PHYSICAL ACTIVITY DEMANDS OF GOLF

by

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SUMMARY

Introduction: *Golf is quite challenging in terms of the physical demands that it places on the body throughout a round of golf, and even more so during a golf tournament, due to the repetitive action. Understanding the fitness characteristics inherent in playing golf can supply prosperous advantages to golf players, including a better and more productive swing as well as improved body mechanics.*

Objectives: *The purpose of the study is to quantify the demands and load being placed on golf players, especially during tournaments, and therefore to assist them with a better construction of their conditioning programmes during golf practice. The study also aimed to determine the distance covered, work to rest ratios, and frequency of movements in golf.*

Methods: *GPS data on a total of twelve (12) amateur golf players were collected and a total of forty rounds of golf (18 holes) were analysed for the study. Therefore, a total of forty (40) GPS data sets (player rounds) were analysed (equivalent to 720 holes were recorded). Minimax X4 Catapult GPS units as well as a Polar HR monitors and chest straps was used to determine the physiological demands on golf players. The variables recorded are distances covered, player load, the maximal velocity during the round, and heart rate (HR) response.*

Players were categorised according to their handicap - handicap<0, handicap=0 and handicap>0. The handicap categories were compared with respect to selected activity variables using a linear mixed model with handicap category (3 levels) as fixed effect, and player as random effect. Fitting player as random effect accommodated potential correlation of the data collected from the same player. Based on this linear mixed model, the mean values (of the activity variable) for each handicap category were estimated, together with their standard errors. Furthermore, the pairwise mean differences between handicap categories were estimated, together with 95% confidence intervals (CIs) for the mean differences and P values associated with the null-hypothesis of zero mean difference between the pair of handicap categories in question.

Results*: The mean value for players with a handicap below zero has the lowest playing duration (<0: = 4.32 hours) in relation to the players with the handicap equal to zero (=0: = 4.71 hours) with a handicap above zero (>0: = 4.88 hours). The total distance covered by players with the handicap below zero (<0: = 10.82km) was the furthest, compared to players with a handicap equal to zero (=0: = 10.52km) as well as player with a handicap above zero (>0: = 10.42km). Total player load was the highest for players with a below zero handicap (<0: = 606.67) followed by those with an above zero handicap (>0: = 587.05) and players with* *handicaps equal to zero (=0: = 583.56). Results also show that players with a handicap above zero (>0: = 2.02) has the lowest player load per minute value. Player load per kilometre was highest amongst players with a handicap below zero (<0: = 56.32) followed by players with handicaps above zero (>0: = 55.61). Below zero handicap (<0: = 42.52) players covered the longest distance per minute of all players. Players with a handicap below zero (<0: = 3.24) had the highest maximum velocity compared to players with handicaps equal to zero (=0: = 2.87), followed by players with handicaps above zero (>0: = 2.73). Significant differences between the players with a handicap below zero and players with a handicap above zero for total duration (p=0.0194) and meters per minute (p=0.021) can be observed.*

Conclusions: *The study reveals the physical profile of and physical demands on amateur golf players and indicates differences between the various handicaps of golf players. These findings emphasise the differences in amateur players regarding handicaps for the load, duration, and distance placed on the players. Coaches and conditioning coaches must implement the findings of the study to develop sport-specific, and more importantly, handicap-specific conditioning programmes.*

Key words: *Golf; Amateur; Physical Demands; Handicaps; Amateur; Player Load; Total Distance; Velocity; Total Duration; Heart Rate*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
B.MIN	Beats per Minute
CHS	Club Head Speed
CIs	Confidence Intervals
CSI	Club Head Speed at Impact
CV	Coefficient of Variation
FSGF	Free State Golf Federation
GPS	Global Positioning System
HCP	Handicap
HR	Heart Rate
HRM	Heart Rate Monitor
HRV	Heart Rate Variability
HZ	Hertz
IGF	International Golf Federation
KM	Kilometre
M/S	Meter per Second
MVC	Maximal Voluntary Contraction
PCT	Percentage
PGA	Professional Golf Association
PL	Player Load
Q-school	Qualifying School
R&A	The Royal and Ancient Golf Club of St Andrews
SAGA	South African Golf Association
SASCOC	South African Sports Commission and Olympic Committee
TMA	Time motion Analysis
USGA	United States Golf Association
VO_2	Average Oxygen Use
WGSA	Women's Golf South Africa

CHAPTER 1: INTRODUCTION AND PROBLEM STATEMENT

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

1.1 Introduction

1.2 Rationale

1.3 Formulating the Problem and Aim of the Study

1.4 Primary Objectives

1.5 Motivation For The Study

1.6 Structure Of The Dissertation

1.1 INTRODUCTION

When it comes to the physical demands of the sport, golf is one of the most underestimated sporting codes in the world today. As indicated by Palacios-Jansen (2012), the words “golf” and “fitness” have hardly ever been cited in the same sentence over countless years. In most countries, golf is regarded as a leisure or recreational activity with very few players at an amateur or professional level.

Loock, Grace, and Semple (2013) state that, besides the increased competitiveness between the amateur golf players, this group expresses an underlying necessity for performance enhancement. Golf is a recurrent action that demands a medium walking speed together with ball striking while standing with the legs slightly bent and the torso in a bent over position. A combination of these activities forms the sport of golf as we know it (Smith, Callister, and Lubans, 2011). This renders golf quite challenging in terms of the physical demands it places on the body throughout a round of golf, and even more so during a golf tournament, due to the repetitive action. Most golf players are not aware of these demands, as golf is seen as less strenuous than other sports that include running or sprinting.

Following the research of Smith *et al.* (2011), the author suggests that, through specific fitness adaptations addressed in a conditioning programme, conditioning itself has the ability to enhance golf performance. Sell, Tai, Smoliga, Meyers, and Lephart (2007) declare that certain fitness characteristics supply various advantages to golf players, including a better and more productive swing as well as improved body mechanics. Through a wide range of motion, enough explosive power must be generated by the golf player. Smith (2010) states that efficient physical conditioning needs to be thoughtfully constructed together with proper observation to correspond with the requirements the golf player is confronted with on the golf course.

Wells, Elmi, and Thomas (2009) add that golf is a very challenging sport to monitor due to the complexity and precision of the golf swing itself. The golf swing has been explained as a very complex whole body movement, due to the fact that power must be transferred through the golf ball to allow the ball to travel with great distance and accuracy. Smith (2010) mentions that the golf player must be able to resist the repeated tension being put on the player’s muscles and joints. If the amount of swings that a golf player produces while competing in a golf tournament is taken into consideration, the value of the physical conditioning can be understood more clearly. Therefore, Smith *et al.* (2011) concludes that golf performance relies on the ability to have an outstanding swing that consists of the capability to reach a maximum strike distance as well as distance control and accuracy.

Hume, Keogh, and Reid (2005) posit that certain physical fitness characteristics affect the golf player's ability to execute force and co-ordinate movement. These physical fitness characteristics include balance, flexibility, strength, and co-ordinated impacts. These characteristics are said to have better estimates in more conditioned golf players as presented through physical fitness analysis. Following the research of Smith *et al.* (2011), fitness characteristics such as players' flexibility, strength, as well as balance did improve, however, when baseline tests were compared to post-test results. Doan, Newton, Kwon, and Kraemer (2006) also declare that, if one were to provide a similar programme to more advanced golf players, the same significant increase in fitness characteristics would not be observed as it would be in a lesser trained group of individuals. Individuals with lower training levels are more likely to adapt and improve from using a programme designed for better trained golf players and will also need a more skilled programme to improve their fitness characteristics.

Golf players such as Tiger Woods and Annika Sorenstam were able to reach their respective number one world ranking spots due to certain factors, such as the inclusion of flexibility, balance, physical conditioning, biomechanical corrections, strength, power, core stability, and cardiovascular fitness into their respective training programmes (Wells *et al.,* 2009). Wells *et al.* (2009) also mention that, through this initiative, both of them changed the sport of golf. The new generation of players are leaner and more muscular type of golf players who dominate the top rankings in golf.

1.2 RATIONALE

Torres-Ronda, Sánchez-Medina, and González-Badillo (2011) declare that the physical prerequisites of golf are not properly recognised; thus research with regards to physical conditioning for performance enhancement in golf is lacking (*cf.* Palacios-Jansen, 2012). Therefore, this study aims to identify and quantify the demands of golf through literature and intensive assessment of amateur golf players in order to provide coaches with a proper body of data to support the conditioning of these players and to improve the player's ability and performance in general. In South Africa there is also a critical shortage of trained golf conditioning experts, which can only be afforded by the bigger golf clubs. Knowledge in the field of physical preparation for golf players will assist coaches in understanding the load placed on each player during competition.

1.3 FORMULATING THE PROBLEM AND AIM OF THE STUDY

Knowledge of player movements and demands during competition is important for effective planning and management of players in preparing them for competition. A better understanding of the demands that golf imposes on players is needed for developing specific training and recovery plans as well as minimising the risk of injury. Therefore, this study aims to identify and quantify the demands of golf through the means an accelerometer (Catapult Minimax X4) and intensive assessments. The findings could provide coaches with a proper body of data to support the conditioning of golf players to improve their ability and performance during competition.

1.4 PRIMARY OBJECTIVE

The data gathered during this research study will ensure that golf coaches as well as conditioning coaches have a better understanding of the load placed on golf players, especially during tournaments. Coaches can therefore better assist players with an improved construction of their conditioning programmes as well as protocols during golf practice.

The purposes of this study are:

1. To determine the total **player load (Load TM.min^{-1} (au))** of amateur golf players during competition and to differentiate between handicaps;
2. To determine the **HR (beats per minute)** response of amateur golf players during competition;

2.1 To further investigate the **Maximum HR (beats per minute)** of amateur golf players during competition; and

2.2 To determine the **Mean HR (beats per minute)** of amateur golf players during competition;

3. To determine the **total distance covered (km)** by amateur golf players during competition and to differentiate between handicaps;

4. To measure the **Maximum Velocity (m/s)** of amateur golf players during competition and to differentiate between handicaps; and

5. To determine the **total duration (hrs)** of amateur golf competition and to differentiate between handicaps.

1.5 MOTIVATION FOR THE STUDY

Knowledge of the physiological demands of athletes during competition is a fundamental requirement in order for conditioning coaches to construct a sport-specific conditioning programme (Miller *et al.,* 1994). A range of methods are available to analyse sport performance; these may be of great value when trying to understand the demands of any sport. These methods include older and more time consuming methods such as Video-Based Time Motion Analysis (TMA) as well as more technologically advanced, but more expensive, TMA methods such as using GPS tracking devices (O'Donoghue, 2010). TMA information can be used by coaches and conditioning coaches to better prepare teams and/or individuals for competition in various sports such as rugby and hockey. Golf is a very popular sport all over the world, whether played for fun, competition, or recreational purposes; however, research regarding the physical demands of the sport for professional and amateur players are in short supply. Therefore, this study makes use of TMA by means of employing a GPS system in order to track amateur golf players in a bid to close the gap in research. Furthermore, the data for the current study was collected from rounds of golf in an arranged competition including players who played in a group (opponents); however, the result of each round was not recorded and the study does not attempt to compare the data collected during the competitions played to the outcome of each player’s round.

1.6 STRUCTURE OF THE DISSERTATION

The dissertation is divided into seven chapters, each with a specific purpose. Chapter One provides the introduction and problem statement to the study. Chapter Two presents a review of established literature relevant to the research aims stated in Section 1.2. An overview of the nature of golf and the all influential factors affecting golf players, physical characteristics, physiological demands of a round of golf, as well as the golf swing, is included. Chapter Three provides a discussion of the research methodology employed in this study, while Chapter Four presents the results and findings of the research. Chapters Five and Six respectively offer a discussion of the findings and the conclusion, limitations, and future research options inherent in this study. Finally, Chapter Seven contains a reflection on the research project. All mentioned chapters are included herewith in accordance with the guidelines provided by the University of the Free State

CHAPTER 2: LITERATURE REVIEW

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

2.1 INTRODUCTION

Golf is an ever expanding showing rapid growth around the world. According to the publication *The Royal and Ancient Golf Club of St. Andrews* (R&A), which is considered to be one of the highest authorities in the world of sport, by 2016 there were more than 33,161 golf facilities in 208 of the 245 existing countries (R&A, 2017). The first rules of the game of golf were established in Scotland in 1744 (Green, 1987). England, however, was the driving force behind the global expansion and internationalisation of golf while developing British imperialism. The first golf clubs established outside the United Kingdom were in India (Bangalore 1820, Calcutta 1829, and Bombay 1842), Ireland (Curragh 1856), Australia (Adelaide 1870), Canada (Montreal 1873), South Africa (Cape Town, 1885) and China (Hong Kong, 1889) (Green, 1987). The sport of golfing has expanded to gain global mainstream popularity across a diverse collection of demographic groups. An estimated 26 million persons in the United States play golf and/or compete at various levels of the sport (Werner, 2000). The challenge of striving to acquire a greater skill level, collegiality, and the natural beauty of golf courses are aspects of the game enjoyed by avid golfers and infrequent participants alike (Amin *et al*., 2017). Like many sports, golf is a game of integers. The minimisation of the number of strokes is generally what determines the winner, whether each of these are associated with the shortest of putts or the longest drives (Otto, 2017). Only a limited number of golf players are allowed to play during professional tours. The amateur golf player or professional golfer who wishes to join the limited number of 150 players competing in the PGA TOUR will be required to progress through a series of qualifying tournaments to gradually trim the applicant pool. This series of 3 tournaments is known as the Q School. Of all Q school participants, only 25 survivors are added annually to the top 125 PGA TOUR performers from the prior year for a total of 150 PGA TOUR professionals (Werner, 2000)

By making use of a wide variety of clubs, golf players competing against one another will aim to hit the ball into every hole on the golf course in the least amount of strokes. This is also known as a precision club and ball sport according to the International Golf Federation (IGF). Unlike other ball games, golf has no fixed area needed for playing golf, but is rather played on golf courses. These golf courses consist of a certain design or layout. Usually every round of golf is composed of 18 holes; certain golf courses comprise only nine holes, and players play two rounds to make up their 18 holes. The start of each hole on the golf course is known as the teeing area, which is indicated by two markers that present the official tee area, the fairway, rough, as well as other problem areas. The putting green that is encircled by the fringe with the pin or flagstick and cup is also indicated by these markers. The IGF further states that the rules of golf define golf as

> …playing a ball with a club from the teeing ground into the hole by a stroke or successive strokes in accordance with the Rules (IGF, 2018).

When a golf player plays for the least amount of strokes to complete the tournament it is called stroke play. Match play is when the golf player or team aims for the least amount of strokes per every round of golf played.

Otto (2017) mentions that the outcomes of golf shots can be influenced by very slight changes, but hopefully in a deterministic sense. A variety of skills can be performed in golf, from the first swing (from tee box to fairway, from fairway to green, from around green to the hole, from bunker to green), or on the green itself (Ma'Mun & Abdullah, 2018). Ma'Mun and Abdullah (2018) identify five golf shot categories according to the importance of each component, namely putting, chipping, pitching, middle-distance iron shots, and driving. These skills can further be subdivided into four skills, namely driving, iron play, short iron play (chipping, wedge, and bunker shots), and putting (Hellström, 2009). Apart from the skills development in golf, physical preparation of players also contributes to each player's level of play. Very little to no research has thus far been conducted on time motion analysis or physical demands of golf in the past 2 years. Most research in golf is related to club-head speed (Coughlan *et al*., 2017; Joyce, 2017), golf course irrigation (Golden *et al*., 2017), and swing mechanics (Gould *et al.*, 2018; Parker, 2018).

2.2 SOUTH AFRICAN PERSPECTIVE ON GOLF

South Africa have some of the world's best golf courses with suitable climates for producing some of the finest fairways and course designs. The South African golf tourism industry, according to Sheard and Veldtman (2003), is a very important sub-sector of sports tourism and has seemingly come about spontaneously; there seems to have been no concerted planning effort to develop and market the country as an international golf tourism destination. A major advantage of the South African golf tourism industry is that golf is considered an all-year-round sport and is, therefore, less likely to suffer from the effects of seasonal demand as experienced by some European golf destinations (Tassiopoulos & Haydam, 2008). South Africa, according to Greeff (2001), is considered the eighth most popular golfing destination for German tourists. Blij (2002) suggests that the number of golf rounds played by golf tourists (club visitors) in the Western Cape during 2002 has increased by 40%. Tassiopoulos and Haydam (2008) also mention that the golf tourist is thus an important, but neglected, niche of the sports tourism market of South Africa.

The South African Golf Association was founded in 1910 and is the national body for the administration of men's amateur golf. Women's Golf South Africa (WGSA) is an associate member of the association. The South African Golf Association is recognised by the International Golf Federation (IGF) as well as the joint world governing body for golf, the R&A, and internally by SASCOC and the Department of Sport and Recreation (SAGA, 2017). Currently, more than 100 different amateur golf tournaments are held annually in South Africa. South Africa boasts some of the best players in the world, including Louis Oosthuisen, Ernie Els, Bobby Locke, Retief Goosen, Charl Schwartzel, Trevor Immelman, and Gary Player. Gary Player won nine major championships and more than 170 tour wins across the world.

2.3 RULES OF GOLF

The following section contains the rule situations that occur most commonly on the golf course and is an abridged version of the full rules as set out by The Royal and Ancient Golf Club of St Andrews (R&A). Rule 1 introduces these central principles of the game: play the course as you find it and play your ball as it lies. Play by the rules and in the spirit of the game. One is responsible for applying your one's penalties if a rule is breached, so that one cannot gain any potential advantage over an opponent in match play or other players in stroke play.

Rule 2 introduces the basic information one should know about the course. There are five defined areas of the course, and there are several types of defined objects and conditions that can interfere with play. It is important to know the area of the course where the ball lies as well as the status of any interfering objects and conditions, because they often affect options for playing one's ball or taking relief.

The three elements inherent in all golf competitions comprise Rule 3: playing either match- or stroke play, playing either as an individual or with a partner as part of a side, and scoring either by gross scores (no handicap strokes applied) or net scores (handicap strokes applied).

Rule 4 covers the equipment that may be used during a round. Based on the principle that golf is a challenging game in which success should depend on individual judgment, skills, and abilities, one:

- Must use conforming clubs and balls;
- Is limited to no more than 14 clubs and normally must not replace damaged or lost clubs; and
- Is restricted in the use of other equipment that artificially enhances play.

How a round is played is covered in Rule 5. This included guidelines such as where and when one may practise on the course before or during your round, when a round starts and ends, and what happens when play has to stop or resume. Players are expected to start each round on time and play continuously and at a prompt pace during each hole until the round is completed. On the player's turn, it is recommended that the stroke is made in no more than 40 seconds, and usually more quickly than that.

Rule 6 covers how to play a hole - such as the specific rules for teeing off to start a hole, the requirement to use the same ball for an entire hole except when substitution is allowed, the order of play (which matters more in match play than stroke play), and completing a hole.

Rule 7 allows players to take reasonable action to fairly search for the ball in play after each stroke. Player should be careful, though, as a penalty will apply if one acts excessively and causes improvement to the conditions affecting the next stroke. No penalty is awarded if the ball is accidentally moved in trying to find or identify it, but the ball must then be replaced in its original spot.

Rule 8 covers a central principle of the game: "play the course as you find it". When the ball comes to rest, players normally have to accept the conditions affecting the stroke and not improve them before playing the ball. However, certain reasonable actions may be taken, even if these actions improve those conditions. There are limited circumstances where conditions may be restored without penalty after they have been improved or worsened.

“Play the ball as it lies” is another primary tenet of the game as expounded in Rule 9. If the ball comes to rest and is then moved by natural forces such as wind or water, one must normally play it from its new spot. If the ball at rest is lifted or moved by anyone or any outside influence before the stroke is made, the ball must be replaced in its original spot. One should take care when near any ball at rest, as causing any movement to one’s own or an opponent’s ball may result in a penalty (except on the putting green).

Rule 10 covers how to prepare for and make a stroke, including advice and other help one may get from others, including the caddie. The underlying principle is that golf is a game of skill and personal challenge.

Rule 11 covers what to do if a ball in motion hits a person, animal, equipment, or anything else on the course. When this happens accidentally, there is no penalty, and the result should be accepted whether favourable or not, and play the ball from where it comes to rest. Rule 11 also restricts one from deliberately taking actions to affect where any ball in motion might come to rest.

Bunkers, which are specially prepared areas intended to test the ability to play a ball from the sand, are specifically addressed in Rule 12. To ensure that this challenge is confronted, some restrictions apply to touching the sand before a stroke is made and where relief may be taken for the ball in a bunker.

Putting greens are specifically governed by Rule 13. Putting greens are specially prepared for playing the ball along the ground. Each putting green contains a flagstick for the hole; consequently, different rules apply than for other areas of the course.

Rule 14 covers when and how the spot of the ball at rest may be marked, the lifting and cleaning of a ball, and placing it back into play in order to play it from the correct place. When a ball has been lifted or moved and is to be replaced, the same ball must be set down in its original spot. When taking free relief or penalty relief, a substituted ball or the original ball should be placed in a particular relief area. Before a ball is played, mistakes may be corrected using these procedures without penalty; however, a penalty is awarded if the ball is played from the wrong place.

Rule 15 covers when and how free relief from loose impediments and movable obstructions may be taken. These movable natural and artificial objects are not treated as part of the challenge of playing the course, and one is normally allowed to remove them when they interfere with play. Again, care should be taken in moving loose impediments near the ball off the putting green, because a penalty will apply if moving objects causes a ball to move.

Taking free relief by playing a ball from a different place, such as when interference by an abnormal course condition or a dangerous animal condition occurs, is addressed by Rule 16. These conditions are not treated as part of your challenge of playing the course, and free relief is generally allowed, except in a penalty area. Relief includes dropping a ball in a relief area based on the nearest point of complete relief. This rule also covers free relief, when a ball is embedded in its own pitch mark in the general area.

Penalty areas, such as bodies of water or other areas defined by the Committee, where a ball is often lost or unable to be played, are discussed in Rule 17. For one penalty stroke, one may use specific relief options to play a ball from outside the penalty area.

