UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

UTILISING TECHNOLOGY IN FOOTBALL TO REDUCE THE RISK OF OVERTRAINING

by

Eugan Govender

Submitted in fulfilment of the requirements for the degree

Master's in Information Technology (Information Systems)

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT & IT

at the

UNIVERSITY OF PRETORIA

Study leader:

Dr Henk Pretorius

Date of submission

16 April 2021

Declaration regarding Plagiarism

The Department of Informatics emphasises integrity and ethical behaviour with regard to the preparation of all written assignments.

Although the lecturer will provide you with information regarding reference techniques, as well as ways to avoid plagiarism, you also have a responsibility to fulfil in this regard. Should you at any time feel unsure about the requirements, you must consult the lecturer concerned before submitting an assignment.

You are guilty of plagiarism when you extract information from a book, article, web page or any other information source without acknowledging the source and pretend that it is your own work. This doesn't only apply to cases where you quote verbatim, but also when you present someone else's work in a somewhat amended (paraphrased) format or when you use someone else's arguments or ideas without the necessary acknowledgement. You are also guilty of plagiarism if you copy and paste information directly from an electronic source (e.g., a website, e-mail message, electronic journal article, or CD ROM), even if you acknowledge the source.

You are not allowed to submit another student's previous work as your own. You are furthermore not allowed to let anyone copy or use your work with the intention of presenting it as his/her own.

Students who are guilty of plagiarism will forfeit all credits for the work concerned. In addition, the matter will be referred to the Committee for Discipline (Students) for a ruling. Plagiarism is considered a serious violation of the University's regulations and may lead to your suspension from the University. The University's policy regarding plagiarism is available on the Internet at *http://upetd.up.ac.za/authors/create/plagiarism/students.htm*.

I (full names & surname):	Eugan Govender
Student number:	U11042258

Declare the following:

1. I understand what plagiarism entails and am aware of the University's policy in this regard.
2. I declare that this assignment is my own, original work. Where someone else's work was used (whether from a printed source, the Internet or any other source) due acknowledgement was given and reference was made according to departmental requirements.
3. I did not copy and paste any information directly from an electronic source (e.g., a web page, electronic journal article or CD ROM) into this document.
4. I did not make use of another student's previous work and submitted it as my own.
5. I did not allow and will not allow anyone to copy my work with the intention of presenting it as his/her own work.

Eugan Govender — Signature

16 April 2021 — Date

ABSTRACT

Overtraining Syndrome is the result of an athlete pushing their body beyond its limit to reach new levels of performance (Kenttä and Hassmén, 2006). There is immense pressure for footballers to continually perform at their highest levels. As a result of this pressure, footballers tend to train much harder and neglect the correct recovery protocols (Kenttä and Hassmén, 2006).

As the years have passed, technology has become rooted in sport. Most professional sports teams have made use of various forms of technology. This technology assists coaching staff to manage players and obtain the best possible results from their players (Liebermann *et al.*, 2002). Technology has the ability to reduce some of the risks of OTS (Bieuzen *et al.*, 2012). There is currently insufficient research around how the risks of OTS can be reduced in football by using technology, especially in South African professional football.

A research study was conducted which involved professional football clubs from South Africa as well as the United Kingdom. Semi-structured interviews were undertaken that contained open-ended and closed-ended questions to gain insight into the current state of OTS in football and how technology can reduce the risk of OTS. Four football coaching professionals from The Premier Soccer League in South Africa as well as one football coaching professional from The English Football League Championship in the United Kingdom were interviewed. A mono-method approach was used to analyse the data collected. An inductive approach was then used to construct new theories by analysing the results of the investigation.

The results of the research study showed that OTS is still an issue in South Africa. Football clubs in South Africa currently use various forms of technology to assist the coaching staff with managing and enhancing player performance. The key finding of this research study revealed that there is a need for a player monitoring system that integrates a player's objective and subjective data to provide the coaching staff with a more holistic view of the player.

ACKNOWLEDGEMENTS

To my Mother and Father,

for your hard work and sacrifice to give me better opportunities in life, as well as your continued support, advice and motivation

I am grateful for the two of you every day

To my Supervisor, Dr Henk Pretorius,

for the effort, support and guidance during this research study

it has been a pleasure to learn from you

To all research participants,

for taking time off their busy schedules to take part in this research study

I am very appreciative

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

Table 1: Abbreviations

OTS	Overtraining Syndrome
TTF	Task-Technology Fit
TPC	Technology-to-Performance Chain
TAM	Technology Acceptance Model
HR	Heart Rate
GPS	Global Positioning System
RPE	Rate of perceived exertion
RPF	Rate of perceived freshness

1 INTRODUCTION TO RESEARCH

1.1 INTRODUCTION

“I learned all about life with a ball at my feet”– Ronaldinho

These words from the great Ronaldinho resonate with many footballers around the world, both professional as well as amateur. As it is called, the beautiful game is adhered to so staunchly as if it were a religion. In a world that has become so autonomous, there are few experiences more exhilarating than watching a competitive sporting encounter involving two teams made up of individualistic, skilled, and human athletes. These athletes are constantly trying to improve their skills to gain a competitive advantage over their opposition with one goal in mind, to win. This is why professional sport is so competitive (Popovych *et al.*, 2021).

Footballers around the world are constantly trying to improve their game and up their level. These are young athletes trying to turn professional or professional athletes trying to remain at the highest level. Either way, the competition is extremely high to earn the prestige of being a professional footballer. Aspiring athletes sacrifice everything to fulfil that childhood dream of living the lives of their football idols. For many, it is seen as a means of survival. The pressure is immense. Athletes are always pushing themselves, striving to be better, faster, stronger. Due to the pressure put on athletes to continually perform at their optimal level, comes the risk of Overtraining Syndrome (OTS).

Pankanin (2018) defines OTS as “overtraining syndrome is the accumulation of training and non-physical stresses, resulting in a long-term reduction in the ability to perform tasks, with the occurrence of physiological and mental symptoms of maladjustment; the return to the form and the period of regeneration can last up to several weeks or months”. Training sessions need to be regulated during periods where players are exposed to increased amounts of competitive matches. Training sessions can be regulated by varying their frequency or intensity. If this is not done effectively, players are at a high risk of OTS (Campbell *et al.*, 2020).

Willett (2012) and Stasulli (2017) discuss how athletic performance is an amalgamation of many different factors, including physical, psychological, and external/environmental factors. OTS has a direct impact on the physical aspect of athletic performance. Djordjevic, Dragojlovic Ruzicic and Jakovljevic (2016) state that during preseason training, OTS can occur due to high levels of training load. Another possible cause of OTS is oxidative stress. Coaches and trainers tweak the training loads by altering the intensity and duration of training sessions. This is done to increase the functional adaptability of players and thus improve performance. Incorrectly balancing training load with recovery could result in chronic fatigue and a reduction in performance. (Djordjevic, Dragojlovic Ruzicic and Jakovljevic, 2016)

From the information above, it is evident that modern-day footballers must deal with high levels of stress to consistently output peak performance. This stress causes the player to constantly try and push their physical and mental boundaries to increase or maintain a high level of performance, thus increasing their risk of OTS.

