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# Performance Indicators in (ATP) Tournaments


By

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## Declaration

I, **Jason Carlisle,** hereby declare that this work presented within this document is my own and have been generated by myself and is the result of my own original research.

I confirm that:

- Where any part of this study has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where the works of others have been quoted, the source is always given. Apart from such quotations, this study is entirely my own work.
- I have acknowledged all main sources of help.

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# Summary

## Introduction

Key performance indicators (KPI's) are vitally important in the context of sport. Being able to analyse and adapt accordingly to the KPI's, would be of great benefit to the athletes as well as the coaches.

## Aim

To differentiate between the KPI's of winning and losing players of matches played and the surface types and their influence on the outcome of matches. (Player height and age, number of aces hit, 1st and 2nd serve accuracy, points won off the 1st and 2nd serves, number of breakpoints faced, and number of breakpoints saved.)

## Methods

The current study was conducted in a retrospective manner as a quantitative design. The data was collected from a public domain, GitHub, and consisted of the 2018 ATP Tour. The data collected varied across three surfaces played on, namely Clay, Grass, and Hard Courts. The outcome of the current study was to determine the effects of the KPI's on the final result of the tennis matches.

## Results

The current study found significant differences between the winning and losing players with regards to Aces, Service Points, 1st Serves Won, 2nd Serves Won, Breakpoints Faced, as well as Breakpoints Saved, however, no significant difference was found between the 1st Serves In ($p=1.368$). The current study also find a significant difference with regards to Aces struck ($p=0.0006$) between Hard and Clay Courts. No other significant differences ($p<0.05$) were reported across the KPI's.

## Conclusion

It is important for coaches and players to note that age and height do not discriminate between winner and losers in men's tennis as well as 1st Serves. However, all the other KPI's show significant differences between winner and losers. This information may assist players and coaches in preparing themselves or their athletes to achieve success.


Key words: ATP tennis, Key Performance Indicators, Winning and Losing.

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## List of Abbreviations and Definitions

- ATP – Association of Tennis Professionals
- ITF – International Tennis Federation
- PRO – Professional
- WTA – Women's Tennis Association

- **Ace** - A ball which is served legally which the opponent is unable to play (Tennis Companion, 2013).
- **Breakpoint** – The final point in the service game needed to be won, to win the service game by winning off the opponents serve. (Tennis Companion, 2013)
- **Deuce** – When both players have reached the score of 40 all (USTA, 2021).
- **Double Faults** – Two consecutive serving faults in tennis that result in the loss of the point for the server. (Merriam-Wbster, n.d.)
- **Game** – Part of the points scoring system in tennis, the player has won 4 points whilst having a lead of two points. After the 4 points are won or after deuce and advantage has been played and won, a game is complete (USTA, 2021).
- **Player Reach** – The distance that a player can extend the arm and racket towards the ball and strike it successfully. This could also be viewed as the player's wingspan (Aracic, 2019).
- **Player Load** – The total amount of stress or work rate intensity placed on the athlete's body, either during training or competitive matches (Catapult, 2018).
- **Return** – Hitting the ball back to the opponent legally (USTA, 2021).
- **Seeding** – A system used to separate top players to ensure that they do not play each other in the early rounds of the tournament, it is calculated according to their previous outcomes in the tournament (Zimmer, 2018).
- **Service Point** – A shot played to start the point in a tennis match (USTA, 2021).
- **Tie-Break** – An extra service game which is played when the set score is 6-6, the player who wins the tie break will win the set (USTA, 2021).

# Chapter ONE: INTRODUCTION AND SCOPE OF DISSERTATION

## 1.1 Introduction

The origins of tennis can be traced back to the 12th century in France where a very similar game was played called “Jeu de Paume” or game of the palm (Bruce & Lorge, 2019). Players used their hands instead of rackets to strike the ball. The first ever rule book to be written for the game of tennis occurred in 1873, a Major Walton Clopton Wingfield (Abramson, n.d.), was responsible for the rule book and he patented the game in 1874. Tennis, is a game that can be played by either two single players or two pairs of players (doubles), opposing one another on a rectangular court, striking a ball of a specific weight, bounce, and size, back and forth over a net.

In the modern era, an investigation by Lane *et al.* (2017) showed approximately 360 million tennis balls are produced annually, these balls are produced according to International Tennis Federation (ITF) guidelines and are subject to testing procedures. The players use racquets which are tautly strung. Tennis was originally played on grass, however the modern era has seen many different surfaces introduced for the game, including grass, clay, hard court, and carpet (Bruce & Lorge, 2019).

The first ever tennis championship was held in 1877 at the All England Croquet club, which was soon after renamed the All England Croquet and Lawn Tennis club. This championship was known as Wimbledon and the first winner of Wimbledon was Mr Spencer Gore. We can therefore see that from the inception of the sport, possibly unbeknown at the time, Key performance indicators (KPI’s) have played a vital role in the player’s performance and ultimately the outcome of the match.

According to Shvorin and Taaffe (2014), there are internal and external inputs that a tennis player needs to contend with: Internal inputs, being those affecting the tennis players personal physique, while the external inputs being the player’s KPI’s. The study then goes on to define a high level of performance:

“*The key to achieving a high level of performance lies within the ability to translate the external inputs and the internal inputs into a winning game plan”* (Shvorin & Taaffe, 2014).

Within the time frame of 60 years, tennis had spread across the globe, with many championships being played in the USA, France, Australia, South Africa, Canada, Spain, Denmark, Egypt, Italy, and Sweden. To conclude, the first women's championship was introduced at Wimbledon in 1884 (Bruce & Lorge, 2019).

Currently two bodies, govern world tennis, on the men's circuit it is the Association of Tennis Professionals (ATP), and for the women's circuit it is the Women's Tennis Association (WTA). The former founded in 1972 and the latter in 1973 (ATP Tour, 2000). Both of these organisations fall under the ITF or International Tennis Federation. These two organisations are responsible for the arranging and execution of tournaments as well as promoting the growth of the game by introducing new tournaments, which the ATP propagated in 2000 (ATP Tour, 2000).

According to Kovacs (2007) and Hurley (2015) involve all racket sports short bursts of high intensity exercise due to their intermittent nature. Conditioning tennis players in the past has been difficult, due to the fact that there were never any non-invasive measurement instruments to determine the player loads. However, modern technology has improved this with instruments such as Hawk-Eye and the Catapult Player Load Metric. This is a non-invasive, highly accurate and reliable device as well as being able to measure real-time power being produced by the player (Reid *et al*., 2016; Catapult, 2018). Tactical as well as physical power characteristics, traits or shortcomings can now be recorded and addressed. According to Ma *et al*. (2013) need a coach normally approximately 10 years working and training with a player to achieve the elite level of tennis required for the modern-day era and competitions.

As mentioned earlier, the outcome of tennis matches is greatly influenced by KPI's, court surfaces, player height and serve accuracy as well as the player's hand dominance (Kilit & Arslan, 2017). The aim of this study was therefore to investigate KPI's in tennis. The effects of the KPI's will be visible in the way players approach the game as well as the manner used to prepare for different tennis events (Kilit & Arslan, 2017).

## 1.2 Problem Statement

Tennis has become a very popular sport and is supported worldwide. Few studies (Shvorin & Taaffe, 2014; Donoghue & Ingram, 2010; Söğüt, 2019) have been conducted on KPI's in the modern era of tennis. Coaches as well as players need this information to adapt and simply improve their skills (O'Donoghue, 2010; O'Donoghue, 2015; Bruce & Lorge, 2019). A better understanding the KPI's in tennis will be a great asset to players and coaches for periodisation planning.

To conclude, it is clear from previous research (O'Donoghue, 2010; Hurley, 2015; Bruce & Lorge, 2019) that there are no standard set of performance indicators used for tennis analysis. Therefore, this is an area of research which would be a useful area to investigate.

*"The performance of professional tennis players in the four major Grand Slam tournaments has always been an important research topic, which advances the understanding of the current development of tennis. However, there is little known about the difference between higher-ranked and lower-ranked players considering match performance statistics"*

(Cui *et al*., 2020)

## 1.3 Study Objective

The objective of this study is to provide information on the KPI's and outcome of a tennis match.

The aims of the study is:

To differentiate between the KPI's of winning and losing players of matches played and the surface types and their influence on the outcome of matches. (Player height and age, number of aces hit, 1st and 2nd serve accuracy, points won off the 1st and 2nd serves, number of breakpoints faced, and number of breakpoints saved.)

## 1.4 Motivation for this Study

A lack of data regarding the KPI's in tennis, with the focus on multiple KPI's was the motivation for this study. Players as well as coaches need to constantly adapt in the world of sport. If the relevant KPI's can be focused on and understood, the adaptation from both player and coach will be able to take place sooner and keep the game of tennis growing and improving. As mentioned earlier in the study, players need to have a game plan, but it needs to be versatile and be able to be adjusted at a moment's notice, the best players in the world are those who are able to analyse their play on court and make the necessary improvements or adjustments.

## 1.5 Overview of the Study

Chapter 1 introduces the theme of the study, providing history as well as the current information on the game of tennis. We also see the Problem Statement being presented as well as the study's objectives, along with the motivation behind the researcher's interest in the field.

Chapter 2 provides the Literature Review of the study. The literature review presents previously published information on the specific topic or area of the research review.

Chapter 3 clarifies the research methodology of the study, how the data was collected as well as the tennis participants, and how these participants were included. Chapter 3 also discusses the statistical analysis of the data as well as the validity and reliability of the public domain database, GitHub, where the data was collected. The ethical aspects as well as the pilot study is also discussed within this chapter.

Chapter 4 introduces the results of the current study, underlying certain tendencies which were discovered by the study. The results are depicted in graphics as well as tabulated.

Chapter 5 provides the discussion of the results found in the current study as well as comparisons with previous studies. Conclusions are made in chapter 5 according to the data presented in chapter 4.

Chapter 6 presents the Conclusion as well as the Summary of the current study. Chapter 6 also provides the reader with an indication of limitations of the study and recommendations for future research.

Chapter 7 offers an insight into the personal remarks of the researcher, a reflection of the research process.

# Chapter TWO: LITERATURE REVIEW

## 2.1 Introduction

Many influences play a role in the outcome of sporting events, with tennis being no different. To show exception, knowing the role of KPI's, they may assist in an athlete's preparation and final style of play during the match or tournament.

According to Shvorin (2017) react tennis players in one of two ways when faced with a situation on court, either "tactically" or "strategically", which in turn will show the athlete's level of sport-specific knowledge as well a their cognitive prowess (Filipcic *et al.,* 2021).

For any athlete to improve, they must truly understand the relationships and effects of all aspects that could possibly have an influence on their sport and the manner of the participation in the sporting code. These indicators take many shapes and forms during a contest, including eye-hand dominance, the player's height in relation to serving ability, and even hand dominance just to name a few examples. These avenues need to be explored further as the game needs to grow and improve (Filipcic *et al.,* 2021).

There are two main concentrations with regards to KPI's in tennis according to Shvorin (2017), namely external and internal factors. Shvorin (2017) further states that internal factors are linked to the athlete's decision-making process and how these could then affect the athletes's stroke and swing technique, or body resources management as well as emotional intensity and input. Tennis is comprised of 5 main strokes, namely; the serve, forehand, backhand, smash, and volley (Hurley, 2015).

However, in this study the researcher has focused more on the external factors, because these factors are the result of external inputs on the decision-making process of the athlete. For example, the type of court surface being played on, the weather conditions during match, even the style of play being utilised by the opposing player. These inputs all have to be calculated, taken into account and acted upon for the athlete to achieve the desired outcome from the match or tournament (Shvorin & Taaffe, 2014).

There are a number of various ATP and WTA sanctioned tournaments played worldwide. The four most prestigious tournaments known as the Grand Slam Tournaments, are the Australian Open, the French Open, Wimbledon, and the US Open (ATP Tour, 2000). In

these tournaments, the top ranked players in the world will receive seeding. The seeding for the tournament will ensure that the higher ranked players will not face off in the round robin stages of the tournaments, these games will be seen during the later stages of the tournament and the draw of the tournament will depend on the number of seeds.

Players are able to build on the world rankings by playing in sanctioned tournaments. On the men's circuit these are ATP 250, ATP 500, and ATP 1000 tournaments, each carrying its own weight in terms of a world ranking points system. The Grand Slam Tournaments carry the most weight in awarding of the world ranking points (Liveaboutdotcom, 2018).

Due to tennis being mainly an outdoor sport, it was always seen as a summer sport. Damp and wet conditions can cause problems with equipment, as well as making the playing surface unsafe in some circumstances, for example, there being no traction on wet clay or hard court. However, as with most professional sports in the modern age, there is no longer a season and tennis is played throughout the year, players merely move with the summer across the globe, new and improved stadiums also allow for tennis to be played indoors and eliminate any potential natural element disturbances. The natural elements do not just affect the game of tennis but the players as well, by influencing the speed of recovery and activity patterns during exposure to the elements while playing matches (Fernandez *et al.,* 2006).

The oldest tournament in the world, Wimbledon, installed a retractable roof over centre court in May 2009 so as to ensure that the finals of the competition and the more high-profile games would reach a conclusion in what can be very wet English summers. The roof is only used when needed, meaning that most matches are still played using natural light and are exposed to the elements (Design Build Network, 2009). Bergeron (2003) stated in this regard that tennis players lose 1.0 to 2.5 litres of body moisture through sweat, per hour when playing in warm to hot conditions during a competitive singles match. This was relevant especially at the Australian Open, which is played outdoors on hard courts, hard courts are often known to increase the on-court temperature by reflecting the heat back towards the players.

## 2.2 Physiological Demands

Over the last 20 years tennis has drastically changed, becoming a fast paced, action packed sport. This in turn has led to many research opportunities due to the increased interest in the sport (Van den Berg *et al.,* 2006; Kovacs, 2007). As in any sport there are physiological demands being placed on the body, (Kilit & Arslan, 2017), whether this be due to running at different speeds, and changing direction rapidly, or due to playing long rallies, there are severe demands placed on the body.

Just like in all sports, tennis does not just test the body but the athlete's mind as well. The cognitive ability to analysis during game play as well as the ability to adapt a game plan as mentioned earlier will also be utilised and tested (Filipcic *et al*., 2021; Reid *et al.,* 2016). It is well known that players are able to make better decisions when they are well conditioned and able to think while an immense strain is being placed on them physically, as mentioned previously in the study.

Research indicated that young or junior level tennis players can cover up to 3.4km in a match with 10-25% of that distance covered during maximum effort (Kilit & Arslan, 2017). A tennis player's style of play will also be determined by their body composition to a certain degree, where tall, lanky players will have a greater reach but are often slow on court, unable to change direction quickly. They will also hit the ball harder as they are able to generate a higher racket head speed with a longer reach. Shorter players as mentioned before are able to return the ball very well and are often far more agile around the court than their taller opponents as stated in a study conducted in 2008 (Juzwiak *et al.,* 2008).

According to Reid *et al.* (2016) players at the Australian Open, (men and women), were recorded covering between 550-575m per set while playing the various points. This study also pointed out that during the 2012 Australian Open final between Rafael Nadal and Novak Djokovic both players surpassed 6km in in-point distances, this match also lasted a mammoth 5 hours and 53 minutes (Reid *et al*., 2016). The main reason for the male players covering such large distances is due to the fact that they play a match spanning 5 sets, this means that on average males will spend more time on court, playing more strokes as well as make covering larger distances than female or junior players.