Rule 18 covers taking relief under penalty of stroke and distance. When a ball is lost outside a penalty area or comes to rest out of bounds, the required progression of playing from the teeing area to the hole is broken; the player must resume that progression by playing again from where the previous stroke was made. This rule also covers how and when a provisional ball may be played to save time when a ball in play might have gone out of bounds or has been lost outside a penalty area.

Rule 19 covers relief options for an unplayable ball. This allows a choice of options - normally with one penalty stroke – for escaping a difficult situation anywhere on the course, except in a penalty area.

Rule 20 covers which actions should be taken when questions regarding the rules should arise during a round, including the procedures (which differ in match play and stroke play) protecting the right to get a ruling at a later time. This rule also covers the role of referees who are authorised to decide questions of fact and apply the rules. Rulings from a referee or the Committee are binding on all players.

Other forms of individual play, including three forms of stroke play where scoring is different than in regular stroke play: Stableford (scoring by points awarded on each hole); Maximum Score (your score for each hole is capped at a maximum); and Par/Bogey (match play scoring used on a hole by hole basis) are governed by Rule 21.

Rule 22 covers foursomes (played either in match play or stroke play), where two partners compete together as a side by alternating in making strokes at a single ball. The rules for this form of play are essentially the same as for individual play, except for requiring the partners to alternate in teeing off to start a hole and to play out each hole with alternate shots.

Rule 23 covers four-ball play played either during match play or stroke play, where a player and a partner compete as a side with each playing a separate ball. The side's score for a hole is the lower score of the two on that hole.

Finally, team competitions during either match- or stroke play, are covered by Rule 24. Team play involves multiple players or sides competing as a team with the results of their rounds or matches combined to produce an overall team score.

2.4 RULES FOR AMATEUR STATUS

The R&A and USGA continue to believe that the distinction between amateur and professional golf should be maintained. Amateur golf has two essential features rarely combined in sport, namely:

1. The rules of the game are applied through self-regulation; and
2. It has an effective system of handicapping that enables any player to compete on equal terms with any other player.

These features are part of the great appeal of the amateur game. However, they combine to leave amateur play open to the possibility that uncontrolled financial incentives could lead to excessive pressures on player integrity, which, in turn, could prove detrimental to the game as a whole. The purpose of the rules is to maintain the distinction between amateur and professional golf and to ensure that amateur golf, which is largely self-regulating with regard to the Rules of Golf and handicapping, is free from the pressures that may follow from uncontrolled sponsorship and financial incentives. Through appropriate limits and restrictions, the Rules are also intended to encourage amateur golfers to focus on the game's challenges and inherent rewards, rather than any financial gain (R&A, 2018).

2.5 GOLF COURSES

The skills developed by golf players are tested on a variety of courses, each with unique challenges. There are various different types of golf courses, all named according to their landscape as well as the distance of the course. Each type of course is also characterised by features such as the type of grass, number of bunkers, and the influence of environmental factors such as wind. From 2019 onwards, the R&A (2018) will introduce course ratings. Each hole is analysed for factors affecting playing difficulty in the areas where various levels of players are likely to land, and the true (effective) playing length of the hole. The Effective Playing Length of a hole is impacted by five factors, namely roll, change in elevation, doglegs and layup, wind, and altitude. Ten obstacle factors are also taken into account: topography, fairway width, green target, recoverability and rough, bunkers, out of bounds, water hazards, trees, green surface, and psychological or visual impact.

Curtin (2018) explains that golf courses are a true work of art and that most comprise natural elements included into the creation of the golf course. The category under which a golf course falls is determined by the way the course was shaped into the natural environment.

2.5.1 Links Course

Golf originated in Scotland, and so did the links golf course. The links course is usually located in narrow parts of sandy land between sea and farmland. The slopes of the lands and the turns are usually brought in, with the fairway that presents a natural roll to them. A big factor contributing to this type of course is the wind (Curtin, 2018).

FIGURE 2.1: AN AERIAL VIEW OF ST. ANDREWS LINKS IN SCOTLAND (CHRIS, 2007 (ONLINE))

2.5.2 Parkland Course

Curtin (2018) explains that a parkland course is usually a well-groomed course with much green grass as well as trees. The fairways are also a great deal smoother than those of other courses. The parkland courses are also further away from the coast compared to the links courses.

FIGURE 2.2: DAVID CANNON (2018) INDICATED THE PARKLAND STYLE GOLF COURSE

2.5.3 Desert Course

As stated by Curtin (2018), desert courses are usually found in the desert in the midst of a very sandy landscape, with an oasis of green. These courses may work in the sandy landscape; however, grass does not occur naturally in these areas, and a great deal of irrigation is needed as a result.

FIGURE 2.3: AN AERIAL VIEW OF THE EMIRATES GOLF CLUB (2018)

2.6 HANDICAP SYSTEM EXPLAINED

According to the South African Golf Association's Handicapping Manual, a handicap is referred to as

> …the number of strokes a player receives to adjust their inherent scoring ability to the common level of scratch or zero handicap golf (SAGA, 2017).

A golf player only qualifies for a SAGA handicap when the golf player is a fellow member of a South African Golf Association club also connected to SAGA or Women's Golf South Africa (WGSA) as well as the Provincial Unions.

The IGF (2018) describes handicap as

> …a numerical measure of an amateur golfer's ability to play golf over the course of 18 holes.

This handicap system is also relevant for both stroke- as well as match play type of tournaments. With both tournaments the handicap indicates the amount of strokes higher than par that the golf player is bound to reach in good conditions. During a stroke play tournament, the golf player's handicap is assigned according to the player's handicap deducted from their total "gross" score after every round in order to determine the "net" score in that the classification will be determined. According to the IGF (2018), the handicap in a match play tournament will be allocated to the golf player on a hole by hole basis. This is in correspondence with the handicap grading of every hole (that of the golf course). The highest amount of handicap strokes is allocated to the toughest holes on the golf course, whereas the holes with lower difficulty will be allocated the lowest amount of handicap strokes. The IGF (2018) mentions that a handicap system is not used in professional golf, because professional golfers score below par for every 18 holes or round of golf most of the time. Therefore their handicap is scored on zero or less than zero. Golfers with these handicap numbers are called scratch golfers.

2.7 SHOT VARIATIONS

The IGF (2018) states that the start of play at every hole on the golf course commences by putting the golf ball into action by hitting the golf ball on the teeing area with a club. The IGF further declares that, when the first shot played at a hole is a very long one, it is suggested that the golf player elevates the golf ball by putting it on a tee. This is not necessary to do before hitting the ball. A variety of shots can be played in golf. Each shot is discussed below (MOGC, [N.D]).

DRIVE

The IGF (2018) explains a shot needs to travel a very long distance is called the drive. According to MOGC (N.D) this type of shot can be played from the tee or the fairway if necessary. The reason for the drive is to get the ball as close as possible to the green by covering a great distance with the shot played. Amateur golf players usually reach drive distances of 182.88m to 237.74m. For some golf players distances greater than 274.32m can be reached; this is mostly the purview of very advanced players.

APPROACH

MOGC (N.D) states that the approach is the second shot played, or any shot thereafter, that aims at bringing the golf ball to the green. The golf player will make use of a suitable iron to accomplish this shot over the required distance.

PUTT

After the approach or lay-up and once the ball is on the green, the golf player will attempt to get the ball into the hole, also known as sinking the putt (IGF, 2018).

LAY-UP

This shot is employed to assure that the golf ball is in the most desirable location to avoid the possible hazards on the golf course, such as water hazards (MOGC, [N.D.]).

CHIP

This is known as a very brief shot without the full swing to avoid a possible hazard like the water or as part of the lay-up (MOGC, [N.D.]).

PUNCH

The punch shot is played to avoid low hanging obstacles like trees. The golf ball then travels very low over the ground (MOGC, [N.D.]).

FLOP

This shot is the reverse of the punch shot. The aim is to get the ball over the obstacles. This shot can also be played when the golf player wants the golf ball to come to a quick stop upon landing (MOGC, [N.D.]).

2.8 EQUIPMENT

Golf originated on the coast of Scotland during the 15th century. Back then, golf players played with pebbles instead of balls and made use of sticks or clubs. It was only post 1750 that golf started to develop into the game we are familiar with today (Bellis, 2017).

Bellis (2017) reports that was not very long before golf players decided to use balls instead of the pebbles. The earliest golf balls comprised thin leather-like bags stuffed with feathers. These did not travel great distances when hit. In 1848 the gutta-percha ball was introduced by Adam Paterson. This ball was created from the Gutta Tree's sap and could travel a great distance of 225 yards. This ball was also much the same as the modern version. The very first one piece rubber cored ball was launched by Coburn Haskell in 1898. When these balls were hit decently it could travel distances of up to 430 yards. The dimpled golf ball introduced by Vincent Mallete had a smooth surface, but after a while when the ball started to become weary from all the hitting, the golf players started noticing the increases in distances the ball travelled with this weary surface (Bellis, 2017).

FIGURE 2.4: LEATHER GOLF BALLS WITH STUFFED FEATHERS [ONLINE]

Bellis (2017) states that the golf ball manufacturer William Taylor was the first to launch the dimple pattern on the golf ball during 1905 through the use of the Coburn Haskell ball. This is where the more modern golf ball gets its form. Golf balls are not allowed to weigh more than 45.93 grams with a diameter of not more than 42.67mm.

The same progression in development applies to golf clubs that improved from being wooden shaft clubs to today's irons. Irons are far more durable and able to withstand the repeated hits that it has to take, together with the weight distribution as well as the graduation utility. The equipment used in golf has been a major part in the history of golf and has since been an increasing feature with regards to optimisation of the technology for performance enhancement in golf (Wallace *et al.*, 2008).

Two other great forces, namely lift and drag, are experiences by the ball when travelling through the air. The explanation for the great distance the ball is capable of travelling through the air is due to these factors. Scott (2005) explains this phenomena based on the fact that there is a changeover from laminar to turbulent airflow on the upstream side of the travelling golf ball. This is the result of the dimples on the outer surface of the golf ball. Masamichi *et al.* (2005) conclude that, when the airflow that surrounds the ball is deformed, it is because of the backspin that generates the lift. Due to the angle of the clubface to the vertical plane, backspin is observed in most shots. There is an upward lift force that is experienced by the ball with backspin, resulting in the ball flying higher as well as longer (DeForest, 1993).

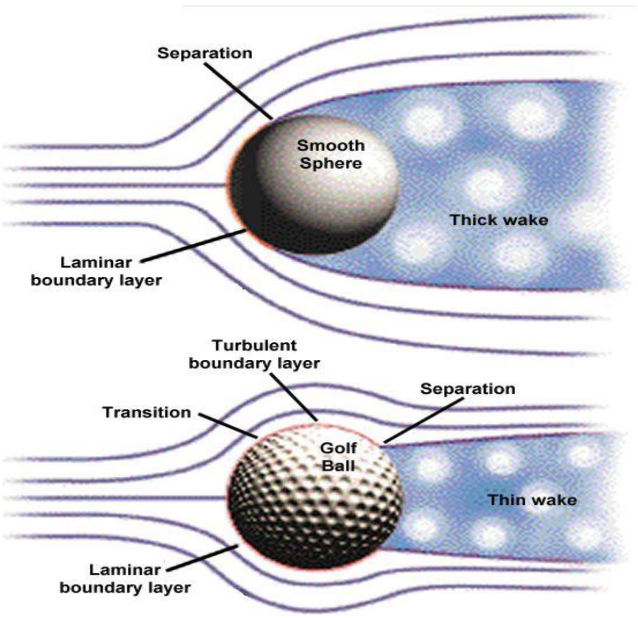

FIGURE 2.5: THE FLOW SEPARATION ON A SPHERE WITH A LAMINAR VERSUS TURBULENT BOUNDARY LAYER (SCOTT, 2005)

The biggest increases in drive distance appeared between 1993 until 2000. This was because titanium-based alloys were utilised in hollow, oversized drivers (Wallace *et al.,* 2008).

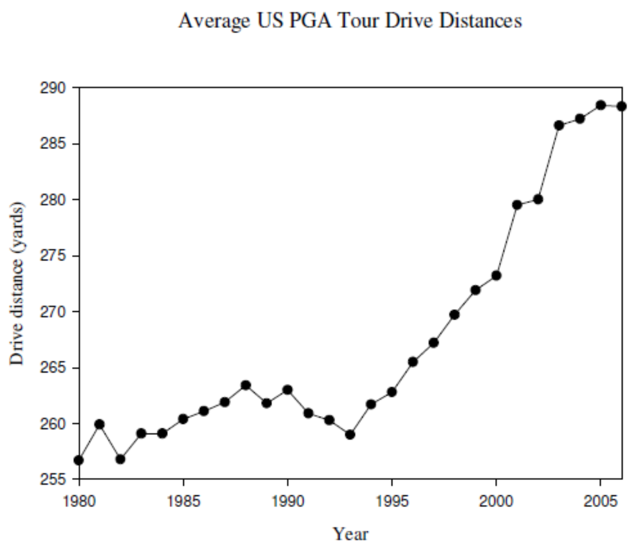

FIGURE 2.6: INDICATION OF THE AVERAGE US PGA DRIVE DISTANCES (WALLACE ET AL., 2008)

Wallace *et al.* (2008) conclude that the rise in drive distances before 1993 was due to conditioning and training of golf players, whereas the abrupt rise in drive distances during 2001 as well as 2003 are an indication of ball variations. The drive distances have been linked to the ball speed off the driver face. This, in turn, is accomplished by decreasing the stiffness of the head for viscoelastic ball deformation to ensure that energy through impact is lost and in turn replaced by the linear elastic head deformation.

A player can choose from a variety of golf clubs during a round of golf. They are called the wood, iron, wedge, putter, hybrid, and the chipper. Each one is discussed below.

FIGURE 2.7: LIST OF DIFFERENT GOLF CLUBS (GLOBALGOLF.COM, 2018)

Wood

The wood is used to reach great distances down the fairway. To increase the club speed of such a club it has a long shaft with a large head. Today the woods are made of a graphite shaft with a lightweight mostly hollow titanium composite or steel head to gain maximum club head speed.

Iron

The irons are composed out of a solid, all metal head with a face that has a flat angled appearance with a shorter shaft to allow the golf player to play a variety of shots during a round of golf on the course. Most of the irons have numbers allocated to them, ranging from one to nine. The irons are also allocated to a specific group according to their mean distance. This also matches the length of the shaft.

Wedge

Wedges are being used for a number of shots, including shots over short distances, in high altitude, high accuracy shots, for placing the golf ball in a favourable position on the fairway, to get it on the green, as well as for getting the golf ball out of hazardous areas and onto the green. The wedges usually consist of a greater loft compared to an iron.

Hybrids

The hybrids are a combination of a wood and an iron; this ensures long distances with a higher launch as well as the known swing of the iron.

Putters

Putters consists of lofts normally not more than 10 degrees. The goal of the putter is to roll the golf ball over the grass from a point on the putting green and into the hole.

Golf club shafts generally consist of one of two kinds of types depending on materials, namely steel or graphite (Lim *et al.*, 2014). The density of a steel shaft is about 1.7 g/cc (grams per cubic centimetre), which is much heavier than graphite shaft, about 1.0 g/cc. The most important characteristics for golf shafts are flexibility, weight, torque (rotational force), and trajectory (portion of bending when thin part is pulled down with fixing the other part) (Lim *et al*., 2014). Other characteristics of golf shaft are RSSR (Recommended Swing Speed Range), shaft tip diameter, and grip size (Kyoungho, 2012).

2.9 PHYSICAL CHARACTERISTICS OF GOLF PLAYERS

Dantas *et al.* (2018) emphasise that increased interest in golf has sparked recent scientific investigations launched to identify key factors that influence the performance of golf players. Golf has been described as one of the most complex, technically demanding, and high precision sports that exist (Ferdinands & Kwon, 2012). Golf is a sport that involves a relatively long duration of low-intensity activity interspersed with short bursts of high-intensity activity (Evans & Tuttle, 2015). The recent increase in the use of fitness conditioning for golf at all levels has seen countless experimental studies aimed at quantifying the effect of fitness conditioning on golf performance (Fletcher & Hartwell, 2004; Keogh *et al.,* 2009). Research conducted focusses on measuring the effects of anthropometry, flexibility, balance, cardiorespiratory fitness, strength, and power on golf performance (Balsalobre-Fernandez *et al.*, 2015). In recent years, golf training and fitness with increased flexibility and strength training have shown improvement in golf performance and shot distance (Gulgin *et al.*, 2014). According to Torres-Ronda *et al.* (2014), physical strength and endurance-related abilities strongly correlate with power, but there is a lack of simple and influential connectivity and programmes for fitness. Upper body and lower body strength, flexibility, and balance ability of a golf player influences power and timing in the golf swing (Nesbit & Serrano, 2005). Improved shoulder mobility and stability, core and hip mobility and stability, hamstring and hip flexibility could be considered vital for improved power in golf players (Kim *et al.*, 2018).

2.9.1 Anthropometry

The influence of anthropometry on golf performance is reported by Keogh *et al.* (2009). This study reports no statistically significant correlations between any anthropometric measures and performance level or skill level in adult golfers. Torres-Ronda *et al*.

(2014) find no relationship between the handicap, approach accuracy, putt accuracy, or anthropometrics of golf players. The work of Coaghlan *et al*. (2017) highlights the importance of anthropometric characteristics, which include height and mass in young golfers, with high to moderate correlations observed with club head speed.

2.9.2 Flexibility

Research by Chettle and Neal (2001) posits that flexibility is an important indicator for golfing performance, and that it creates a decreased resistance to swing plane and a decreased stretch reflex, which allows for a greater range of motion (ROM) in the backswing (Keogh *et al.*, 2009). Dantas *et al.* (2018) report that flexibility is considered an essential component of fitness to increase the successful execution of the golf swing. Vandervoort *et al*. (2012) also show that elite level golf players present increased levels of musculoskeletal range of motion. Adequate range of motion with no risk of injury to a given joint or a group of joints is needed to improve athletic performance (Dantas *et al.* 2018). Dantas *et al.* (2018) also report that it is very likely that specific enhancement is due to the adaptive changes triggered by the repetitive task that exposes the joint to a specific range of motion and will assist to perform a sportive gesture. With the appropriate use of stretching exercises and progression, sport specific skills can be performed with a greater range of motion, strength, velocity, and efficiency (ACSM, 2011).

2.9.3 Balance

Sell *et al.* (2007) show that high level golfers (HCP<0) display significantly better balance in the single leg test than lower level counterparts (HCP>0), especially when studying anterior/posterior and medial/lateral ground reaction force. Currently it is not clear whether balance characteristics are vital indicators in golf performance, as there has been minimal work in this area (Coaghlan *et al.*, 2017). Wells *et al.* (2009) also evaluate single leg balance, and measure the total time a golf player can balance on one leg. Significant relationships between the dominant leg balance and the greens in regulation (the ability to hit the green in 2 fewer shots than par) (r=-0.43) and between non-dominant leg balance and average putt distance post chip shot (r=0.50) are found.

2.9.4 Strength and Power

Read *et al.* (2013) evaluate the relationships between field-based strength and power measurements and club head speed (CHS) and find significant correlations between both seated (r=0.70) and rotational (r=0.63) medicine ball throws with CHS. Keogh *et al.* (2009) report that muscle strength will not be a factor for either approach- or putting accuracy in golf. The results of a study conducted by Coaghlan *et al.* (2017) indicate a significant relationship between several physical characteristics related to strength and power in high level youth golfers. Keogh *et al.* (2009) find high correlations between the driving ball speed and upper- and lower-body dynamic strength; the study suggests that golf players perform some kind of resistance training, as well as trunk strength development by means of medicine ball throws, to simulate the swing movement.

2.9.5 Cardiovascular Fitness

Murray *et al.* (2016) report that golf has the potential to provide improved physical activity, and therefore holds health and social benefits to all players and from all ages. Coaghlan *et al.* (2017) report that golf players' cardiorespiratory fitness improves the ability to tolerate the demands of practice, competition, and training more efficiently. In contrast to the relatively low-intensity demand of the rest of the game, a full swing action requires a rapid expenditure of energy (Evans & Tuttle, 2015). Szabo *et al.*, (2012) show that a higher level of physical activity is connected to better accuracy in synchronisation.

Wells *et al.* (2009) report significant positive correlations between the Leger multi-test run score and the performance measures of golf players. The study suggests that the findings may not necessarily reflect the importance of the cardiorespiratory fitness for golf players, but rather show a cross-training effect from other physical work that a more competitive golfer is likely to undertake as part of preparation. There were varied results in oxygen uptake. Garber *et al.* (2011) indicate that the VO_2max of golf players are classified as light (37%–45% VO_2max), moderate (46%–63% VO_2max) and vigorous (64%–90% VO_2max).

Heart rate data of a golf round were gathered by Zienius *et al.* (2015) using a golf personal statistical protocol and employing Suunto t6 HR monitors. Observers recorded behavioural patterns during the pre-shot routines. The subjects' pre-shot routines for approach shots were significantly shorter ($p < 0.05$) than their pre-shot routines for tee shots. HR increased significantly ($p < 0.05$) from the start to the end of the pre-shot routines for tee and fairway shots; the number of practice swings had the strongest relationship with the increased HR from the start to the end of the pre-shot routines for tee ($r = 0.474$; $p < 0.05$) and fairway ($r = 0.373$; $p < 0.05$) shots.

2.10 BIOMECHANICS OF THE GOLF SWING

According to Ball and Best (2007b), Nesbit (2005), Fradkin *et al*. (2004a, 2004b), Teu *et al*. (2006), and Sprigings and Mackenzie (2005), the power generation of the golf swing is of chief importance in determining the range of the drive shot and can also be calculated through the utilisation of club head speed at impact (CSI). One of the most important factors, which also influences power generation, is rotational biomechanics. Previous studies of non-amateur golf performance mainly focussed on episodes that occur at certain time intervals during the game; however, none of these studies record norms that indicate professional golf performance through the focus of the entire golf swing in correlation with certain phases during the swing (Ball and Best, 2007a, 2007b; Hume *et al*., 2005; Teu *et al*., 2006; Gluck *et al*., 2007; McLaughlin and Best, 1994; Zheng *et al*., 2008a, 2008b. A starting point for strategic training can be initiated with norms based on professional golf performance (Meister *et al*., 2011).

