of overall and region-specific injury in professional South African golfers.

The specific objectives of this study had the following outcome:

To determine the incidence of overall and region-specific injury in professional golfers, over a single season:

At the conclusion of the Summer Swing season, the incidence rate of injuries amongst this population was 3.27/1000hrs playing golf. The overall index injury count was 23, while 17 (60.7%) of the 28 participants reported an injury at some point during the season.

To determine whether decreased shoulder mobility (internal rotation; external rotation; and horizontal adduction) is an intrinsic factor for overall and region-specific injury in professional golfers:

As a result of the study being underpowered by the sample size, it could not be determined whether shoulder mobility serves as an associated risk factor to injury in professional golfers. However, a statistically significant difference (p=0.04) in horizontal adduction of the leading shoulder was found with a decreased range of motion in the injured group compared to the uninjured group. Furthermore, a significant decrease in internal rotation of the trailing shoulder was found in the group complaining of a shoulder- (p=0.040) or a hip (0.048) injury. There was also a statistically significant difference in the measurements of external rotation of the leading shoulder (p=0.026) between the group complaining of a wrist injury and the group without a wrist injury. Finally, there were statistically significant differences in external rotation of the trailing shoulder (p=0.031) when comparing the group with lower back pain and the group with no lower back pain; in horizontal adduction of the trailing shoulder (p=0.015); and horizontal adduction of the leading shoulder (p=0.029).

To determine whether decreased thoracic rotation is an intrinsic risk factor for overall injury and region-specific injury in professional golfers:

Decreased thoracic spine rotation had no statistically significant influence on the overall incidence of injury nor did it on region-specific injuries amongst this professional golfing population.

To determine whether decreased lumbar extension is an intrinsic factor for overall injury and region-specific injury in professional golfers:

There was no statistically significant difference in the measurement of lumbar spine extension between the group complaining of injury and the group reporting no injuries throughout the season. There were also no region-specific injuries which showed a statistically significant difference in lumbar spine extension measurement when comparing the injured to the uninjured group of each anatomical region respectively.

To determine whether decreased hip mobility (internal- and external rotation) is an intrinsic factor for overall and region-specific injury in professional golfers:

As a result of the study being underpowered by the sample size, it could not be determined whether shoulder mobility serves as an associated risk factor to injury in professional golfers. The leading hip rotation range of motion had no statistically significant findings when comparing the injured and uninjured groups. However, there was a strong association (p=0.003) between a decreased leading hip internal rotation and participants reporting lower back pain. Furthermore, there was statistically significant difference (p=0.004) in the measurement of the leading hip external rotation between the group complaining of hip pain compared to the group without hip pain***.***

To determine whether training load is an extrinsic risk factor for overall injury and region-specific injury in professional golfers:

There were no statistically significant findings when comparing the total hours spent training the components golf, playing rounds of golf, nor other types of training. However, during the second week, the injured group presented with a statistically significantly (p=0.02) higher training volume compared to the uninjured group. The injured group also presented with a statistically significantly (p=0.03) lower number of hours of total training hours compared to the uninjured group during the eleventh group, which may be due to the higher number of injuries during this week. Training load had no association with region-specific injuries. Training load was not found to be an associated risk factor for injury in professional golfers.

6.2. Conclusion

In conclusion, there is a high incidence and prevalence of injury amongst professional golfers. The anatomical regions most frequently affected are the lower back and the shoulder. The range of motion of the shoulder joint played a significant role in determining overall and region-specific injury. Improving shoulder range of motion in horizontal adduction and internal- and external rotation could potentially minimize the risk of sustaining an injury amongst professional golfers. Improving the mobility of the hip joint could also minimize the potential of sustaining either hip or lower back injury. Therefore, the findings of this study suggest that incorporating mobility exercises as part of a professional golfers general conditioning program could potentially serve as an important injury preventative strategy. According to the results of this study, training load does not seem to be a major predictor of injury amongst this population. However, future research should address the effect that the hours missed due to injury has on the outcome of determining the influence of training loads as an injury predictor.

Appendices

Appendix A- Informed consent and consent form

RE: Informed Consent for participant

I am a physiotherapist, currently completing my Masters degree in Sports and Exercise Physiotherapy at the University of Cape Town, with the Department of Health and Rehabilitation Sciences. I am conducting a study to determine what types of injuries our professional golfers in South Africa are struggling with and if we cannot perhaps identify the characteristics which increases their chances to sustain these injuries. This research study has been given ethics approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (731/2019).