1.2 BACKGROUND

The increased competitive nature in the game of football has caused many clubs to enhance their training regimes to get the most value out of their players. This combined with a player's own desire to be the best in the business has pushed players beyond their physical thresholds, thus increasing the risk of OTS. An athlete's performance can therefore be negatively impacted in the attempt to improve it. (Kenttä and Hassmén, 2006)

The core theme around coaching is to design a training plan that can create the desired levels of intensity while at the same time lowering the risks of an athlete pushing past their physical threshold (Kuipers and Keizer, 2009). Piesik *et al.* (2017) state that failing to reverse training-induced fatigue through resting periods is the core symptom of OTS. The diagnosis of OTS is made through subjective assessments of symptomatic athletes. Symptoms of OTS include persistent fatigue, deteriorated performance, sleep disorders, depression, intensified stress, reduced motivation, lethargy, reduced appetite, increased resting heart rate (HR), upper respiratory tract infections, reduced concentration and muscle/joint aches (Piesik *et al.*, 2017).

Past research has shown evidence of OTS. An article by Ekstrand, Waldén and Hägglund (2004) discusses how the amount of football a player is exposed to has a direct impact on the injuries and performance of that player. Large football clubs have the benefit of rotating their squad more regularly, as the number of quality players they possess is greater than a smaller club. Players at a large club are more likely to be given more time to rest during the season. As the season reaches its finale, many tournaments and the league reach the business end. During this time coaches want to field their strongest sides. As a result of this, the star players are expected to start most matches, thus decreasing their resting periods and increasing their chances of injury. It was seen that players who played fewer matches during the closing stages of the season performed better at the 2002 Football World Cup indicating that a busier schedule led to underperformance and increased fatigue, which are both symptoms of OTS.

A study by Lovell, Townrow and Thatcher (2010) uncovered how drastically the mood state of a professional football player changes during the course of a season. It was seen that a professional footballer started the season more positively than an amateur football player. As the season progressed, the professional footballer's mood state decreased at a greater rate than that of the amateur footballer. By the end of the season, the professional footballer's mood state had suffered a greater negative change than that of the amateur footballer. From this study, it is evident that the stress and higher demands placed on professional footballers to constantly play at the peak of their abilities triggers excessive mental strain.

A study conducted by Verardi *et al.* (2014) further delves into how different footballers playing different positions are prone to different levels of stress. A comparison was made between a forward player and a goalkeeper. It was seen that goalkeepers, in general, were much more prepared for negative responses from the public after poor performances and thus handled stress better. Forward players, on the other hand, tend to feel extremely stressed to perform and score goals. This is a result of the forward player's perception of the situation.

From the above examples, it is evident that OTS needs to be managed by the use of objective and subjective data. Objective data is the physical performance of a player

whereas subjective is the psychological responses of the player. This is where technology can assist. As with most areas of modern life, technology has become extremely involved in modern-day sport. This technology is used to improve and manage player performance (Liebermann *et al.*, 2002). Various forms of technology are currently utilised in sport to limit the risk of injury. Heart Rate Monitoring is one of the oldest technologies still being used in sport (Cardinale and Varley, 2017).

Along with heart rate monitoring, Global Positioning Systems (GPS) have become popular tools for measuring a footballer's performance during matches and training sessions. The data generated by these devices can be analysed by coaching staff in real-time (Cardinale and Varley, 2017). Besides objective data collection from devices, football teams also make use of a rate of perceived exertion (RPE) monitoring (Clemente *et al.*, 2017). This involves collecting subjective data from players regarding muscle soreness, fatigue, sleep perception and stress (Clemente *et al.*, 2017).

Sports teams currently use various devices such as Heart Rate monitors and GPS devices to collect objective data. They also collect subjective data via RPE monitoring. There is currently a need to synthesize the data from these objective and subjective data sources to provide meaningful insights to coaching staff (Ryan, Kempton and Coutts, 2021).

Reducing the risks of OTS using technology is still a very open field as technology and sport science continues to evolve and adapt as football does. Clubs want results, and the only way to get these results is to limit the risk of OTS to ensure that players are not plagued by injury and are able to reach their full potential.

1.3 PURPOSE OF THE STUDY

The purpose of this study is to investigate the underlying factors of OTS in South African professional football and the technology used to measure these underlying factors with the aim of proposing an improved system for the measurement and management of these factors.

A theoretical framework will be used as a lens to look at how various technologies are used for measuring factors related to OTS and then translating the findings into a system that would provide a more holistic measurement and management. The theoretical framework will be discussed in section 3.

1.4 MOTIVATION FOR THE STUDY

The key segment of this investigation will involve acquiring knowledge about the holistic training regime of professional footballers in South Africa with the aim of investigating the adoption of technology for the measurement and management of factors related to the risk of overtraining syndrome in football.

Technology has the power to reduce a footballer's risk of OTS. A study by Bieuzen *et al.* (2012) shows the positive effects of technology on the recovery methods of elite football players. Low recovery times are one of the major causes of OTS. This investigation demonstrated how modern technology can tackle issues around football training and recovery.

All footballers should have a fair chance of proving their worth and achieving their goals. Technology is a powerful instrument that can assist these players in averting OTS.

1.5 PROBLEM STATEMENT

Addressing the issue of OTS using technology is still a very open field as technology and sport science continues to evolve and adapt at a fast rate. There is currently insufficient research around how the risks of OTS can be reduced in football by using technology, especially in South African professional football.

OTS is an amalgamation of both psychological and physical factors. A player can become demotivated due to the pressures of training and thus their performance is hindered. Increased training can also negatively affect a player's physical state, thus impeding their performance. Research is required into the technology used to measure the underlying

factors surrounding OTS in South African professional football to propose an improved system for the measurement and management of these factors.

1.6 RESEARCH OBJECTIVES AND QUESTIONS

1.6.1 Main research objective

The main objective of this research study is to investigate the adoption of technology for the measurement and management of factors related to the risk of overtraining syndrome in football.

1.6.2 Sub-research objectives

1. To investigate previous cases of overtraining syndrome and their underlying reasons. This sub-research objective aims to identify any similarities amongst previous cases in the attempt to find common root causes of overtraining syndrome in football.
2. To determine all non-physical related contributing factors to overtraining syndrome. This sub-research objective plans to gain a holistic view of all elements involving a football player and overtraining syndrome.
3. To understand the current training methods and recovery processes utilised in modern-day professional football teams. Training and recovery are critical to the physical development and management of a football player. This sub-research objective aims to determine the relationship between training, recovery, and overtraining syndrome.
4. To identify and analyse the current training technology encompassing a football player. This sub-research objective aims to look for existing gaps and possible improvements concerning the various technologies used to assist football players during training.