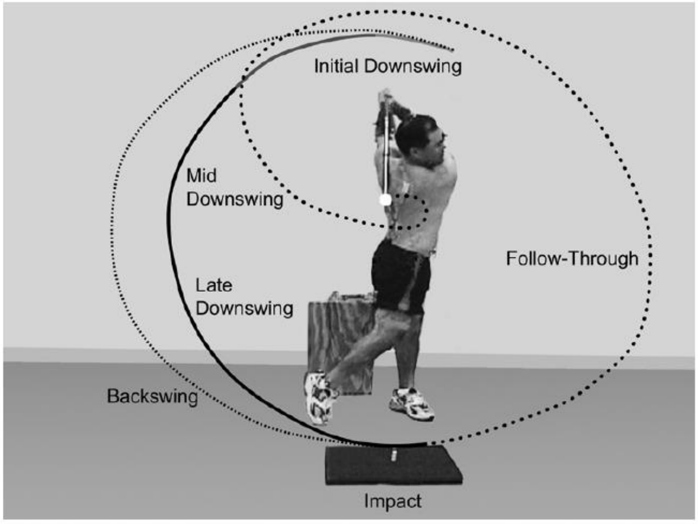

FIGURE 2.8: THE MOST IMPORTANT PHASES OF THE GOLF SWING ARE SET OUT AFTER ADDRESSING THE BACKSWING, DOWNSWING, IMPACT, AS WELL AS FOLLOW-THROUGH (MEISTER ET AL., 2011)

The study conducted by Meister *et al*. (2011) focussed on rotational biomechanics through the entire golf swing and the correlation thereof to power generation. The backswing starts with a clockwise rotation of the upper torso as well as the pelvis in the horizontal plane, with pelvic rotation starting to move into the opposite direction before the start of the downswing. This is immediately followed by a reversed movement from the upper torso, as indicated by Meister *et al*. (2011) in Figure 2.9 below.

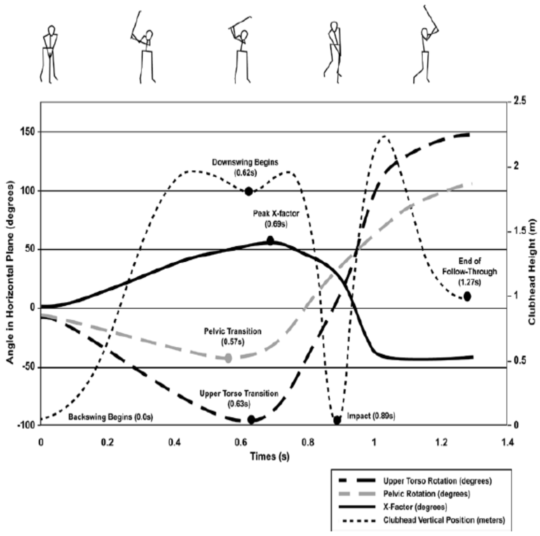

FIGURE 2.9: THE MAIN BIOMECHANICAL EVENTS THAT OCCUR THROUGH A DRIVE SHOT (MEISTER ET AL., 2011)

Other studies mention that pelvic transition occurs before upper torso transition, thus increasing the X-factor through the early stages of the downswing (Adlington, 1996; Burden *et al*., 1998; Grimshaw and Burden, 2000; Cheetham *et al*., 2000; Rehling, 1955; Hume *et al*., 2005; McTeigue *et al*., 1994).

According to Gluck *et al*. (2008) the X-factor is known as the separation angle. This is because of the "X" that is caused by the lines drawn just at the end of the backswing and just before the start of the downswing.

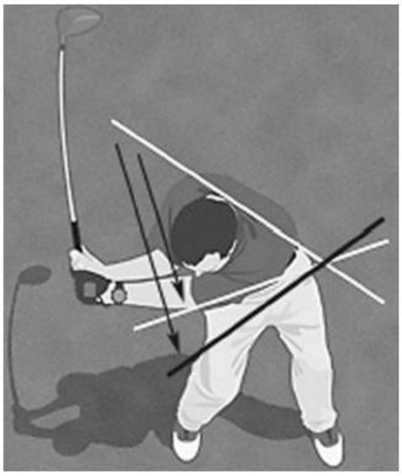

FIGURE 2.10: THE STATIC X-FACTOR (WHITE LINES) AND THE DYNAMIC X–FACTOR (BLACK LINES) (GLUCK ET AL., 2008)

Through the entire downswing the pelvis continuously leads the upper torso. During the impact, the upper torso is almost level in relation to the line of flight, and therefore rotates further than the pelvis during the follow-through phase (*cf.* Figure 2.10 above).

Significant differences are found between biomechanical factors in amateur and non-amateur golf players. It is also expected and determined that beginner players exhibit more differences in biomechanical factors than those of a more skilful amateur in relation to professional golf players. A basis for strategic training may be given because of norms that illustrate the dissimilarities in the biomechanics of non-amateur golf players and amateur golf players (Meister *et al*., 2011).

Meister *et al*. (2011) further indicate that various golf swing biomechanical factors show a clear linear raise from easy to hard swings. These factors include club head speed at impact, the peak free moment per kilogram, X-factor at impact, peak X-factor, peak upper torso rotation, O-factor at impact, as well as S-factor at impact. This emphasises the importance of these factors in power generation of the golf swing as well as the driving distance. There is no clear linear raise in peak pelvic rotation easy to hard swings. This indicates that upper torso rotation might affect the X-factor to a greater extent than pelvic rotation.

Mchardy *et al*. (2006) and Theriault and Lachance (1998) state that one of the principal causes of golf-related injuries is faulty golf swing mechanics. A previous case study found that lowering the X-factor through training programmes and coaching strategies greatly improve lower back pain (Grimshaw and Burden, 2000).

In Meister *et al*.'s (2011) study, it is recorded that rotational biomechanics (such as peak free moment per kilogram, peak X-factor, peak upper torso rotation, as well as peak S-factor) are very persistent. However, it is also related to CSI and is important for power generation of the golf swing for non-amateur golf players.

According to Smith *et al*. (2015), five important technical variables can be identified after an in-depth analysis of the golf swing. These five variables are posture, body rotation, club motion, arm and wrist action, as well as sequential movement and body segments.

Smith *et al*. (2015) state that most coaches cite the various technical variables of the golf swing at certain phases through the entire swing. Firstly, address and impact are cited as the most important phases of the golf swing by different coaches. The address phase involves the position of the ball, the adjustment of the golf player towards a specific target, as well as their body position just prior to the swing of the club. Some coaches provide distinct consideration to where the ball is placed in relation to the golf player. Certain adjustments to the golf player's biomechanics are associated with the inappropriate placement of the golf ball in relation to the golf player's stance (Smith *et al*., 2015). Secondly, coaches cite the backswing phase, which is twofold in definition. The first definition describes the backswing phase as the point where it is no longer possible for the golf player to rotate his/her shoulders, while the second definition refers to when movement starts after the club stops at the top of the swing (Smith *et al*., 2015). Thirdly, the downswing phase is as mentioned. According to Smith *et al*. (2015), the downswing phase lasts from the moment when the golf club starts to move and until it reaches the point of impact. Finally, coaches refer to the follow-through phase - the period where the golf player's arms are in a fully extended position and the golf club has stopped (Smith *et al*., 2015).

Posture is identified by coaches and Smith *et al*. (2015) as an important aspect of the golf swing. The golf player's body alignment during the address phase as well as the capability to ensure posture retention throughout the entire swing are mentioned as vital components. Posture is further subdivided into two categories, namely spine angle and postural balance. The angle of the spine is known as the forward flexion of the trunk in correlation to the pelvis, also viewed as a rotary axis. Postural balance is defined as the golf player's attempt at creating a balanced body position.

Winter (1995) states that biomechanical literature explains posture as the alignment of the body in correlation to the vertical. This is referred to as postural kinematics, and involves parameters like lateral bend as well as trunk flexion. An analysis of the important biomechanical specifications of the golf swing consists of initiating and preserving the posture from the address phase up to the end of the swing (Hume *et al*., 2005). Hume *et al*. (2005) further state that the best posture at address phase is described as having the trunk bent or flexed at a 45 degree angle and bent at 16 degrees from the vertical. This is seen as the optimal position for power generation as well as control throughout the entire golf swing. McTeigue *et al*. (1994), however, disagree with this posture being the ideal, because continual flexion of the trunk might account for too much side bending as well as backward bending at TB, which might lead to injury.

Smith *et al*. (2015) conclude by saying that the description of posture - as stated by coaches - is the forward flexion and side flexion in the spine angle of the golf player as well as postural balance. The coaches also believe that controlling a constant trunk angle through the entire swing will ensure that the club position is consistent. This is, however, not entirely supported by existing literature – some results do not agree with this perception, and matters such as trunk flexion throughout the entire golf swing has not yet been fully measured

Furthermore, golf coaches also trust that rotation of the trunk and pelvis during backswing is an option for the generation of a powerful, persistent, as well as simple swing through the production of energy that shifted to the golf ball at impact (Smith *et al*., 2015).

Gluck *et al*. (2008) state that golf developed into a well-known sport and is also much appreciated amongst people of various ages, genders, and capabilities. Gluck *et al.* (2008) further describe both the modern and the classic golf swings. Initially, the golf swing seems like a straight forward action, but it is far more complex than it seems. The swing is unique to every person participating in the sport and differs from person to person. Gluck *et al*. (2008) emphasise that the modern swing type focusses on a wider shoulder turn together with a smaller hip turn. The smaller hip turn is achieved by the foot in front being flat on the surface throughout the entire swing. This, in turn, allows for a more persistent hitting of the golf ball. There is also the matter of increased hip/shoulder separation angle which enlarges the torsional load within the spine, thus allowing to stretch the viscoelastic elements.

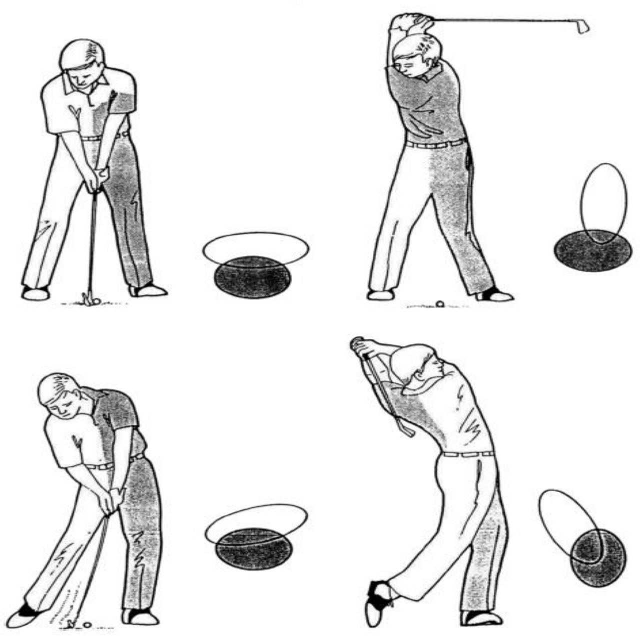

FIGURE 2.11: AN ILLUSTRATION OF THE MODERN GOLF SWING WHERE THE SMALLER HIP TURN IS INDICATED BY THE SHADED OVAL AND THE SHOULDER POSITION IS INDICATED BY THE UNSHADED OVAL (GLUCK ET AL., 2008)

For the classic golf swing the focus relies on decreasing the X-factor; this is achieved by lifting the heel of the front foot through the backswing phase to allow a greater hip turn through the reduction of the backswing phase, or both. This, in turn, will reduce the hip-shoulder separation angle as well as the torque being placed on the lower back (Gluck *et al.,* 2008).

Grimshaw and Burden (2000) claim that some case reports cite the golfer's upright posture, where the player is closer to the golf ball, as a factor lowering the chances of lower back pain.

When non-amateur golf players are compared to amateur golf players, it is evident that, even though the golf swing might be a concern, the way in which an injury is sustained can also be different. The non-amateur golf player who regularly practices golf swings in order to attain more precise and controlled swings, injury is most likely due to repetitive action, causing overuse injuries. The amateur, who does not practice the swing as often, might have a few irregularities in the swing. Therefore it might lead to injuries such as lower back pain because of faulty swing mechanics (Stover *et al*., 1976; Parziale, 2002).

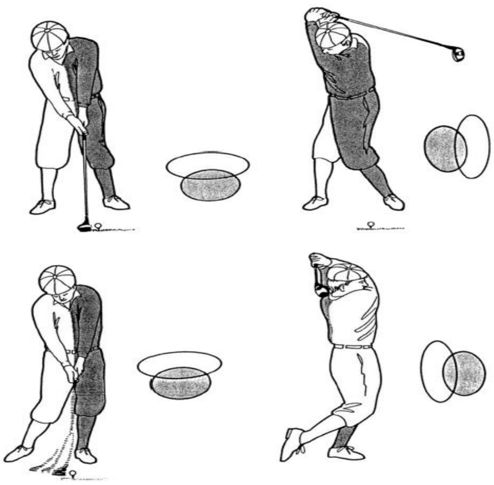

FIGURE 2.12: THE CLASSIC GOLF SWING WHERE THE HIP AND SHOULDER TURN IS MUCH GREATER. THE UNSHADED OVAL INDICATES THE SHOULDER POSITION AND THE SHADED OVAL INDICATES HIP POSITION (GLUCK ET AL., 2008)

2.11 MUSCLE INVOLVEMENT IN GOLF

During the golf swing almost all the muscles and joints are employed. The major muscles and joints involved during the golf swing are discussed below.

2.11.1 Muscles Involved in the Backswing

Davies and DiSaia (2010) state that the backswing phase is the least strenuous part of the entire golf swing. Most important for this phase during the swing is neuromuscular control, proprioception, as well as mobility, as opposed to muscle strength. Even though this phase relies mostly on the mobility of the golf player, certain muscle groups ensure stability while others might increase movement. The golf player should place load on the quadriceps, gluteus medius, as well as the gluteus maximus muscle groups in the trial leg as well as the oblique muscles as the golf player reaches the end of this phase. The moment these muscles work as they should the muscles of the latissimus dorsi, infraspinatus, rhomboids, obliques and the multifidi can work properly to ensure the golf player reaches the full position of this phase.

2.11.2 Muscles Involved in the Downswing

Transitioning into this phase directly after the backswing phase takes a great deal of coordination by the golf player and tests the player's capability to divide the lower body from the upper body (Davies and DiSaia, 2010). This is evident when the golf player shifts from the backswing phase into the downswing phase by moving the lower body into the proper position to ensure the most effective muscular movement. The most important point is for the target-side knee to be placed in a position over the outside aspect of the target foot. This ensures alignment so that the quadriceps muscles can contract to initiate hip extension. The hip rotator muscles are the piriformis, gluteus-medius and minimus, as well as the obturators. This allows the muscles to contract and ensures lateral stability on the target-side leg. The trail-side leg involves muscles such as the quadriceps, adductor magnus, the hamstrings, gluteus maximus, and gastrocnemius muscles to initiate knee extension, hip extension, as well as plantar flexion. This assists the golf player with driving the player's weight on the left side.

2.11.3 Muscles Involved in the Follow-Through

Davies and DiSaia (2010) argue that this phase is the most strenuous during the golf swing, as the body enters a deceleration state to ensure that the arms stay in a straight position after the impact. The muscles of the oblique, quadratus lumborum, psoas major, as well as transverse abdominis and rectus abdominis operate at their peak to initiate force and decelerate the body. Under great velocity the muscles of the shoulder blade as well as the latissimus dorsi and rotator cuff muscles protect the shoulder joint in reaching its end range of motion.

2.12 CONDITIONING IN GOLF

In professional golf tournaments, putting on the green accounts for about 40-45% of all the swings played in golf. This renders putting a determining factor of the success in the final score (Smith, 2013). Golf players not only should be able to accomplish putting control, but also distance control; the latter is hardest to accomplish (Tanaka and Masato, 2018). Golf players must therefore be able to precisely recognise and perform putting distance. As such, Tanaka and Masato (2018) describe sense of distance as the capability to foresee the intensity of impact. Non-amateur golf players have a greater sense of distance compared to beginner players, even though there is not yet a method created to test for these differences in skill level, nor the cognitive capability involved. The study further argues that sense of distance might be taught through different skills, such as motor control of the putter head, the ability to perceive the impact force, and the ability to determine the distance the golf ball travelled.

According to Hosea *et al*. (1994) and Hosea *et al*. (1990) it is estimated that the execution of the golf swing creates in amateur golf players about 6100 ± 2,413N of spinal compression force. In non-amateur golf players this load is about 7,584 ± 2,422N, or approximately eight times the body weight of the golf player. The fact that non-amateur or dedicated golf players execute the swing upwards at about 2000 times during the week could account for the high number of golf players vulnerable to overuse injuries (Jobe and Pink, 1996).

About 80% of the injuries sustained in golf are overuse injuries (Gosheger *et al*., 2003). The areas mostly involved in overuse injuries are the back, elbow, shoulder, knee, and the wrist and hand. Lindsay *et al*. (2009) state that improving flexibility and strength of the wrist and forearm muscles, together with the correction of any faulty grip of swing mechanics, might aid in preventing injury. Certain prevention strategies are in place to prevent golfing injuries; these are discussed below.

2.12.1 Cardiovascular Progression

The walking distance on the golf course is about 10 kilometres; this arguably indicates sensible cardiovascular endurance. During a round of golf consisting of 18 holes a golfer burns roughly 1500 calories (Lindsay *et al*., 2009). Sell *et al*. (2008) state that carrying golf bags add 10-15% calorie consumption to this number. For male golf players the maximum intensity for heart rate reached is 70% of the maximum depending on the age as well as the type of golf course (Bronman *et al*., 2004). These numbers might not look very intensive; however, it still indicates a moderate amount of cardiovascular stress being placed on the golf player. Furthermore, according to Sell *et al*. (2008), a misunderstanding exists that golf needs a great amount of aerobic fitness; however, the average oxygen use (VO_2) is shown to be 22.4mL/min/kg. This might also vary between 35 and 46ml/min/kg (Dobrosielski *et al*., 2002; Murase *et al*., 1989). Murase *et al.* (1989) indicate that, during an 18 hole round of golf, players display VO_2max readings of 35-41%. This indicates a minimal aerobic need. Read *et al*. (2013) state that, because of the minimal aerobic need during golf, conditioning programmes should focus on short bursts of exercise in order for players to produce greater levels of ground reaction forces as well as the angular velocity of the club head.

Lindsay *et al*. (2009) suggest that golf players must still gradually raise their cardiovascular tolerance in order to avoid injuries and to meet the physical challenges posed by golf. It might be advantageous to raise weekly walking distances during times approaching tournaments. Over the last 20 years, heart rate monitors (HRMs) have become a widely used training aid for a variety of sports. Abundant evidence from cross-sectional studies show that trained individuals have higher Heart Rate Variability (HRV) than untrained individuals (Achten & Jeukendrup, 2003).

2.12.2 Musculoskeletal Progression

The golf swing is a very special dynamic movement (Lindsay *et al*., 2008) and consists of powerful sequences of muscle contractions in a coordinated manner. As previously mentioned, compression forces placed on non-amateur as well as amateur golf players are about two and a half times greater than those exerted by running. Investigating knee and hip loads are also of much importance. Stover *et al*. (1976)

determine that the trial hip experiences far less rotational torque than that of the leading hip in the downswing phase.

Gatt *et al*. (1999) state that the amount of force placed on the knee of the golf player during a swing is the same as that caused by running to the side or by cutting movements. Through the use of electromyography the muscle activation during a swing can be analysed. Pink *et al*. (1990) studied the activation of muscles in the shoulder and find that, even though golf might not seem like a very demanding activity of the arm, it still involves a great simultaneous activity of rotator cuff musculature to secure the glenohumeral joint.

After analysing muscle activity in the shoulder throughout the golf swing, Kao *et al*. (1995) found that activity in the trailing arm appeared mainly through various phases of the golf swing, whereas the activity in the leading arm appeared within the acceleration phase. Activity in the trunk muscles of amateur golf players were also reviewed by Pink *et al*. (1993), who found that much of the activity in the oblique muscles is reported during almost all the phases of the swing. In a study that focussed on non-amateur golfers, Watkins *et al*. (1996) determined that the trunk muscles are active throughout the acceleration phase of the golf swing.

According to Lindsay *et al.* (2009) there is not much research available that illustrates what a proper golf-specific training programme should look like.

2.12.3 Strength and Flexibility Enhancement

Lindsay *et al*. (2009) describe the perfect golf swing as one that needs a relative amount of range of motion in the joint as well as muscle strength from all areas of the body, especially in rotational patterns. The golf swing also turns out to be less efficient and unsafe without the necessary flexibility.

SET-UP POSTURE

According to the study by Lindsay *et al*. (2009), the proper golf posture is attained when the feet is turned to a 25 degree angle with the knees bilaterally in a 25 degree bent position, and the trunk is shifted forward in a 25-30 degree angle whilst the spine is kept in a straight position.

According to Dillman and Lange (1994) the golf swing is one of the hardest and most difficult motions in sport. In the past, some research studies have shown that roughly 20.2%-26.8% of energy gained by the body during the downswing is carried over to the club (Nesbit and Serrano, 2005).

Read and Lloyd (2013) state that golfer conditioning is currently appreciated much more in comparison to previous years and is seen as a necessity for injury prevention as well as for overall performance improvement. Some studies also confirm that post strength and power training improves club head speed. There is, however, still little data available today that highlights the importance of implementation of strength programmes. Traditionally, attention was paid to enhancing golfing equipment rather than improving physical performance (Whittaker, 1998). Recently, however, focus has shifted towards improving the golf player's strength, flexibility, and balance in order to improve swing mechanics, prevent injuries, and to better the performance of the golf player in some high level settings (Farrally *et al*., 2003). Certain studies also indicate increases in club head speed through the involvement of strength and power training (Doan *et al*., 2006; Thompson *et al*., 2007; Read *et al*., 2013). According to Read *et al*. (2013) very little information regarding strength and conditioning programmes and their benefits in golf exist.

2.12.4 The Biomechanical Analysis of the Golf Swing for Conditioning

Hume *et al*. (2005) describe the greatest shift within the golf swing mainly as an activity of the angular club head velocity as well as the nature of the arm/club lever at the time of impact with the golf ball. The nature of the arm/club lever at the time of impact with the golf ball is mainly decided through the anthropometrics of every golf player - angular velocity of the club head is brought about by elements of ground reaction forces and displacement of body weight as well as the consecutive total of forces and execution of the eccentric-concentric coupling. The responsibility of the conditioning specialist is to ensure improvement in the creation of angular club head velocity by the success of a golf player's capability to create greater ground reaction forces and speed movement (Hume *et al*., 2005).