A study conducted by Filipcic *et al*. (2021) showed that one third of the time players spent on court was actively playing rallies, this relates to roughly 10m per rally and 1,8km per match. However, Kilit and Arslan (2017) showed that the largest physiological demands and responses occurred once the player took the lead in the match. Conditioning and preparing for this time in the game could be used to appropriately and adequately prepare junior as well as professional tennis players in the future.

Due to the game of tennis requiring a various array of different movements performed by the player such as, sprinting, stopping, overhead arm action, as well as direction changes, the game varies from low to high intensity (Fernandez *et al*., 2006).

Tennis places immense stress loads on the player's lower and upper body, as reported by, Ellenbecker *et al.* (2009), unfortunatly this can lead to injury patterns. Many areas of the movement planes need to be addressed during tennis conditioning, especially when one considers the service movements through the lower back and shoulder. Flexibility is also of vital importance and is often overlooked as stated by the study conducted by Kovacs and Ellenbecker (2011) and Kovacs (2007). More research needs to be done on determining the cause and prevention of injuries in tennis.

Adding to physiological demands placed on the body, many tournaments are played outdoors and the environmental factors often place additional stressors on the players. The demands of the game have forced many players to adapt their training and preparation for events, both aerobic and anaerobic systems are used in short intermittent intervals (Fernandez *et al., 2*006).

A study conducted by Reid *et al.* (2016) and Filipcic *et al*. (2021) showed that players at Grand Slam level had an average return time of 0.7s when playing a ball from a serve. This is then followed up by the posibility of up to 1000 ground strokes per match, with a percentage of between 76-81% of the strokes being played from the baseline. This calls for excessive endurance in the athletes as well as good muscle strength and core stability to handle the high number of repetitions on the body. The demand placed on the athletes is to often exceeds the performance indicators they are faced with.

## 2.3 Performance Indicators in Tennis (KPI's)

O'Donoghue (2010) stated that performance analysis (PA) differs substantially from other disciplines because it analyse actual sport performance. In the past laboratory tests or indirect tests were mostly used. Performance analysis is really useful to inform decision making to enhance performance and it is an important tool in the analytical process for coaches.

It is also clear from the literature that there is a great increase in PA (Mellalieu *et al*., 2008, O'Donoghue, 2010, Bampouras *et al*., 2012; Hurley 2015; Reid *et al.,* 2016; Filipcic *et al*., 2021). According to Hughes and Barlett (2002) can PA be split into two broad domains, namely "technical analysis" and "tactical analysis". Technical analysis refers to the performance of skills, for example the execution of a successful ace serve in tennis, whereas "tactical analysis" is more concerned with using these skills in such a way as to achieve success (O'Donoghue, 2010). A practical example in tennis is the decision of the player where to place the ball in relation to the opposition player.

Hughes and Franks (2008) suggest 5 practical uses of performance analysis in practice namely:

- Tactical analysis,
- Technical evaluation,
- Analysis of movement,
- Development of a database and modelling
- Educational use for coaches and athletes.

O'Donoghue and Mayes (2013) comment that tactical analysis can be used to provide quality feedback during the coaching process to adapt the training process to enhance performance. It is really important to note that O'Donoghue (2010) also indicate that precise operational definitions of KPI's should be established before the analysis takes place. Hayen *et al*. (2007) agree and reason that this allows the analyst to draw reliable conclusions from the data to give to coaches and athletes.

It is clear from the literature that there are no standard set of performance indicators in tennis. However, Hughes and Clarke (1995) suggested player positioning, ball placement and rally times. Taylor and Hughes (1998) agree and stated also that rallies were also important in tennis, especially the number of shots made per rally, but they also acknowledged that winners to errors ratio, and the quality of serves and returns are also of great importance. Hurley (2015) examine service placement in relation to gender differences and comparing 1st to 2nd serves.

The literature also indicates that research in tennis varied considerable, and there are many different areas which can be further developed and linked with other aspects of the game. Studies for example on the effects of ball compression on match outcomes has been studies, with significant differences being found for variables such as rally speed and shots played from the net (Kachel *et al*., 2015).

There have been a number of studies concerned with one of the KPI's but very few have focussed on more than one KPI. In a study conducted by Shvorin and Taaffe (2014), a winning game plan must be able to be adapted to the KPI's that are facing the player in that situation. No game plan is perfect due the human performance element involved.

It is a closed loop of trial and error which leads to the player's improvement. According to Martinez-Gallego *et al.* (2013) the winner of games played at the 2011 Valencia ATP tournament spent less time in a defensive state. This was due to players being able to adapt their game plan and dominate by using the performance indicators in their favour.

*"A game plan could change at any time due to a change in the internal or external inputs. A winning game plan can be considered similar in its process to quality methodologies seen in production systems."*

Shvorin, (2017)

Filipcic *et al.* (2021) stated that for long term development in any form of tennis, in-match play analysis is of vital importance. Players will need to adjust to the performance indicators which they are confronted with, only then will they be able to succeed, especially at a higher level of play.

Further investigation has be done into the following KPI's:

### 2.3.1 The Serve

It is well known that the importance of the serve in tennis is not a discussion point. However, Filipčič *et al*. (2011) suggested three factors which would significantly differentiate statistically between winners and those players who were defeated. These three factors were:

- Number of double faults,
- Percentage of points won on own serve,
- Total number of points won in the match.

Filipčič *et al*. (2011) indicate that it is clear from these results that successful players had a more reliable serve, a higher success rate on their 2nd serve and won more points in the match, as they performed fewer double faults than players who were defeated. However, Filipčič *et al*. (2011) stated that there was no conclusive evidence on whether the serve is the most important part of a player's game, it did show that having a successful and consistent serve gives the player a distinct advantage against their opposition. Furthermore, the tennis serve has been greatly improved in the period post 2002. It is also the only shot to be played in tennis in which the player is 100% in control (Kovacs & Ellenbecker, 2011; Kolbinger & Lames, 2013). Due to players being in control of the stroke, players will want to minimise the amount of double faults as much as possible. The optimal as well as the desired outcome for the server will be to serve as many aces as possible. Therefore, the serve is of vital importance in a tennis match as the game is unable to commence without it.

The first serve accuracy at the French Open from 2002 to 2009 has risen from 60.2% to 64.2% (Ziagkas *et al*., 2017), and the average first serve speeds from 165.1 km/h to 188.9 km/h. However, the impressive speeds could be detrimental, as Miller (2006) shows that the modern rackets are very stiff as well as the balls becoming harder, therefore the rackets place more strain on the players arm and joints which could lead to injuries, although this does not only occur in the service motion, but during general play as well.

Filipcic *et al*. (2015) investigated the difference of performance from 1991 to 2010, where he found that on faster courts, such as hard courts or grass courts, players had a better chance of winning a point off their own serve if the ball was placed near the T and the return of serve then being played wide (Filipcic *et al.,* 2015). Vaverka and Cernosek (2012) agree and have also indicate that the technique of the complete serve and the ball toss is just as important, the ball needs to be struck at a minimum height of 2.74m above the ground to be landed within the service box which grants the player an opportunity of either converting the service point with an ace, or forcing the opposing player into an unstable phase, (this will be discussed later in the current study), for the return of service.

However, Söğüt (2019) found that male professional tennis players served a higher percentage of double faults as well as aces on grass courts compared to all other surfaces. The research conducted by Hurley (2015) found that players want to serve as many legal serves as possible to allow themselves the best opportunity of winning the match, this statement is supported by the study conducted on the statistics of the Olympic Tennis matches winners and losers by Frenandez-Gracia *et al.* (2019), showing that the players with the highest percentage of first serves won, breakpoints won, and the break return of serve points won, would go on to win the match.

Body height is a highly influential variable in the serve speed as well as accuracy. Another contributing factor to serve accuracy is the flexibility level of the player (Ali, 2015; Kovacs & Ellenbecker, 2011), allowing the player to increase power in strokes by being able to generate higher racket head speed.

The serve is comprised of 8 different stages namely the start, release, loading, cocking, acceleration, contact, deceleration, and finish (See figure 1 below) (Reid *et al.,* 2013).

Söğüt (2019) concluded that players who have a height advantage over their opponent, have a higher probability of winning the match. This is due to the taller player being able to hit the ball at the optimal contact point of 2.47m above the playing surface (Kovacs & Ellenbecker, 2011; Vaverka & Cernosek, 2012; Hurley, 2015) which allows for a bigger service box area for the ball to land in, furthermore, height also plays an important role in the control of a serve and the direction of the ball. However, due to this fact, the players

which are shorter in stature have far better return-related statistics than those players which enjoy the height advantage (Söğüt, 2019). This can also be accredited to the fact that shorter players are more agile on court (Juzwiak *et al.,* 2008).

Rackets are set up according to guidelines provided by the ITF, the technology used in producing rackets has vastly improved from the older heavier, wooden rackets to the more modern, graphite rackets (Miller, 2006) which are much lighter and stronger. This enables players to swing faster and hit the ball harder by generating higher impact speeds.


*Figure 1: Side view of Tennis Serve*

### 2.3.2 Various Playing Surfaces

The playing surface on which the match or tournament is played, affects the style of play of professional tennis players as it influences the movement of the player as well as the behaviour of the tennis ball due to the friction created between the ball and the surface (Miller, 2006).

Although tennis was originally known as Lawn Tennis and played on grass (Bruce & Lorge, 2019), today a variety of surfaces are utilized, mainly clay, grass, and hard court. Hard courts normally comprises of concrete as well as having a layer of padding, this is then painted over with a mixture of sand and paint (Reason, n.d.). Traditional wood

flooring for indoor courts has made way for synthetic surfaces such as hard court and carpet (Bruce & Lorge, 2019).

Grass courts demonstrate a low level of friction and therefore the ball does not bounce but rather slides off the court, however due to the low level of friction, the players lose the ability to turn and change direction as quickly as they would have been able to on a hard court.

Due to the different surfaces, tennis players will need to adapt their game to suit the surface the match is played on. Shvorin (2017) stated in this regard that this relates to stroke selection as well ensuring the execution of specific skills and abilites as mentioned earlier with regards to changing direction. It can clearly be distinguished that carpet courts are a fast, low bouncing surface, whereas playing on clay courts, players are able to slide great distances to reach balls for return shots. Serves that are hit wide on clay courts have a higher chance of being won by the server than the returner due to the slow nature of the court caused by the highest amount of friction on any of the surfaces used for tennis. Many players and fans alike prefer the slower clay courts as it creates more a spectacle, these slower courts allow for more tennis, longer, and more tightly contested rallies (Reason, n.d.). Gillet *et al.* (2009), examined serve and serve-return placement strategies on clay court surfaces for men's singles. The outcome of the study revealed that servers win significantly more points from topspin serves than from slice serves, with 2nd serves being more likely to be aimed at the players backhand from each side. They concluded that serves and serve-returns highly influence match results for elite male tennis players.

Furthermore, Söğüt (2019) found that the return game percentages were significantly lower on grass than when compared to hard court and clay surfaces due to the varying speed of the courts and the players having longer or shorter reaction periods per surface. Filipcic *et al.* (2010), stated that players that play with a higher accuracy in terms of unforced errors dictate terms during the matches.

O'Donoghue (2009) also indicate serving placement between right and left handed players where he showed that players tend to serve to their opponents' backhand,

regardless of whether the player is right or left handed. Loffing *et al.* (2009) agree with O, Donoghue (2010) and found also a significant difference in service placement between left handed and right handed players.

The dimensions of a tennis court, no matter the type of surface in both singles and doubles matches, remains the same as depicted in figure 2. The effect of the playing surface on injury rate showed that the highest rate of incomplete matches in male professional tournaments from 1978 to 2005 occurred on the hard courts of the US Open (Dragoo & Braun, 2010). These injuries were mainly observed as being overuse injuries with environmental factors also playing a large role in the injury rate.

Reid *et al*. (2016) stated that players practice and training sessions should be consistent with the match play demands, as well as the playing surface demands, placed on the players to acclimatize the athlete's bodies. This will also come into effect when coaches and players analyse the court surface which will be used, the study found that more ground strokes are played on clay courts which exposes the players to longer rallies and a higher level of endurance is required.

According to Söğüt (2019) professional male tennis players participate in 24 tournaments per year, this relates to about 60 competitive matches a year. These matches are divided up between the 3 surfaces, hard court 58%, clay court 32%, and grass court 10%, this means that players need to adapt their training, including their conditioning programs, and playing styles continuously throughout the year.

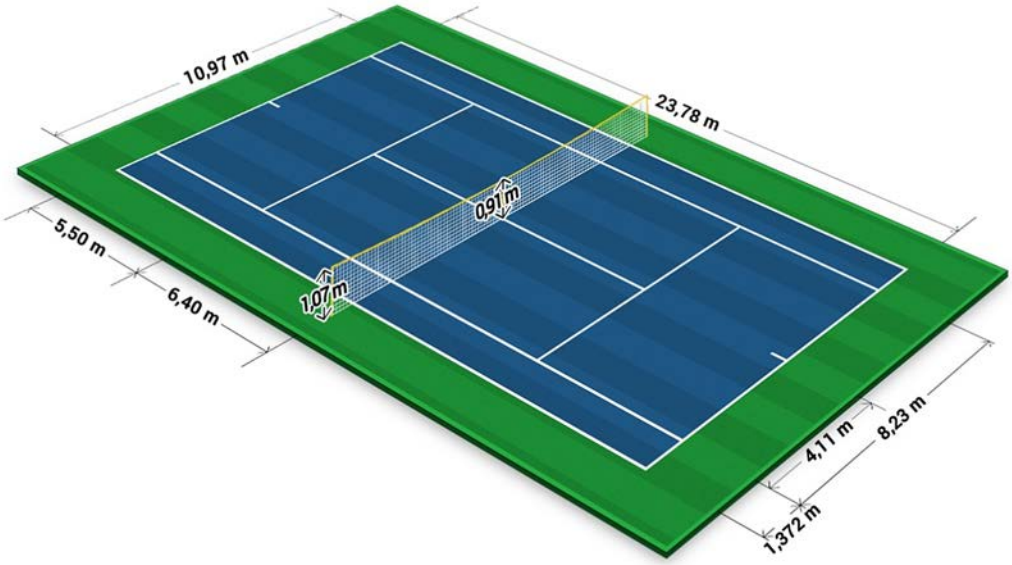


*Figure 2: Dimensions of a Tennis Court on all surfaces played.*

Different playing surfaces (see figure 3), will also cause the ball to be degraded in different ways, which in turn, as mentioned earlier by Shvorin and Taaffe (2014), becomes an external input for the players (Mighty Goods, 2018). This will also influence the way players strike the ball as well as how the return shots are played by having to get into better positions. Balls are expected to degrade at the same rate, and during international events; it is common to find a set of six balls on the court during a set (Lane *et al.,* 2017). The first set of balls to be used will be used for the warm up and will be changed after the 7$^{th}$ game. The ball change will then proceed every nine games after this. Lane *et al.* (2017) also stated that changes in the material composition (felt and rubber), normal impact forces, contact distance and speeds are all relevant factors in tennis ball wear and are determined by a combination of the pre-impact conditions (speed,angle, and spin) and the surface interaction between the ball and court.