1.6.3 Main research question

How can technology be utilised in football to manage the contributing factors of overtraining syndrome?

1.6.4 Sub-research questions

1. What are the underlying causes of previous cases of overtraining syndrome and can any similarities/themes be uncovered?
2. What are all the non-physical related factors contributing to overtraining syndrome in football players?
3. What are the current training methods and recovery processes of footballers and how do they influence the player's risk of overtraining syndrome?
4. What current training technologies are used by football players and how is this technology used to address overtraining syndrome?

1.7 STRUCTURE OF THE DISSERTATION

A description of the dissertation structure is provided in this chapter. This dissertation comprises six chapters as indicated in Figure 1.

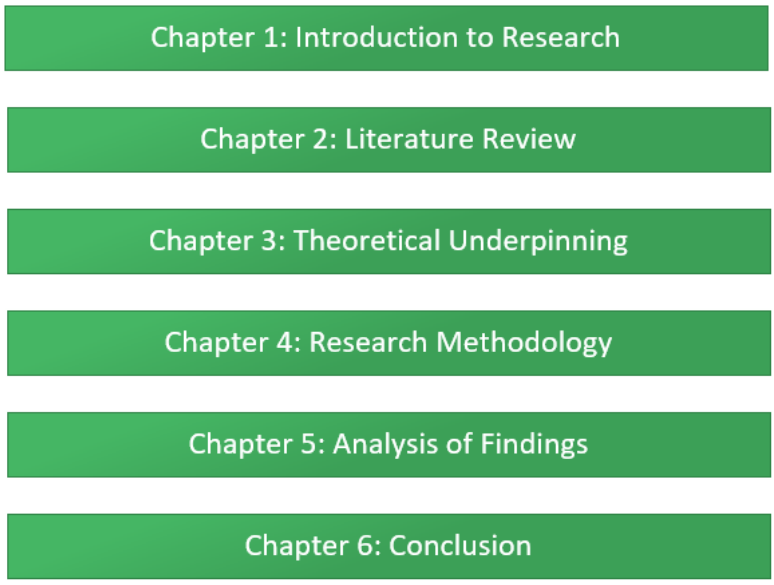


Figure 1: Structure of the Dissertation

The dissertation structure shown in Figure 1 will be discussed in detail below:

Chapter 1: Introduction to Research

The first chapter of this dissertation introduces the background of OTS in football. The main problem statement and research motivation are compiled, from which, the research objectives and their corresponding research questions are derived.

Chapter 2: Literature Review

Existing literature is investigated in this chapter to obtain a solid understanding of the concepts surrounding the research problem. The rest of the dissertation is built upon the information assembled in this chapter. This literature is partitioned into the various themes listed below:

Theme 1: Overtraining Syndrome
The concept of OTS is discussed during theme 1.

Theme 2: Previous Cases of Overtraining Syndrome
Previous cases of OTS are examined during theme 2.

Theme 3: Current Football Training Methods
Theme 3 deals with various training methods that are currently used in football. As mentioned earlier, the training aspect of football has a significant impact on OTS.

Theme 4: Football Training Technology
Theme 4 involves looking at literature concerning technology used in football and sport in general.

Chapter 3: Theoretical Underpinning

Various research frameworks are discussed in this chapter. These research frameworks will be used to analyse the research study. It was seen that the Technology-to-Performance Chain (TPC) allows a more holistic approach to assessing the performance of a technology. As a result of this, it was decided that the TPC model would be best suited for this study.

Chapter 4: Research Methodology

Research design choices are further discussed along with motivations for the selection of each design choice. This chapter will provide details around the research methodology, data collection techniques as well as data analysis techniques that will be utilised for this study.

Chapter 5: Analysis and Discussion

Data collected is dissected and discussed in this chapter. The results of the investigations conducted to answer each research question are examined in this chapter.

Chapter 6: Conclusion

The research findings of each research objective are summarised in this chapter. A summary of the contributions made to the body of knowledge as well as suggestions of future research ideas is further discussed.

1.8 CONCLUSION

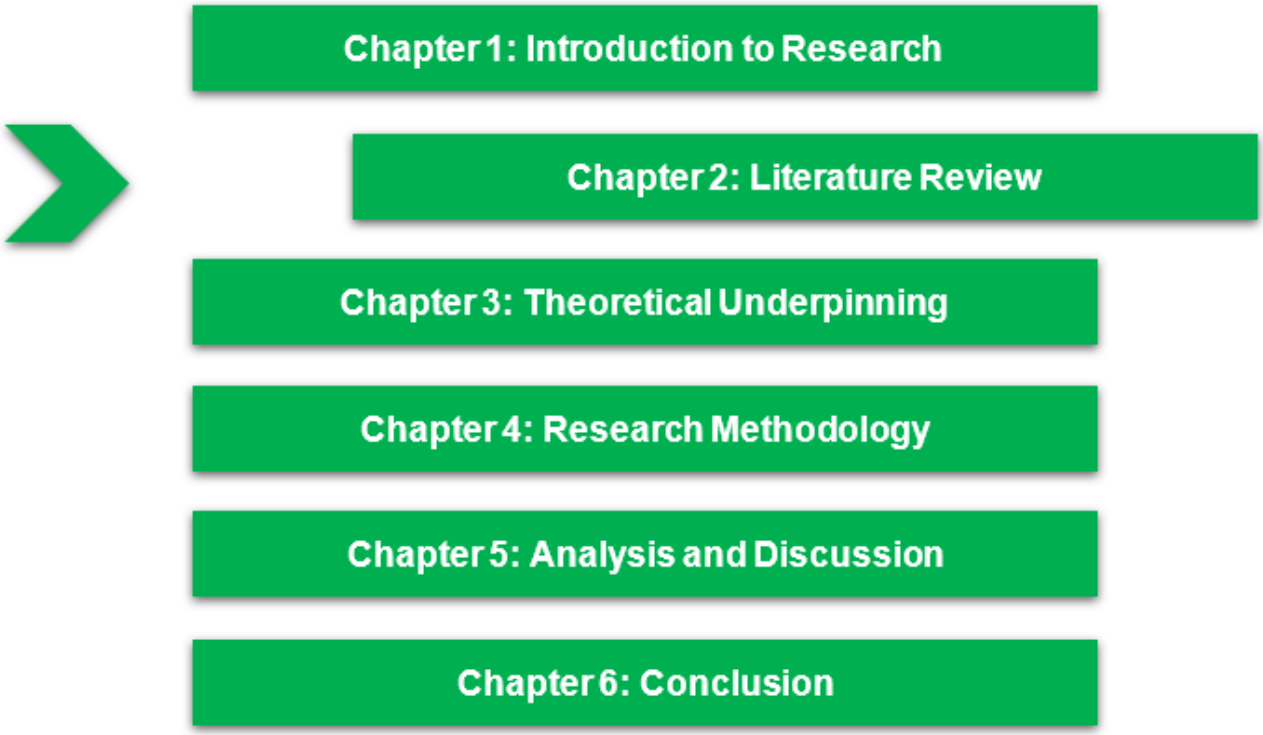
This chapter has discussed what causes OTS and how it is linked with modern-day football. The focus of this study will involve investigating how technology can play a part in reducing the risks of OTS for South African professional footballers. The summary of Chapter 1 is presented in Table 2.