Barrentine *et al*. (1994), Hume *et al*. (2005), as well as Jobe *et al*. (1986) state that the golf swing can be split into four parts. The first part of the swing is the set-up, which consists primarily of isometric actions. Secondly, Hume *et al*. (2005) mentions the backswing, which is utilised for proper club head placement to allow a more precise and powerful downswing. The muscles and structures accountable for the production of power during the downswing are the agonist muscles and joints, which are then stretched or pre-loaded. The third part is the aim of the downswing, where the club head returns to the ball at a proper angle with a great amount of velocity. Finally, the eccentric muscle contractions are mainly involved in the follow-through phase (Jobe *et al*., 1986).

A confluence of certain muscles, namely the hip abductors, adductors, as well as the hip and knee extensors (Bechler *et al*., 1995), play an important role in the production of the necessary torque involved in the drive shot (Read *et al*., 2013). This is also true for the extensors in the spine (Pink, 1993) and the internal rotators of the shoulder joint stated (Jobe *et al.,* 1986). Okuda *et al*. (2002) state that, for the downswing, the bigger, more proximal muscles initiate the movement where the shoulders, trunk, and the hands and wrists follow suit. For the fulfilment of reaching the greatest club head speed, the order in which the torque is produced appears to happen in a proximal to distal manner (Sprigins and Neal, 2000).

In order to gain strength and/or power, conditioning programmes provided should address full body dynamic movement. This is also true for putting the focus on ground up force production in order to gain more benefit from training, as opposed to isolated, uni-articular approaches (Hume *et al.,* 2005; McHardy *et al*., 2006; Hellström, 2009).

According to Pink *et al*. (1993) and Theriault and Lachance (1998), the non-amateur player performs more than 2000 golf swings on a weekly basis, both during training and during tournaments. Consequently, golf players are prone to injuries, and the conditioning coach should pay special attention to the muscles and joints involved during golf, as well as the importance in which these are utilised during the swing in conjunction with the amount of use. To further hamper possible injuries to the spine, McGill *et al*. (1999) suggest appropriate phases of symmetry of the trunk muscles as well as endurance on a postural level, as these are very important factors. The fact that golf is a very asymmetrical game implies an inherent contrast between left and right; however, management rather than trying to accomplish an even left and right would be a better option (Read *et al*., 2013). The author further states that it would be more beneficial to the golf player to have access to individualised training programmes in order to prevent injuries. Concluding the Read *et al*. (2013) study, it is clear that, in order to produce strength as well as power through a ground up perspective, using strength- and power training components are an important aspect in a general training programme.

2.13 HEART RATE (HR) RESPONSE TO DETERMINE THE INTENSITY OF GOLF

The first HR monitor was developed during the early 1980s and consisted of a receiver (in the form of a watch-like monitor) and a transmitter (either disposable electrodes or an elastic electrode belt). More recently, HR monitors have been developed to include a calorie-counting feature; these monitors can also estimate the athlete's maximal oxygen uptake (VO_2max). Measuring HR variability (HRV), which is described as the variation in time between two consecutive heart beats, is another feature that recent HR monitors are equipped with (Achten *et al.,* 2003).

2.13.1 Factors Influencing HR

Monitoring HR during competition has proven useful in determining the physiological demands of an athlete during competition or training; however, the accuracy of HR monitoring may be influenced by certain factors (Kraak, 2011). Achten *et al.* (2003) also enumerate several physiological factors that may influence HR response to exercise. The first of these influential factors is cardiovascular drift. This term refers to the gradual decrease in stroke volume and the gradual increase in HR after the first few minutes of moderate intensity exercise. Cardiovascular drift is associated with numerous factors, such as dehydration and heat stress. It is reported that environmental factors such as temperature may also influence HR response (Achten *et al.*, 2003). Exercise in hot conditions is associated with higher HR recordings (as high as 10 beats per minute more) than exercise at the same intensity in cold temperatures (Achten *et al.*, 2003).

2.13.2 Heart Rate Responses in Sport

HR responses in intermittent sport such as soccer are reported to range from 152 to 186 beats per minute (b.min-1) (Krustrup *et al.,* 2005). Abdelkrim *et al.* (2007) also found mean HR values for basketball match play to be within a similar range to soccer players at 171b.min-1. Chandler *et al.* (2014) furthermore compared HR during match play to HR during training, and reported a mean HR of 174 beats per minute (b.min-1) during a netball match. McCabe (2014) states that mean HR ranges from 152 – 178 b/min for court sports.

2.14 THE USE OF A GLOBAL POSITIONING SYSTEM IN GOLF PERFORMANCE

Williams *et al.* (2018) report that the unique loads experienced by golfers created the necessity to develop a load monitoring tool which could effectively capture the integral components of a golf player's preparation. According to Wundersitz *et al.* (2015), the player's physical demands are calculated through the usage of maximum impact accelerations of the accelerometer; however, the accuracy of the readings cannot be guaranteed. Wundersitz *et al.* (2015) posit that the Minimax X S4 accelerometer can calculate the physical-collision peak impact accelerations correctly if data is processed at a 20 Hz cut-off frequency.

A wearable apparatus used to calculate performance variables has become very popular in the sporting environment. These apparatuses usually earmark sport coaches, trainers, athletes, as well as scientists in order to ensure performance enhancement through the adjustment of training approaches by coaches and also to reduce the possible risk of injury as stated (Malone *et al.,* 2016; Halson, 2014). It is, however, suggested that the same device should be used on the same athlete tested throughout the entire testing period to ensure accurate readings and to avoid the inter-device variability that might have an effect on the data gathered (Nicolella *et al.,* 2018).

2.14.1 Variables Explained

Total Distance Covered

Belka *et al.* (2014) remark that the distance covered by athletes during competition is one of the most studied variables in the field of sport science. Aughey (2011) suggests a strong relationship between distance covered and Load$^{TM}\cdot$min^{-1} (au) in elite Australian Football players. As previously mentioned, limited research on movement patterns and physiological demands on golf players exist. Total distance covered has been measured in various team sports and varies from 5-6km covered in under 19 Rugby Union matches (Cunningham *et al.*, 2016) to 5-8km covered in Rugby League matches (Twist *et al.*, 2014) and 8-12km covered during a soccer match (Mohr *et al*., 2003). Total distance covered by racquet sport athletes depends on the length of the game until victory is reached. Badminton players cover a mean total distance of 2km (Liddle *et al.,* 1996) during a match. The distance walked during golf tournaments was first measured by Luscombe *et al.* (2017), who conclude that the distance is highly variable depending on the course, and that values can range from 6.4 to 11.3km for an 18 hole round and 4.4–5.3km for a 9 hole round.

Total Duration of Play

Golf is a unique sport with no set time limit to play, but players will be asked to keep a steady pace of play without holding other players up in the process. As much as 60% of the time taken to play a round of golf is spent preparing and performing swings, and of this time, 25% is spent putting on the green (Derksen *et al.,* 1996). On average, a round of golf lasts approximately four hours on a weekday and four and a half hours over weekends (Tracking Research, [N.D]). The four hour duration can equate to about half the amount of an occupational work day, which matches an average round of a game of golf (McGee, 2017). Magnusson *et al*. (1998) report that golf courses vary in length and terrain, so a round of 18 holes can take between 3.5 and 6 hours to play, and, if the players are walking, results in a low to moderate intensity form of aerobic exercise.

HEART RATE

All training programmes consist of three key components: frequency of exercise sessions, duration of each session, and exercise intensity (Achten *et al*., 2003). By determining the relationship between HR and VO_2, HR can then be utilised to estimate VO_2, which will give a fair reflection of the intensity of work being performed (Achten *et al.*, 2003). HR has become the most commonly used method to obtain an indication of exercise intensity in the field. HR is easy to monitor and shows a very stable pattern during exercise. Athletes can immediately use the HR data to adjust the intensity of a work bout if necessary (Achten *et al*., 2003). The intensity of an exercise bout is a key factor in determining the effect of a training session. HR shows an almost linear relationship with VO_2 at submaximal intensities and can therefore be used to accurately estimate the exercise intensity (Achten et al., 2003).

TOTAL PLAYER LOAD (PL)

To determine physical activity of players, the Catapult Minimax X4 accelerometer unit measures accelerations in the frontal-, sagittal-, and transverse axes of movement to determine a variable called player load (PL) (Gabbett, 2012). In other words, Boyed *et al.* (2011) describes PL as a variable developed and captured by the Catapult Minimax X4 during match play as a measure of physical activity by measuring the accumulation of accelerations in all three planes of movement - frontal, sagittal, and transverse (Chandler *et al.,* 2014).

PL is calculated using the following formula (Boyed *et al.*, 2011):

$$PlayerLoad = \frac{\sqrt{((\mathrm{Ac1} - \mathrm{Ac1}-1)\ 2\ +\ (\mathrm{Ac2} - \mathrm{Ac2}-1)\ 2\ +\ (\mathrm{Ac3} - \mathrm{Ac3}-1)\ 2\ )}}{100}$$

where

Ac1 = Forward Acceleration

Ac2 = Sideways Acceleration

Ac3 = Vertical Acceleration

The different types of acceleration are measured by the Catapult Minimax X4 (sampling at 100 Hz). Murray *et al*. (2017) report several factors that influence the intensity of physical activity during golf play, such as the use of a golf cart, the course profile, age, weight, sex, and baseline fitness of players. Burkett and Von Heijne-Fisher (1998) posit that there is no significant difference in energy expenditure in relation to level of skill, despite lower level players using a higher number of shots in total and on average being less accurate in advancing the ball. However, Zunzer *et al.* (2013) report that riding in a golf cart results in significantly lower energy expenditure compared to players who pulled or carried their golf clubs.

Player Load per Minute

Player Load per Minute is the rate of accumulation of Player Load, and is treated as a measure of intensity.

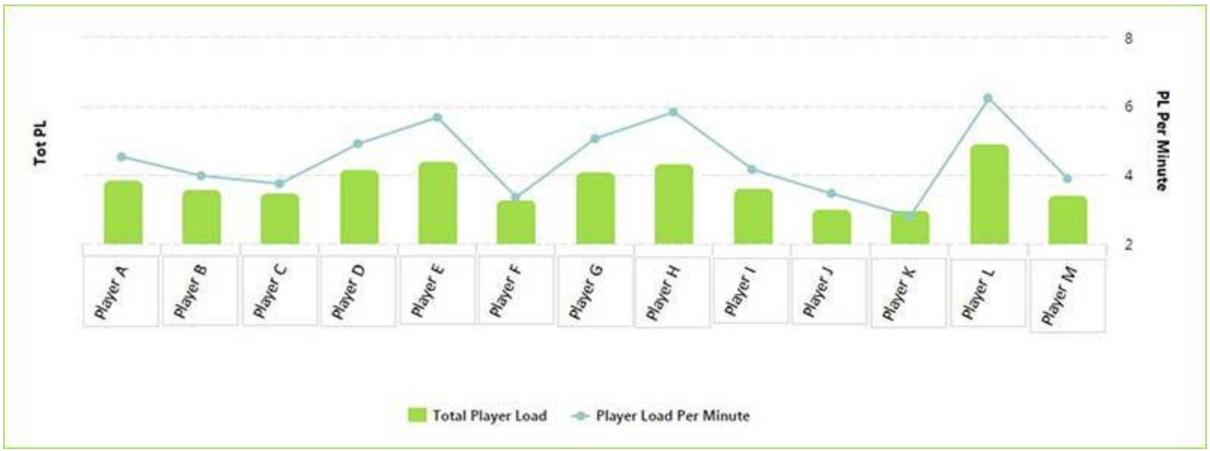

FIGURE 2.13: VIEW OF THE “VOLUME” VS. “INTENSITY” SNAPSHOT OF A SINGLE SESSION

Maximum Velocity and Acceleration

Dwyer *et al.* (2012) report that a sprint lasting only one second can cover up to 4.2 meters, and that sprints lasting two seconds could cover 7 meters. However, these activities would technically not be classified as sprints, because the maximum velocities of these sprints were not greater than the traditional sprint velocity threshold of 5.6m.s^{-1}. Unfortunately, no previous research on movement patterns in golf has been conducted while making use of absolute values for velocity bands. Research published on Australian Football by Farrow *et al.* (2008) organises moderate velocity as 2m.s^{-1} and high velocity as 4m.s^{-1}. Farrow *et al.* (2008) also classify high accelerations as >4m.s^{-2}. In contrast, Aughey (2011) reports an acceleration of 2.78m.s^{-2} to be an appropriate threshold for maximum acceleration of Australian Football players. Golf accelerations and velocities will be much lower due to slower movement of players. Golf does not make use of any form of running or sprinting, nor does it make use of direction changes. Players might be moving faster for longer periods of time due to driving and shot distances. Accuracy of shots may also affect the time spent walking or searching for a ball.

TABLE 2.1: VELOCITY ZONES

Author	*Population*	*Zone 1*		*Zone 2*		*Zone 3*		*Zone 4*		*Zone 5*		*Zone 6*	
		Speed	**Description**	**Speed**	**Description**	**Speed**	**Description**	**Speed**	**Description**	**Speed**	**Description**	**Speed**	**Description**
Coutts et al. (2010)	Australian football players	0 – 0.7 km h^{-1}	Standing	0.7 - 7 km h^{-1}	Walking	7 – 14.4 km h^{-1}	Jogging	14.4 - 20 km h^{-1}	Running	20 - 23 km h^{-1}	Higher-speed running		
Aughey et al. (2010)	Australian football players	0.1 – 4.17 $m.s^{-1}$	Low-intensity									4.17 - 10 $m.s^{-1}$	High-intensity
Jennings et al. (2012)	Elite male hockey players	0.1 – 4.17 $m.s^{-1}$	Low-speed									>4.17 $m.s^{-1}$	High-speed
Farrow et al. (2008)	Australian football players	2 $m.s^{-1}$	Moderate velocity									4$m.s^{-1}$	High velocity
Johnston et al. (2013)	Sub-elite male rugby league players	0 – 4.72 $m.s^{-1}$	Low-speed									>4.75 $m.s^{-1}$	High-speed

Suarez – Arrones et al. (2012)	Rugby union	0.03 – 1.64 $m.s^{-1}$	Standing and walking	1.66 – 3.31 $m.s^{-1}$	Jogging	3.33 – 3.86 $m.s^{-1}$	Cruising	3.86 – 4.98 $m.s^{-1}$	Striding	5 – 5.53 $m.s^{-1}$	High intensity	>5.56 $m.s^{-1}$	Sprinting
Macutkiewicz et al. (2011)	Elite female hockey players	0 – 0.17 $m.s^{-1}$	Standing	0.19 – 1.67 $m.s^{-1}$	Walking	1.69 – 3.06 $m.s^{-1}$	Jogging	3.08 – 4.17 $m.s^{-1}$	Running	4.19 – 5.28 $m.s^{-1}$	Fast running	>5.28 $m.s^{-1}$	Sprinting
Carling et al. (2012)	Elite soccer players	<0.17 $m.s^{-1}$		1.94 – 1.97 $m.s^{-1}$		4 – 5.47 $m.s^{-1}$		>5.5 $m.s^{-1}$					
Clarke et al. (2015)	Female rugby union	<2 $m.s^{-1}$	Low-intensity	>3.5 $m.s^{-1}$	Moderate intensity					>5 $m.s^{-1}$	High-intensity		
Dwyer et al. (2012)	Male soccer	0 – 0.1 $m.s^{-1}$	Standing	0.2 - 2 $m.s^{-1}$	Walking	2.1 – 3.7 $m.s^{-1}$	Jogging	3.8 - 6 $m.s^{-1}$	Running	6.1 $m.s^{-1}$	Sprinting		
Dwyer et al. (2012)	Female soccer	0 – 0.1 $m.s^{-1}$	Standing	0.2 – 1.6 $m.s^{-1}$	Walking	1.7 – 3.3 $m.s^{-1}$	Jogging	3.4 – 5.3 $m.s^{-1}$	Running	5.4 $m.s^{-1}$	Sprinting		
Dwyer et al. (2012)	Male hockey	0 – 0.1 $m.s^{-1}$	Standing	0.2 – 1.7 $m.s^{-1}$	Walking	1.8 – 3.2 $m.s^{-1}$	Jogging	3.3 – 5.6 $m.s^{-1}$	Running	5.7 $m.s^{-1}$	Sprinting		

Dwyer et al. (2012)	Female hockey	0 – 0.1 $m.s^{-1}$	Standing	0.23 – 1.7 $m.s^{-1}$	Walking	1.8 – 3.6 $m.s^{-1}$	Jogging	3.7 – 5.3 $m.s^{-1}$	Running	5.4 $m.s^{-1}$	Sprinting
Dwyer et al. (2012)	Australian football	0 – 0.1 $m.s^{-1}$	Standing	0.2 – 2.4 $m.s^{-1}$	Walking	2.5 – 3.5 $m.s^{-1}$	Jogging	3.6 – 5.6 $m.s^{-1}$	Running	5.7 $m.s^{-1}$	Sprinting

2.15 DIFFERENCES BETWEEN LEVELS OF PLAY

Between the various levels found in golf, namely beginner-, amateur-, and professional golf players, a difference in club use choice, swing technique, and conditioning can be observed. Highly skilled golfers tend to have different physical characteristics than less proficient golfers (Sell *et al.*, 2007). How many errors players make also vary depending on the different levels. The differences found between these levels are greatest between the beginner and the amateur, compared to the difference between the amateur and the professional, especially when it comes to the choice regarding which club to use for a certain shot. Overall muscle activity when using a 5 iron reaches 90% of maximal voluntary contraction (MVC) for amateurs and 80% for professionals (Hosea *et al.*, 1990).

When one studies equipment choices between these levels, it becomes evident that beginners use bigger clubs; in other words, clubs are thicker because the sweet spot on the club is bigger, and the shaft is less rigid compared to that of clubs used by amateurs and professionals. Tucker *et al.* (2013) found that a group of highly skilled golfers maintain consistency of ball speed despite variability in movement of individual body segments during the swing. Amateurs and professionals use more or less the same - the only difference is when they choose a shaft that is stiffer or extra stiff. This is determined by technique and experience, as certain clubs are customised for professional golf players according to individual swing technique, taking into consideration their height as well as how far they tend to hit the ball. It would be more difficult for a beginner to play with a professional player's clubs, as the same technique would make the shot played very inaccurate. Grouping a golfer based on handicap intuitively makes the most sense – skilled golfers have more consistent swing kinematics than unskilled golfers, and therefore any changes post-intervention are more likely to be a result of the intervention rather than due to measurement error (Evans & Tuttle, 2014).

As far as various golf clubs are concerned, beginner golfers tend to use graphite shafts instead of steel shafts, as the more serious amateur or professional golf player would. This is due to the higher durability of steel shafts as compared to graphite over time, especially if daily play occurs. Steel shafts also cost more than graphite shafts, which may account for beginner golfers making use of less expensive equipment.

When it comes to chipping on the green, beginner golfers more frequently use sand- or pitching wedges, whereas professional golfers use a lob wedge instead. The lob wedge has as higher degree compared to the other two, and ideal to use especially if you the ball needs to travel over a hazardous area. Beginner golf players also make use of the club tees, which are shorter in distance. Professional and more serious amateur golf players make use of the championship tees, which are also the furthest in distance and take longer to complete.

As far as the technique of these golf players is concerned, there are clear differences as to what exactly distinguishes a professional golf player from an amateur golf player (GoGolf, 2017). Both the amateur and the professional golf payer play for the love of the game. It is regarded as a full-time job for the professional golf player compared to the beginner, who mainly accepts it as a social or leisurely event. The amateur golf player's viewpoint would be more similar to that of the professional golf payer, except for the fact that amateur golf players are not allowed to gain any money from playing in tournaments and are also allowed to compete in amateur events only. Professional golf players also have professional instructors or coaches that assist them during their training sessions on the golf course. For the amateur golf player that wants to make a living out of golf, training sessions under the guidance of a professional coach are necessary and something that most already participate in. The beginner golf player would not necessarily take up any coaching lessons, golf is played for recreational purposes only.

Professional golf players rarely make use of the driving range when training; sometimes, more serious amateur golf players also prefer not to make use of the driving range so much compared to the beginner golf player. The more serious amateur golf player as well as the professional focus far more on rounding off instead of hitting the ball over a great distance. Consequently, a major difference between the swing styles of these various golf players is observed. The biggest difference noted between a beginner golf player's swing style and that of a professional and serious amateur is in the downswing (GoGolf, 2017). This is because the professional golf player chooses to hit the ball from the inside of the target line to give the club a greater speed at impact, whereas the beginner golf player hits the ball from the outside of the target line, in effect forcing them to pull the club across their body to play the shot.

GoGolf (2017) further states that this way would result in less accuracy as well as decreased speed of the club head. Amateur golf players also do not perform a full shoulder rotation during the backswing, causing the left arm in a right handed golf player to be bent during the backswing, forcing a shot that is less accurate and controllable in the downswing. Professional golf players keep the left arm in a straight position, which affords a more powerful shot.

The conditioning differences between these various levels of golf players are also clear. Beginner golf players not in training for a specific golf tournament and playing for recreational purposes do not seek extra assistance in terms of conditioning as a more serious amateur or professional would. Golf players such as Tiger Woods and Annika Sorenstam were able to reach their respective number one world ranking spots due to certain factors such as the inclusion of flexibility, balance, physical conditioning, biomechanical corrections, strength, power, core stability, and cardiovascular fitness into their respective training programmes (Wells *et al.,* 2009). This changed the sport of golf and has set challenges for all professionals and amateurs coming through the ranks.

Golf has become very competitive over the past few years with the new generation of golf players setting a high boundary for the youngsters wanting to turn their golf into a career. Conditioning is one way to improve golf, and, along with coaching lessons, will count in the player’s favour and possibly aid in faster technique improvement.

2.16 ENVIRONMENTAL FACTORS

During a golf tournament or even training, certain environmental factors may influence the way of play as well as the outcome after playing a shot. Sometimes the effect of the environment plays a much greater role in the end result of a golf tournament than one might think.