*Figure 3: Various Court Surface Types (Hard, Clay, Grass)*

To conclude, previous research clearly shown that court surfaces influence the importance of the serve (Hughes & Clark, 1995; O'Donoghue, 2001), in particular, serves seem to be of greatest importance on grass courts at Wimbledon (O'Donoghue & Brown, 2008).

### 2.3.3 Hand Dominance

The influence of hand dominance as a KPI has not been investigated fully as yet. However, studies conducted on the hand dominance of elite tennis players, like the one study conducted by Bačić and Gazala (2016), do show that left handed elite tennis players make up at least 15% of the top 100 male players in the ATP rankings. This can then be compared to the worldwide general population which shows only 10% of males are left handed (Worldatlas, 2018). Thus, the study encourages parents and coaches to venture into multi-disciplinary skills training with their children or clients.

Many key advantages were observed by Bačić and Gazala (2016), when left-handed players took on right-handed opposition, these ranged from the trajectory of the ball to developing cross-court rally assertiveness. According to Loffing *et al.* (2010), left handed players enjoy an advantage of having to play far fewer backhand strokes than that of right handed players, the left handed players also have far superior forehand strokes in terms of strength and accuracy when compared to right handed players. Due to these findings

it is believed that left handers enjoy a tactical advantage over their right handed counterparts (Loffing *et al*., 2010).

## 2.4 Winning and Losing

In tennis we can see a complex system with the interaction between cause and effect, this relationship plays a vital role in the outcome of a point and eventually the match as it affects the performance level of the both the players, either positively or negatively (Shvorin, 2017).

According to Martin and Lames (2006), tennis player's move in phases, the more the phases become disrupted, the more the KPI's affect the eventual outcome of a point being won or lost. When players find themselves in a relative phase, both are in similar proper positions to play the ball and no player enjoys true advantage, however, as the play starts moving and the ball is hit to different areas of the court the players move to an unbalanced phase. During the unbalanced phase, players are not in stable and proper positions to play the ball and this could lead to the point being lost (Lames, 2006). Therefore, opponents will try to force one another into as many of the unbalanced phases as possible. This will then be able to give one of the players a clear advantage during points, rallies and service games, having a great influence on the outcome of a match.

When it comes to the result of a tennis match, there can only be one winner and one loser. Ma *et al*. (2013) concluded in winning matches in men's singles at grand slams showed that there are four factors, which play a role, namely:

- Number 1: the environmental conditions,
- Number 2: the match conditions,
- Number 3: the playing strategies of both players, and
- Number 4: the personal characteristics of the two players on court.

Here again we see the internal and external inputs found in the study conducted by (Shvorin & Taaffe, 2014). The study found that one of the largest contributors to winning tennis matches was the individual's personal characteristics, i.e. the player's drive and will to win, although skill is also a vital part of the outcome, being able to hit more aces or

being highly accurate with shot placement (Ma *et al*., 2013) wins the game.

Another factor that has been mentioned under the “Physiological Demands”, is that players need to be efficiently physically conditioned. An athlete that is well conditioned is able to think more clearly under strenuous physical strain, conditioning has become a vital aspect in the successful outcome of tennis matches (Reid *et al*., 2016).

Momentum is a term often used in any sporting code when it comes to winning a competition, however, Vergin (2000) shows that there is very little evidence to support momentum in individual sports. He would rather suggest that momentum could become a factor to bring into reckoning when analysing a season’s results. Furthermore, the study concludes that there is too much importance placed on momentum. A study performed by Covassin and Pero (2004) in the United States of America on college tennis players saw the winners of these matches exude confidence and have fewer internal mood disturbances, which allowed them to perform at a higher level throughout the season. Frenandez-Gracia *et al*. (2019) confirmed in this regard that the winners of Olympic Tennis matches were the players that played more offensively. The confidence of the players allowed them to put their opponents into more unbalanced phases.

An important factor that also plays a role in the winning and losing of tennis matches, is the players seeding. However, to ensure that tennis tournaments remain lucrative and attract large crowds, the seeding system ensures that matches of a larger scale and higher seeding, will play at the latter stages of a tournament. According to Della Croce, *et al*. (2018) this can be seen as unfair towards the lower seeded players who miss out on the later stages of tournaments with regards to prize money and sponsorship deals.

The study shows that for absolute fairness a system must be applied to ensure that an unseeded player cannot be matched with a seeded player for two tournaments consecutively (Della Croce *et al*., 2018). As mentioned previously in the study, the development of players lies in their ability to analyse and adapt on court while they are playing. Shvorin (2017) concluded that playing against seeded players will only strengthen and improve the game of the non-seeded players in the tournaments.

## 2.5 Conclusion

It is clear from the literature that tennis is an ever-changing sporting code, and thus the need for continuous learning, research and development for all involved in the sport. We are able to ascertain the developments that have taken place and the effect that these developments have had on the sport code, i.e. when taking strokes like the serve, and the amount of time and research spent on perfecting the art of serving. We are also able to acknowledge the effect the different surface types have and how the playing styles of players are affected, adversely or not.

As reported in the literature above, strength and conditioning are becoming a far more important factor in the preparation of tennis athletes, the physiological demands, the external factors as well as the condensed playing schedule, creates excessively high workloads for the athletes. Deduced from what was observed under the heading, Winning and Losing, we are able to see that winning is not something that just happens, it takes a set of complex actions, preparation and training, all coordinated to happen in sequence. This in turn leads to interesting outcomes.

# Chapter THREE: RESEARCH METHODOLOGY

## 3.1 Introduction

The reason for this study is that, considering that there are not many studies conducted on tennis, especially regarding the key performance indicators (KPI's) of the game and how these indicators could possibly influence the outcome of matches an analysis is done.

The method that will be used to investigate the problem will be to analyse data collected from the ATP circuit (Season 2018) and to investigate the influence of the KPI's.

The influences and effects that these KPI's have been used by players, coaches, and sport scientists to better prepare players and allow them to adapt better and faster to certain situations. This has advanced the game of tennis as players can determine the weaknesses of their own game as well as that of their opponents. Having learnt how to better use their own strengths against certain opponents has been of great benefit.

## 3.2 Research Design

The study will be conducted in a retrospective manner and will be a quantitative study design.

## 3.3 Population and Sampling Participants

The population of this study is the ATP professional men's 2018 circuit i.e. the men playing in ATP sanctioned tournaments, regardless of their seeding or ranking numbers. The population does not take into account the age of the players, they must play on the ATP Men's Tour. The sample will be taken from 1400 matches from different ATP tournaments across the globe in 2018.

### 3.3.1 Inclusion Criteria

- Players must be part of the ATP Circuit, no ranking is required.
- Matches must be played in ATP Professional (Pro) Circuit sanctioned tournaments.
- Player must be a male.
- Game must have been played during 2018.

### 3.3.2 Exclusion Criteria

- Any players that do not adhere to inclusion criteria.

## 3.4 Data Collection and Analysis

### 3.4.1 Data

Data was collected from various ATP men's pro tournaments played across the world on a variety of surfaces. These tournaments include the Grand Slam tournaments; Wimbledon, Australian Open, US Open, and the French Open (International Tennis Federation, 2019). The data included performance characteristics such as:

- The two players' names
- The winner of the match
- The players' height
- The players age
- The number of aces hit by each player
- The number of $1^{st}$ serves in by each player
- The number of $1^{st}$ serves won each player
- The number of breakpoints faced and the number of breakpoints saved by winning and losing player

### 3.4.2 Analysis Objective

The objectives of the statistical analysis were the following:

To differentiate between the KPI's of winning and losing players of matches played and the surface types and their influence on the outcome of matches. (Player height and age, number of aces hit, $1^{st}$ and $2^{nd}$ serve accuracy, points won off the $1^{st}$ and $2^{nd}$ serves, number of breakpoints faced, and number of breakpoints saved.)

### 3.4.3 Statistical Analysis

#### 3.4.3.1 Descriptive Statistics

Quantitative variables were summarized using descriptive statistics (mean, SD, minimum, median, maximum), and were provided overall, separately for winners and losers, and separately for the different playing surfaces (again by winners, losers and overall).

#### 3.4.3.2 Comparison of winners and losers

In order to compare winners and losers of each match, the difference "winner – loser" for each performance characteristic was calculated. These differences were then analysed using a mixed linear model fitting a fixed intercept (the mean difference between winners and losers with respect to the performance characteristic in question), and the name of the winner and loser as two random effects. Fitting these random effects allowed one to model the correlation between match data due to the fact that different matches could involve the same players.

From the mixed model analysis, a point estimate and 95% confidence interval for the mean difference between winners and losers were calculated, together with the associated P-value. A statistically significant mean difference for a given performance characteristic would indicate that winners and losers differ significantly with regard to that performance characteristic.

Box Plots were created to visualize the relationships form between the statistics collected. A boxplot is a standardized way of displaying the distribution of data based on a five number summary ("minimum", first quartile (Q1), median, third quartile (Q3), and "maximum"). This can report what one's outliers are and what their values are. It can also tell if one's data is symmetrical, how tightly the data is grouped, and if at all, the data is skewed (Galarynk, 2008). This will be achieved by interpreting the whisker length and to which side of the box the whisker length lies. Should the median be in the center of the box the data will be symmetrically distributed, however should the median lie towards the upper or lower of the box, the data will either be skewed positively or negatively.

#### 3.4.3.3 Comparison of playing surfaces

In order to compare playing surfaces, the sum “winner + loser” was calculated for relevant performance characteristics. These sums were then analysed using a mixed linear model fitting “surface” as categorical fixed effect (the mean sum “winner + loser” for each playing surface with respect to the performance characteristic in question), and the name of the winner, the name of the loser and “tournament” random effects. Fitting these random effects allowed one to model the correlation between match data due to the fact that different matches could involve the same players, as well as the correlation between matches played in the same tournament.

From the mixed model analysis, point estimates and 95% confidence intervals for the pairwise mean differences between three playing surfaces were calculated, together with the associated P-values. A statistically significant mean difference for a given pairwise difference and performance characteristic would indicate that playing surfaces in question differ significantly with regard to that performance characteristic.

| Tournament | Surface | Winner's name | Winner- Dominant Hand | Winner-Height | Winner-Age |
|---|---|---|---|---|---|
| Brisbane | Hard | Nick Kyrgios | R | 193 | 22.6830937714 |

| Winner - Aces | Winner- Service Points | Winner - 1st serve in | Winner - 1st serve Won | Winner -2nd serve Won |
|---|---|---|---|---|
| 17 | 56 | 40 | 33 | 9 |

This is an example of the data has been arranged for the study and from which the conclusion will be drawn.

## 3.5 Pilot Study

A pilot study has been conducted by using the Junior ATP results-2018 season focussing mainly on the Junior Grand Slam Tournaments to gather data. This data is also freely and publicly accessible on the GitHub platform.

## 3.6 Ethical Aspects

Background of GitHub:

Analysis of opponents has become a major area in all sports. Notational analysis is a technique used by coaches and sport scientists to gather objective data on the performance of athletes, and has existed in a rudimentary form for centuries (Hughes & Franks, 2004).

The company GitHub was founded in October 2007, their headquarters are situated in San Francisco, United States of America. The main idea behind the website is a place for developers to have a platform upon which ideas and information can be freely shared looking mainly at tackling the problem of employment. Jeff Sackman is one of the contributors towards the platform by providing breakdowns of various ATP tournaments, including the amateur circuit as well as the professional

circuit, in terms of player profiles but also how the points of matches as well as the Grand Slam Tournaments were won.

The data collected from these games is freely available to anyone that enters the site with no registration or sign up required to access the tournament data. The site and the information from the site has been used before in studies involving tennis, a study done on the Fairness and Diversification in WTA and ATP Tennis Tournaments Generation by Della Croce *et al.* (2018). The website GitHub has been used in education as a platform for students to stay up to date with multiple versions of analytic content for data (Fiksel, *et al*., 2019). Research in the study shows that allowing GitHub into the classroom leads to students having a far better understanding and grasp of project management. This study concluded by advocating for the use of GitHub as a base for the learning material before customizing it to suit individual educators needs, as it would empower students with tools desired by future employers and was more time efficient (Fiksel *et al.,* 2019).

*'These resources are also essential for collaborative software projects because they enable the organization and sharing of programming tasks between different remote contributors.'*

(Perez-Riverol *et al.,* 2016:12)

The study conducted by Perez-Riverol *et al*. (2016) demonstrates the importance to these freely available platforms of information when it comes to compiling studies. The website also offers a platform for improvement in the coding world and helps improve developers and researchers through an open network (Perez-Riverol *et al.,* 2016).

Please see Appendix E for personal communication between the researcher and GitHub.

### 3.6.1 Validity and Reliability

The following paragraph is taken verbatim from the GitHub website's privacy policy:

"*We may share your information with third parties under one of the following circumstances: with your consent, with our service providers, for security purposes, to comply with our legal obligations, or when there is a change of control*

*or sale of corporate entities or business units. We do not sell your personal information and we do not host advertising on GitHub*."

(GitHub, 2020)

Anyone posting to GitHub website is checked thoroughly by the team of developers as well as the information being double-checked by the team before posting it to the website. The website does hold a valid licence and is freely available to the public.

"*We take all measures reasonably necessary to protect the confidentiality, integrity, and availability of your personal information on GitHub and to protect the resilience of our servers*."

(GitHub, 2020)

As well as the free public access of all the information could have been viewed on various media platforms throughout the tournaments, for example TV, internet streaming, or social media sites. A recent study conducted by Coelho *et al*. (2020) shows Github to be one of the largest contributers of information to the open-sourced development market. According to the study, users are able to access historical data as well as popularity based figures (Coelho *et al.,* 2020). This study also found that only 16% of the projects on GitHub become unmaintained, therefore 84% are continously being upgraded and worked on.

# Chapter FOUR: RESULTS

## 4.1 Introduction

The primary aim of this study was to differentiate between the KPI's of winning and losing players of matches played and the surface types and their influence on the outcome of matches. (Player height and age, number of aces hit, 1st and 2nd serve accuracy, points won off the 1st and 2nd serves, number of breakpoints faced, and number of breakpoints saved.)

A total of 1400 (N=1400) matches were analysed during the 2018 season. The season spanned across 68 tournaments on three surface types, namely clay, grass, and hard court (ATP Tour, 2000). The 1400 matches were played by a player base of 677 male players throughout the season (ATP, 2018). The KPI's were compared between the match winner and the loser, namely player height and age, as well as the number of aces hit, 1st and 2nd serve accuracy, the points won off the 1st and 2nd serves, the number of breakpoints faced and the number of breakpoints saved.

This chapter will present and depict the results found from the study. *Box plots provide a graphic illustration of the variable that is plotted. "The box plots illustrate the range between the first to the third quartile of the data. In other words the box displays the central 50% of the data. The difference between the third and the first quartile is referred to as the inter-quartile range (IQR). The whiskers drawn from the box display the most extreme point that is less than or equal to 1.5 times the IQ). Values higher or lower than the 1.5 times the IQR are displayed by a "+" or a "o" sign"* Shaw (2018).
The interpretation and the discussion of the findings will follow in Chapter 5.