Table 2: Summary of Chapter 1

Problem Statement	Research is required into the technology used to measure the underlying factors surrounding OTS in South African professional football to propose an improved system for the measurement and management of these factors.
Main Research Objective	To investigate the adoption of technology for the measurement and management of factors related to the risk of overtraining syndrome in football.
Motivation	All footballers should have a fair chance of proving their worth and achieving their goals. Technology is a powerful instrument that can limit human injury and assist these players in averting OTS.

In the next chapter, academic literature is provided detailing the current causes of OTS in modern-day football as well as the current training methods and technology embedded in a modern footballer's training regime.

2 LITERATURE REVIEW



2.1 INTRODUCTION

The last chapter provided an in-depth explanation of the research problem. A motivation as to why the research study is necessary was also provided. The research objectives and questions were defined to provide a guideline for solving the research problem. This chapter will provide the academic literature around the latest research conducted in this research field.

2.2 SCOPE OF LITERATURE

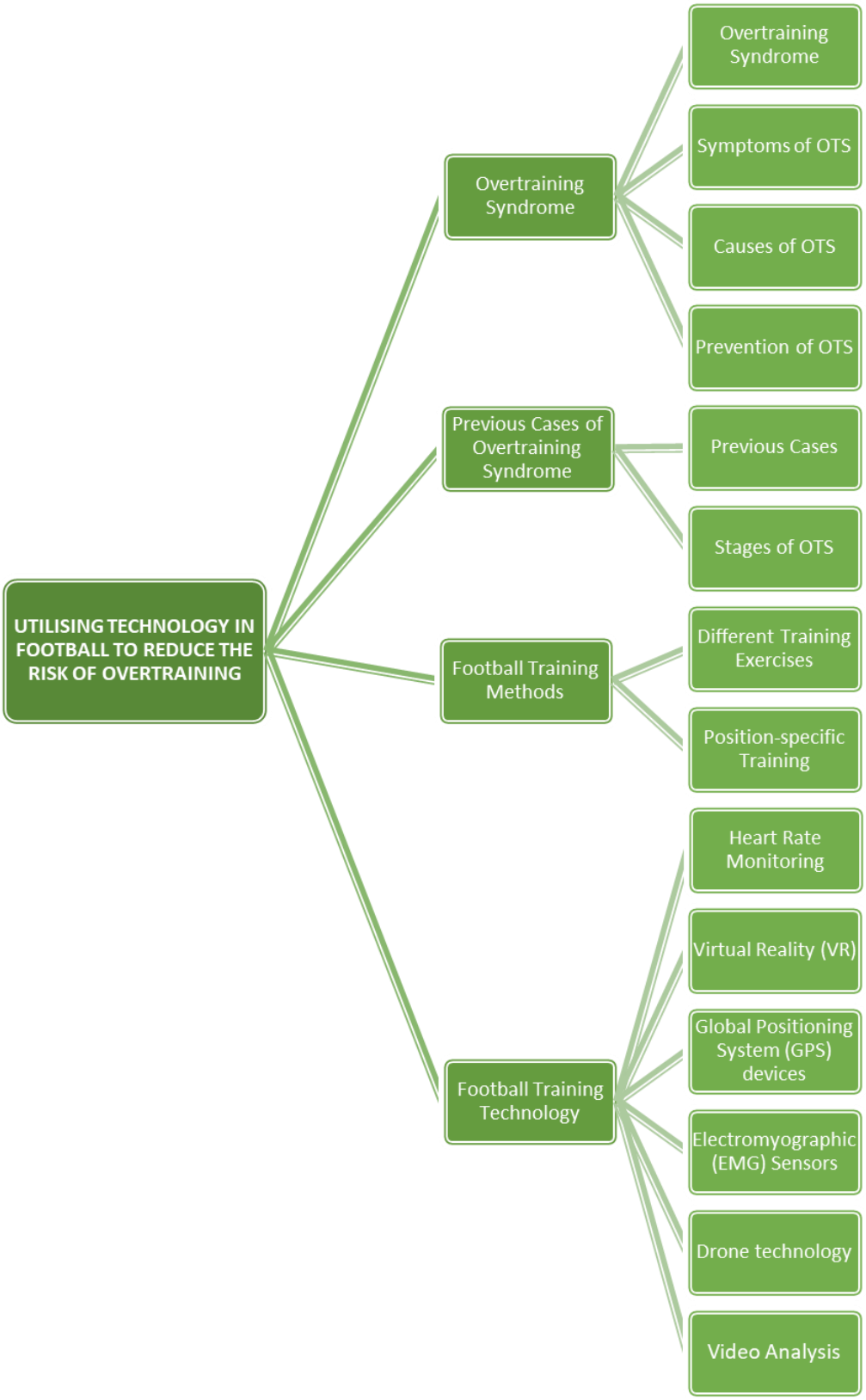


Figure 2: Scope of the Literature

Figure 2 portrays how the academic literature is structured. Four themes are formulated using the research topic, research objectives and research questions derived in Chapter 1. These themes are Overtraining Syndrome (OTS), Previous cases of OTS, Football training methods and Football training technology. The first theme, Overtraining Syndrome, is further broken down into five sub-themes namely, Overtraining Syndrome, Symptoms of OTS, Causes of OTS and Prevention of OTS. The second theme, Previous cases of OTS, is further broken down into two sub-themes namely, Previous Cases and Stages of OTS. The third theme, Football training methods, is further broken down into two sub-themes namely, Different training exercises and Position-specific training. The last theme, Football training technology, is further broken down into six sub-themes namely, HR Monitoring, Virtual Reality (VR), Global Positioning System (GPS) devices, Electromyographic (EMG) Sensors, Drone Technology and Video Analysis.

2.3 LITERATURE

2.3.1 Theme 1: Overtraining Syndrome

This theme provides theoretical knowledge on OTS. Topics such as symptoms, causes and prevention of OTS are discussed.