Golf players choose to play with different irons depending on the conditions. A 7 iron, for instance, plays the ball further compared to an 8 iron. This is because each iron has a certain degree. A 9 iron is 45 degrees whereas the 8 iron is 42 degrees. In golf terms, this means that, for more humid conditions where the ball does not travel that far, players will choose to play with one club or iron more, as a 7 iron, for example, allows the ball to travel further than an 8 iron. A few of these environmental factors are discussed below.

2.16.1 Altitude

Playing at a higher altitude will allow the golf player to hit the ball further compared to playing at a lower altitude. This in effect changes the way the player might decide to play the shot differently at sea level as well as inland. The ball travels a distance around 10% shorter when playing at sea level compared to when you playing inland. In Johannesburg, for instance, the ball will travel 10 -15% further than at the coast. When the altitude is really high, the player might end up playing with an iron with a higher number. The golf ball flies further at high altitudes mainly due to the change in air density, which decreases as elevation increases (Aoyama, [N.D.]). Thinner air exerts less drag force on the ball. Bahill *et al.* (2009) report that altitude and weather affect air density, which in turn affects how far a batted baseball or softball travels. The ball moves more easily through the air and does not slow down as quickly as it flies, resulting in greater distance. The force of gravity also decreases the further one moves away from the earth's centre, but the change in force is too small to have any significant effect on the ball (Aoyama, [N.D.]).

2.16.2 Windy Conditions

Among all the environmental factors that affect the accuracy of golf shots, wind is perhaps the most important. The direction and strength of the wind alters the aerodynamic forces exerted on a ball in flight, and consequently on its speed, distance, and direction of travel (Yaghoobian & Mittal, 2018). To play in strong wind conditions is not always favourable, and it may affect players emotionally and/or mentally. Besides for the mental effect, windy conditions also changes the gameplay. When the golf player has to play a shot against the wind they would normally, depending on how strong the wind blows, choose to play with 1 iron higher or even 2 irons higher. The same counts for playing a shot with the wind from behind or from the side. The golf player would in such conditions choose to aim more or less 20m more to the left or right. The whole style of play constantly changes as the wind conditions changes. Any such analysis is complicated by the effect of the local terrestrial and vegetation topology, as well as the inherent complexity of golf ball aerodynamics. In addition to the scientific challenge inherent in predicting this wind-induced variability on golf shots, any tools that can be developed to predict this variability could serve as an aid to competitive golfers, and could enrich the discussion and technical analysis of golf (Yaghoobian & Mittal, 2018).

2.16.3 Rainy Conditions

In rainy conditions, humidity is higher than normal, which in turn causes the golf player to automatically play with 1 iron higher than usual, due to the fact that the ball does not travel as far in humid conditions. Couceiro *et al.* (2013) report that players are faced with multiple possible ball trajectories, slopes, and changing weather conditions (sun, rain, wind, and snow).

2.16.4 Course Layout

Cutten (2016) reports that there is a lack of research that examines the influence golf course architecture has had on the evolution, and current state, of the game of golf. The layout can at times be physically demanding for the golf player in terms of the distance of the whole course that the golf player has to walk or the elevation of the course. From initial research it is clear that the typical golf course is constructed within an ordered set of design principles, like most competitive sporting landscapes. Certainly, football fields and golf courses are on opposite sides of the spectrum with regard to the regularity of their makeup and dimensions (Yoder, 2015). This plays a significant role in the performance outcome of the golf player.

When the course is very hilly, the player may fatigue quicker, causing the concentration levels as well as the technique of the player to decrease.

CHAPTER 3: METHODOLOGY

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

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3.1 Introduction

3.2 Study Participants

3.2.1 Inclusion Criteria

3.2.2 Exclusion Criteria

3.2.3 Withdrawal of Study Participants

3.3 Data Collection

3.4 Global Positioning System

3.5 Reliability of the Catapult Minimax X S4 Accelerometer

3.6 Pilot Study

3.7 Analysis

3.8 Implementation of Findings

3.9 Ethical Aspects

3.10 Referencing

3.11 Time Schedule

3.12. Budget

3.1 INTRODUCTION

This chapter on methodology will provide information with regards to the study design and study participants – a section in which the inclusion criteria, exclusion criteria, as well as the withdrawal of study participants will be explained in more detail. This will be followed by an overview of the data collection process, reliability of the Catapult Minimax X S4, analysis of the findings, implementation of findings, as well as the ethical aspects, time schedule, and budget are explained. Electronic databases such as EbscoHost, Kovsiekat, and Pubmed were used to gather the information for the literature.

The study design is a quantitative cross-sectional study where the researches gathers information to describe the physical fitness components necessary in amateur golf players.

3.2 STUDY PARTICIPANTS

This study used a non-random convenience sample. Permission was obtained from the Free State Golf Federation (FSGF) to make contact with 20 male provincial golf players from the Free State to take part in this research study (Appendix B2). The study participants involved in this research study were male amateur golf players who represent the Free State Province in an average of four to five golf tournaments annually over a period of three to four months around the country. The golf players are all part of the Free State Golf Academy and therefore also receive their conditioning at the Free State Sport Science Institute. The sport scientist (also the researcher) responsible for the conditioning of these golf players contacted the players directly with regard to possible participation in this research study after ethical approval from the Health Sciences Research Ethics committee of the University of the Free State was received and permission from the Free State Golf Federation was granted. The golf players are all based in the Bloemfontein area.

3.2.1 Inclusion Criteria

Study participants had to adhere to the following criteria to be included in the study:

1) The participant must be male;
2) The participant must, at the very least, represent the Free State Province in golf tournaments that consists of an average of four to five tournaments over a period of three to four months;
3) The participant must be free of any injuries before the start of the test protocol and should therefore be medically fit to participate in this research study;
4) The participant must give consent in English to participate in this study; and
5) If the participants are under the age of 18 years, the parent(s)/guardian(s) of the particular athlete must give permission/sign the consent form on behalf of the participant to participate in this research study, and minor participants must sign the assent form.

3.2.2 Exclusion Criteria

Participants were excluded from the research study if they did not meet the criteria as outlined above.

3.2.3 Withdrawal of Study Participants

The study participants were allowed to withdraw from this research study in the following instances:

1) Should a participant sustain an injury;
2) Should the participant became ill and therefore be unable to participate further during the study;
3) Should a participant decide to withdraw from the study.

3.3 DATA COLLECTION

The golf players involved in this study all train at the Free State Sport Science Institute. The sport scientist responsible for these golf players at the Free State Sport Science Institute is the researcher self; therefore, direct contact with participants regarding participation in this research study was imminently possible. The procedures followed in order to conduct this research study and to obtain the necessary information and the measurements of physical fitness components related to golf are outlined below.

Once ethical approval was received, 12 male provincial golf players were contacted and invited to participate in the study. Once consent was obtained from the players themselves or their parent(s)/guardian(s), in the case where the player might be under age, the execution of the protocol began. GPS data on a total of twelve (12) amateur golf players were collected and a total of forty rounds of golf (18 holes) were analysed for the study. Therefore, a total of forty (40) GPS data sets (player rounds) were analysed (equivalent to 720 holes). The research study was conducted at the Bloemfontein Golf club. The study participants needed to arrive at the course where assessment would take place at least 30 minutes before play so that the procedure of the day's assessment could be explained, and to ensure that participants understood the procedures and what was expected from them during the test. Figure 3.1. represents the data collection process.

The following variables were measured through the means of a GPS system called the Catapult Sport System:

1) The distance travelled by the golf player on the golf course during 18 holes of play;
2) The individual duration of play over 18 holes;
3) Heart rate response;
4) The total player load;
5) The player load per minute;
6) The player load per kilometre;
7) The meterage per minute;
8) The player load 1D side;
9) The maximum velocity;

10) The acceleration Band 4: total effort count;
11) The acceleration Band 5: total effort count;
12) The acceleration Band 4: distance; and
13) The acceleration Band 5: distance.

The study participants had to complete 18 holes of golf like they would during a normal golf tournament. This was called a straight medal to raise the motivational level of the golf player. Each player was assigned a number that corresponds to the catapult sensor and heart rate monitor to ensure anonymity of the player once the data was retrieved. No names were used to identify players or data. The golf players were asked to wear the catapult vest underneath the golf shirt. The tester made sure that the heart rate belt was comfortable and that the catapult sensor was placed in the pocket behind the back in the vest, and that it was switched on and ready for use. When the athlete felt comfortable and everything was set up and ready for use the participant was allowed to start his 18 holes. The catapult system and heart rate monitor provided data with regards to the 12 different variables listed above.

Six rounds were recorded for players handicap <0 (1-12 handicap), 21 rounds were recorded for handicap =0 (scratch) and 13 rounds for handicap >0 (plus handicap). A greater number of rounds were recorded for players handicapped =0 and >0 as they will be more likely to be included in provincial teams as these are the more exceptional players. Players were categorized into three groups according to their handicap, namely handicap <0 (1-12 handicap – average golf player), handicap =0 (scratch - good golf player), and handicap >0 (plus handicap - exceptional golf player).

The golf player was allowed to remove the heart rate monitor and catapult system after completion of the 18 holes. From the 12 (n=12) participants, nine (n=9) played 3 rounds each, two (n=2) players played 4 rounds each, with 1 (n=1) player having played 5 rounds. Data were collected with at least 18 -24 hours recovery between rounds, as some competition in golf is played over 4 days. The tester was with the golf player at all times to ensure that equipment stayed intact during the assessment of the golf player. Test data were saved and analysed afterwards to determine the necessary components when composing a physical profile for the golf players to further enhance the sport performance of those golf players. Each player was evaluated over two to three rounds of golf.

The Catapult unit includes a tri-axial accelerometer with extremely responsive motion sensors used to measure the frequency and magnitude of movement in three dimensions, namely anterior-posterior, mediolateral, and longitudinal (Krasnoff *et al.,* 2008). The Minimax X S4 units measures accelerations in the frontal-, sagittal-, and transverse axes of movement to determine a variable called player load (Gabbett., 2012) and has been proven highly reliable with a coefficient of variation of <2% (Boyd *et al.,* 2011). Chandler *et al.* (2014) used two variations of player load (PL) to determine physical demands, namely total PL and PL in each axis (frontal, sagittal, and transverse). All measurements were normalised for playing time (minutes: seconds) and reported as arbitrary units Load$^{TM}\cdot$min^{-1}(au). The current study used the same method to calculate PL.

The GPS units were housed in custom made harnesses that prevented unwanted movement and held units in place in the middle of the upper back, therefore limiting any potential hindrance on performance. Participants received the accelerometer as well as the harness, which hosted the accelerometer prior to warm up. Accelerometer data recording only commenced at the beginning of the tournament and would end immediately after the final hole was played. Thereafter, the accelerometer data (Load$^{TM}\cdot$min^{-1}(au)) from individual-medio-lateral, Y - anterior/posterior - and Z - vertical vectors - were downloaded after the 18 holes of play using manufacturer specific software (Openfield) and divided by playing time to calculate PL (Load$^{TM}\cdot$min^{-1}(au)). According to Cormack *et al.* (2013), Load$^{TM}\cdot$min^{-1}(au) has demonstrated high levels of validity and reliability in team sport specific movements (coefficient of variation [*CV*] = 1.9%).

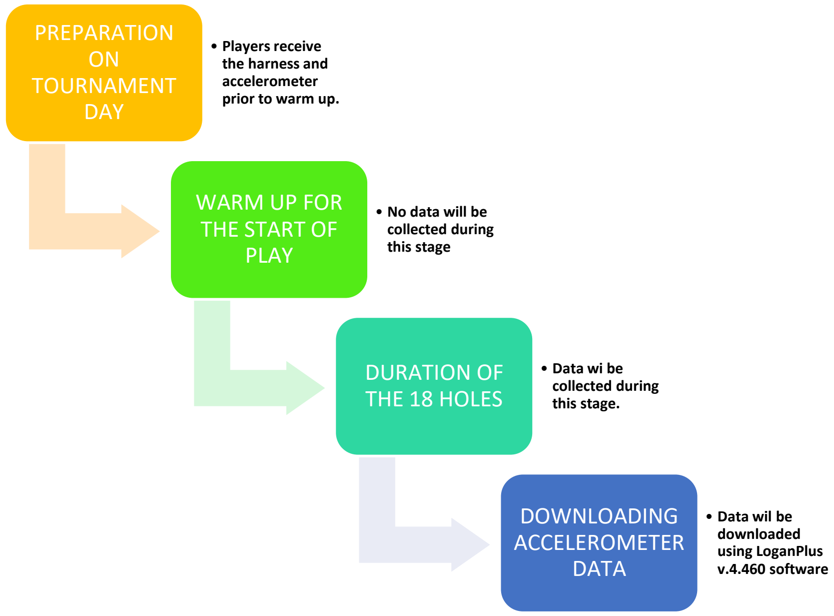

FIGURE 3.1: SCHEMATIC REPRESENTATION OF THE DATA COLLECTION PROCESS

3.4 GLOBAL POSITIONING SYSTEM

Using the results from Letham (2001) research, it is outlined that the global positioning system is a configuration of about 24 satellites orbiting the earth in different orbital paths. A satellite orbits the earth at least once every 12 hours; thus it is able to track the location, velocity, as well as time of all GPS receivers on earth while in orbit (Mcnamee, 2005). Mcnamee (2005) shows that this is possible through a method known as triangulation as well as through precise timing. Furthermore, by using triangulation, satellites can track any location possible when the distance of three other positions are known (Mcnamee, 2005). Using research from StarCaddy.com, modern GPS systems are so advanced that they can be implemented for most outdoor activities. Certain GPS systems are able to show one’s exact position on the golf course as well as the layout of every hole (Mcnamee, 2005).

3.5 RELIABILITY OF THE CATAPULT MINIMAX X S4 ACCELEROMETER

Accelerometers have been reported to have good reliability in the measurement of biomechanical load. The reliability of the Minimax X S4 accelerometer proves to be acceptable both within and between devices under controlled laboratory conditions, and between devices during field testing. Furthermore, it can confidently be utilised as a reliable tool to measure physical activity in team sports across multiple players and repeated bouts of activity (Boyd *et al.,* 2011). Various team sports, including Australian football (Coutts *et al.,* 2010), rugby codes (Deutsch *et al.,* 1998), and hockey (Johnston *et al.,* 2004) have used various methods to determine the physical demands placed on athletes during training or competition. Methods for measuring physical demands include heart rate monitoring, time motion analysis through video analysis, and GPS monitoring. The shortcoming with these methods is that the validity of heart rate monitoring is questionable when activity is intermittent and at high intensity (Terbiza *et al.,* 2002) such as during netball. Video analysis is time consuming and one can only monitor one athlete at a time. Moreover, this method is also prone to human error and cannot be done in real time (Edgecomb *et al.,* 2006). Jennings *et al.* (2010) further state that Global Positioning System (GPS) time motion analysis presents some issues and report poor reliability and validity (coefficient of variation [*CV*] ≤ 34%) in measuring distance, especially at high speeds over short distances.

On the other hand, tri-axial accelerometers measure movement in the anterior-, posterior-, mediolateral-, and longitudinal dimensions (Krassnoff *et al.,* 2008). Johnston *et al.* (2012) agree with Jennings *et al.* (2010) and Coutts *et al.* (2010) that validity and interunit reliability of 1 Hz and 5 Hz GPS units decreases when measuring small distances and sharp changes in direction at high speeds. However, Johnston *et al.* (2014) report that 10Hz and 15Hz GPS units are valid and reliable measuring instruments for gauging total distance covered and are more reliable measures of movement demands than 1Hz and 5Hz GPS units. Dispite a tendency to overestimate total distance covered, the 10Hz GPS units provide a valid measure of total distance covered (<1% error). Therefore, this study will use the Catapult Minimax x S4 10Hz GPS unit to collect movement data throughout 18 holes of tournament golf.

3.6 PILOT STUDY

A pilot study can, firstly, be described as a trial run used by the researcher before the actual research investigation is implemented in order to determine any flaws in the measuring procedure. Secondly, the pilot study identifies unclear or ambiguously formulated items, and thirdly provides the opportunity for researchers and assistants to notice non-verbal behaviour on the part of the participants (De Vos *et al.,* 2005). This study drew on two rounds of 18 holes played by two golf academy members at the Bloemfontein Golf Club as the pilot study. The pilot study helped to identify any possible problems in the proposed method of conducting the study. The researcher collected the data and downloaded it to a personal computer using GPS software where data analysis was performed from the two rounds of golf played. Data from the pilot study were not included in the final dataset.

3.7 ANALYSIS

The data gathered from using the Catapult Minimax X S4 were used to determine the physical demands placed on the golf player during the 18 holes of play by paying attention to certain aspects included in a physical demands profile for golf players. These demands include variables such as:

1) The distance travelled on the golf course during 18 holes of play;
2) The duration of play over 18 holes by each player;
3) The heart rate over 18 holes of play;
4) The total player load;
5) The player load per minute;
6) The player load per kilometre;
7) The meterage per minute;
8) The player load 1D side;
9) The maximum velocity;
10) The acceleration Band 4 total effort count;
11) The acceleration Band 5 total effort count;
12) Acceleration band 4 distance; and
13) Acceleration band 5 distance.

Players were categorised into three groups according to their handicap, namely handicap <0 (1-12 handicap), handicap =0 (scratch), and handicap >0 (plus handicap). The handicap categories were compared with respect to selected activity variables using a linear mixed model with handicap category (three levels) as fixed effect, and player as random effect. Fitting player as random effect accommodated potential correlation of the data collected from the same player. Based on this linear mixed model, the mean values (of the activity variable) for each handicap category were estimated, together with standard errors. Furthermore, the pairwise mean differences between handicap categories were estimated, together with 95% confidence intervals (CIs) for the mean differences and P values associated with the null hypothesis of zero mean difference between the pair of handicap categories in question. All data was statistically analysed by a bio-statistician from the University of the Free State's Consultation Unit. All statistical analyses were performed using the SAS software package (SAS, 2013).

3.8 IMPLEMENTATION OF FINDINGS

The results will be used to draw conclusions regarding the physical demands placed on amateur male golf players. The value of this study is twofold. Firstly, the research information will be used to compile a physical demands profile for amateur male golf players in South Africa. Secondly, this research study will enable the researcher to give detailed feedback about the conditioning of amateur golf players so that there will be a better understanding with regards to the conditioning of this type of athlete to help enhance the sport performance of golf players. This research study will provide the athlete with valuable information about his own strengths and weaknesses with regards to certain physical demands involved in golf. Moreover, this will also be of value to golf coaches and fitness professionals, helping these individuals to develop a proper conditioning programme to enhance the athlete's performance in golf.

3.9 ETHICAL ASPECTS

Each study participant had to sign the informed consent form from the University of the Free State before the study was undertaken, wherein the specifications of the research study were outlined (Appendix A2). In the case of minors, parents or legal guardians had to give consent and assent from such minors in order to participate in the study (Appendix C). The informed consent form included matters such as the purpose of the research study, procedures to be followed on the day of assessment, the time commitments expected from the players, possible risks and benefits involved with participating in this research study, statements with regards to the participants' privacy and confidentiality during the research study, and that participation during this research study is voluntary - participants may choose to withdraw from the study at any given time during the study (Appendix A2).

GPS data on a total of twelve (12) amateur golf players were collected and a total of forty rounds of golf (18 holes) were analysed for the study. Therefore, a total of forty (40) GPS data sets (player rounds) were analysed (equivalent to 720 holes). No participant was allowed to take part in this study without the reading and signing of the information sheet (Appendix A1) as well as the reading and signing of the informed consent form (Appendix A2). Basic elements of informed consent will include the following:

- A fair explanation of the procedures to be followed;
- A description of the value and benefits of their participation;
- An offer to answer any enquiries concerning the processes;
- An indication that the participant is free to withdraw consent and to discontinue participation on the project or activity at any time;
- The rights of the participant will be considered by the researcher;
- The right to privacy or non-participation;
- The right to remain anonymous;
- The right to confidentiality; and
- The right to expect experimenter responsibility.

It was made clear to all participants that they would not receive any financial compensation for their contribution in the study. However, all participants received feedback after every match played regarding their own performance during the match.

Any information obtained in connection to this study that could be linked to a specific study participant remained confidential and was disclosed only with the study participant's permission or as required by law. Confidentiality was maintained by means of allocating numbers to each golf player. Information was kept with the investigator only and raw data held under lock and key. All processing of data was governed by a personal computer password protector. Only the findings will be published with the strictest of confidentiality to the individual athletes.

Written permission to conduct the research study was obtained from the following professional bodies: The Health Sciences Research Ethics committee (Appendix D) of the University of the Free State, Free State Golf Federation (see Appendix B2), the participating coach (Appendix B1), and the Department of Exercise and Sport Sciences at the University of the Free State

3.10 REFERENCING

The figure below illustrates the referencing method that has been used throughout this text.

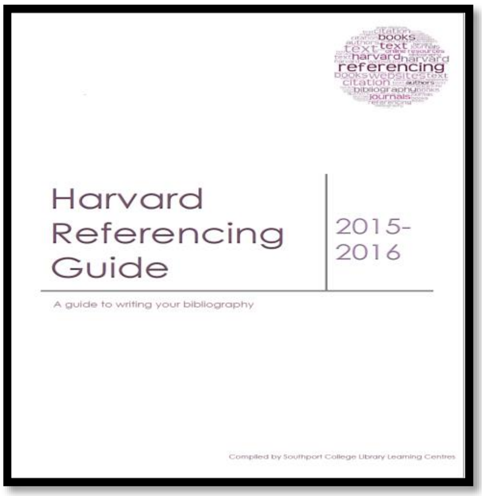

FIGURE 3.2: REPRESENTATION OF THE REFERENCING METHOD USED THROUGHOUT THIS TEXT

3.11 TIME SCHEDULE

The following time schedule was followed for the study.

TABLE 3.1: TIME SCHEDULE

Literature review	**November 2016 - January 2017**
Writing of the protocol	January - February 2017
Evaluation committee	March 2017
Seeking ethical approval	June 2017
Data collection	September - November 2017
Data analysis	February - March 2018
Writing up	March - September2018
Handing in of the dissertation	November 2018
Writing of articles	December 2018
Presenting the results	December 2018

3.12 BUDGET

The following budget represents the costs for the study.