## 4.2 Comparison of Winning and Losing Players

Boxplots illustrate the distribution of the variables; body height (Figure 4.1), and age of the winner and loser in tennis matches. Descriptive statistics for these variables are presented in Table 4.1.

As we can see in table 4.1 and figure 4.1 the average height of winning players is slightly higher (186.7cm) than that of the losing players (186cm), however no noticeable age difference was reported (27.6 years versus 27.5 years). The minimum, median, and maximum height and age of winning and losing players were the same.

*Table 4.1: Participating Player's Height and Age*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Age** | N | 1395 | 1397 | |
| | Mean | 27,6 | 27,5 | 27,5 |
| | Min | 15 | 15 | 15 |
| | Median | 28 | 28 | 28 |
| | Max | 39 | 39 | 39 |
| **Height** | N | 825 | 922 | |
| | Mean | 186 | 186,7 | 186,3 |
| | Min | 163 | 163 | 163 |
| | Median | 185 | 185 | 185 |
| | Max | 208 | 208 | 208 |

N = Number of players with data

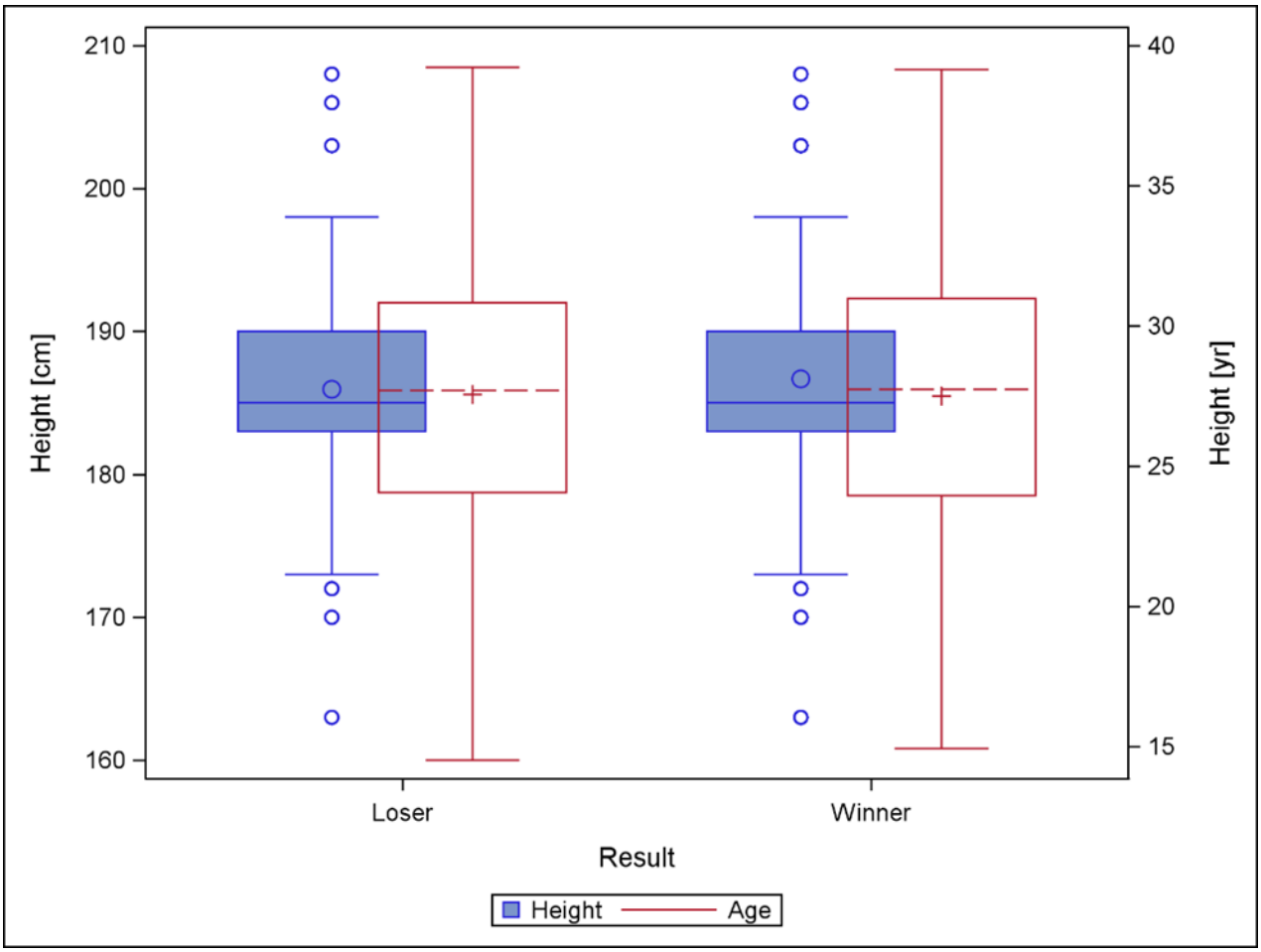


*Figure 4 Box Plot: Age and Height of Participating Players*

*Table 4.2: Aces by Winning and Losing Players*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Aces** | N | 1400 | 1400 | |
| | Mean | 5,1 | 6,6 | 5,8 |
| | Min | 0 | 0 | 0 |
| | Median | 4 | 5 | 4 |
| | Max | 52 | 53 | 53 |

N = Number of matches

*Table 4.3: Number of service points won by Winning and Losing Players*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Service Points** | N | 1400 | 1400 | |
| | Mean | 79,7 | 76,8 | 78,2 |
| | Min | 11 | 9 | 9 |
| | Median | 75 | 72 | 74 |
| | Max | 213 | 225 | 225 |

N = Number of matches

Tables 4.2 and 4.3 and Figure 4 summarize the number of aces and service points of winning and losing players. The service points showed a higher mean for the losing player (79.7) than for the winning player (76.8); this in turn has a connection to the number of breakpoints faced which will be discussed later in the current study.

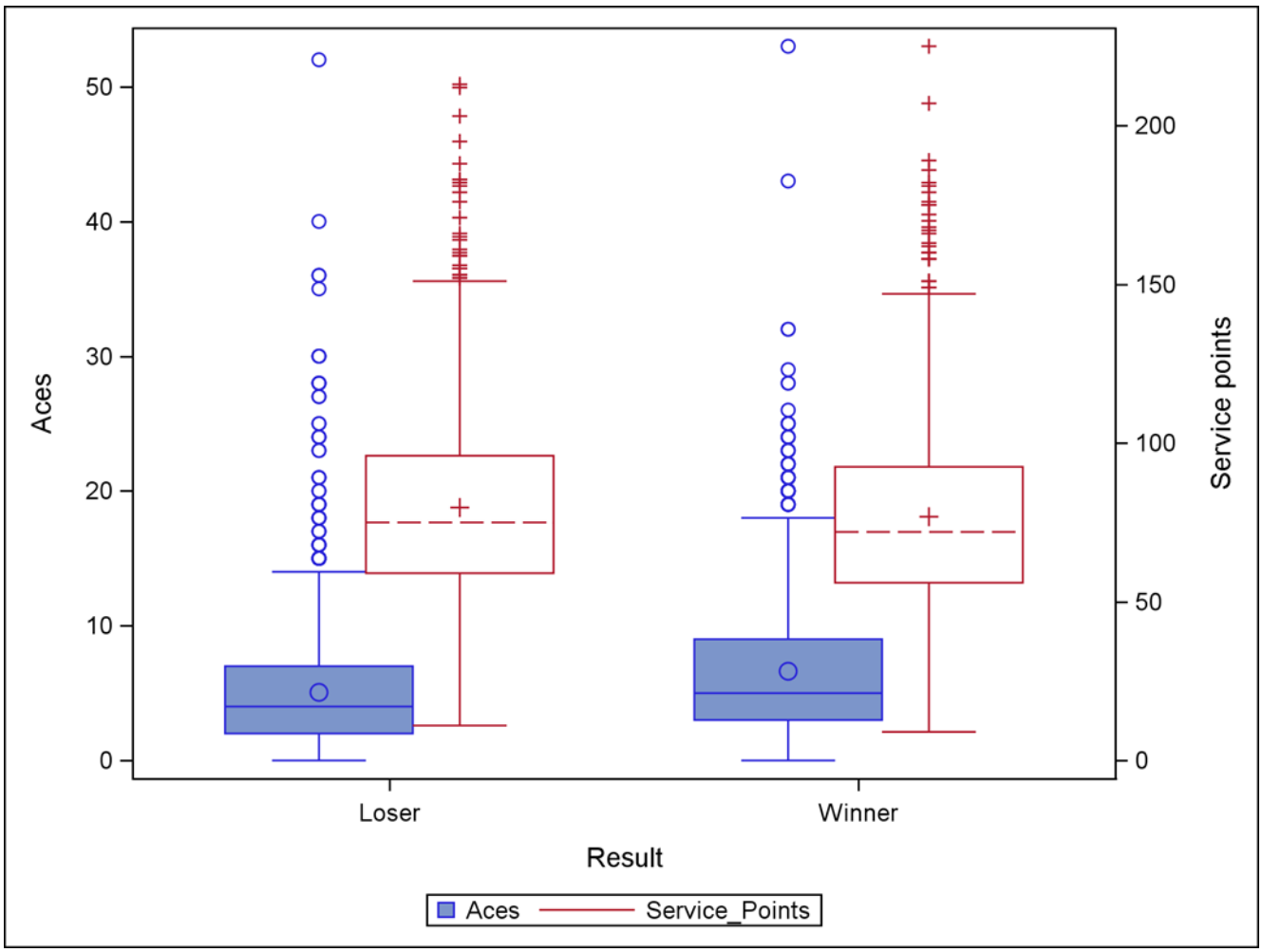


*Figure 5 Box Plot: Service Variables of Winning and Losing Players*

Figure 5 illustrates a number of outliers in the data set, that is, matches with unusually high number of aces or service points. The data for both the winning and losing player, in terms of aces served, was skewed to the right or positively skewed. This can be ascertained by examining the mean and the median. The Mean for the winning players is (6.6) while the Median is (5), the Mean for the losing players is (5.1) and the Median is (4).

*Table 4.4: Number of 1st Serves in by Winning and Losing Players*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **1st serve in** | N | 1400 | 1400 | |
| | Mean | 48,4 | 47,7 | 48 |
| | Min | 6 | 5 | 5 |
| | Median | 46 | 45 | 45 |
| | Max | 143 | 153 | 153 |

N = Number of matches

*Table 4.5: Number of 1st Serves Won*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **1st serve Won** | N | 1400 | 1400 | |
| | Mean | 32,2 | 35,9 | 34,1 |
| | Min | 1 | 4 | 1 |
| | Median | 30 | 33 | 32 |
| | Max | 110 | 117 | 117 |

N = Number of matches

Table 4.4 demonstrates the number of 1st serves in over the 1400 matches and reports a higher mean for the losing player of 48.4 compared to that of the winning player which was 47.7.

Table 4.5 reports on the relationship between the number of 1st serves won between the winning and losing players. Winning players have a higher mean of 1st serves won (35.9) compared to that of the losing player (32.2). In contrast, the average number of first serves in is similar for winning and losing players.

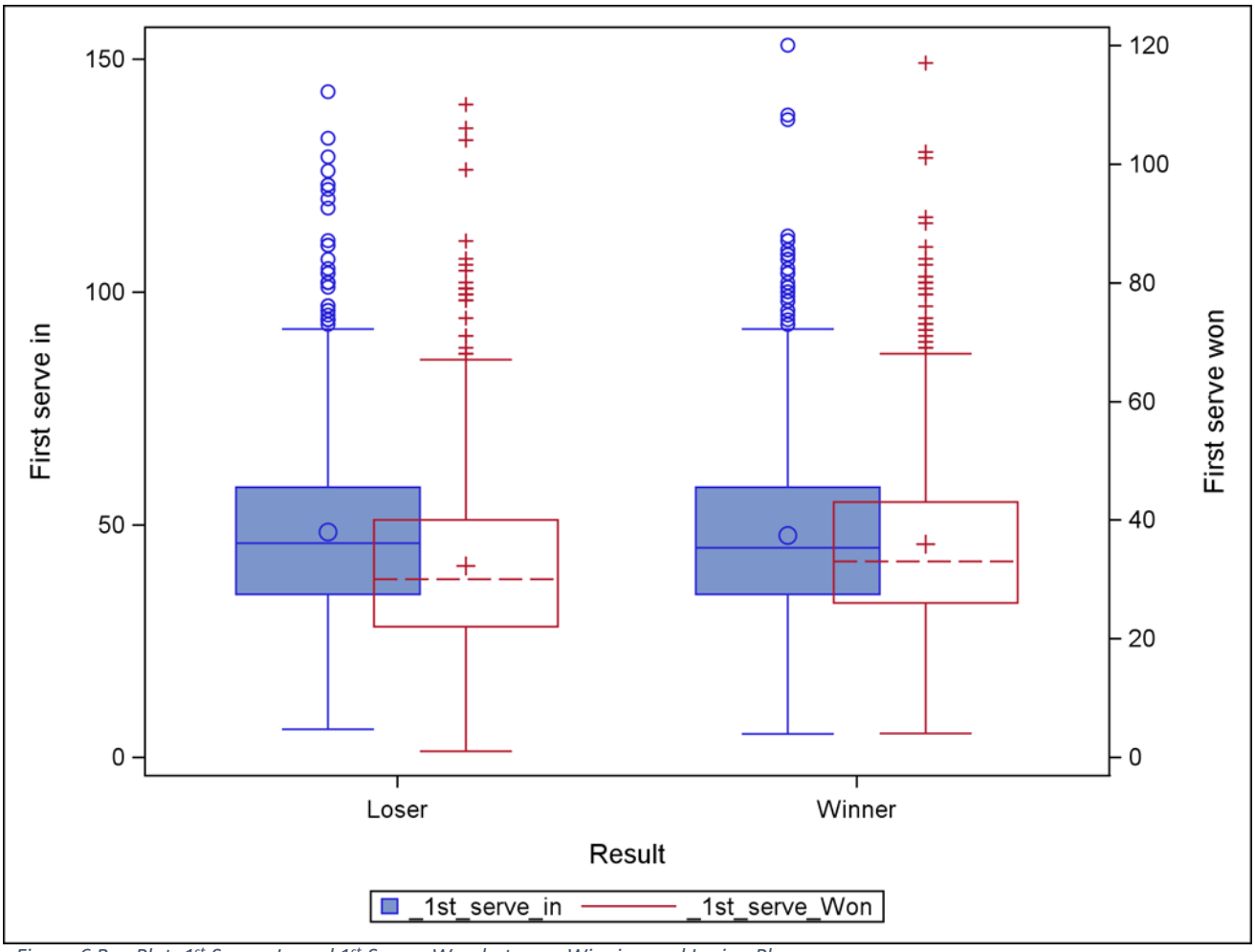


*Figure 6 Box Plot: 1st Serves In and 1st Serves Won between Winning and Losing Players*

Figure 6 is a boxplot which illustrates the 1st serve in and won in matches.