2.3.1.1 Overtraining Syndrome

Overtraining Syndrome (OTS) is defined as “a physical activity followed by a long period of decreased performance, which may or may not involve physiological changes, with recovery/improvement of performance a few weeks or months later”. OTS is a result of high-intensity training and low rest periods coupled with private life stressors (Pankanin, 2018). Fagundes *et al.* (2019) also mention how travelling for matches reduces the resting periods of players. During the season, a player faces an increasing number of stresses. This is caused by an increase in training load and the number of competitions. Stress is also caused by a constant demand for results and the competition between players for a starting spot. The best players are constantly expected to perform at the highest levels (Fagundes *et al.*, 2019).

Bian (2018) states that OTS is divided into two categories, namely short-term overtraining and OTS. Short-term overtraining is also called overwork and can be overcome within days. If an athlete endures sustained periods of overwork, this can lead to OTS. A four-step process of the development of OTS is shown in Figure 3.

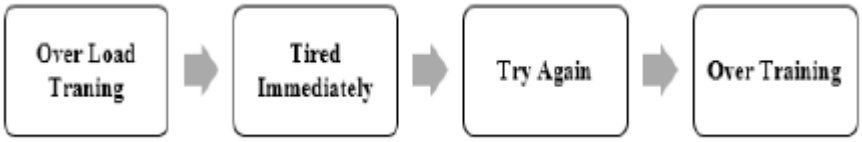


Figure 3: A four-step process of the development of OTS. Source: (Bian, 2018)

Overload Training: The player continually overworks to push their body beyond its limit
Tired Immediately: Due to the overworking, the player is worn out quicker
Try Again: The player continues to push themselves physically
Over Training: If the first three steps are performed continuously over a period, OTS will occur

This section has built a foundation about OTS. This foundation will be expanded on in the next section about the symptoms of OTS.

2.3.1.2 Symptoms of OTS

Common signs of OTS include consistent underperformance despite ample recovery time and a decrease in positive mood state (Kreher and Schwartz, 2012). Pankanin (2018) mentions the following symptoms of OTS (Pankanin, 2018):

- **Fatigue** – Due to insufficient recovery
- **Performance decline** – The player is not 100% physically and mentally, thus their performances deteriorate
- **Sleep disorders and Weight Loss** – Due to many factors like stress, family issues or concerns about declining performance

- **Negative attitude towards training** – The player's mental health is affected by factors such as declining performance, fatigue and personal issues
- **Muscle and joint pain** – The body is overworked and not given enough recovery time
- **Greater susceptibility to injury** – Due to overworking and insufficient recovery, the body is more prone to injuries

Diagnosing OTS still proves to be a difficult task because of the lack of tools and varying symptoms. OTS can only be diagnosed once other conditions with similar symptoms are removed from the equation (Pankanin, 2018). The following methods have been proposed by scientists to diagnose OTS (Pankanin, 2018):

- **Measurement of certain hormones, physiological parameters or the immune system** – This is done to eliminate the possibility of other organic illnesses
- **Fitness tests** – Players results will be analysed to find any red flags
- **Mood tests** – Players complete questionnaires about their mental well-being

2.3.1.3 Causes of OTS

Pankanin (2018) mentions several causes which are discussed in Table 3. Kreher and Schwartz (2012) discuss the triggers of OTS which are described in Table 4.

Table 3: Causes of OTS. Source: (Pankanin, 2018)

Increased training load – Training load is increased to improve player performance. Not increasing the resting period will negatively impact players. Training load is also increased because of poor performances.
Training monotony – Training methods could include repeated exercises or exercises that target the same muscle groups which cause overtraining of that muscle.
Too many competitions – Too many competitions mean less time to rest between training sessions and competitions, thus the body begins to suffer.
Personal emotional problems – Players are humans at the end of the day, meaning they also have personal issues to deal with. These personal problems affect the mental and

emotional state of the player.
Perfectionism – Many professional footballers are perfectionists, one of the reasons they have made it to the top level. However, the continual drive to improve one's performance by training more intensely may start to have a negative impact at some stage.

Table 4: Possible Triggers of OTS. Source: (Kreher and Schwartz, 2012)

The monotony of training - Training methods are similar and repeatedly target the same muscle groups, therefore not allowing muscle recovery.
An increased amount of training without sufficient recovery - Recovery is essential after intense training sessions. During recovery, muscles repair and grow, becoming stronger. Without recovery time, this growth and repairing of the muscles will not occur.
An increased number of competitive matches - Increased matches mean more muscle exhaustion and less recovery time.
Interruption in sleep patterns - Sleep is another essential part of muscle growth and repair. Sleep also allows the body and mind to recover after intense workouts and stress.
Stress - Stress releases cortisol into the body which has negative effects on the body and mind, thus affecting performance.
Change in the climate such as change of altitude - Higher altitudes have lower amounts of oxygen in the air meaning the lungs take in less oxygen and pass less oxygen to the muscles via the blood. The lower amount of oxygen in the muscles cause cramp and injury.

A football team's coaching staff and sports scientists find it difficult to control OTS. OTS is made up of three factors (Fagundes *et al.*, 2019):

- A reduction in a player's sense of accomplishment
- A player not finding value in playing the sport
- Mental and Physical fatigue

This section as well as the previous section have discussed the causes and symptoms of OTS. The next section will discuss how OTS can be prevented.

2.3.1.4 Prevention of OTS

Pankanin (2018) mentions the prevention methods of OTS in Table 5. Kreher and Schwartz (2012) discuss possible methods that can be used to prevent OTS in Table 6.

Table 5: Prevention methods of OTS. Source: (Pankanin, 2018)

Regeneration time and quality – There must be adequate resting periods to balance out the training load. Resting periods must be increased when the training load is increased. A general model called the "scissors-model" states that increasing stress must be coupled with increasing recovery as a stable stress-state balance needs to be maintained (Fagundes *et al.*, 2019). The model also described how optimal performance can be achieved by combining intermediate levels of stress with sufficient recovery (Fagundes *et al.*, 2019).
Individualised training – Training must revolve around the player's current physical state.
Constant player monitoring – Players must continuously be monitored to determine their response to training stress.
Diet – Diet and significant hydration are extremely important.
Performance assessments – Regular performance assessments should be conducted and analysed to identify any drastic changes in performance that could indicate OTS.
Personal life – Sleep quantity and quality are crucial as well as eradicating personal stress.
Monitoring psychological factors – A player's mental and emotional state should be closely monitored to swiftly identify drastic changes.

Table 6: Possible prevention techniques of OTS. Source: (Kreher and Schwartz, 2012)

Decreasing training load when matches are approaching – As match days approach, training intensity and training load should decrease to give the body enough time to recover and fuel up to max capacity.