Study title:

"The incidence and associated risk factors of injury in professional golfers."

Why is the study being done?

There is currently no published research done on South African golfers. Golf is a physically demanding sport, which leaves too many of our top players side-lined due to injury. I would like to identify these injuries and see if we cannot determine why we have so many of them. If we can determine possible causes, we can address them and potentially minimize the risk of injury in our players. As a registered professional golfer, you are asked if you are willing to participate in the study to assist me in collecting data regarding the topic.

What is being done?

If you decide to take part in this study, you will meet with myself or one of the physiotherapists on duty at the treatment area anytime during the tournament. You will be asked to complete a questionnaire (which is attached to the email), which will take approximately 3-5min to complete. The physiotherapist will go through the questionnaire with you, at the tournament, to ensure that you understand the questions at hand. Thereafter physical tests will be done where we will use tools to measure the amount of movement you have in the shoulders and the spine. The tool will be placed on your skin at the level of the joint being measured and then you will move the involved limb or the back while we take the measurement.

The tests will be done as follows:

1) Lower back (Lumbar spine) extension:

You will be in a standing position, with your feet more or less shoulder width apart. A measuring tool (goniometer) will be placed on the side of your hip. You will be asked to lean back as far as possible, without bending your knees. As soon as you have reached your maximum range, a measurement will be recorded. This test should not take longer than 30 seconds and will be done once.


Starting position


End position

2) Upper back (Thoracic spine) rotation:

You will be sitting in a comfortable position with both feet firmly on the ground. A small ball will be placed between your knees, to ensure that the hips are kept as still as possible during the movement. A wooden bar will be placed horizontally across your shoulders. A measuring tool (goniometer) will be placed on your upper back. You will then be asked to rotate the upper body as far as you can, and we will measure the degrees of movement. You will be asked to repeat the same action to the other side. The test should not take longer than 1min and will only be done once.


Starting position

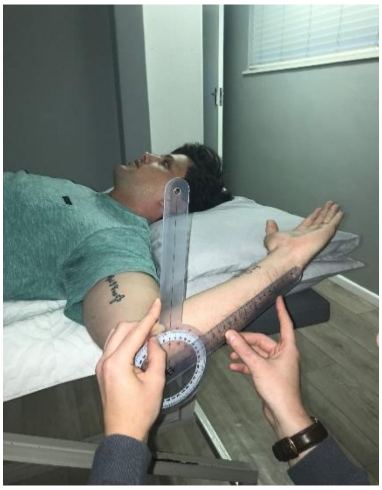

End position

3) Shoulder internal and external rotation:

You would be lying on your back with your shoulder out to the side and the elbow bent. The tool (goniometer) will be placed against your forearm and elbow. The shoulder will be rotated either "forwards" or "backwards" and the measurement will be taken by the therapist. The same exercise will be repeat on the opposite shoulder, whilst you remain in the same position. This measurement should not take longer than 2-3 min and is done only once.

Starting position

Internal rotation



External rotation

4) Shoulder horizontal adduction:

You will remain on your back, as you did for the previous test. The therapist will stand at the head of the table and facing you.

The arm to be tested will be taken out to the side, the elbow bent, and the therapist's other hand will be on under your shoulder, to stabilize the shoulder blade. The arm will then be moved by the therapist across your chest to the other side, another therapist will quickly take the measurement by using the goniometer tool. The test will be repeated on the other side in the exact same sequence. This test should not take longer than 2 min and is done only once on each side.

Starting position

End position

5) Hip internal- and external rotation:

You will still be lying on your back. The goniometer will be used to measure how far your hips can rotate to either side. It will be placed against your knee. The hip will first be rotated inwards and measured and then the same hip will be rotated outwards and measured. The test will be repeated on the other side. The test is done once and should not take longer than 2 min to complete.

Starting positions

Hip Internal rotation

Hip External rotation

You will also be asked to log the hours that you spent either on training or during competition and whether you picked up any injuries during the week, whether you continued playing through the discomfort or if you had to stop playing. I will follow-up with you on a weekly basis via email or Whatsapp just to get the info from you, so I can log in the data on my side. This will be done over a 12-week period. **On the following page is an example of what the logbook looks like**:

Week 1	Hours of golf training	Hours of other training	Hours playing rounds	Injury (Yes or No) Check definition, please!	New or old	Area of injury
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						

Possible risks involved:

There are no direct risks involved when participating in this study as there is little chance of you getting hurt by doing the physical tests and functional activities. I will do everything I can to make sure that you do not hurt yourself but in case, this does happen; I will refer you to the nearest hospital for an assessment and should you need physiotherapy, I will provide you with treatment free of charge. However, if you are currently struggling with an injury, you will be excluded from participating with the study.