*Table 4.6: 2nd Serves Won*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **2nd serve Won** | N | 1400 | 1400 | |
| | Mean | 14,5 | 16 | 15,3 |
| | Min | 1 | 2 | 1 |
| | Median | 14 | 15 | 14 |
| | Max | 45 | 52 | 52 |

N = Number of matches

*Table 4.7: Service Games across the (n=1400) Matches*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Service Games** | N | 1400 | 1400 | |
| | Mean | 12,1 | 12,3 | 12,2 |
| | Min | 2 | 2 | 2 |
| | Median | 11 | 11 | 11 |
| | Max | 34 | 34 | 34 |

N = Number of matches

Table 4.6 shows that the losing player won fewer 2nd serves than the winning player, with means of 14.5 and 16, respectively. This is supported by Figure 7. Table 4.7 reports on the number of service games played.

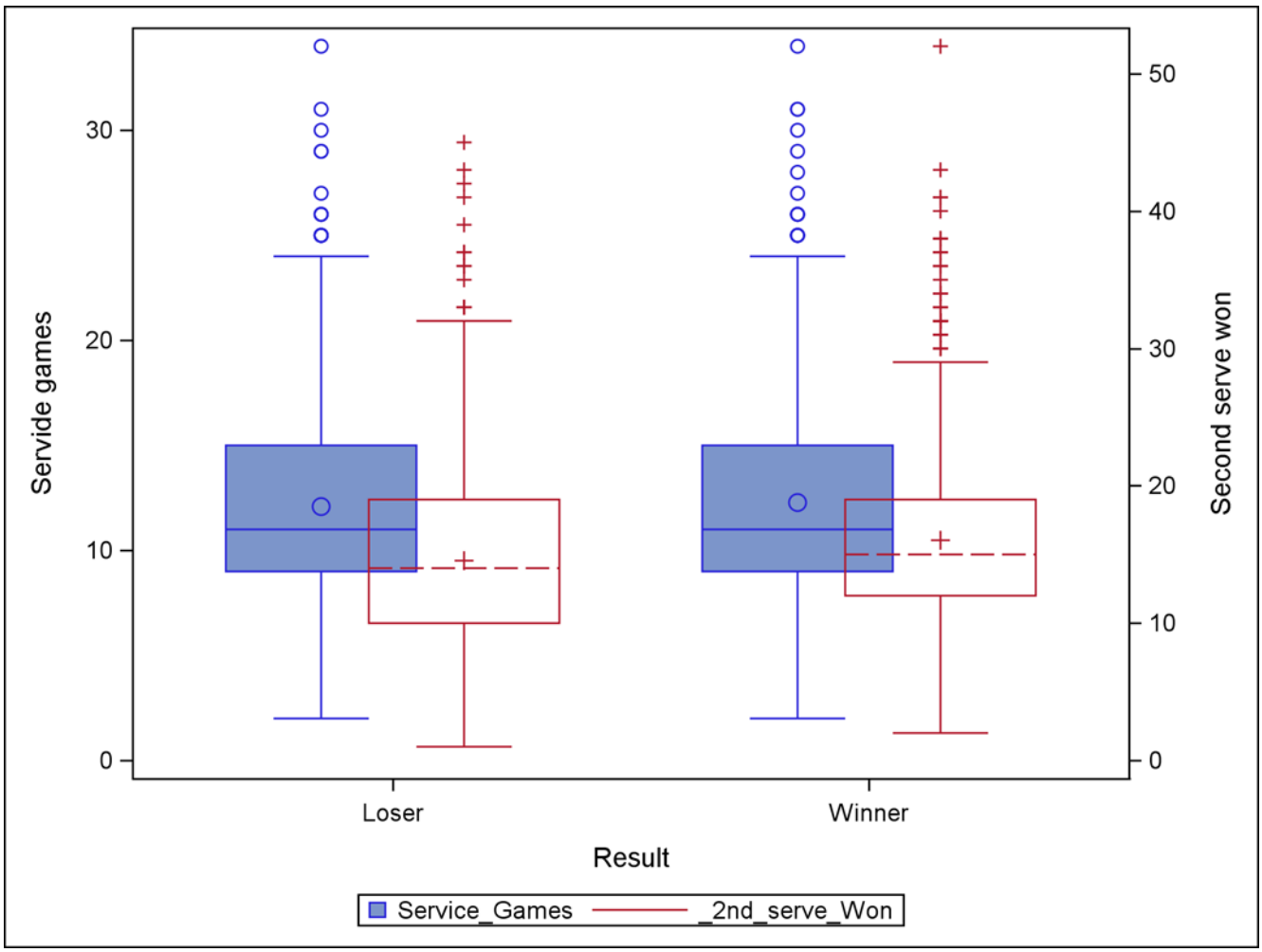


*Figure 7 Box Plot: Illustration of Service Games and 2nd Serves Won*

*Table 4.8: Number of Breakpoints faced by Winning and Losing Players*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Break Points Faced** | N | 1400 | 1400 | |
| | Mean | 8,4 | 5 | 6,7 |
| | Min | 0 | 0 | 0 |
| | Median | 8 | 4 | 6 |
| | Max | 27 | 25 | 27 |

N = Number of matches

*Table 4.9: Number of Breakpoints Saved by Winning and Losing Players*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Break Points Saved** | N | 1400 | 1400 | |
| | Mean | 4,7 | 3,4 | 4 |
| | Min | 0 | 0 | 0 |
| | Median | 4 | 3 | 3 |
| | Max | 22 | 19 | 22 |

N = Number of matches

Tables 4.8 & 4.9 show that winning players faced on average only 5 breakpoints compared to the 8.4 breakpoints of the losing player. Consequently, the average number of breakpoints saved by the winning player (3.4) was lower than that and of the losing player (4.7).

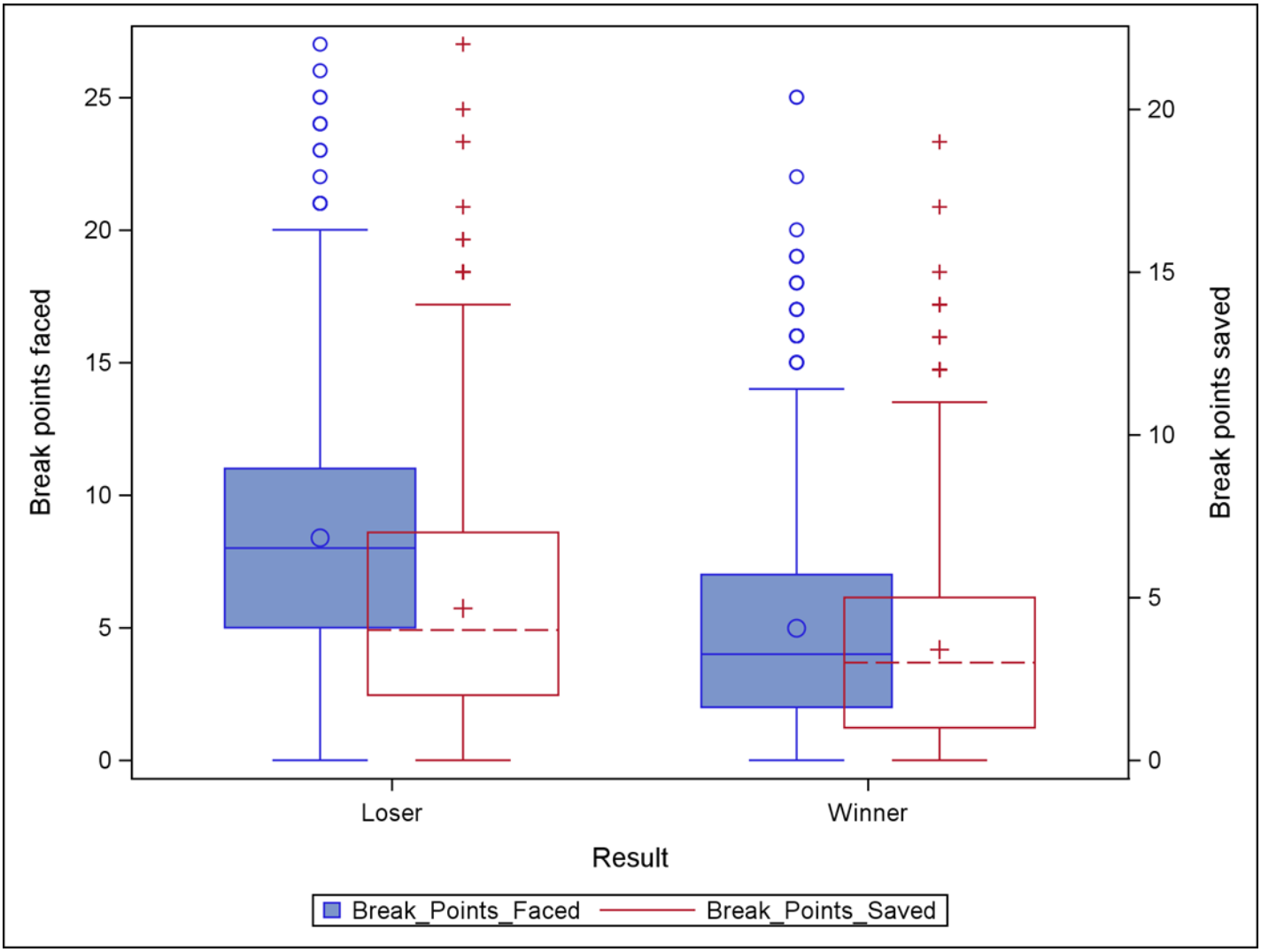


*Figure 8 Box Plot: Representation of Breakpoints Faced and Breakpoints Saved*

*Table 4.10: KPI's Comparison of Winning and Losing Players*

| Performance Indicator | Group Means | | Mean difference: Winner – Loser | | |
|---|---|---|---|---|---|
| | Winner | Loser | Point Estimate | 95% Confidence Interval | P-value |
| Height | 186.7 | 186 | 0.05 | -3.1 to 3.1 | 0.9520 |
| Age | 27.5 | 27.6 | -0.006 | -2.71 to 2.8 | 0.9856 |
| Aces | 6.6 | 5.1 | 1.3 | 0.7 to 2.0 | <0.00001 |
| Service Points | 76.8 | 79.7 | -2.6 | -3.6 to -1.7 | <0.0001 |
| 1st Serve In | 47.7 | 48.4 | -0.6 | -1.4 to 0.2 | 0.1368 |
| Number 1st Serve Won | 35.9 | 32.2 | 3.6 | 3.1 to 4 | <0.0001 |
| Number 2nd Serve Won | 16 | 14.5 | 1.5 | 1.2 to 1.9 | <0.0001 |
| Breakpoints Saved | 3.4 | 4.7 | -1.2 | -1.5 to -0.9 | <0.0001 |
| Breakpoints Faced | 5.0 | 8.4 | -3.3 | -3.6 to -2.9 | <0.0001 |

Crude means (simple averages not based on mixed model).
Point estimate and 95% confidence interval of for the mean difference "Winner – Loser" from a mixed model of individual differences "Winner – Loser", fitting Winner Name, Loser Name and Tournament as random effects.
P-value for t-test of the null-hypothesis that the mean difference is 0 (that is, null-hypothesis of no difference between Winner and Loser, from the mixed model.

Table 4.10 reports the statistical comparison of winning and losing players with respect to the various performance indicators. The mean values in the table are crude means, that is, the simple averages from the above descriptive statistics. Furthermore, a point estimate, 95% confidence interval (CI) and P-value for the mean difference between winners and losers are reported from the mixed model analysis of individual differences (winner – loser) of each match. The table shows that winners and losers differed significantly with respect to the number of aces, service points, 1st serves won, 2nd serves won, breakpoints saved, and breakpoints faced.

## 4.3 Comparison of Winning and Losing Players by the Various Playing Surfaces

As mentioned earlier in the current study, the ATP Tour is played on the various surfaces, namely; Clay, Grass and Hard Courts.

Since data from only seven matches played in grass courts was available, only the data for clay and hard courts will be discussed.

*Table 4.11: Height of the Players during Clay Matches*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Height** | **N** | 360 | 399 | 759 |
| | **Mean** | 185.7 | 185.5 | 185.6 |
| | **Min** | 163 | 163 | 163 |
| | **Median** | 185 | 185 | 185 |
| | **Max** | 208 | 208 | 208 |

N = number of players with data

*Table 4.12: Age of the Winning and Losing Players on Clay Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Age** | **N** | 596 | 595 | 1191 |
| | **Mean** | 27.9 | 27.7 | 27.8 |
| | **Min** | 18 | 16 | 16 |
| | **Median** | 28 | 28 | 28 |
| | **Max** | 39 | 39 | 39 |

N = number of players with data

*Table 4.13: Number of Aces Struck on Clay Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Aces** | **N** | 596 | 596 | 1192 |
| | **Mean** | 3.7 | 4.9 | 4.3 |
| | **Min** | 0 | 0 | 0 |
| | **Median** | 3 | 4 | 3 |
| | **Max** | 30 | 32 | 32 |

N = number of players with data

Tables 4.11 and 4.12 show no large differences between the winning and losing players, a difference of (0.2) between the means for both Height and Age. Table 4.13 reports a higher mean for the winning player of (4.9) compared to (3.7) for the losing player with regards to the number of aces served on clay courts.

*Table 4.14: Number of Service Points on Clay Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Service Points** | **N** | 596 | 596 | 1192 |
| | **Mean** | 76.4 | 73 | 74.7 |
| | **Min** | 13 | 9 | 9 |
| | **Median** | 72 | 69 | 71 |
| | **Max** | 188 | 182 | 188 |

N = number of players with data

*Table 4.15: Number of 1st Serves In for Winning and Losing Players on Clay*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **1st Serve In** | **N** | 596 | 596 | 1192 |
| | **Mean** | 47.1 | 45.8 | 46.4 |
| | **Min** | 7 | 5 | 5 |
| | **Median** | 45 | 43 | 44 |
| | **Max** | 118 | 112 | 118 |

N = number of players with data

*Table 4.16: Number of 1st Serves Won by Winning and Losing Players on Clay*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **1st Serve Won** | **N** | 596 | 596 | 1192 |
| | **Mean** | 30.5 | 33.8 | 32.2 |
| | **Min** | 1 | 4 | 1 |
| | **Median** | 29 | 32 | 30 |
| | **Max** | 87 | 80 | 87 |

N = number of players with data

*Table 4.17: Number of 2nd Serves Won on Clay*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **2nd Serve Won** | **N** | 596 | 596 | 1192 |
| | **Mean** | 13.7 | 15.1 | 14.4 |
| | **Min** | 1 | 2 | 1 |
| | **Median** | 13 | 15 | 14 |
| | **Max** | 43 | 38 | 43 |

N = number of players with data

Tables 4.14 and 4.15 summarize the serving tendencies which were reported in the current study when players were playing on the clay surface. We are able to identify losing players had the higher mean in both the number of service points (76.4) as well as the number of 1st serves in (47.1). However, in tables 4.16 and 4.17 we see that the winning player has the higher mean, 1st serves won (33.8-30.5) and 2nd serves won (15.1-13.7).