Periodisation of training – Training should be broken down into smaller intervals instead of one big session, thus promoting muscle recovery and repair.
Using performance and mood to regulate training load – A player's mood state should be considered before training sessions. A positive mind means a positive body, thus greater outcomes from training.
Correct hydration and caloric intake according to training intensity – Nutrient refuelling must be directly proportionate to the intensity of training. Whatever nutrients are lost must be recouped with extra amounts to promote muscle growth.
Maintaining sleeping patterns and amount of sleep – As mentioned earlier, good sleep cycles are vital.
Educating players on the risks of OTS – A player must be aware of how they can protect their bodies. They have the greatest role to play.
Providing mental support for players – Mental health must be constantly monitored as a positive mind leads to increased performance.
Rest periods of greater than six hours between training sessions – Rest allows the body to recuperate and grow.
No training sessions after illness or high levels of stress – Training must be gradually introduced after illness or stressful periods as the body needs to build up to original levels. Gradual introduction to training prevents the body from going into shock.
Avoid exposure to extreme weather conditions – Training during extreme conditions should be avoided as the body is placed under unnecessary strain.

A study by Fagundes *et al.* (2019), which utilised psychometric questionnaires, demonstrated that enhanced sports performance is promoted by keeping soccer players motivated and creating a healthy balance between stress and recovery. Intrinsically motivated players are more eager to improve their game. Monitoring amotivation proved to be the most effective way of predicting the onset of OTS. Early identification of OTS signs is crucial for the prevention of OTS. Predictive modelling can be used to provide insight into the control and monitoring of training load according to a player's mood state. This allows the coaching staff to make prompt interventions to prevent potential harm to a player's career and the team (Fagundes *et al.*, 2019).

Professional athletes are required to continuously find new performance levels. Athletes feel this pressure from their family, the coaching staff, sponsors, the club they play for and most of all, themselves. If regular training combined with a balanced diet and adequate rest is not religiously maintained, the risk of OTS increases. Not just professional athletes face these risks, amateur athletes attempting to increase performance levels are also at risk.

2.3.1.5 Summary of Theme 1

Table 7: Theme 1 summary of findings

Theme 1 provided literature on topics such as OTS, Symptoms of OTS, Causes of OTS and Prevention of OTS. The various stages of OTS were discussed. Some of the most common symptoms of OTS were fatigue, performance decline, sleep disorders and a negative attitude towards training. Some of the most common causes of OTS were increased training load, training monotony, stress, diet, and poor sleep. Some of the best methods of preventing OTS were good diet, adequate sleep quality, constant player monitoring and adequate resting periods.

2.3.2 Theme 2: Previous cases of Overtraining Syndrome

There is not much literature on previous cases of OTS, especially in the South African football context. This chapter will discuss literature from previous cases of OTS around the world. This theme provides theoretical knowledge on previous cases of OTS to find any similarities. The different stages of OTS are also discussed in detail.

2.3.2.1 Previous Cases

An article by Hägglund, Waldén and Ekstrand (2006) looked at various factors surrounding injuries in Swedish elite football. Adult male footballers experienced injuries at a rate of between 12 and 35 injuries per 1000 hours of match play. It was seen that a vast majority of the OTS injuries transpired during training sessions. A study by Ehrmann *et al.* (2016) found the opposite to be true in that the professional player is more susceptible to injuries

during a match rather than training. Under 50 percent of OTS injuries were re-injuries (injuries that returned) and over 60 percent of re-injuries were OTS injuries. From this, it is evident that OTS had a significant adverse effect on a player once they had injured themselves. Most of the OTS injury cases occurred during preseason training. This can be attributed to the less intense training sessions during the season and the fact that more emphasis is placed on recovery and tactical sessions. A study by Woods *et al.*(2002) also found that the number of OTS related injuries were greater during the preseason. Possible explanations for this are the sudden increase in training intensity coupled with training on a new surface. A study by Ehrmann *et al.* (2016) contradicts what was found by Hägglund, Waldén and Ekstrand (2006) and Woods *et al.* (2002). The study by Ehrmann *et al.* (2016) analysed injuries per player during the preseason and the main season. It was seen that most injuries occurred during the main season. It was also observed that OTS injuries were frequent and caused players to miss out on playing time. Footballers playing at the highest level had busy schedules consisting of 28 days of either training or matches in a month. As a result of hardly having any days off, their chances of injury were greatly increased (Hägglund, Waldén and Ekstrand, 2006). A study by Kajaia *et al.* (2017) also found that too much training combined with inadequate resting periods caused OTS.

The study by Hägglund, Waldén and Ekstrand (2006) found that most injuries occurred in the lower leg areas such as the knees and ankles. The study by Ehrmann *et al.* (2016) found that the most common injuries in descending order were hamstring strain, calf strain, ankle sprains and groin strains. It was discovered that the injured players covered more meters/minute in the time leading up to their injury in comparison to their season average. The injured players were also involved in more high-intensity and very high-intensity running leading up to their injury as opposed to their season average. However, the injured players had a much lower new body load average in the time before the injury as compared with their season average. Most injuries are non-contact. It was discovered that injury rates increase when the recovery days fall below four days. This shows a direct relationship between recovery and injury (Ehrmann *et al.*, 2016).

The competitive nature within a football team may also influence a player to not inform the medical team of any injury they might be experiencing as missing out on a match could result in a lost place in the starting line-up for some time (Hägglund, Waldén and Ekstrand, 2006). A study by Björnsdóttir (2018) studied the effect of OTS on mental health. It was

discovered that players who suffered from OTS had higher levels of anxiety. This anxiety could be attributed to the player knowing they may lose their place in the starting line-up due to OTS. Early signs of OTS injuries may be noticed by the players themselves, but if the medical team are unable to find any visible symptoms, they may not be able to find the root cause. Kajaia *et al.* (2017) discovered that non-training stressors such as nutritional, educational and social stresses contributed to OTS. An article by Culvin (2019) also mentions cases of OTS that were related to social stresses. The article discussed previous cases where players acquired OTS because of trying to prove their value to the team as well as trying to satisfy the coach. The complexity of determining the correct amount of rehabilitation time for an OTS injury contributes to a player returning to full training too early, thus increasing their chances of re-injury (Hägglund, Waldén and Ekstrand, 2006).

Specific periods of the season can also cause an increase in the risk of injury. The number of important matches may be concentrated during a certain period. An article by Kajaia *et al.* (2017) agreed with this and found that too many competitions contributed to players acquiring OTS. A study by Ehrmann *et al.* (2016) found that the concentration of injuries was the highest during the middle of the season. This could be due to an increase in competitions. This coupled with the environmental season can negatively impact footballers. Playing conditions may become tougher during the dry seasons, thus placing more strain on the body (Hägglund, Waldén and Ekstrand, 2006).