Benefits for participating in the study:

There are no direct benefits by participating in this study. You will however contribute to the information needed to help decrease injuries in professional South African golfers. You will also be provided with feedback regarding the findings when the study is completed and an appropriate suggestion to address these findings would be provided. These findings could aid in potential injury prevention and performance enhancement.

Voluntary participation:

Participation in this study is completely voluntary. No payment will be made for participating in the study. You are free to refuse the use of any data about your training or injuries. You should, under no circumstances feel obliged to participate in this study. If you decide to participate, you are free to change your mind and withdraw at any time without penalty, explanation or prejudice.

Confidentiality:

All information obtained during the investigation will be kept confidential. Information will be stored securely and will be protected by lock or password, known only to the investigator. The participants identity would be kept anonymous by assigning a random number to participants, rather than using their name during the processing of data. The information will not be made available to anyone else other than the investigators and will be destroyed after the completion of the study. No reports or publications will identify you or any participants in this study in anyway. As soon as the study is completed, your information will be deleted.

The University of Cape Town (UCT) has insurance cover for the event that research-related injury or harm results from your participation in the trial. The insurer will pay all reasonable medical expenses in accordance with the South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI) in the event of an injury or side effect resulting directly from your participation in the trial. You will not be required to prove fault on the part of the University.

The University will not be liable for any loss, injuries and/or harm that you may sustain where the loss is caused by

· The use of unauthorised medicine or substances during the study

· Any injury that results from you not following the protocol requirements or the instructions that the study doctor may give you

· Any injury that arises from inadequate action or lack of action to deal adequately with a side effect or reaction to the study medication

· An injury that results from negligence on your part

"By agreeing to participate in this study, you do not give up your right to claim compensation for injury where you can prove negligence, in separate litigation. In particular, your right to pursue such a claim in a South African court in terms of South African law must be ensured. Note, however, that you will usually be requested to accept that payment made by the University under the SA GCP guideline 4.11 is in full settlement of the claim relating to the medical expenses. "

An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study doctor immediately of any side effects and/or injuries during the trial, whether they are research-related or other related complications.

UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while you were taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected. Copies of these guidelines are available on request.

Questions

Any questions regarding the study should be directed to:

Mrs Candice Hendricks (Supervisor): candice.hendricks@uct.ac.za

Dr Niri Naidoo (Co-supervisor): niri.naidoo@uct.ac.za

Mr Jaco Visagie (Researcher): vsgjac006@myuct.ac.za or (072) 386 6287

The UCT's Faculty of Health Sciences Human Research Ethics Committee can be contacted on 021 406 6338 in case you have any ethical concerns or questions about your rights or welfare as a participant in this research study.

Consent

I …………………………………………………………………………………. (full names), have read the information letter. I understand the content of the information letter and the role that is expected of the research participant. An opportunity was given to me to ask questions, and my questions were answered. I understand that my participation in this study is completely voluntary, and that I am able to withdraw from this study at any time, with no resultant harm being cause to me. If I agree to take part, I will be given a signed copy of the consent form to take part in the study, as well as the participant information sheet, which is a written summary of the research.

'What happens if I get hurt taking part in this study?'

If I do sustain an injury because of participating in the physical tests and the health promotion programme, I understand that the researcher has insurance at UCT. I understand that I can claim for all my medical expenses in accordance with the South African Good Clinical Practice guidelines (DoH 2006), in the event of an injury resulting directly from my participation in the intervention.

I understand that according to ABPI guidelines that the researcher should compensate me, without having to prove that she / he was at fault for any injury resulting from participating in the procedures carried out according to the protocol of the study.

I understand that the researcher will not be responsible for any loss, injuries and/or harm that I may sustain where the loss is caused by:

· The use of unauthorised medicine or substances during the study

· Any injury that results from me not following the protocol requirements or the instructions that the researcher may give me

· Any injury that arises from inadequate action or lack of action to deal adequately with a side effect or reaction to the intervention

· An injury that results from negligence on my part

By agreeing to participate in this study, I do not give up my right to claim compensation for injury where I can prove negligence. If I claim from UCT's insurance and I am successful in the claim, I will state that I accept this payment as full settlement of my claim. But making this statement does not mean that I give up my right to pursue a separate claim, based in negligence, against the researcher. It is my right to pursue such a claim in a South African court in terms of South African law.