*Table 4.18: Number of Service (n=596) on Clay*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Service Games** | **N** | 596 | 596 | 1192 |
| | **Mean** | 11.5 | 11.7 | 11.6 |
| | **Min** | 2 | 2 | 2 |
| | **Median** | 11 | 11 | 11 |
| | **Max** | 27 | 28 | 28 |

N = number of players with data

*Table 4.19: Number of Breakpoints Saved by Winning and Losing Players on Clay*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Breakpoints Saved** | **N** | 596 | 596 | 1192 |
| | **Mean** | 4.7 | 3.3 | 4 |
| | **Min** | 0 | 0 | 0 |
| | **Median** | 4 | 3 | 3 |
| | **Max** | 17 | 19 | 19 |

N = number of players with data

*Table 4.20: Number of Breakpoints Faced on Clay*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Breakpoints Faced** | **N** | 596 | 596 | 1192 |
| | **Mean** | 8.5 | 4.9 | 6.7 |
| | **Min** | 0 | 0 | 0 |
| | **Median** | 8 | 4 | 6 |
| | **Max** | 25 | 20 | 25 |

N = number of players with data

Tables 4.19 and 4.20 depict the breakpoint variables for the points on the clay courts. We are able to ascertain from the two tables that the winning player on average faced fewer breakpoints (4.9) and therefore had fewer breakpoints to save (3.3).

*Table 4.21: Height of Players involved in Hard Court Matches*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| Height | N | 464 | 520 | |
| | Mean | 186.2 | 187.6 | 186.9 |
| | Min | 163 | 163 | 163 |
| | Median | 185 | 188 | 185 |
| | Max | 208 | 208 | 208 |

N = number of players with data

*Table 4.22: Age of Winning and Losing Players on Hard Court*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| Age | N | 792 | 795 | |
| | Mean | 27.3 | 27.3 | 27.3 |
| | Min | 15 | 15 | 15 |
| | Median | 28 | 28 | 28 |
| | Max | 39 | 39 | 39 |

N = number of players with data

Tables 4.21 and 4.22 represent the height and players involved in the hard court matches on the ATP Tour in 2018. There were no noticeable tendencies present in terms of the player's age however the winning players enjoyed a height advantage of 1.4cm.

*Table 4.23: Number of Aces on Hard Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| Aces | N | 797 | 797 | |
| | Mean | 6.1 | 7.9 | 7 |
| | Min | 0 | 0 | 0 |
| | Median | 5 | 7 | 6 |
| | Max | 52 | 53 | 53 |

N = number of players with data

*Table 4.24: Number of Service Points (n=797) in Matches*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Service Points** | **N** | 797 | 797 | |
| | **Mean** | 82.1 | 79.6 | 80.9 |
| | **Min** | 11 | 12 | 11 |
| | **Median** | 77 | 77 | 77 |
| | **Max** | 213 | 225 | 225 |

N = number of players with data

*Table 4.25: Number of 1st Serves In on Hard Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **1st Serve In** | **N** | 797 | 797 | |
| | **Mean** | 49.4 | 49.1 | 49.2 |
| | **Min** | 6 | 6 | 6 |
| | **Median** | 46 | 46 | 46 |
| | **Max** | 143 | 153 | 153 |

N = number of players with data

Tables 4.23 and 4.24 report on the number of aces and service points on hard court surfaces, the winning player had the higher mean of aces served (7.9) however the losing player depicted a higher mean in service points (82.1). Table 4.25 illustrates the number of 1st serves in and offers an idea of the accuracy of serving which shows a higher mean for the losing players (49.4-49.1).

*Table 4.26: 1st Serves Won on Hard Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **1st Serve Won** | **N** | 797 | 797 | |
| | **Mean** | 33.5 | 37.5 | 35.5 |
| | **Min** | 3 | 6 | 3 |
| | **Median** | 31 | 35 | 33 |
| | **Max** | 110 | 117 | 117 |

N = number of players with data

*Table 4.27: Number of 2nd Serves Won on Hard Court*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **2nd Serve Won** | **N** | 797 | 797 | |
| | **Mean** | 15.2 | 16.7 | 16 |
| | **Min** | 2 | 3 | 2 |
| | **Median** | 14 | 16 | 15 |
| | **Max** | 45 | 52 | 52 |

N = number of players with data

*Table 4.28: Number of Service Games on Hard Courts (n=797)*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Service Games** | **N** | 797 | 797 | |
| | **Mean** | 12.5 | 12.7 | 12.6 |
| | **Min** | 2 | 2 | 2 |
| | **Median** | 11 | 11 | 11 |
| | **Max** | 34 | 34 | 34 |

N = number of players with data

Tables 4.26 and 4.27 explore the number of points won off 1st serves as well as 2nd serves. Both tables report a higher mean for the winning player (37.5) and (16.7) respectively. Table 4.28 indicates the number of service games played on hard courts n = 1594 service games.

*Table 4.29: Number of Breakpoints Saved by Winning and Losing Players on Hard Court*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Breakpoints Saved** | **N** | 797 | 797 | |
| | **Mean** | 4.7 | 3.5 | 4.1 |
| | **Min** | 0 | 0 | 0 |
| | **Median** | 4 | 3 | 3 |
| | **Max** | 22 | 17 | 22 |

N = number of players with data

*Table 4.30: Number of Breakpoints Faced on Hard Courts*

| | | Result | | All |
|---|---|---|---|---|
| | | Loser | Winner | |
| **Breakpoints Faced** | **N** | 797 | 797 | |
| | **Mean** | 8,3 | 5 | 6.7 |
| | **Min** | 1 | 0 | 0 |
| | **Median** | 8 | 4 | 6 |
| | **Max** | 27 | 25 | 27 |

N = number of players with data

Table 4.29 and 4.30 report on the breakpoints saved as well as the breakpoints faced on hard courts. The tendency shows a higher mean for the losing players in both tables. Winning players however showed a better conversion rate of saving breakpoints. Breakpoints faced (5) and Breakpoints saved (3.5) while losing players faced (8.3) breakpoints and saved (4.7).

On the whole, differences between winning and losing players on both clay and hard courts tended to be of the same sign and similar magnitude as for the overall comparison.

## 4.4 Comparison of Various Playing Surfaces

*Table 4.31: Player Heights across the 3 Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| Height | N | 759 | 4 | 984 |
| | Mean | 185.6 | 185.5 | 186.9 |
| | Min | 163 | 183 | 163 |
| | Median | 185 | 186 | 185 |
| | Max | 208 | 188 | 208 |

N = number of players

*Table 4.32: Ages of Players competing on the Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| Age | N | 1191 | 14 | 1587 |
| | Mean | 27.8 | 28.5 | 27.3 |
| | Min | 16 | 16 | 15 |
| | Median | 28 | 30 | 28 |
| | Max | 39 | 38 | 39 |

N = number of players

Tables 4.31 depicts no noticeable difference in height across the 3 various surfaces played on. The largest difference in means across the surfaces is between Grass and Hard Court of (1.4cm). Table 4.32 reports the highest mean for age was found on Grass (28.5) and the lowest on Hard Court (27.3).

*Table 4.33: Number of Aces Struck on Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| Aces | N | 1192 | 14 | 1594 |
| | Mean | 4.3 | 7.3 | 7 |
| | Min | 0 | 0 | 0 |
| | Median | 3 | 6 | 6 |
| | Max | 32 | 20 | 53 |

N = number of matches

*Table 4.34: Service Points Played on Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| **Service Points** | **N** | 1192 | 14 | 1594 |
| | **Mean** | 74.7 | 77.2 | 80.9 |
| | **Min** | 9 | 40 | 11 |
| | **Median** | 71 | 80 | 77 |
| | **Max** | 188 | 116 | 225 |

N = number of matches

*Table 35: 1st Serves In on Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| **1st Serve In** | **N** | 1192 | 14 | 1594 |
| | **Mean** | 46.4 | 44.4 | 49.2 |
| | **Min** | 5 | 21 | 6 |
| | **Median** | 44 | 49 | 46 |
| | **Max** | 118 | 68 | 153 |

N = number of matches

Table 4.33 reports the highest amount of aces were struck on Grass Courts (7.3) while the lowest amount was struck on clay Courts (4.3). In table 4.34 we are able to see that the most service points were played on Hard Courts (80.9). The highest number of 1st serves in (49.2) were hit on Hard Courts as reported in table 4.35.

*Table 4.36: Number of 1st Serves won on 3 Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| **1st Serve Won** | **N** | 1192 | 14 | 1594 |
| | **Mean** | 32.2 | 33.3 | 35.5 |
| | **Min** | 1 | 13 | 3 |
| | **Median** | 30 | 34 | 33 |
| | **Max** | 87 | 55 | 117 |

N = number of matches

Table 4.36 indicates the highest mean for 1st serves won was on hard courts (35.5) followed by grass courts (33.3) and then clay courts (32.2).

*Table 4.37: 2nd Serves Won on the 3 Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| 2nd Serve Won | N | 1192 | 14 | 1594 |
| | Mean | 14.4 | 17 | 16 |
| | Min | 1 | 6 | 2 |
| | Median | 14 | 18 | 15 |
| | Max | 43 | 32 | 52 |

N = number of matches

*Table 4.38: Number of Service Games Played on Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| Service Games | N | 1192 | 14 | 1594 |
| | Mean | 11.6 | 11.9 | 12.6 |
| | Min | 2 | 8 | 2 |
| | Median | 11 | 12 | 11 |
| | Max | 28 | 17 | 34 |

N = number of matches

Table 4.37 reports that the highest mean of 2nd serves won belonged to grass courts (17) while the lowest was clay courts with a mean of (14.4). Table 4.38 depicts the number of service games played, hard courts had the highest mean with (12.6).

*Table 4.39: Number of Breakpoints Saved on Various Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| Breakpoints Saved | N | 1192 | 14 | 1594 |
| | Mean | 4 | 3.8 | 4.1 |
| | Min | 0 | 0 | 0 |
| | Median | 3 | 4 | 3 |
| | Max | 19 | 8 | 22 |

N = number of matches

*Table 4.40: Number of Breakpoints Faced across the 3 Surfaces*

| | | Surface | | |
|---|---|---|---|---|
| | | Clay | Grass | Hard |
| **Breakpoints Faced** | **N** | 1192 | 14 | 1594 |
| | **Mean** | 6.7 | 6.1 | 6.7 |
| | **Min** | 0 | 1 | 0 |
| | **Median** | 6 | 7 | 6 |
| | **Max** | 25 | 11 | 27 |

N = number of matches

Table 4.39 reports on the number of breakpoints saved across the 3 surfaces, we are able to ascertain that hard courts had the highest mean for breakpoints saved (4.1) and grass courts had the lowest (3.8). In table 4.40 the number of breakpoints faced is illustrated, we are able to see that hard courts as well as ay courts shared the highest mean for breakpoints faced (6.7) while grass courts only had a mean of (6.1).

*Table 4.41: Pairwise Comparison of KPI's across the 3 Various Surfaces*

| Performance indicator [count] | Surface mean | | | Pairwise difference | Pairwise mean difference | | |
|---|---|---|---|---|---|---|---|
| | Clay | Grass | Hard | | Point Estimate | 95% Confidence Interval | P-value |
| Aces | 8.6 | 14.4 | 12.0 | Clay - Grass | - 5.8 | -13.0 to 1.4 | 0.1156 |
| | | | | Clay - Hard | -3.3 | -5.2 to -1.5 | 0.0006 |
| | | | | Grass - Hard | 2.5 | -4.7 to 9.7 | 0.4979 |
| Service points | 156.6 | 156.4 | 152.9 | Clay - Grass | 0.14 | -55.2 to 55.5 | 0.9961 |
| | | | | Clay - Hard | 3.6 | -11.3 to 18.6 | 0.6276 |
| | | | | Grass - Hard | 3.5 | -51.5 to 58.5 | 0.8998 |
| First Serves In | 97.1 | 89.9 | 93.2 | Clay - Grass | 7.3 | -27.4 to 41.9 | 0.6796 |
| | | | | Clay – Hard | 3.9 | -5.4 to 13.1 | 0.4039 |
| | | | | Grass - Hard | -3.4 | -37.9 to 31.1 | 0.8463 |
| First Serves Won | 66.7 | 69.1 | 66.7 | Clay - Grass | -2.4 | -28.4 to 23.6 | 0.8543 |
| | | | | Clay - Hard | 0.1 | -6.8 to 6.9 | 0.9877 |
| | | | | Grass - Hard | 2.5 | -23.4 to 28.3 | 0.8503 |
| Second Serves Won | 29.9 | 34.5 | 29.7 | Clay - Grass | -4.6 | -16.2 to 6.9 | 0.4288 |
| | | | | Clay - Hard | 0.2 | -2.8 to 3.2 | 0.9020 |
| | | | | Grass - Hard | 4.8 | -6.7 to 16.4 | 0.4085 |
| Break Points Saved | 8.2 | 7.3 | 7.8 | Clay - Grass | 1 | -3.2 to 5.2 | 0.6451 |
| | | | | Clay - Hard | 0.5 | -0.5 to 1.4 | 0.3075 |
| | | | | Grass - Hard | -0.5 | -4.7 to 3.7 | 0.8160 |
| Break Points Faced | 14.2 | 11.8 | 13 | Clay - Grass | 2.4 | -4.3 to 9 | 0.4853 |
| | | | | Clay - Hard | 1.2 | -0.6 to 3 | 0.1744 |
| | | | | Grass - Hard | -1.2 | -7.8 to 5.4 | 0.7311 |

Means, point estimate and 95% confidence interval of for pairwise mean differences between surfaces from a mixed model of total count of performance indicator, fitting Surface as fixed effect and Winner Name, Loser Name and Tournament as random effects.
P-value for t-test of the null-hypothesis that the mean difference is 0 (that is, null-hypothesis of no difference between the two surfaces in question, from the mixed model.

Means, point estimate and 95% confidence interval of for pairwise mean differences between surfaces from a mixed model of total count of performance indicator, fitting Surface as fixed effect and Winner Name, Loser Name and Tournament as random effects. P-value for t-test of the null-hypothesis that the mean difference is 0 (that is, null-hypothesis of no difference between the two surfaces in question, from the mixed model.

Table 4.41 presents the statistical comparison of playing surfaces with regard to the performance indicators form a mixed model analysis. Means, point estimate and 95% confidence interval of for pairwise mean differences between surfaces from a mixed model of total count of performance indicator, fitting Surface as fixed effect and Winner Name, Loser Name and Tournament as random effects.

There is only one significant difference between the playing surfaces, namely between clay and hard surface ($p < 0.0006$) with respect to the number of aces scored.

# Chapter FIVE: DISCUSSION OF THE RESULTS

## 5.1 Introduction

As previously stated in the study, KPI's, are a unit of measure which can be used to quantifiably evaluate the success of a sport. However, it is clear from previous research (O'Donoghue, 2010; Hurley, 2015; Bruce & Lorge, 2019) that there is no standard set of performance indicators used for tennis analysis. Therefore, this is an area of research which would be useful to investigate.

The recent but limited studies conducted on KPI's in tennis has been shown to provide important data for the long-term development of tennis. As reported in the literature review, player's accuracy while serving has improved, player's game plans, athletic conditioning, as well as coaching methods have been vastly improved upon. Performance indicators can be used to provide athletes and coaches with superior information which can be used for better preparation of the athlete.