2.3.2.2 Stages of OTS

An athlete's performance undergoes various stages of change as the athlete acquires OTS (Bian, 2018). These stages are discussed below:

Stage 1:

- No effect on motor performance – The physical performance of the player is not affected
- Neuron function begins to change – The functioning of a player's neurons begin to change, however, this does not affect their motor performance

Stage 2:

- Little to no effect on motor performance – The physical performance of the player is not affected and any effects on physical performance are negligible or unnoticeable
- Motor unit recruitment[1] begins to change – The manner in which motor units are activated by voluntary muscle contractions begins to change

Stage 3:

- The excitement of skeletal muscles changes – The process where the skeletal muscles receive signals from the nervous system to contract is altered
- Increased HR – The heart rate of the player is increased
- Changes to immune function and emotional anxiety – The functioning of the player's immune system changes and the player's mental state is affected

Stage 4:

- Ability to make effort is adversely affected – Due to changes in motor performance and skeletal muscle activation, the player's ability to exert a force is hampered
- Increased risk of infection and disease – Due to changes in the player's immune system function, the player is more susceptible to infections
- Worsening sleeping pattern – Sleeping patterns are affected due to the increase in emotional anxiety as well the increased heart rate
- Worsening mood – The player's mood state continues to deteriorate. This could be due to the player experiencing an increased number of physical and mental changes

Figure 4 below describes the workout-recovery process and identifies at which point a performance decline is most likely to occur.

[1] The successive activation of the same and additional motor units with increasing strength of voluntary muscle contraction. Source: (Sandbrink and Culcea, 2010)

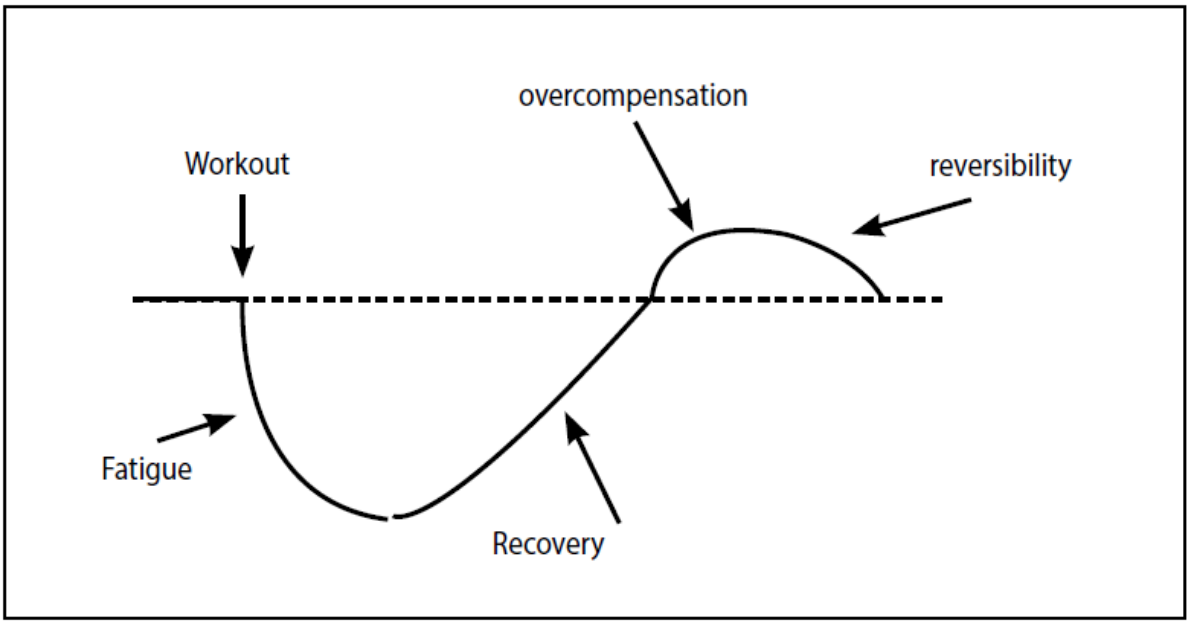


Figure 4: Describing different stages in the workout-recovery process. Source: (Savioli *et al.*, 2018)

- **Post-Workout:** After a player completes a workout, they experience fatigue as well as a decrease in performance.
- **Recovery:** Sufficient rest and a good diet are required for the player to prepare for the overcompensation phase.
- **Overcompensation:** Performance improvement occurs here. If a workout is not completed during this phase, an increase in performance will not occur.
- **Reversal:** Occurs if players do not work out during the overcompensation phase.
- **Performance Decline:** Occurs if a player's workout is performed during the recovery phase.

As described in Figure 4, the player must complete many stages of the workout-recovery process to achieve maximum performance gain. An increase in performance occurs when players work out during the overcompensation phase. A decrease in performance occurs if players work out during the recovery phase. This decline in performance will contribute to OTS.

2.3.2.3 Summary of Theme 2

Table 8: Theme 2 summary of findings

Theme 2 discussed literature on topics such as cases of OTS and similarities in OTS cases. It was discovered that little to no research exists on previous cases of OTS in South African professional football. Previous cases mostly occurred during the full season, preseason training sessions and on the lower leg area. More playing time, as well as more intense playing, led to OTS. The four stages of performance change were also discussed. The workout-recovery process showed how performance decline occurs when a workout is performed during the recovery phase. This will lead to OTS.

2.3.3 Theme 3: Football Training Methods

Training methods play a vital role in the development of footballers. This theme focuses on the different types of training methods used in professional football and how these methods aim to reduce the risk of OTS. This section starts by discussing the general training exercises and then focuses on player-specific training exercises.

2.3.3.1 Different Training Exercises

Training load has become a popular research area in recent times with a focus on external load. The core reason behind the increased interest in this area is improving individual player performance and preventing OTS. The most common types of training involved progressive overload training. The human physiological system is improved through a well-constructed training regime. The opposite is also true for a poorly constructed training regime. The training program is tailored according to a player's responses during training. This can be measured using a player's training load. This training load can be broken up into internal and external training loads. The internal load being the impact on the player's physiological systems and the external load being the physical work done by the player. External loads can be categorised as acute (seven days), chronic (lasting four weeks) and a ratio of the acute and chronic. It has been seen that emphasis must be placed on the ratios at which acute and chronic external loads are combined. Spikes in acute load have

been known to bring a higher risk of injury. It needs to be stressed that it is best to monitor the external load of each player as many variables play a part in injury risk (Cardinale and Varley, 2017).

Examples of external load measures include speed, acceleration and tackles made. The main goals of measuring external load are to determine whether training techniques are benefiting a player and to prevent injury and OTS. The coaching staff can then analyse these measures and create player-specific training programs to extract the best possible results. The validity and reliability of the devices used are extremely important when monitoring a player over time (Cardinale and Varley, 2017).