TABLE 3.2: BUDGET

ITEM	MOTIVATION	COST
Administration fees (printing, stationary, paper)	Printing of data forms, printing of protocol and final dissertation, buying of paper and stationary that will be used for collecting the data and presenting the results	R 1000.00
Telephone cost	Contacting the participants, and coaches (R1.20 per minute)	R250.00
Travelling costs (petrol, wear and tear)	R3.15 per km and petrol cost for traveling to all the matches played during the time of testing.	R2000.00
Accommodation		R0.00
Language editing		R10 000.00
Internet costs		R1000.00
Binding of protocol and thesis		R1500.00
Total		**R15 750.00**

The researcher was responsible for all costs.

CHAPTER 4: RESULTS

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

4.1 INTRODUCTION

The aim of this study was to determine the physical demands placed on golf players during tournaments played. Twelve male golf players were tested over 40 rounds of golf played. Table 4.1.illustrates the mean values of the player load, the velocity, and the acceleration of golf players for the different handicaps (below zero, scratch, and above zero).

4.2 MEAN VALUES FOR DIFFERENT ACTIVITY VARIABLES

Beneath the player load, the velocity and the acceleration for the different variables are given.

4.2.1 Player Load

For player load, the following activity variables were listed as important components to be measured for golf performance:

- Total duration (hours);
- Total distance (kilometres);
- Heart rate;
- Total player load;
- Player load per minute;
- Player load per kilometre

TABLE 4.1: TABLE 4.1: DESCRIPTIVE STATISTICS FOR MEAN VALUES OF PLAYER LOAD (GOLF PLAYERS WITH ALL HANDICAPS)

		Handicap		
		<0	0	>0
Player load				
Total Duration (H)		4.32	4.71	4.88
Total Distance (Km)		10.82	10.51	10.42
Heart rate (Bpm)	Mean	118.5	113.7	123.1
Total Player Load		606.67	583.56	587.05
Player Load Per Minute	Mean	2.40	2.09	2.02
Player Load Per km		56.39	55.61	56.32
Meterage Per Minute		42.52	37.55	35.89

Table 4.1 illustrates that the mean value for the player with the handicap below zero has the lowest playing duration (<0: = 4.32 hours) in relation to the player with the handicap equal to zero (=0: = 4.71 hours), followed by the player with the handicap above zero (>0: = 4.88 hours). The total distance covered was the furthest by the player with the handicap below zero (<0: = 10.82km) compared to the player with the handicap equal to zero (=0: = 10.52km). The player with the handicap above zero (>0: = 10.42km) covered the least amount of distance over a round of 18 holes of golf played. The mean heart rate values for the player with the handicap above zero (>0: = 123.1) is the highest for all handicaps. The lowest mean heart rate was measured for the handicap below zero (<0: = 113.7).

Total player load was the highest for the player with the handicap below zero (<0: = 606.67) followed by the player with the handicap above zero (>0: = 587.05) and the player with the handicap equal to zero (=0: = 583.56), the lowest over 18 holes of golf played. It also shows that the player with the handicap above zero (>0: = 2.02) has the lowest value for the player load per minute, where the player with the handicap equal to zero (=0: = 2.09) exhibits a higher value than the handicap above zero, and the player with the handicap below zero (<0: 2.40) had the highest player load per minute.

Player load per kilometre was the most for the player with a handicap below zero (<0: = 56.32) followed by the player with the handicap above zero (>0: = 55.61), while the zero handicap player displayed the lowest value for player load per kilometre. The player with the handicap below zero (<0: = 42.52) covered the furthest distance per minute than the player with the handicap equal to zero (=0: = 37.55) followed by the player with the handicap above zero (>0: = 35.89), which was the least over 18 holes played.

4.2.2 Velocity

Maximum velocity (m/s), shown beneath velocity in the table below, was found to be an integral component in optimal golfing performance.

TABLE 4.2: DESCRIPTIVE STATISTICS FOR THE MEAN VALUES OF THE VELOCITY FOR THE GOLF PLAYERS WITH ALL HANDICAPS

		Handicap		
		<0	0	>0
Velocity				
Maximum Velocity (m/s)	Mean	3.24	2.87	2.73

Table 4.2 shows that the player with the handicap below zero (<0: = 3.24) had the highest maximum velocity compared to the player with the handicap equal to zero (=0: = 2.87), followed by the player with the handicap above zero (>0: = 2.73), who had the lowest maximum velocity score.

4.2.3 Acceleration

The following activity variables are listed as important components related to acceleration for optimised performance in golf:

- Acceleration band 4: total effort count;
- Acceleration band 5: total effort count;
- Acceleration band 4: distance percentage; and
- Acceleration band 5: distance percentage.

TABLE 4.3: DESCRIPTIVE STATISTICS FOR THE MEAN VALUES OF THE ACCELERATION FOR THE GOLF PLAYERS WITH ALL HANDICAPS

		Handicap		
		<0	0	>0
Acceleration				
Acceleration Band 4 Total Effort Count		4837.25	4997.00	4979.74
Acceleration Band 5 Total Effort Count		6298.37	6508.17	6266.42
Acceleration Band 4 Distance pct	Mean	45.92	45.99	45.54
Acceleration Band 5 Distance pct		54.06	53.96	54.44

The total effort count for acceleration band 4 was the highest for the player with the handicap equal to zero (=0: = 4997.00). The player with the handicap above zero (>0: = 4979.74) had the second highest value, followed by the player with the handicap below zero (<0: = 4837.25) with the lowest value. According to table 4.3, total effort count for acceleration band 5 was again the highest for the player with the handicap equal to zero (=0: = 6508.17). The second highest rating was for the player with the handicap below zero (<0: = 6298.37) with the player with the handicap above zero (>0: = 6266.42) exhibiting the lowest rating.

The rating for the distance of acceleration band 4 was highest for the player with the handicap equal to zero (=0: = 45.99). Just below that the player with the handicap below zero (<0: = 45.92) had the second highest rating and the player with the handicap above zero (>0: = 45.54) had the lowest rating.

The distance for acceleration band 5 was highest for the player with the handicap above zero (>0: = 54.44).The second highest was for the player with the handicap below zero (<0: = 54.06) and the lowest for the player with the handicap equal to zero (=0: = 53.96).

4.3 COMPARISON OF DIFFERENT HANDICAPS

4.3.1 Total Duration

TABLE 4.4: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO TOTAL DURATION

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Total duration [h]	**<0**	4.32 (0.19)	**Mean difference**	-0.39	-0.56	-0.17
	=0	4.71 (0.10)	**95% CI**	-0.83 to 0.05	-1.03 to -0.10	-0.51 to 0.16
	>0	4.88 (0.13)	**P-value**	0.0796	0.0194	0.2986

The table above represents the comparison of the different handicap categories for the various activity variables. For the handicap category below zero versus equal to zero (<0 versus = 0) the mean difference was -0.39, where the values for the 95% Confidence Interval as well as the P value were -0.83 to 0.05 and 0.0796 respectively.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was -0.56. The P value was 0.0194 that indicated a significant difference between the two handicaps.

In the handicap category of equal to zero versus above zero (=0 versus >0) the value was -0.17 for the mean difference. The P value read 0.2986 that indicated no significance.

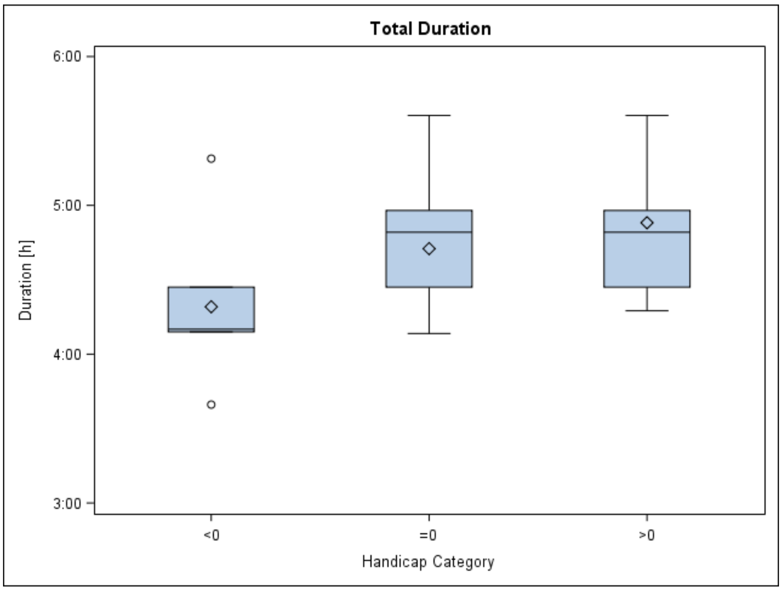

FIGURE 4.1: BOX PLOT - TOTAL DURATION OF DIFFERENT HANDICAPS

The box plot in Figure 4.1 indicates that the below zero handicap golf players have a shorter playing duration than other handicaps, as the upper quartile of duration is equal to or lower than the lower quartile in all other handicaps. The IQR of handicaps equal to zero and greater than zero overlap and suggests no significant difference.

4.3.2 Total Distance

TABLE 4.5: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO TOTAL DISTANCE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Total distance [km]	**<0**	10.82 (0.51)	**Mean difference**	0.31	0.40	0.09
	=0	10.51 (0.29)	**95% CI**	-1.00 to 1.62	-0.98 to 1.78	-0.93 to 1.12
	>0	10.42 (0.35)	**P value**	0.6087	0.5298	0.8414

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 0.31 and showed no significant difference ($p = 0.6087$).

The mean difference between the handicap categories of below zero versus above zero (<0 versus >0) were 1.78 and also showed no significant difference (p = 0.5298).

In the handicap category of the equal to zero versus above zero (=0 versus >0) the value was 0.09 for the mean difference. The P value read 0.8414 that recorded no significant difference.

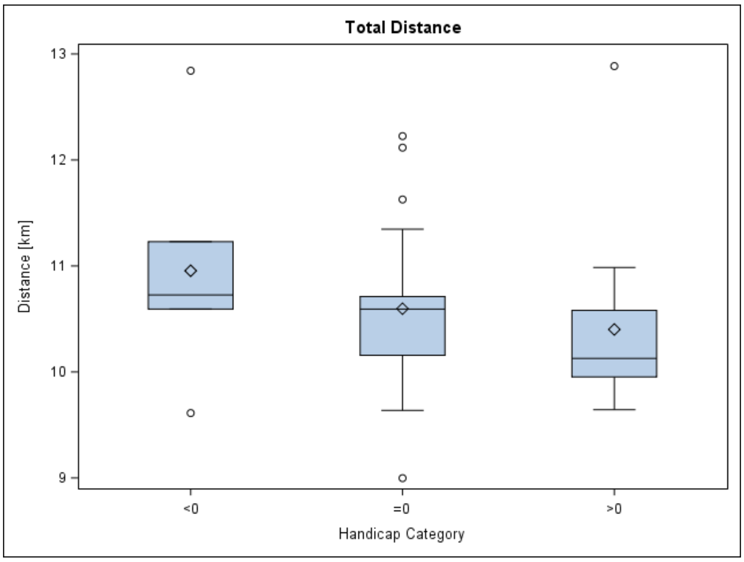

FIGURE 4.2: BOX PLOT - TOTAL DISTANCE OF DIFFERENT HANDICAPS

Figure 4.2 suggests that the below zero handicap golf players cover a greater distance than all other handicaps. The lower quartile of below zero golfers are equal to or higher than the upper quartiles of all other handicap golf players.

4.3.3 Heart Rate

4.3.3.1 Maximum Heart Rate

TABLE 4.6: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO MAXIMUM HEART RATE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Max Heart rate [b/min]	**<0**	168.99 (9.86)	**Mean difference**	9.83	10.1	9.21
	=0	167.94 (5.46)	**95% CI**	-24.14 to 26.23	-39.74 to 13.28	-33.71 to 5.16
	>0	182.22 (6.64)	**P value**	0.9279	0.2926	0.1315

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 9.83, where no significant difference was indicated between handicap categories. The P value read 0.9279.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 10.1. The P value read 0.2926 and also suggested no significant difference between the handicaps.

For the handicap category of the equal to zero versus above zero (=0 versus >0) the value was 9.21 for the mean difference, whereas the P value read 0.1315 and indicated no significant difference between the handicap categories.

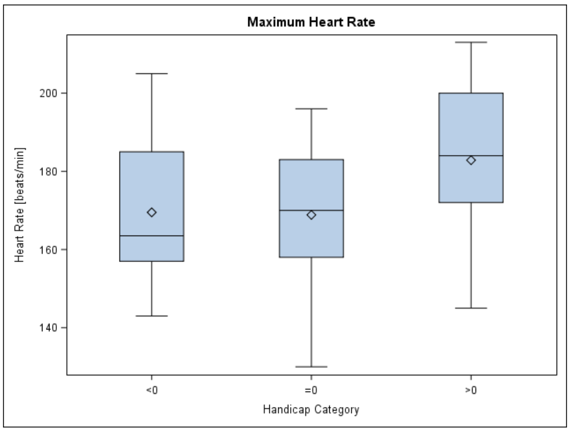

FIGURE 4.3: BOX PLOT - MAXIMUM HEART RATE OF DIFFERENT HANDICAPS

Figure 4.3 suggests that above zero handicap golf players have a higher overall heart rate compared to the other handicaps. The above zero handicap also shows a higher upper quartile compared to other handicaps and the lower quartile is higher or equal to the other handicaps.

4.3.3.2 Mean Heart Rate

TABLE 4.7: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO MEAN HEART RATE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Mean heart rate [b/min]	**<0**	120.57 (7.68)	**Mean difference**	9.68	9.64	9.24
	=0	112.97 (4.36)	**95% CI**	-12.16 to 27.37	-22.69 to 19.13	-24.88 to 6.11
	>0	122.35 (5.31)	**P value**	0.4102	0.8528	0.2049

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 9.68 and indicate no significant difference. The P value read 0.4102.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 9.64, indicating no significant difference, while the P value was 0.8528.

In the handicap category of the equal to zero versus above zero (=0 versus >0), the value was 9.24 for the mean difference, indicating no significant difference. The P value read 0.2049.

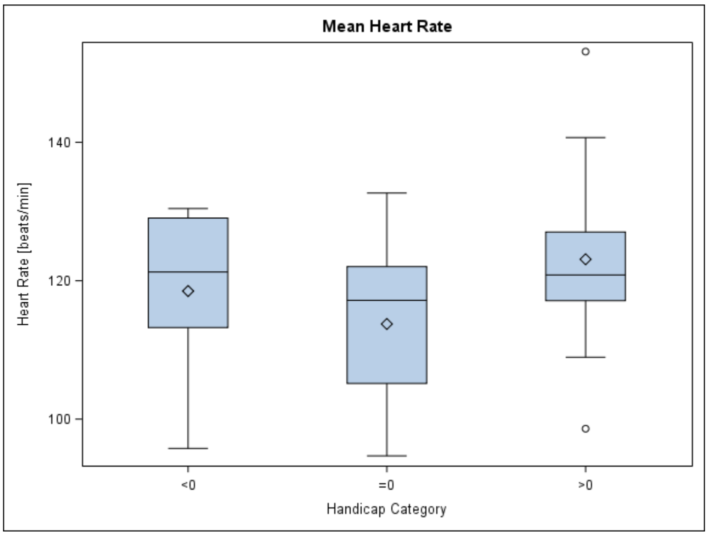

FIGURE 4.4: BOX PLOT - MEAN HEART RATE OF DIFFERENT HANDICAPS

Figure 4.4 suggests that golf players with a handicap equal to zero have a lower mean heart rate compared to those in the other handicap categories. The upper quartile of the equal to zero handicap is equal to or lower than the lower quartiles in the other handicaps. The lower quartile of the equal to zero handicap is lower overall than the other handicaps.

4.3.4 Total Player Load

TABLE 4.8: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO TOTAL PLAYER LOAD

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Total player load	**<0**	606.67 (47.81)	**Mean difference**	23.11	19.62	-3.49
	=0	583.56 (27.41)	**95% CI**	-100.64 to 146.86	-111.53 to 50.78	-101.01 to 94.04
	>0	587.05 (33.49)	**P value**	0.6843	0.7441	0.9375

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 23.11, suggesting no significant difference for the two handicaps and the P value was 0.6843.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 19.62. The P value read 0.9375 also indicating no significant difference between the two handicaps.

For the handicap category of the equal to zero versus above zero (=0 versus >0) the value was -3.49 for the mean difference, while there was no significant difference found between the two handicaps, with the P value that read 0.9375.

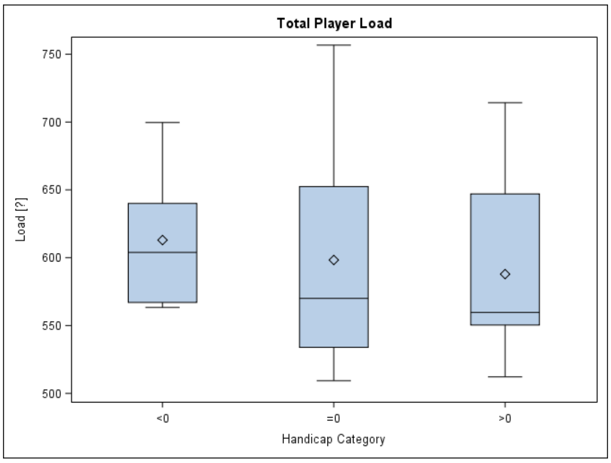

FIGURE 4.5: BOX PLOT - TOTAL PLAYER LOAD FOR DIFFERENT HANDICAPS

Figure 4.5 suggests that below zero handicap golf players have a higher total player load than the other handicaps. The below zero handicap's upper quartile is higher than or equal to the other handicaps, where the lower quartile of the below zero handicap is higher than or equal to the other handicaps' lower quartiles.

4.3.5 Player Load per Minute

TABLE 4.9: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO PLAYER LOAD PER MINUTE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Player load per minute	**<0**	2.40 (0.19)	**Mean difference**	0.32	0.38	0.06
	=0	2.09 (0. 11)	**95% CI**	-0.17 to 0.80	-0.13 to 1.00	-0.32 to 0.44
	>0	2.02 (0.13)	**P value**	0.1738	0.1270	0.7116

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 0.32, while there was no significant difference recorded for these handicaps. The P value read 0.1738.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 0.38. There was no significant differences between the two handicaps. P value was 0.1270.

For the handicap category of equal to zero versus above zero (=0 versus >0) the value was 0.06 for the mean difference. P value read 0.7116 and indicated no significant difference.

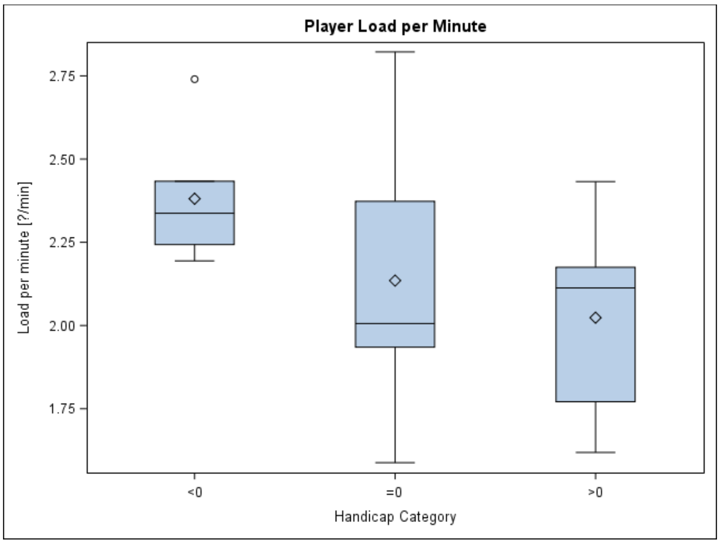

FIGURE 4.6: BOX PLOT - PLAYER LOAD PER MINUTE FOR DIFFERENT HANDICAPS

Figure 4.6 suggests that below zero handicap players have a higher player load per minute than the other handicaps. Players with a below zero handicap have a higher or equal upper quartile that the other handicaps, where the lower quartile of the below zero handicap is higher than the other handicaps'.

4.3.6 Player Load per Kilometre

TABLE 4.10: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO PLAYER LOAD PER KILOMETRE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Player load per kilometre	**<0**	56.39 (2.44)	**Mean difference**	0.78	0.07	-0.71
	=0	55.61 (1.38)	**95% CI**	-5.47 to 7.03	-6.54 to 6.68	-5.60 to 4.19
	>0	56.32 (1.69)	**P value**	0.7874	0.9819	0.7526

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 0.78, while the P value of 0.7874 suggested no significant difference.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 0.07. The P value was 0.9819 indicating no significant difference for the two handicaps.

In the handicap category of equal to zero versus above zero (=0 versus >0) the value was -0.71 for the mean difference. The P value read 0.7526 also indicating no significant difference between the two handicaps.

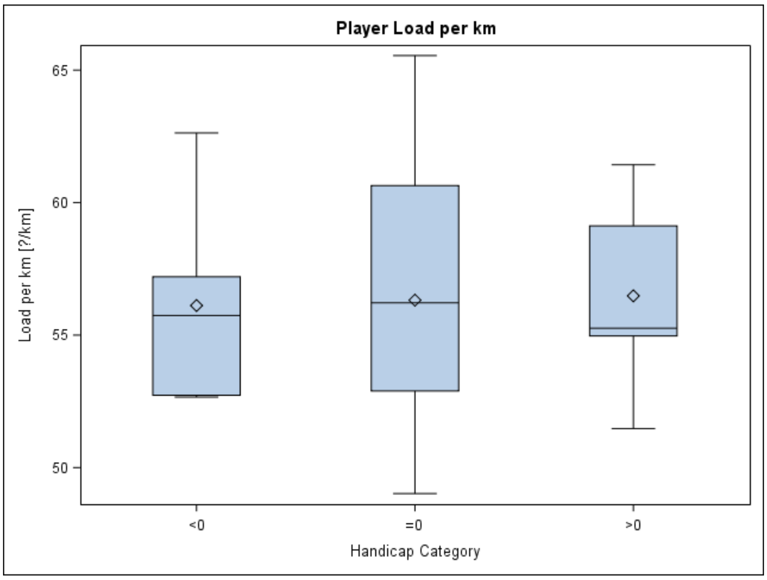

FIGURE 4.7: BOX PLOT - PLAYER LOAD PER KILOMETRE FOR DIFFERENT HANDICAPS

Figure 4.7 suggests that the below zero handicap golf players have an equal player load per kilometre than the other handicaps. The below zero handicap have an equal upper quartile than the other handicaps, where the lower quartile are equal to the other handicaps.