## 5.2 Key Performance Indicators (KPI's) between Winning and Losing Players

### 5.2.1 Participating Player's Height and Age

Table 4.1 and figure 4.1 shows that the average height of winning players is slightly higher (186.7cm) than that of the losing players (186cm), and no noticeable age difference was reported (27.6 years versus 27.5 years). Therefore the median height and age of winning and losing players were the same. According to My Tennis HQ, (2021) and Hizan *et al*. (2011) the average height of male tennis players within the top 500 of the world rankings is 185,5cm which is almost identical to our study (186.3cm). However, Hizan et al. (2011) indicated that 222 tennis players in their study ranged in height from 183 – 188cm.

Frenandez-Gracia *et al.* (2019), reported that the players with the highest percentage of first serves won, breakpoints won, and the break return of serve points won, would go on to win the match. Söğüt (2019) argued in this regard that players who have a height advantage over their opponent, have a higher probability of winning the match. This is due to the taller player being able to hit the ball at the optimal contact point of 2.47m

above the playing surface while serving (Kovacs & Ellenbecker, 2011; Vaverka & Cernosek, 2012; Hurley, 2015) which allows for a bigger service box area for the ball to land in, and furthermore, height also plays an important role in the control of a serve and the direction of the ball. Ziagkas *et al.* (2017) also mentioned that the taller players are able to generate higher ball speeds on slow courts due to a longer swing and higher generation of racket head speed. The higher racket head speed allows tennis balls to reach speeds of over 200 kilometres per hour traveling speed (Söğüt, 2016). Player's height will not only affect the service but also the reach the player will have and the ability to return balls and keep the point as well as the ball in play. Having a wider reach also means that the player will have to move less and therefore expend less energy than a shorter player during a rally. It seems that the range in height of elite players is very limited.

Although body height, a highly influential variable is in the serve speed, as well as accuracy, is another contributing factor to serve accuracy  the flexibility level of the player (Ali, 2015; Kovacs & Ellenbecker, 2011), allowing the player to increase power in strokes and by being able to generate higher racket head speed.

However, as stated in our study was the height of the winners (186.7cm) and losers (186cm) are very similar. A possible reason for that is due to the fact that, the players which are shorter in stature have far better return-related statistics than those players which enjoy the height advantage (Söğüt, 2019). This can also be accredited to the fact that shorter players are more agile on court (Juzwiak *et al.,* 2008).  It seems that differences in height is not a variable that significantly contributes to a KPI. To conclude, it seems that all elite players are tall and there is no significant difference ($p < 0.05$) in height between winners and losers.

An interesting statistic presented in table 4.1 shows also that the mean age of the winners and losers is very similar. This implies that experience of players does not play an important role in winning and losing.  One expected that older players would be settled in their own game, as well as style of play, but also being able to analyse opponents on court and adapt accordingly.

However, Tennishead (2018) has shown that the average age of tennis players has dramatically risen in the last 10 years. In the early 1970s when player rankings were first incorporated, the average age of male players was 23.74 years. By the end of 2017 that number had risen to 28.26 years, which is similar to our finding. Possible reasons for that can be accredited to better fitness training including periodization, injury prevention, and recovery techniques, as well as advancements made in the sport sciences as well as nutritional fields (Tennis Head Editor, 2018). According to Cohen-Zada *et al.* (2017) mens tennis players a tendancy to choke under pressure, however with experience and the previous knowlegde of having been in the situation before, this choking could be combated.

To conclude, it is clear from our study and the literature that winners and losers in tennis do not differ significantly ($p < 0.05$) in height and age, however height is an advantage in serving and reaching for the ball. Experience is also a advantage, however this study suggest that body height and age is not a significant KPI in professional men tennis players.

### 5.2.2 Aces, Service Points and Breakpoints for Winning and Losing Players

Knight and O'Donoghue (2012) states that "t*he probability of winning games of tennis has been modelled in terms of the probability of the server winning an individual point."* Reid *et al.* (2013) agrees and argues that without serves a tennis match would not be able to take place and therefore they are a vital part of the game and a part of the game which is often targeted by players. Due to players being in control of the stroke, players will want to minimise the amount of double faults as much as possible. The optimal as well as the desired outcome for the server will be to serve as many as aces as possible

The current study agrees with previous research and found a highly significant difference ($p = 0.001$) between winners (6.6 aces) versus losers (5.1 aces) during the 1400 matches recorded (See Table 4.2 - 4.9 and Figure 4.2 - 4.5). As expected, this study also showed a highly significant difference ($p < 0.001$) in service points (winning players 76.8 versus losing players 79.7), Number 1$^{st}$ serve in (winner 47.7 versus loser 48.4), number of 1$^{st}$ serves won (winner 35.9 versus loser 32.2), number in 2$^{nd}$ serve won (winner 16 versus

loser 14.5), breakpoints saved (winner 3.4 versus loser 4.7) and breakpoints faced (winner 5.0 and loser 8.4) (See Table 4.9). Table 4.10 shows the statistical comparison of winning and losing players with respect to the various KPI's which differ significantly ($p < 0.05$):

- Body Height and Age of Winning and Losing Players
- Number of Aces by Winning and Losing Players,
- Service Points in matches for Winning and Losing Players,
- Number of 1st Serves In,
- Number of 1st Serves Won,
- Number of 2nd Serves Won,
- Number of Breakpoints faced by Winning and Losing players
- Number of Breakpoints saved by Winning and Losing players.

Filipčič *et al*. (2011) indicated that those players with the highest percentage of points won on their own serve would go on to become the winners of a match. Hizan *et al*. (2011) also indicated that a professional men's tennis player will hit one ace in every eight good serves. The rate of aces has been speculated by Hizan *et al.* (2011) could be due to the physique of the players as well as service speed generated. O'Donoghue and Brown (2015) concluded that the server enjoyed the advantage of scoring more points in the service game than the returning player in men's elite level tennis. Filipčič *et al*. (2011) also mentioned that there was no conclusive evidence on whether the serve is the most important part of a player's game, however, it did show that having a successful and consistent serve gives the player a distinct advantage against their opponent. It is also the only shot to be played in tennis in which the player is 100% in control of (Kovacs & Ellenbecker, 2011; Kolbinger & Lames, 2013).

Ziagkas *et al*. (2017) also highlighted an important finding, the first serve accuracy at the French Open from 2002 to 2009 has risen from 60.2% to 64.2%. This is another fact which shows the importance of the first serve, however in our study this KPI was not significant. O'Donoghue and Brown, (2008) also highlighted the importance of the first serve as the advantage of the serve is lost on the second serve by the 3rd shot of the rally.

Frenandez-Gracia *et al.* (2019), concluded that the players with the highest percentage of first serves won, breakpoints won, and the break return of serve points won, would go on to win the match. This is in-line with the findings of this study (See Table 4.10). However, as stated our results suggest, that only 1st serve in, is not a significant KPI ($p = 0.1368$) between winners and losers in a tennis match, however all other KPI's, aces, service points, number 1st serve won, number 2nd serve won, breakpoints saved and breakpoints faced differ significantly ($p < 0.01$) between winners and losers in men's tennis.

## 5.3 Comparison of Winning and Losing Players by the Various Playing Surfaces

The differing stops on the ATP Tour not only poses a problem for the players from an environmental and traveling aspect but also the fact that the tour is played on different court surfaces. Many studies have been conducted on how this influences play and the styles of play from the players.

According to Miller (2006) affects the playing surface on which the match or tournament is played, the style of play of professional tennis players. The reason for that the surface influences the movement of the player as well as the behaviour of the tennis ball due to the friction created between the ball and the surface. The implication is that players need to do proper periodisation planning regarding their training, including their conditioning programs, and playing styles continuously throughout the year. Therefore, due to the different surfaces, tennis players will need to adapt their game to suit the surface the match or tournament is played on.

Söğüt (2019) indicated in this regard that professional male tennis players participate in 24 tournaments per year, this relates to about 60 competitive matches a year. These matches are divided up between the 3 surfaces, hard court 58%, clay court 32%, and grass court 10%. It is clear that most of the tournaments is played hard courts and clay courts.

Since data from only seven matches played on grass courts was available, only the data for clay and hard courts will be discussed. However, the literature applicable to grass courts will also be highlighted in the discussion.

### 5.3.1 Body Height and Age of the Winning and Losing Players on Various Surfaces

As discussed previously, Söğüt (2019) argued that players who have a height advantage over their opponent, have a higher probability of winning the match. Ziagkas *et al.* (2017) agrees and indicates that the taller players are able to generate higher ball speeds on slow courts (for example clay courts) due to a longer swing and higher generation of racket head speed. Kovacs and Ellenbecker (2011) also indicated that not only the body height is important, but another contributing factor will be the flexibility of the player, by allowing the player to increase power in strokes and by being able to generate higher racket head speed.

Our study (Tables 4.11 and 4.12) show no significant differences between the winning and losing players, a difference of only (0.2cm and 0.2 years) between the means for both body height and age when played on clay. Therefore, we conclude that our study and the literature that winners and losers in tennis does not differ significantly ($p < 0.05$) in height and age regarding playing surface when play on clay.

The mean age was of winning and losing players was excactly the same when playing on hard courts (Table 4.21 and 4.22) however, as expected the winning players enjoyed a height advantage of 1.4cm. As discussed previously, literature indicated the advantage of body height on a hard surface and generally in tennis.

### 5.3.2 Aces, Service Points and Breakpoints for Winning and Losing Players

Tables 4.14 and 4.15 show the serving tendencies which were reported in the current study when players were playing on the clay surface. An unexpected result, losing players had the higher mean in both the number of service points (76.4) as well as the number of 1$^{st}$ serves in (47.1). However, in tables 4.16 and 4.17 as expected, we see that the winning player has the higher mean, 1$^{st}$ serves won (33.8-30.5) and 2$^{nd}$ serves won

(15.1-13.7). Tables 4.19 and 4.20 depict the breakpoint variables for the points on the clay courts, and as expected we are able to ascertain from the two tables that the winning player on average faced fewer breakpoints (4.9) and therefore had fewer breakpoints to save (3.3).

However, when playing on hard courts Tables 4.23 and 4.24 the number of aces and service points, the winning player had the higher mean of aces served (7.9) while the losing player depicted a higher mean in service points (82.1).Table 4.25 illustrates the number of 1st serves in and offers an idea of the accuracy of serving which shows a higher mean for the losing players (49.4-49.1). Tables 4.26 and 4.27 shows the number of points won off 1st serves as well as 2nd serves. Both tables report a higher mean for the winning player (37.5) and (16.7) respectively when playing on a hard court.

Table 4.29 and 4.30 reports on the breakpoints saved as well as the breakpoints faced on hard courts. The tendency shows a higher mean for the losing players in both tables. Winning players however showed a better conversion rate of saving breakpoints. Breakpoints faced (5) and Breakpoints saved (3.5) while losing players faced (8.3) breakpoints and saved (4.7). On the whole, differences between winning and losing players on both clay and hard courts tended to be of the same sign and similar magnitude as for the overall comparison.

It is interesting to note, that our study suggest (Table 4.40) that only in aces on clay and hard courts differ significantly ($p < 0.006$). No other significant differences ($p < 0.05$) is observed (Table 4.40) between the three different surfaces in service points, number of 1st serves in, number of 1st serves won, number of 2nd serves won, number of break points saved and number of breaks points faced between winning and losing players.

However, Reid *et al*. (2016) stated that players practice and training sessions should be consistent with the match play demands, as well as the playing surface demands, placed on the players to acclimatize the athlete's bodies. This will also come into effect when coaches and players analyse the court surface which will be used, the study found that more ground strokes are played on clay courts which exposes the players to longer rallies and a higher level of endurance is required.

Hurley, (2015) stated that players will try to serve more legal serves than their opponents to allow themselves the best opportunity to win the match. Serving aces is therefore the most desireable for all players. Fitzpatrick *et al*. (2019) recently report that the highest number of aces (14.4) is served on grass courts while the lowest number (8.6) were served on clay courts. As perviously discussed in the literature, the higher level of friction found on clay courts leads to a higher bounce of the ball, and therefore slows the speed of play down, Carre *et al.* (2002) and Cross, (2006) and Fitzpatrick, *et al.* (2019) argue that this allows players more time to return balls or get into positions to return balls that would not have been possible on other courts surfaces such as hard or grass surfaces. Fitzpatrick *et al.* (2019) also concluded that serving on grass was far more effective than when players served on clay courts.

A study exploring the impact of the service speed in Grand Slam tennis showed that more sets of tennis played at Wimbledon (grass court) required tiebreaks than sets of tennis played at Roland Garros (clay court), depicting the importance of the serve on grass courts (Fitzpatrick *et al.,* 2019). This is also relevant for hard courts in serving.

As mentioned previously, in the current study, the serve is often a targeted shot by players as it is the only shot within a tennis match that the server has complete control over (Kovacs & Ellenbecker, 2011). The score within a set, in terms of service games, has proven to influence the individual performance in men's singles Grand Slam Tennis Tournaments. Players are able to use their serve to place themselves in the best phase to win the point, either with groundstrokes or aces (Shvorin, 2017; Kovacs & Ellenbecker, 2011). However, Hizan *et al*. (2011) concluded that players were only able to win 30% of the points when receiving their opponent's first serve. However, when it comes to the second serves that number drops off to a mean of 16. They argue that this could be due to the fact that tennis players often serve the second serve at a slower pace or defensively to ensure the ball and point will be in play. However, this make the ball easier to return due to sufficient time for the player to move into position as well as make better decisions about the returning shot and ball placement (Hizan *et al.* 2011) Hizan *et al.* (2011) also found that the 2$^{nd}$ serve is the hardest point to win and argue that a possible reason for this finding is the increased service speed in the professional men's game over the last

10 years. Our study support Hizan *et al*. (2011) and also find that the mean estimates for the various surfaces fell by more than half from the 1st serves won to the 2nd serves won. In our study, Clay fell from a mean of 66.7 to 29.9, while Hard Courts fell from a mean of 66.7 to 29.7.

Knight and O'Donoghue (2012) conclude that the grass courts of Wimbledon proved the hardest to break the opponets serve. However, Knight and O'Donoghue, (2012) has found that the highest amount of physical tennis is played on clay courts.

Fitzpatrick *et al.* (2019) reported that players in Grand Slams had to adapt their style of play to suit the various surfaces with points won off first serves having a large connection to the success and the outcome of the matches. Players will look at playing a variety of different strokes according to the surface played on (Carre *et al*. 2002; Fitzpatrick *et al.* 2019).

A breakpoint in tennis can be of vital importance due to the fact that the receiving player may be able to win a game in the match while not serving themselves. Therefore, the more breakpoints played and won the greater the advantage the player gains. The breakpoints variables observed in the current study were the number of breakpoints faced and the number of breakpoints saved. A study conducted in by Meffert *et al*. (2018) illustrated that the world number 1 player in 2016 only won 56% of all the points played in his matches that year while the number 9 ranked player in the world won 51.8% of the all points played in his matches. The reason for these points being so important as stated by Meffert *et al.* (2018) is that one service game lost could result in a set being lost, therefore the winning players have demonstrated a better ability of being able to perfrom under pressure.

The current study supports this view as the winning players displayed a higher number of 1st serves won as well as 2nd serves, and faced less breakpoints during the matches. As indicated in table 4.30 we can ascertain that the losing players had more faced breakpoints (8.3 versus 5) in the matches played on hard surface, this inturn will explain as to why the losing player saved more breakpoints during the matches.