I hereby grant consent to participate in your study. I also grant permission to having physical tests done and answer some questions related to my personal health and sport. I understand that there is little risk for injury during the testing. I also understand that great care will be taken to prevent injury but in the unfortunate case that this does happen, the physiotherapist will provide me with appropriate treatment free of charge.

I understand that the information gathered from this study will be possibly used in future studies, reports and publications and hereby consent to do this (please tick the box to confirm if you understand this statement or not):

YES ☐ **NO** ☐

……………………………………………….. ………………………………………………
Date: Place:

……………………………………………… ……………………………………………..
Participant's Name: Participant's Signature:

……………………………………………. …………………………………………….
Participant's Email: Participant's Phone Number

……………………………………………. ……………………………..
Researcher's Name: Researcher's Signature:

Appendix B- Letter to tournament officials

RE: Letter to tournament officials

I am a physiotherapist, currently completing my Masters degree in Exercise and Sports Physiotherapy at the University of Cape Town, by the Department of Health and Rehabilitation Sciences. I am conducting a study regarding our professional golfers and the injuries they sustain during and prior to the season. I would also like to see if we cannot identify specific physical characteristics leading to these injuries and hopefully in the future, further studies can intervene to minimize our players' risk for these injuries, with the information I provide with this current study.

My focus is going to be specifically on the South African professional golfers, who are actively competing on the tour. The research will be conducted during tournament times; by the team of physiotherapists appointed to work at the tournament. Testing will be done at the physiotherapy department of the tournament. With permission, the players will be sent an informational email prior to the tournament; containing the reason for the study and what the procedures would entail.

The testing includes a questionnaire and range of movements testing of a few joints which are relevant to golfers. We will be using a standard tool for the assessment of the joint ranges, which will have to be applied to the players skin of the players in a non-invasive manner.

If a player does not want to participate in the study, they are under no obligation to do so. They are allowed to withdraw at any time that they wish, without consequence or prejudice. No players will be contacted without permission from the tour organisers and no testing will be done without the consent of the player.

The testing will form part of normal physical assessment and will in no way harm any of the players, nor will it influence their performance during the tournament or their experience of the tournament in a negative manner. The player will be tracked weekly over a 3-month period via email or if they prefer, telephonically. This would be to get an updated on their current injury status and training loads.

To my knowledge, there has been no published articles directly linked to the injuries of South African golfers and South Africa prides itself on its extremely talented golfing community. I wish to contribute in the growth of the sport and assist in the best possible outcome regarding the players' health.

Please feel free to contact me at any time if you have questions, concerns or suggestions.

Yours sincerely

Jaco Visagie
BSc Physiotherapy (US)
Email: vsgjac006@myuct.ac.za
Cell phone: (072) 386 6287

Supervisor: Mrs Candice Hendricks
candice.hendricks@uct.ac.za
Co-supervisor: Dr Niri Naidoo
niri.naidoo@uct.ac.za

Appendix C- Letter to head physiotherapist

Letter to: Tournament Head Physiotherapist

RE: Data collection during tournament

I am a physiotherapist, currently completing my Masters degree in Exercise and Sports Physiotherapy at the University of Cape Town, by the Department of Health and Rehabilitation Sciences. I am conducting a study regarding our professional golfers and the injuries they sustain during and prior to the season. I would also like to see if we cannot identify specific physical characteristics leading to these injuries and hopefully in the future, further studies can intervene to minimize our players' risk for these injuries, with the information I provide with this current research study.

My focus is going to be specifically on the South African professional golfers, who are actively competing on tour. The research will be conducted during the Alfred Dunhill tournament; by the team of physiotherapists appointed to work at the tournament. Testing will be done at the physiotherapy department of the tournament. With permission, the players will be sent an informational email prior to the tournament; containing the reason for the study and what the procedures would entail.

The tests that would be done include the range of motion measurements of the shoulders and thoracic spine. The players will also fill in a questionnaire at the beginning of the session, collecting their demographic information, training and injury history. I will be tracking the players on a weekly basis to gather injury- and training load information.

Please feel free to contact me at any time if you have questions, concerns or suggestions.