4.3.7 Maximum Velocity

TABLE 4.11: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO MAXIMUM VELOCITY

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Maximum velocity [m/s]	**<0**	3.24 (0.42)	**Mean difference**	0.37	0.51	0.14
	=0	2.87 (0.24)	**95% CI**	-0.71 to 1.46	-0.64 to 1.66	-0.71 to 1.00
	>0	2.73 (0.29)	**P value**	0.4613	0.3427	0.7196

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 0.37, while the P value read 0.4613 indicating no significant difference between the handicaps.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 0.51. There were no significant difference found for the two handicaps. P value was 0.3427.

In the handicap category of equal to zero versus above zero (=0 versus >0) the value was 0.14 for the mean difference. The P value read 0.7196 and suggested no significant difference between the two handicaps.

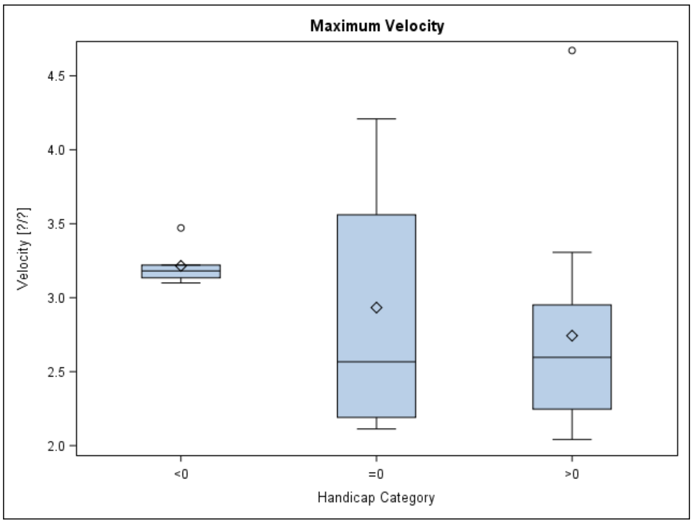

FIGURE 4.8: BOX PLOT - MAXIMUM VELOCITY FOR DIFFERENT HANDICAPS

Figure 4.8 suggests that below zero handicap golf players have a higher maximum velocity than the other handicaps. The below zero handicap section shows a higher upper quartile than the above zero handicap and an equal upper quartile to the equal to zero handicap. The lower quartile of the below zero handicap is higher than the other handicaps.

4.3.8 Acceleration Band 4: Total Effort Count

TABLE 4.12: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO ACCELERATION BAND 4: TOTAL EFFORT COUNT

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Acceleration Band 4 total effort count	**<0**	4837.25 (335.03)	**Mean difference**	-159.75	-142.49	17.26
	=0	4997.00 (191.26)	**95% CI**	-1032.69 to 713.20	-1067.07 to 782.09	-669.41 to 703.92
	>0	4979.74 (233.36)	**P value**	0.6885	0.7352	0.9557

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was -159.75, but showed no significant difference between the two handicaps with the P value reading 0.6885.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was -142.49. The P value was 0.7352 and indicated that there is no significant difference between the involved handicaps.

For the handicap category of equal to zero versus above zero (=0 versus >0) the value was 17.26 for the mean difference. The P value read 0.9557 and showed no significant difference between handicaps.

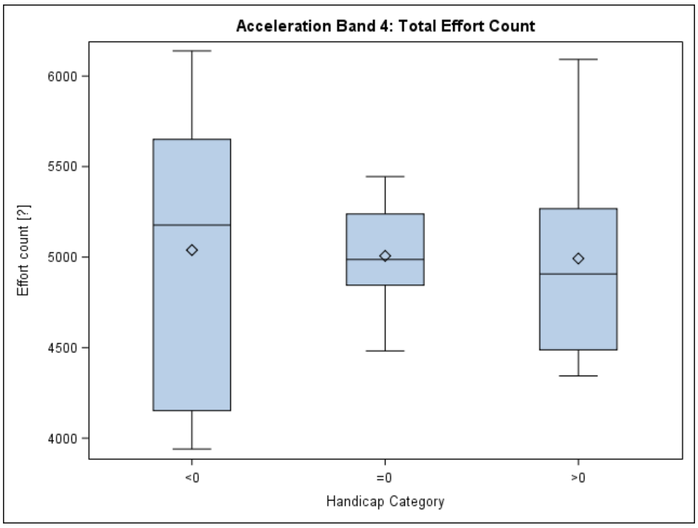

FIGURE 4.9: BOX PLOT - ACCELERATION BAND 4 (TOTAL EFFORT COUNT FOR DIFFERENT HANDICAPS)

Figure 4.9 suggests that below zero handicap golf players have a greater value for Acceleration Band 4: Total Effort Count than players with other handicaps. The below zero handicap presents a higher upper quartile than the other handicaps where the lower quartile of the below zero handicap is equal to the other handicaps.

4.3.9 Acceleration Band 5: Total Effort Count

TABLE 4.13: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO ACCELERATION BAND 5: TOTAL EFFORT COUNT

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Acceleration Band 5 total effort count	**<0**	6298.37 (368.27)	**Mean difference**	-209.80	31.95	241.75
	=0	6508.17 (208.05)	**95% CI**	-1165.04 to 745.44	-977.74 to 1041.64	-505.23 to 988.73
	>0	6266.42(253.35)	**P value**	0.6316	0.9446	0.4805

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was -209.80, where the P value read 0.6316 indicating no significant difference.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 31.95. The P value was 0.9446 with no significant difference between the two handicaps.

For the handicap category of equal to zero versus above zero (=0 versus >0) the value was 241.75 for he mean difference and showed no significant difference between the two handicaps with the P value that read 0.4805.

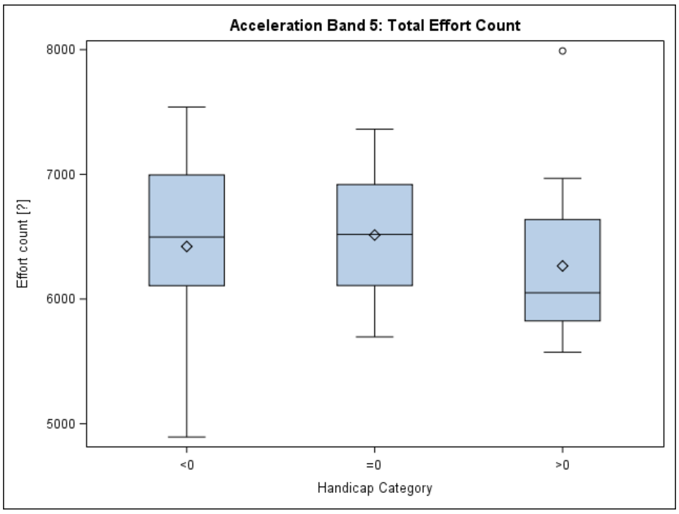

FIGURE 4.10: BOX PLOT - ACCELERATION BAND 5 (TOTAL EFFORT COUNT FOR DIFFERENT HANDICAPS)

Figure 4.10 suggests that the below zero handicap golf player has a greater or equal value for Acceleration Band 5: Total Effort Count than the other handicaps. The below zero handicap has a higher or equal upper quartile than the other handicaps, where the lower quartile is equal to or higher than the other handicaps.

4.3.10 Acceleration Band 4: Distance Percentage

TABLE 4.14: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO ACCELERATION BAND 4: DISTANCE PERCENTAGE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Acceleration Band 4 distance percent	**<0**	45.92 (0.83)	**Mean difference**	-0.07	0.38	0.45
	=0	45.99 (0.47)	**95% CI**	-2.20 to 2.07	-1.87 to 2.64	-1.22 to 2.12
	>0	45.54 (0.57)	**P value**	0.9450	0.7123	0.5585

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was -0.07. The P value of 0.9450 showed no significant difference between the two handicaps.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was 0.38. The P value was 0.7123 and indicated no significant difference between these handicaps.

In the handicap category of equal to zero versus above zero (=0 versus >0) the value was 0.45 for the mean difference, while not showing any significant difference. The P value read 0.5585.

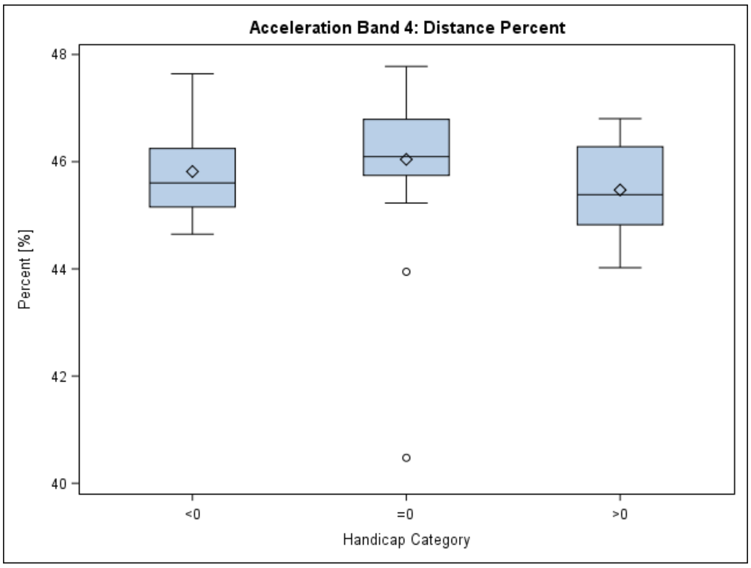

FIGURE 4.11: BOX PLOT - ACCELERATION BAND 4 (DISTANCE PERCENTAGE FOR DIFFERENT HANDICAPS)

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Figure 4.11 suggests that the equal to zero handicap golf players have a higher acceleration band 4: distance percent value than the other handicaps. The equal to zero handicap have a higher or equal upper quartile than the other handicaps, where the lower quartile are higher than the other handicaps.

4.3.11 Acceleration Band 5: Distance Percentage

TABLE 4.15: COMPARISON OF HANDICAP CATEGORIES WITH REGARD TO ACCELERATION BAND 5: DISTANCE PERCENTAGE

				Comparison of Handicap Categories		
Activity Variable	**Handicap Category**	**Mean** (Standard Error)	**Statistic**	**<0 versus =0**	**<0 versus >0**	**=0 versus >0**
Acceleration Band 5 distance percent	**<0**	54.06 (0.82)	**Mean difference**	0.10	-0.37	-0.48
	=0	53.96 (0.47)	**95% CI**	-2.02 to 2.23	-2.62 to 1.87	-2.14 to 1.19
	>0	54.44 (0.57)	**P value**	0.9148	0.7169	0.5329

For the handicap category below zero versus equal to zero (<0 versus =0) the mean difference was 0.10, while there is no significant difference between the two handicaps. The P value read 0.9148.

The mean difference value for the handicap category below zero versus above zero (<0 versus >0) was -0.37. The P value was 0.7169 and indicated no significant difference.

In the handicap category of equal to zero versus above zero (=0 versus >0) the value was -0.48 for the mean difference. The P value read 0.5329 and showed no significant difference.

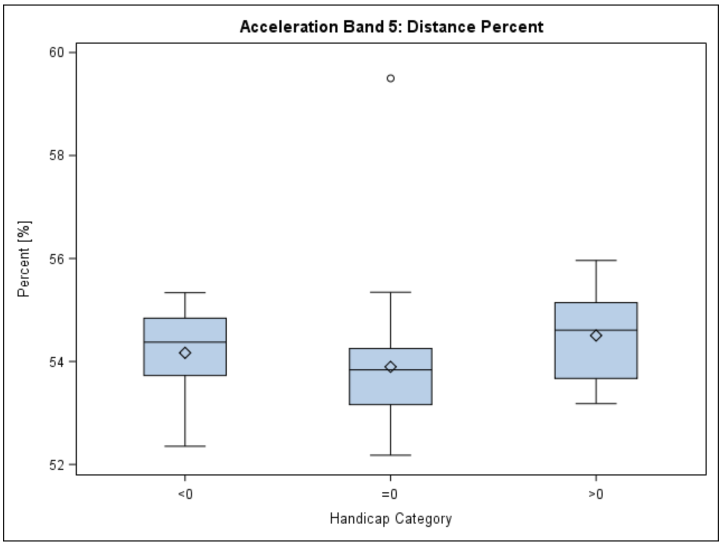

FIGURE 4.12: BOX PLOT - ACCELERATION BAND 5 (DISTANCE PERCENTAGE FOR DIFFERENT HANDICAPS)

Figure 4.12 suggests that above zero handicap golf players have a higher Acceleration Band 5: Distance Percentage than players with other handicaps. The upper quartile of the above zero handicap is higher or overlaps with the other handicaps, where the lower quartile overlaps with the other handicaps.

CHAPTER 5: DISCUSSION

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

5.1. Introduction

5.2. Total Duration

5.3. Total Distance

5.4. Heart Rate

5.5. Total Player Load

5.6. Player Load per Minute

5.7. Player Load per Kilometre

5.8. Meterage per Minute

5.9. Velocity

5.10. Acceleration According To Band 4 And 5

5.1 INTRODUCTION

This chapter will discuss possible reasons for changes in behaviour when the various handicaps of golf players are compared. It must be noted that golf is played on different courses and that a variety of environmental influences may alter the physical activity demands on players during a round of golf. Shot selection, equipment, and competition format can greatly influence golfers' mind set and approach to the round of golf. It should also be mentioned that the various handicaps can vary in the distance and accuracy of shots and can influence the distance covered by golf players.

5.2 TOTAL DURATION

The average duration of play for golf players of various handicaps varied between 4.32 and 4.88 hours. This data echoes that of McGee (2017), who reports play durations of approximately 4 to 4.5 hours of play. The study further corresponds with that of Magnusson *et al.* (1998), who report rounds of golf lasting between 3.5 and 6 hours. Players with the better handicap scores (>0) played the longest compared to players with a handicap of zero (=0) and below zero (<0). This might be due to golfers with lower handicaps spending more time evaluating possible shot selections. These players also take more time in reading the green before putting by taking all possible influences on the shot into account. Derksen *et al.* (1996) conclude that 60% of golfing time is spent on performing or preparing for shots, while 25% is spent on the green. As players' handicaps improve, more influences are taken into consideration, and players will also consult with caddies to select the most suitable and appropriate shot. Furthermore, the results show that duration of play increases linearly as the handicap improves. This is indicative of the increased time that players spend on shot selection. Evans and Tuttle (2015) agree that golf is a sport that involves a relatively long duration at low intensity. Course length can also greatly influence the time that players spend on walking and increases playing time.

Comparisons between handicaps indicate a significant difference ($p=0.0194$) between players with weaker handicaps (<0) and those with the best handicaps (>0); however, no significance was recorded between scratch handicap (=0) players and any other handicap groups. The significance between certain handicaps supports the finding that better handicap players need greater fitness and patience than players with other handicaps due to longer time spent on the course.

5.3 TOTAL DISTANCE

The average distance covered between the various handicaps ranged from 10.42-10.82 kilometres over 18 holes of golf played. This supports findings by Luscombe *et al.* (2016), who conclude that the distance is highly variable according to the course, but can range between 6.4km and 11.3km per round of golf. Players with the best handicaps covered the shortest distance over 18 holes of golf played, whereas weaker handicap players covered the longest distance. This might be because the player with the weakest handicap has to walk further as proficiency in straight shots are not as high as that of players with better handicaps, resulting in having to search for a ball in rougher parts of the course. As is the case with total duration, total distance is influenced by course length. Most golf course lengths are calculated from the tee box to the green, but do not measure the distance from the green to the next hole. Total distance increases linearly from the better handicap players to that of the weaker handicap players. Distances covered in golf exceeds the distances covered in under 19 rugby union games, which is 5-6 km (Cunningham *et al.,* 2016), and the possible 5-8km covered in rugby league games (Twist *et al.,* 2014).

Comparisons between handicaps yielded no significant differences between the three handicap categories, largely due to courses having set lengths. Irrespective of the handicap, the course length is the same for all golf players depending on the course played. Due to the fact that all players were evaluated on the same course, the small amount of extra walking undertaken by weaker handicap golf players is due to shots not being as straight as those taken by the best handicap golf players.

5.4 HEART RATE

The mean heart rate was the highest for the most improved handicap golf players, likely due to the players finding themselves in high pressure situations more often than other players. Mean heart rate varied from 112 $b.min^{-1}$ to 122 $b.min^{-1}$ between the three handicaps, which echoes Evans and Tuttle's (2015) theory that that golf has a relatively low-intensity demand. Heart rate measures of other sports, such as soccer at 152 to 186 $b.min^{-1}$ (Krustrup *et al.,* 2005) and netball at 174 $b.min^{-1}$ (McCabe, 2014), are much higher than what is reported for golf in the current study. Correct and precise shot execution increases pressure on golfers with better handicaps through the increase of practice swings; these tense situations may contribute to an increased heart rate. Zienius *et al.* (2015) report that the number of practice swings taken during a game has the strongest correlation with increased heart rate of all measured variables. Increased heart rate in weaker handicap golf players may be due to greater physical demand placed on these players, who may not be used to playing multiple rounds of golf in a small amount of time. The comparison of maximum- and mean heart rate between the different handicaps also reveals no significant differences. Similar heart rate responses are attributed to similar pace and tempo of play. Longer distances covered by golfers with better handicaps can increase the activity demand on these players; conversely, weaker handicap golf players may not always exhibit sustained duration, but may have to play a greater number of shots during a round. These findings supports that of Burkett and Von-Heijne-Fisher (1998), who find no significant difference between different skill levels despite lower handicap golf players having to play more shots.

5.5 TOTAL PLAYER LOAD

The mean total player load varies from 587.05 to 606.67 for players of different handicaps. Players with weaker handicaps exhibit the highest player load, likely due to the player having to cover a greater distance during play while during shorter playing duration. Better handicap players display the second highest player load, which is due to shorter distance covered combined with having a longer duration of play. Scratch handicap players are the most balanced, as these players experience the lowest player load through longer duration coupled with shorter distances when compared to those of weaker handicap players. Results show no significant difference between any of the three handicaps regarding player load. The study agrees with Murray *et al.* (2017) who report that a number of factors that can influence the intensity of the activity in golf, for example the course profile and the baseline fitness of players.

5.6 PLAYER LOAD PER MINUTE

Values for player load per minute varies between 2.02 and 2.40 for various handicaps. The player with the best handicap scored the lowest player load per minute due to having the highest total play duration and covering the shortest distance. Aughey (2011) suggests a strong relationship between total distance covered and load per minute experienced in Australian football. Players with improved handicaps can hit the ball straighter, which results in players knowing where to walk and walking in a straight line towards the ball. Players with the weakest handicaps show the highest player load per minute due to greater distances covered during a round of golf. No significant differences are evident between the different handicaps, which can be attributed to very similar pace and tempo of the rounds of golf played as the course is the same for all handicaps.

5.7 PLAYER LOAD PER KILOMETRE

Player load per kilometre varies between 55.61 and 56.39 and shows very little difference between the three different handicaps. Weaker handicap golf players exhibit the highest load per kilometre due to greater distances covered. No significant differences are detected between the different handicaps, likely due to the similar distances covered by all three handicap categories.

5.8 METERAGE PER MINUTE

Golfers with weaker handicaps exhibit higher meterage per minute due to greater distances covered during a round, which indicates a faster walking pace to ensure that the game is not held up because of a missing ball. Improved handicap golf players have a slower walking pace, influenced by long periods of standing still while evaluating shot selection or waiting for other players to finish shots.

5.9 VELOCITY

Maximum velocity supports the meterage covered per minute, as players with weaker handicaps walk at roughly 3.24 meters per second, which is about 50cm per second faster than the better handicap golf players. There is no significant difference between any of the three different handicaps. Players will move at a predetermined speed according to the completed shot. Once all players complete their shots, players start moving towards their balls. Shots with greater distance or which are not straight elicit a more brisk walk to ensure the flow of play.

5.10 ACCELERATION ACCORDING TO BAND 4 AND 5

The distance covered recorded by scratch handicap golf players in acceleration 4 and 5 was the highest, with most of their distance covered in acceleration band 5 (53.96%). Below zero handicap golf players had the lowest distance covered in acceleration band 4 and also spent most of their distance covered in acceleration band 5 (54.06%). Players with handicaps above zero had the lowest distance covered in acceleration band 5, but still exhibited the majority of the distance covered during a round of golf (54.44%).

CHAPTER 6: CONCLUSION AND FUTURE RESEARCH

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

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6.1. Introduction

6.2. Conclusion

6.3. Recommendations

6.4. Practical Application

6.5. Future Research

6.1 INTRODUCTION

Most golf players worldwide are recreational players, but for the handful of amateur and professional players, fitness has become just as important as developing the skills needed in golf. Golf is a highly technical sport which requires high level of skills in order to be successful. The last two decades has seen dramatic improvement in the physical fitness of golf players, which contributed to increases in driving and shot distances by players. It is likely that the biggest difference between different handicap golf players will still be the skill level, execution of the skill, and the biomechanics of the skill.

6.2 CONCLUSION

The only statistically significant finding in this study is the comparison between players with a handicap above and those with a handicap below zero regarding the total duration of a round of golf. Even though very few statistical differences were found, the study still holds practical value for both the golf- professional and player. Better handicapped players have the longest duration of play, higher maximum heart rate, higher mean heart rate, lowest player load per minute, and the lowest maximum velocity. These findings are indicative of more skilled players, as these players take more time to select the correct shot and experience greater pressure and repeated practice swings before addressing the ball. Due to the better handicap players' ability to hit the ball straight, the distance covered is shorter and occurs at a slower pace. Players with weaker handicaps exhibit the lowest duration, greatest distance covered, highest player load, highest player load per minute and per kilometre, and the highest velocity. This indicates that weaker handicap golf players do not spend as much time pondering shot variations. These players' lower shot accuracy results in greater distances walked in search of a ball in wider areas off the side of the fairway. The load is greater due to the haste of these players attempting to find the ball and playing more shots per round, which increases intensity. Scratch handicap golf players display the lowest mean heart rate, lowest player load, and the lowest load per kilometre. These players experience less pressure to perform well, but are still skilled enough to hit the ball accurately.