According to a study conducted by Knight and O'Donoghue (2012) Grand Slam tennis shows a signifcantly higher probability of the receiver winning a breakpoint than a non breakpoint, reason being that players lose motivation when faced with a breakpoint on a surface such as grass which is proven to be more difficult to break serve on. This study further reports that the probability of a server winning a point when faced by a break pont is 0.58 and that number moves up to 0.62 when faced by a non-breakpoint. However, players in Grand Slam tournaments generate more breakpoints opportunities as well as actually breaking serve than expected (O'Donoghue & Brown, 2008).

Our study also found that that more breakpoints were faced on clay courts, because these courts are slower, allowing for more tennis to be played as well as mitigating a faster serving speed to some extent, O'Donoghue and Brown, (2008) also concluded that players had difficulty in winning “important” points. It can be concluded that saving breakpoints on clay courts may be essential to winning tennis matches due to the higher volume of breakpoints available. It is important to note, that only a pairwise difference of KPI’s across the various surfaces was found between Hard courts and Clay courts ($p = 0.0006$).

To summarise we are able to ascertain that there was no significant difference ($p<0.05$) in player Height or Age between the winning and losing players, while the player who was able to win the most service points, 1$^{st}$ and 2$^{nd}$ serve, went on to win the match. When comparing the different surfaces, the study reported that the faster courts, grass and hard courts, were harder to break serve on and the slower clay courts allowed for more tennis to be played. However, no significant differences, except for Aces struck on Clay and Hard Courts ($p=0.0006$), were identified between the various surfaces.

# Chapter SIX: SUMMARY AND CONCLUSION

## 6.1 Introduction

The world of sport is constantly evolving, and all athletes and coaches need to remain relevant with all new playing conditions as well as tactics and strategies. In today's professional sporting world talent can only take you so far, and tennis is no different. There are many external factors which can a play a role in the outcome of a tennis match. This study was conducted to determine the effect of those external factors or rather, performance indicators, on the outcome of professional men's tennis matches. As stated in a study conducted by Shvorin and Taaffe (2014), the players need a winning game plan and by conducting this study the performance indicators can be used to the players advantage as well being able to prepare for certain aspects in the match. Therefore, this study can be of great benefit to not just the players but the coaching staff as well.

In this chapter the findings will be concluded as well as limitation highlighted.

The study objective for this study was to identify the KPI's in ATP tournaments and to determine their influence on the outcomes of these tournaments. (Player height and age, number of aces hit, 1$^{st}$ and 2$^{nd}$ serve accuracy, points won off the 1$^{st}$ and 2$^{nd}$ serves, number of breakpoints faced, and number of breakpoints saved.)

Studies have been compiled according to these perfromance indicators but they generally focus on only won of the performance indicators per study. This study analyse a wide variety of KPI's.

## 6.2 Conclusion

The main objective of this study was to differentiate between the KPI's of winning and losing players of matches played and the surface types and their influence on the outcome of matches. (Player height and age, number of aces hit, 1$^{st}$ and 2$^{nd}$ serve accuracy, points won off the 1$^{st}$ and 2$^{nd}$ serves, number of breakpoints faced, and number of breakpoints saved.)

- The Player's Height and Age
    - This study conclude that body heigt and age do not differ significantly ($p<0.05$) between winners and losers in a tennis match.

- The number of Aces hit by both players
    - The current study reports that the winning players of the tennis matches on the ATP tour hit more aces than the losing players and the most aces were struck on grass and hard courts, and the least on the clay courts. Therefore, the Ace is very important on these surfaces as indicated

- The 1st and 2nd Serves Won and Service Games
    - The current study reported significant differences between the winning and losing players in terms of 1st and 2nd serves won, on both occasions the winning player had the higher mean, this concludes that the player who was able to win more service points ultimately won the match.

- Breakpoint Variables
    - This study also conclude that grass courts are the most difficult to break serve on, however this was only on 7 matches analysed. Clay courts proved to be the easiest to break serve on with the most breakpoints faced.

- The Surface Type on which the match is played
    - No significant difference was identified across the various surfaces. The current study reported that the surface type did not have an influence on the outcome of the match.

In conclusion, the current study found significant differences across the KPI's in the comparison of the winning and losing players ($p < 0.05$), however, no significant difference was identified when examining the various surfaces and their influence on the outcome of the match.

## 6.3 Limitations and Future Research

There were a number of limitations for this study which could aid further research.

- The current study only observed professional male players. Therefore, the researcher would be unable to comment and conclude if the results would be applicable to female as well as amateur tennis.
- The current study only assessed the KPI's in terms of performance, however an opportunity for further research could be to examine the epidemiology of injuries in these matches and on various surfaces. More research needs to be done on determining the cause and prevention of injuries in tennis.
- Further research could possibly look into the biomechanics of the shots played as well as the hand dominance of players and the effect on the style of play.

The data for the current study was collected from a public domain database, and only certain KPI's were available to be analysed.

- We recommended that further research must include as much as possible KPI's in tennis and prediction models must be developed which KPI's predict success.

# Chapter SEVEN: REFLECTING ON THE RESEARCH PROCESS

## 7.1 Introduction

In the ever changing world of sport, research is required to stay abreast of new developments, techniques, and training methods. This opens the research world to a massive extent and can be helpful in guiding athletes to become the best they possibly can. As a Strength and Conditioning Coach, new exercise trends develop on a daily basis and one must be able to distinguish between the absurd and the adequate. Being able to take literature and practically implement it successfully makes for a good coach, as every situation is unique but having that understanding makes the world of difference.

*"There is only one way to eat an elephant: one bite at a time"*

Arch-Bishop Desmond Tutu

In the wise words of Arch-Bishop Desmond Tutu, there is only one way to tackle a research study, one article at a time. All the hours of reading, writing, and re-writing will eventually get you to the final product. The process can be painstakingly slow and very frustrating but completely rewarding, as it enlightens so many areas of life. Not just academically but in the practical world as well. There were times during the study that I felt it was not heading in any direction and wanted to throw in the towel but that's not me. I also learned a lot about myself in terms of what I find acceptable work and what is not. Also being willing to speak to others, asking for help, and also listening to those who have been in this exact position.

As I mentioned earlier the world of sport is ever changing and to stay on top of the changes one needs research. There is no escaping the fact that without the literature no effective training would be able to take place and the field of Strength and Conditioning would collapse.

## 7.2 Reflecting on the Research Process

Looking back at the research process, I have come to the conclusion that athlete preparation and training is very subjective. Coaches will follow their own way and approach even with research proving it to be insufficient. The process also highlighted the fact of how far sport has evolved and how many aspects of a match or tournament are actually being analysed, players have very little room for error in the modern world of sport. Weaknesses and strengths are quickly found and pointed out either to be exploited or to be avoided. The research process also gives you a new perspective and respect towards the players that have managed to dominate the sport for years. I truly believe that this study will and has already added benefit to my career as a Strength and Conditioning Coach. I have implemented information from the research into the conditioning of the University's High Performance Tennis Group. This has definitely opened my eyes to the importance of research in furthering your own learning and I will try my level best to continue the learning and growth within the field.

## 7.3 Personal Remarks

This has been a long and painful process as someone who does not enjoy academic reading or writing, this was a tough challenge. A tough challenge definitely but I truly feel it has been a challenge that I have benefitted from in various aspects. From a professional point of view it has given me insight into a sporting code that I can now further explore and from a personal point of view I have grown in the sense of determination and drive to finish something that I can personally be proud of. I am also thankful for my support system, my parents, Dr Glen and Liesl Carlisle, have always had my back and supported me in whatever I do. Even if every phone call has to start with, "How far is your masters?" My sister, Leigh-Anne, for being the brains of the family and always making me compete academically.

*I can do all things through Him who gives me strength*

(Philippians 4:13)

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# APPENDICES:

## Appendix A: Cover Letter


5 Anton Prinsloo Street
Gold Stone Estate No 26
Langenhoven Park
BLOEMFONTEIN
9301

THE CHAIR: HEALTH SCIENCES RESEARCH ETHICS COMMITTEE
FACULTY OF HEALTH SCIENCES
UNIVERSITY OF THE FREE STATE

Dear Chair

**PROJECT TITLE:**
**Performance Indicators in (ATP) Tournaments.**

Enclosed please find the above research protocol for your evaluation and approval.

Yours faithfully

Signature of Researcher
Mr. J Carlisle

CarlisleJP@ufs.ac.za
083 734 6509

## Appendix B: Summary

A Retrospective Study of the Key Performance Indicators in the Outcome of Professional Tennis Matches.

**Principal Investigator:** Mr. J Carlisle

**Where will the study be conducted?**

Bloemfontein, University of the Free State, Kovsie Sport

**What population will be included in the study?**

Male Professional Tennis players playing in ATP sanctioned tournaments during 2018.

**What method will be used?**

The aim of this study is to determine if different performance indicators have an influence on the result of tennis matches. Coaches and players will then be able to use this information to their advantage when preparing for tournaments as well as playing against certain opponents.

Different aspects of the player's games will be observed and evaluated, such as hand dominance, player height linked to serve accuracy, as well as the different court surfaces, also looking at the number of break points faced and saved throughout the entire match. The data will be collected from a public domain which is freely available to the public and is approved of for academic use. The data from the 2018 season on the website will then be investigated and a conclusion will be drawn from this set. The only player's data that will be used are the players playing in the pro-section of any ATP sanctioned tournaments. Tournaments played on all surfaces will be taken into account.

**What treatment will be administrated to participants?**

N/A

**What control method will be used?**

N/A

**Expected outcome of the research?**

The research project assists in determining if there is any influence on the result of professional tennis matches. Mainly from key performance indicators aspect of the players and court themselves and not based on other factors such as the weather

## Appendix C: Ethics Approval Letter

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

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

**Health Sciences Research Ethics Committee**

27-May-2021

Dear **Mr Jason Carlisle**

Ethics Clearance: **Performance Indicators in (ATP) Tournaments**
Principal Investigator: **Mr Jason Carlisle**
Department: **Exercise and Sport Sciences Department * (Bloemfontein Campus)**
Submission Page

**APPLICATION APPROVED**

Please ensure that you read the whole document

With reference to your application for ethical clearance with the Faculty of Health Sciences, I am pleased to inform you on behalf of the Health Sciences Research Ethics Committee that you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence is:**UFS-HSD2021/0169/2906**

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

**Where applicable, notification of NHREC and Free State Department of Health approval needs to be uploaded in RIMS prior to initiation or recruitment for the study.**

We request that any changes that may take place during the course of your research project be submitted to the HSREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

A progress report should be submitted within one year of approval, and annually for long term studies. A final report should be submitted at the completion of the study.

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; International Council for Harmonisation (ICH) Harmonised Guideline, Integrated Addendum to ICH E6(R1), Guideline for Good Clinical Practice (GCP) E6(R2), 2016, SAHPRA Guidelines as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

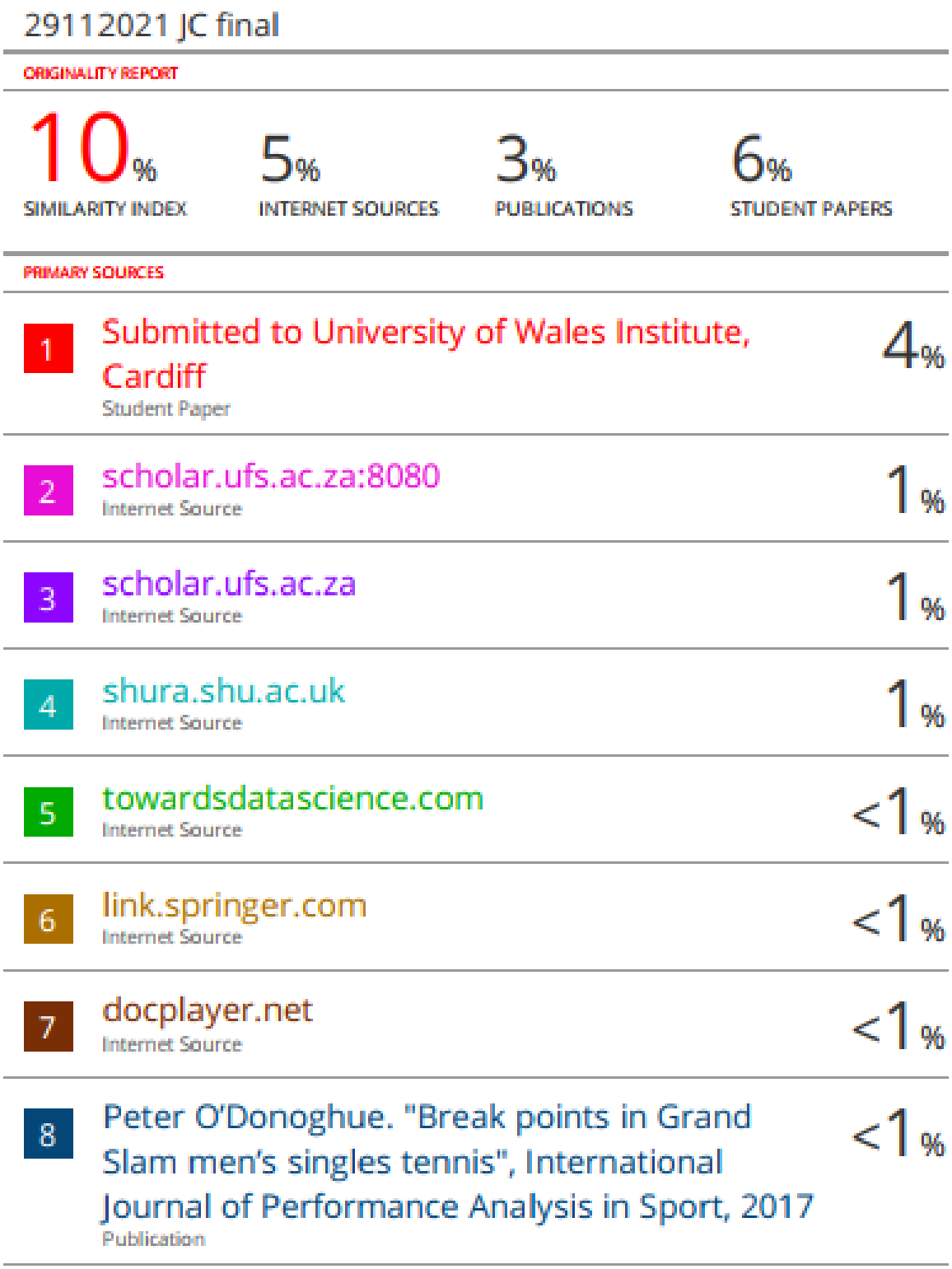
For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours Sincerely

Prof. A. Sherriff
Chairperson: Health Sciences Research Ethics Committee

## Appendix D: Turnitin Report



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| 8 | Peter O'Donoghue. "Break points in Grand Slam men's singles tennis", International Journal of Performance Analysis in Sport, 2017<br>Publication | <1% |

## Appendix E: GitHub Communication



**Jason Carlisle**
Jun 18, 2020, 1:26 PM UTC

Good Day

I have come across data on your platform by Jeff Sackman with regards to tennis. I would like to use this data for a Masters degree in Sport Science at the University of the Free State in South Africa.
I would like to receive confirmation that this would be allowed.

Thank You and Kind Regards
Jason Carlisle