Yours sincerely

Jaco Visagie
BSc Physiotherapy (US)
Email: vsgjac006@myuct.ac.za
Cell phone: (072) 386 6287

Supervisor: Mrs Candice Hendricks
candice.hendricks@uct.ac.za
Co-supervisor: Dr Niri Naidoo
niri.naidoo@uct.ac.za

Appendix D- Questionnaire

Date:

Please complete section A to D:

A. Personal Information:

Name:

Age: ___________ Height: ___________cm Weight: ___________kg

Golf Handed: Right ☐ Left ☐ Handed: Right ☐ Left ☐

B. Golf Training History:

In this section of the questionnaire we would like to determine more or less the time you spend on training each component of your game (excluding competition time). Driving includes the use of irons or drivers.

Please tick the most appropriate box

If the answer is 0 min, please leave the row blank

Winter-Swing Season (March to November):

Hours per week	0-30min	30min-1hr	1-2hrs	2-3hrs	3-4hrs	4-5hrs	5-6hrs	6-7hrs	>7hrs
Golf-Driving									
Golf-Short Game									
Golf-Putting									

Summer-Swing Season (November to February):

Hours per week	0-30min	30min-1hr	1-2hrs	2-3hrs	3-4hrs	4-5hrs	5-6hrs	6-7hrs	>7hrs
Golf-Driving									
Golf-Short Game									
Golf-Putting									

C. Non-golf Training History:

Please tick the most appropriate box

If the answer is 0 min, please leave the row blank

Winter-Swing Season (March to November):

Hours per week	0-30min	30min-1hr	1-2hrs	2-3hrs	3-4hrs	4-5hrs	5-6hrs	6-7hrs	>7hrs
Upper Limb Resistance (Weights)									
Lower Limb Resistance (Weights)									
Core									
Plyometrics (Explosive exercise)									
Cardiovascular (Cycling, running, swimming)									
Stretching Lower Limb									
Stretching Upper Limb									
Stretching Neck									
Stretching Back									
Other training (Surfing, tennis, yoga, Pilates)									

Summer-Swing Season (November to February):

Hours per week	0-30min	30min-1hr	1-2hrs	2-3hrs	3-4hrs	4-5hrs	5-6hrs	6-7hrs	>7hrs
Upper Limb Resistance (Weights)									
Lower Limb Resistance (Weights)									
Core									
Plyometrics (Explosive exercise)									
Cardiovascular (Cycling, running, swimming)									
Stretching Lower Limb									
Stretching Upper Limb									
Stretching Neck									
Stretching Back									
Other training (Surfing, tennis, yoga, Pilates)									

D. Injury History

- Have you had an injury/injuries (preventing you from training or competition) in the past 12 months? Yes □ No □
- If "Yes", please complete table below:

Injury	Symptoms		Diagnosis			Medical practitioner who made the diagnosis				
	Gradual	Sudden	No	Yes	Specify	Doctor	Physio	Chiro	Bio	Other
Neck										
Shoulder										
Elbow										
Wrist										
Hand										
Upper back										
Lower back										
Hip										
Knee										
Ankle										
Foot										

---END---

Appendix E- Physical Tests

2) Joint ROM

Movement	**Left (˚)**	**Right (˚)**
Thoracic Rotation		
Shoulder Internal Rotation		
Shoulder External Rotation		
Shoulder Horizontal Adduction		
Hip Internal Rotation		
Hip External Rotation		

Movement	**Degrees (˚)**
Lumbar Extension	

Date	
Time	
Subject number	
Physiotherapist Name	
Physiotherapist Signature	

Appendix F- Players' logbook

Dear Player
Thank you for completing the logbook
Glossary:

- **Golf training= Driving range practice, short game practice, putting practice etc. (you do not need to give the individual hours, only all the hours added together for the day).**
- **Other training= Strength training in the gym, flexibility training, cardiovascular training (you do not need to give the individual hours, only all the hours added together for the day)**
- **Playing rounds= Tournaments, practice of 9 to 18 holes with full intensity.**
- **Injury= New injury or the same one from last week, and ONLY IF THE INJURY CAUSED YOU TO MISS TRAINING OR COMPETING. If you have an injury write "Yes", if you are pain free write "No"**
- **It is a new injury or you did not have an injury in that area last week.**
- **Area: Shoulder/ back/ elbow etc. If there is more than one area, write all of them down.**

Week 1	Hours of golf training	Hours of other training	Hours playing rounds	Injury (Yes or No) Check definition, please!	New or old	Area of injury
Monday						
Tuesday						
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						

Appendix G- STROBE Checklist

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

1

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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