6.3 RECOMMENDATIONS

It is recommended that all players pay attention to physical fitness in order to cope with the increased demands players face during competition. Coaching professionals and players should be aware of the demands during competition. Players should also understand the factors which can influence performance and adhere to fitness standards set by the conditioning coach for improved performance. Weaker handicap golf players should see marked changes in the intensity of physical activity as the skill level increases, while better handicap golf players should improve cardiovascular fitness in order to improve recovery during the round and before the next round of golf.

6.4 PRACTICAL APPLICATION

The results of this study will be very useful for training amateur and professional golf players. It provides an outline of the physical demands exerted in completing a round of golf and can lead to more precise and accurate programme prescription. Players should be more active in gaining access to sport scientists and conditioning coaches who specialise in golf training to develop golf specific attributes. Improvement in golfers' physical abilities will also improve concentration and driving distances in all clubs.

6.5 FUTURE RESEARCH

Direct measures of golf performance (e.g. strokes per round and performance during tournaments) are lacking (Evans & Tuttle, 2014). This study is one of the first studies to measure physical performance during competition and to differentiate between the various handicaps. Further research is needed to evaluate the various shot intensities performed by players, such as driving, iron shots, chipping, and putting. Another possible area of research would be to determine work to rest ratios in golf competitions and evaluate time spent on each activity. It is also necessary to take in to consideration that there were only 12 golf players tested, which in itself is a small sample size and thus these results gathered are only a reflection of a small portion of golf players out there. The sample size should still be increased for a more true reflection of findings.

CHAPTER 7: REFLECTION ON THE RESEARCH PROCESS

Referencing within the chapter, as well as the list of references at the end thereof, are completed in accordance with the guidelines prescribed by the University of the Free State

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7.1 INTRODUCTION

From the inception of my studies in 2009 I knew that research is definitely something that I would want to undertake one day. I never thought that it would be so time consuming and mentally challenging, as it is a very lonely process indeed. There is always a need for research to allow the world of science to move forward and to improve in methods to train individual athletes’ sport performance, since professional sport not only South Africa but also in the rest of the world grows exponentially each year, with records being broken every season. Therefore, research will never be seen as a fruitless exercise, because there will be someone that might benefit from any information.

For myself as a sport scientist and biokineticist working in the field, research is always needed and appreciated for the improvement of my own capabilities, as well as for the improvement of the athletes training methods and performance.

7.2 REFLECTING ON THE RESEARCH PROCESS

What I have learnt over the past three years of conducting this research is that one must be sure what exactly it is that you want to research. It is never an easy task, and therefore performing your own research on certain topics you are interested in will also help you better understand the topic. It will also clarify what research has already been conducted that you can build on or improve. You must also never be afraid to ask someone for advice and never leave a task for the next day. Always do a small part every day in the end the work load would be so much less.

7.3 PERSONAL REMARKS

This research topic I chose is something that I strongly feel needs investigation, because the sport of golf is not only very popular amongst every age group and gender, but is also a very highly paid sport that requires a great deal of time for the golfing athlete to be successful. I honestly feel that this can be taken to a higher level by looking at other golf courses in other provinces to eventually be able to inform the coach and the golf player as to how they can prepare for a certain course knowing what the statistics for that specific golf course are.

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APPENDIX A1: PARTICIPANT INFORMATION LETTER

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

School for Allied Health Professions (SAHP),

UV/UFS, Bloemfontein 9300

INFORMATION LETTER TO PARTICIPANTS

UNIVERSITY OF THE FREE STATE - FACULTY OF HEALTH SCIENCES

Study title: Physical fitness profile for semi elite golf players.

I, Tania Brink, am doing research as part of the fulfilment of the degree Magister Artium - Human Movement Science. The purpose of this research study is to compile a physical fitness profile for semi elite golf players in South Africa. The data gathered during this research study will ensure that golf coaches as well as conditioning coaches have a better understanding of the load being placed on golf players, especially during tournaments and therefore assist them with a better construction of their conditioning programmes as well as protocols during golf practice. Permission was obtained from the Free State Golf Federation to proceed with this study.

Twenty male provincial golf players will be contacted and asked to participate in this study. Each participant will receive an information letter in English, stipulating requirements and details of their participation in the study. Each participant will sign an informed consent when accepting to participate in the study with the understanding that their participation is completely voluntary without penalty. In the case of minors, parents or the legal guardian must give consent and assent from such minors in order to participate in the study. Participants may withdraw from this study at any given time.

A scheduled briefing session will be held with the prospective participants and the parents / legal guardians during which the researcher will provide the written information and consent form to the participants. During the briefing session, the researcher will explain the purpose of the study, the physical tests which will be done, time commitment (duration), risks, benefits, and confidentiality aspects that apply.

Participant's signed consent forms will be collected immediately after the briefing session.

The study will only commence once ethical approval has been obtained from the Ethics Committee of the Faculty Health Sciences. The contact details of Secretariat and Chair is: Ethics Committee of the Faculty of Health Sciences, University of the Free State: Telephone number (051) 4052812.

The results will be used to draw conclusions on the physical fitness profile of semi elite golf players. The value of this study is twofold. Firstly the research information will be used to compile a physical fitness profile for semi elite male golf players in South Africa. Secondly this research study will enable the researcher to give detailed feedback about the conditioning of provincial golf players so that there will be a better understanding with regards to the conditioning of this type of athlete to help enhance the sport performance of provincial golf players.

Invitation to participate:

You are hereby invited to participate in this research study.

What is involved in the study?

Once the Ethics Committee have gave permission to continue with this study a briefing session with the possible study participants will be held to explain what will be expected from them by choosing to participate during this study. During this briefing session the information sheet as well as the consent forms will also be handed out to the participants where they will be allowed time to read through the forms and ask questions if they feel necessary to do so. The researcher, Miss Brink, a qualified Sport Scientist as well as Biokineticist, will collect all the data during the day of testing. Testing will be conducted over a period of at least 3 months where each participant will be asked to play at least 2-3 rounds of golf while wearing a GPS sensor to track distance travelled and rotations for the duration of 18 holes of play. This may take place during a tournament or during practice sessions. Testing sessions will be scheduled as closed as possible to the players scheduled training times on the course or during a tournament.

If you chose to participate, you will be one of approximately 20 male golf players chosen over the Free State Province and South Africa to participate in this research study.

Risks associated with this study:

The chances of experiencing any potential risks as well as discomforts during this research study is very low as golf do not contain contact or high intensity movement. Equipment will not impede with the natural movement of the golf player.

Benefits you can gain from this study:

This research study will provide the athlete with valuable information about his own strengths and weaknesses with regards to certain fitness components involved in golf. This however will also be of value for golf coaches as well as fitness professionals to help them conduct a proper conditioning programme to enhance the athlete's sport performance in golf.

Participation in this study:

Participation is voluntary and the participant may discontinue participation in this study at any given time.

Reimbursements:

Participation is completely voluntary and no financial reimbursements will be provided.

Confidentiality:

All data gathered for this study is confidential and to ensure confidentiality the participants' names will not be recorded in the research study. Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed as personal information may be disclosed if required by law. Organisations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Ethics Committee for Medical Research.

Contact details of researcher(s)

Tania Brink

Cell phone number: 076 833 1887

Email address: brink.tk@sacr.fs.gov.za or kristel.brink@yahoo.com

APPENDIX A2: INFORMED CONSENT FORM

INFORMED CONSENT

Physical fitness profile for semi elite golf players

You are asked to participate in a research study conducted by Tania Brink, from the Exercise and Sports Science Department, University of the Free State, the results of which will form part of the dissertation for her Master's Degree. You were selected as a possible participant in this study because you are a provincial Golf player and this dissertation is based on semi elite male Golf players in South Africa.

1. PURPOSE OF THE STUDY

The purpose of this research study is to compile a physical fitness profile for semi elite male golf players by means of data that is captured with regards to various components related to the physical fitness of golf players through a 18 hole play as simulated during a tournament so that information can be given to the coach as well as the conditioning coach to help enhance the sport performance of the golf player.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following:

For performance analysis measurements the use of the Catapult sports system will provide the necessary data with regards to the distance travelled during the 18 holes of play, the heart rate during play, the amount of torso rotations to the left and right, the time spent to complete 18 holes of play, the time spent during each activity such as walking and running, the speed at which the player is moving as well as the player load. These measurements will thus provide us with important information on how to compile a physical fitness profile for golf players that is necessary for optimal golf performance.

Testing of the athletes will take place on the golf course. Each and every athlete that takes part in the testing of this research study will warm up for about 30 minutes before testing will start. The warm up will include dynamic warm up drills as well as shots played.

Every athlete will be fitted with the Catapult sport system vest that will include the sensor that is being put into its sack behind the back. This vest will be worn underneath the golf shirt for the duration of the 18 holes. The athlete will be asked to play his 18 holes like he would during a normal competition. The Catapult system will constantly provide data with regards to the components mentioned above.

All the data captured during testing will be analysed after testing is done.

3. POTENTIAL RISKS AND DISCOMFORTS

The chances of experiencing any potential risks as well as discomforts during this research study is very low.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

This research study will provide the athlete with valuable information about his own strengths and weaknesses with regards to certain fitness components involved in golf.

This however will also be of value for golf coaches as well as fitness professionals to help them conduct a proper conditioning programme to enhance the athlete's sport performance in golf.

5. PAYMENT FOR PARTICIPATION

Unfortunately there is no payment for your participation in this study, but a comprehensive report of your results will be given to you on request after data has been captured and analysed.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of allocating numbers to golf players. Information will be kept with the investigator only and raw data held under lock and key. All processing of data will be governed by a PC password protector. Only the findings will be published with the strictest of confidentiality to the individual athletes.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this research study or not. If you volunteer to be in this research study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the research study. Your position in the Provincial squad will not be affected whether or not you choose to participate in this study.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Tania Brink (076 833 1887; email: kristel.brink@yahoo.com or Dr. R. Schoeman (051 401 3207- Exercise and Sports Science Department, University of the Free State).

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Dr Katinka De Wet (+27 (0)51 4012918 at the Research Ethics Committee ("REC") of the Faculty of Humanities of the University of the Free State ("UFS").

SIGNATURE OF RESEARCH SUBJECT OR LEGAL GUARDIAN

The information above was described to me, ________________________by Tania Brink in *English* and I am in command of this language. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent to voluntarily participate in this study /I hereby consent that the subject/participant may participate in this study. I have been given a copy of this form.

____

Name of Participant

____

Name of Legal Guardian (if applicable)

____ ________________

Signature of Subject/Participant or Legal Guardian Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ___________________ and her representative _____________________ was encouraged and given ample time to ask me any questions. This conversation was conducted in English and *no translator was used.*

_____________________ ______________

Signature of Investigator **Date**

________________________ ________________

Participants signature **Date**

_________________________ ________________

Researcher's signature **Date**

APPENDIX B1: PERMISSION REQUEST

Free State Golf

FREE STATE GOLF UNION
VRYSTAAT GHOLF UNIE

President:	Alec Levin	Secretary:	C. Fourie
Tel Cell:	083 2510061	Tel:	057 899 1724
Address:	Po Box 1345	Fax:	086 616 5167
	Bloemfontein 9300	Address:	P.O. Box 124
E-mail:	alec@aleclevin.co.za		Wesselsbron 9680
		E-mail:	fsnc@mweb.co.za

TO: **QUINTIN WILLIAMS**
HEAD COACH
FREE STATE GOLF

RE: PERMISSION TO RECRUIT PROVINCIAL MALE GOLF PLAYERS FOR A MAGISTER RESEARCH PROJECT

Permission is sought from the Free State Golf Federation to conduct an empirical research study as part of the fulfilment of the degree Magister Artium (Human Movement Science) of Miss Tania Kristel Brink. The purpose of this research study is to compile a physical fitness profile for provincial golf players.

Twenty provincial golf players will be recruited to participate in this study. Each participant will receive a consent and indemnity form in English, stipulating the purpose and processes involved from their participation in the study. Each participant will sign an informed consent when accepting to participate in the study with the understanding that their participation is completely voluntary without penalty. Participants may withdraw from this study at any given time.

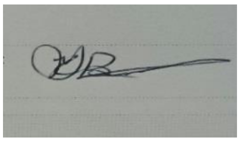
A scheduled briefing session will be held with the prospective participants during which the researcher will provide the written information and consent form to the participants. During the briefing session, the researcher will explain the purpose of the study, the physical tests which will be done, time commitment (duration), risks, benefits, and confidentiality aspects that apply. Participant's signed consent forms will be collected immediately after the briefing session.

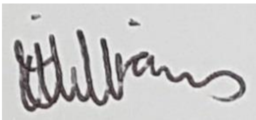
The study will only commence once ethical approval has been obtained from the Ethics Committee of the Faculty Health Sciences. The contact details of Secretariat and Chair is: Ethics Committee of the Faculty of Health Sciences, University of the Free State: Telephone number (051) 4052812.

Data collection from the testing procedures will take place at the Bloemfontein and Schoeman Golf Clubs in Bloemfontein over a period of at least 3-4 months. The researcher, Miss Brink, a qualified Biokineticist and Sport Scientist, will collect all the data. All data gathered for this study is confidential and to ensure confidentiality the participants' names will not be recorded in the research study.

The results will be used to draw conclusions on the physical fitness profile of provincial male golf players. The value of this study is twofold. Firstly the research information will be used to compile a physical fitness profile for provincial male golf players in South Africa. Secondly this research study will enable the researcher to give detailed feedback about the conditioning of provincial golf players so that there will be a better understanding with regards to the conditioning of this type of athlete to help enhance the sport performance of provincial golf players.

Regards





Tania Brink
Tel: 051 407 3597
Cell: 076 833 1887
Email: kristel.brink@yahoo.com

Mr. Quintin Williams
Cell: 083 383 4113
Email: quintinwilliams5@yahoo.com

APPENDIX B2: PERMISSION REQUEST

Free State Golf

FREE STATE GOLF UNION
VRYSTAAT GHOLF UNIE

President:	Alec Levin	Secretary:	C. Fourie
Tel Cell:	083 2510061	Tel:	057 899 1724
Address:	Po Box 1345	Fax:	086 616 5167
	Bloemfontein 9300	Address:	P.O. Box 124
E-mail:	alec@aleclevin.co.za		Wesselsbron 9680
		E-mail:	fsnc@mweb.co.za

TO: QUINTIN WILLIAMS
FREE STATE GOLF

RE: PERMISSION TO RECRUIT PROVINCIAL MALE GOLF PLAYERS FOR A MAGISTER RESEARCH PROJECT

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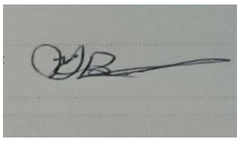
A scheduled briefing session will be held with the prospective participants during which the researcher will provide the written information and consent form to the participants. During the briefing session, the researcher will explain the purpose of the study, the physical tests which will be done, time commitment (duration), risks, benefits, and confidentiality aspects that apply. Participant's signed consent forms will be collected immediately after the briefing session.

The study will only commence once ethical approval has been obtained from the Ethics Committee of the Faculty Health Sciences. The contact details of Secretariat and Chair is: Ethics Committee of the Faculty of Health Sciences, University of the Free State: Telephone number (051) 4052812.

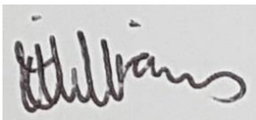
Data collection from the testing procedures will take place at the Bloemfontein and Schoeman Golf Clubs in Bloemfontein over a period of at least 3-4 months. The researcher, Miss Brink, a qualified Biokineticist and Sport Scientist, will collect all the data. All data gathered for this study is confidential and to ensure confidentiality the participants' names will not be recorded in the research study.

The results will be used to draw conclusions on the physical fitness profile of provincial male golf players. The value of this study is twofold. Firstly the research information will be used to compile a physical fitness profile for provincial male golf players in South Africa. Secondly this research study will enable the researcher to give detailed feedback about the conditioning of provincial golf players so that there will be a better understanding with regards to the conditioning of this type of athlete to help enhance the sport performance of provincial golf players.

Regards



Tania Brink
Tel: 051 407 3597
Cell: 076 833 1887
Email: kristel.brink@yahoo.com



Mr. Quintin Williams
Cell: 083 383 4113
Email: quintinwilliams5@yahoo.com

APPENDIX C: ASSENT FORM FOR MINORS

Skool vir Aanvullende Gesondheidsberoepe (SAGB)/School for Allied Health Professions (SAHP)
Posbus/PO Box 339, Bloemfontein 9300, Republiek van Suid-Afrika/Republic of South Africa
Department of Exercise and Sport Sciences / Departement Oefen- en Sportwetenskappe

MINOR ASSENT FORM

You are being asked to take part in a research study being done by the University of the Free State. In this study, we are interested to know more about your movement patterns and performance during 18 holes of golf. We have asked your parent or legal guardian whether it is OK for you to participate, but now we want to see if it is OK with you. If you decide to take part in this study, you will be given a GPS monitor to wear while playing a round of golf during competition. The monitor will not hinder you in anyway while playing and will add no additional weight.

All the information we collect will be kept confidential and you don't have to share any of your information with anybody else. We will not use your name so everything will remain private. By signing this you are showing that you understand what is going to be happening and have asked any questions you may have about the research. You can also ask questions later if you cannot think of them now. Signing this form does not mean that you have to finish the study- you can pull out from the study at any time without explaining why.

____________________ ______________________________

Name of participant Parent signature

________________________ ______________

Minor's signature Date

APPENDIX D: ETHICS COMMITTEE APPROVAL LETTER

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

26 July 2017

MS TK BRINK
DEPT OF EXERCISE AND SPORT SCIENCES
FACULTY OF HEALTH SCIENCES
UFS

Dear Ms TK Brink

HSREC 82/2017 (UFS-HSD2017/0740)
PRINCIPAL INVESTIGATOR: MS TK BRINK
SUPERVISOR: DR R SCHOEMAN
PROJECT TITLE: PHYSICAL ACTIVITY DEMANDS OF GOLF

HELD OVER - MODIFICATIONS REQUIRED

1. You are hereby kindly informed that, at the meeting held on 25 July 2017, the Health Sciences Research Ethics Committee (HSREC) reviewed the above research project. A decision could not be reached as there are modifications required to the protocol / outstanding requests from the HSREC. Please see below for details:

1.1. Application Form:

1.1.1. nr 2 qualitative research correct?? see proposal 3.1
1.1.2. nr 10 Expand on where/how recruitment would be done - see 3.2 in proposal
1.1.3. nr 14 Add Free State Golf Federation; Bloemfontein Golf Club
1.1.4. Qualitative research? Please clarify.

1.2. Proposal:

1.2.1. Please clarify how it will be possible to provide individual participants their results, whilst also assuring anonymity?
1.2.2. Is the following person a person other than the researcher? The Sport Scientist responsible for the conditioning of these golf players will contact the players directly with regards to possible participation in this research study
1.2.3. Parents give consent not assent p 5. Please update.
1.2.4. Legal guardian, not legal representative. Please update.
1.2.5. What will recruitment entail?
1.2.6. 3.6 needs to specify who does the analysis
1.2.7. 3.8 needs to outline the issue of parental/guardian consent for minors and assent from such minors
1.2.8. Time schedule needs adjustment. Anticipated date of data collection cannot be 15 July.
1.2.9. Information document must describe the issue of minors assent/parental consent
1.2.10. How will the parental consent be arranged/obtained? – currently the process described just covers the participant signing at the information meeting
1.2.11. Information document refers to 2-3 rounds - was this mentioned in the Data collection of protocol?
1.2.12. Information document needs to contain the following (these are just mentioned and stated will be given in briefing session but they seem to be listed on the information document – rather put all the relevant info on information document): the purpose of the study, the physical tests which will be done, time commitment (duration), risks, benefits, and confidentiality aspects that apply.
1.2.13. Assent/consent form: legal guardian – not caregiver and have space for the name of the participant who the person is signing for
1.2.14. Minor assent Form: This form states that monitoring will only take place during competitions, whilst the proposal indicated that it could also be done during 18 hole "training" rounds. Please clarify.

1.3. Permission outstanding:

1.3.1. Form A: Ministerial consent for non-therapeutic research on minors must be submitted to the HSREC for approval
1.3.2. Free State Golf Federation

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | F: +27 (0)51 444 4359 | E: ethicsfhs@ufs.ac.za
Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa
www.ufs.ac.za

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1.3.3. *Free State Sport Science Institute (Since the relationship between Free State Golf Federation and the Sport Scientist employed at Free State Sport Science Institute, has not been clarified)*

1.3.4. *NB Evaluation committee: not clear whether the following happened – form not signed by the chair of evaluation committee. Corrections must be sent to chair of committee who will distribute it electronically to the committee members for final approval and recommendations. Not clear whether the submitted protocol is the revised protocol after initial evaluation committee meeting. Please clarify and submit the correct report via RIMS.*

1.3.5. *Letter from Biostatistician*

PLEASE NOTE: Upon receipt of the updated documentation/other request(s) from the HSREC in RIMS, the project will be re-considered at the next meeting to be held on **29 August 2017**.

Please highlight all changes made before resubmitting on RIMS.

If anything is unclear, please contact HSREC Administration.

2. Kindly use the **HSREC NR** as reference in correspondence to HSREC Administration.

3. The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite); Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines; Constitution of the HSREC of the Faculty of Health Sciences.

Yours faithfully

....

DR SM LE GRANGE
CHAIR: HEALTH SCIENCES RESEARCH ETHICS COMMITTEE

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Hanta Henning
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DECLARATION

Hereby I, Johanna Gertruida (Hanta) Henning, declare that I completed the proofreading and formatting of the thesis **Physical Demands of Golf** by Tania Kristel Brink submitted to the Department of Exercise and Sport Sciences, School of Health Sciences, University of the Free State, in partial fulfilment of the degree Magister Artium in Health Sciences.

The document was proofread for correctness and clarity of language, syntax, grammar, and concord. Numbering and page numbering as well as page layout were all completed by the proofreader. I do not take any responsibility for referencing/citation/bibliography errors, as this was not part of the services required by the client. I acted according to my client's requests and instructions only.

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