It was seen that new body load was decreased in the period leading up to injury. The injury could have occurred because the player was unprepared for the demands of a competitive match as the training load was decreased. An article by (Cardinale and Varley, 2017) also found that a low external load may cause injury because of a player not being conditioned for tough match conditions whereas a high external load may cause injury due to the player pushing their body past their maximum load threshold during training. The concept of individuality comes into play here again. Each player will have their load threshold. Players could also be holding back during training if they are dealing with a lingering injury or are feeling a general soreness from training or matches (Ehrmann *et al.*, 2016). These may also be signs of OTS. It has been seen in the past that players continue to train with an injury without informing the coaches or staff. Matchplay tends to expose these players as they are not able to pace themselves as they do in training. At the end of the day, further damage is done to the players themselves (Ehrmann *et al.*, 2016).

Sports scientists, as well as coaches, look to combine different training methods. By using these mixed methods, players can improve neuromuscular performance. Functional exercises have become the main focus as a player trains using dynamic movements which are required in sport (Loturco *et al.*, 2017). Plyometric training (PT) is used to increase a player's explosiveness and strength. During this type of training, the muscles are required to exert maximum force over a short period to improve dynamic performance. This training involves the high-intensity contraction and extension of the muscles. Examples include jumping drills. It has been seen that lower-body power increases when PT is utilised (Wang and Zhang, 2016). An article by Morgans *et al.* (2014) describes how a football

player needs to be able to perform various kinds of complex movements. These movements include sprinting, jogging, walking, and changing direction while performing any one of these movements. Both aerobic, as well as anaerobic energy, is required to perform these movements at any given stage during a match of football. The article continues to stress the importance of a training regime that improves the footballer's strength and flexibility and in doing so allows the player to increase performance in tasks such as passing and shooting.

A multi-dimensional training method that targets both the muscles and energy systems of the player is desired. In recent times, the coaching staff have dedicated more time to tactical training sessions, thus players have less time to strengthen their physical condition. During the season, increased amounts of travelling and the physical demands of important matches force coaching staff to cut back on physical training. Thus, it becomes clear that dynamic training methods need to be developed to target all aspects of football training in the time available (Morgans *et al.*, 2014).

A theoretical framework by the name of Periodisation has been developed to ensure that there is a variation in the training loads that a player is exposed to (Morgans *et al.*, 2014). By using this framework, the probability of OTS and subsequent injury is greatly decreased. For the body to handle increased levels of work, the training load needs to be increased gradually. Training load is increased by increasing any of the following three factors: volume, intensity, and frequency. Emphasis needs to be placed on the concept of individuality. Every player is different in the way they respond to training. To extract the best results, training should be player-specific. However, this is not the case in football, as most training is conducted in groups. Training methods should also target specific roles in football as the match movements differ amongst the playing positions

An article by Alves *et al.* (2010) shows how the increase in muscle strength from strength training used in conjunction with regular football-specific movements improves performance in sprinting and squat jumps. Studies have shown that footballers' endurance is increased when training methods involving short-duration intermittent running are implemented. An increase in aerobic capacity allows a footballer to increase performance in most aspects of their game.

The sprint distance covered by less successful football teams decreases drastically as a match progresses. This points to the fact that sustained levels of high performance are a necessity for success. Players need to be able to consistently perform near their maximum physical threshold. It is therefore imperative that modern-day training methods include a large portion of high-intensity aerobic drills. Football training includes training without the ball as well as training with the ball. Both methods have their advantages and target different areas (Iaia, Rampinini and Bangsbo, 2009).

2.3.3.2 Position-specific training

It was observed that the aerobic training benefit of training in small groups was sufficient (Iaia, Rampinini and Bangsbo, 2009). An article by Morgans *et al.* (2014) agrees that small group training is beneficial. The article states that exercise intensity is inversely proportional to the number of players. When players train in small groups, their physical activity is much higher as a result of many different movements, as opposed to large group training where a player has a lower amount of involvement time. Small group training provides more time for players to work on technical skills and physicality as they interact more with the ball. Large group training will focus more on position-specific training (Morgans *et al.*, 2014).

Central defenders were seen to have the lowest distance covered as well as a lower amount of high intensity running as compared to other playing positions. As the match progresses, the high-intensity running of attacking players significantly decreased. This could be attributed to the fact that these players have many quick bursts during shorter periods (Iaia, Rampinini and Bangsbo, 2009). An article by (Ade, Fitzpatrick and Bradley, 2016) agreed that players of different positions run at different intensities, for different durations and complete different movements during a football match.

The article by (Ade, Fitzpatrick and Bradley, 2016) describes the various movements completed by a footballer during a match below:

1. **Wide midfielders**: More high intensity running compared to other positions
2. **Full backs**: Highest percentage of high-intensity running (relative to total running)
3. **Central midfielders**:

- More frequent runs with low amounts of recovery compared to other positions
- Attempt and complete more passes than other positions

4. **Forwards and Central Midfielders**:
    - More touches per instance of ball possession compared to other positions
    - The least number of long passes compared to other positions
5. **Midfielders**:
    - Least 0-90-degree turns compared to other positions
    - Least time spent standing compared to other positions
    - Most number of short passes compared to other positions
6. **Defenders**:
    - Lower time spent sprinting compared to other positions
    - More time moving backwards compared to other positions

Training drills are created according to these positional characteristics. Factors such as pitch location, combination-play and possession status should also be considered when creating training drills. This will allow the coaching staff to design drills that consist of various player types which have been seen to increase player enjoyment (Ade, Fitzpatrick and Bradley, 2016).

Players respond differently to different training programs. There is also a difference between training and match conditions. Therefore, the results collected will differ greatly depending on whether it is training or a match or depending on what type of training is conducted. Comparison between results collected needs to be strictly situationally categorised (Cardinale and Varley, 2017).

2.3.3.3 Summary of Theme 3

Table 9: Theme 3 summary of findings

Theme 3 discussed literature on topics such as different training exercises and position-specific training. Training load is broken up into internal and external training load. Functional exercises allow players to develop dynamic movements. PT is used to increase

a player's explosiveness and strength. Periodisation varies the training load players are exposed to, thus reducing the risk of OTS. Small group training allows players to develop their technical skills and physicality whereas large group training works on position-specific training. The literature also discussed how players in different positions perform different movements and different runs with different intensities. Training drills are designed to target these position-specific movements and runs.

This theme has provided the basis to move onto the next theme which will discuss the types of technology used in football training.

2.3.4 Theme 4: Football Training Technology

The previous theme introduced theoretical knowledge on the current training methods used in professional football. This theme will build on this and discuss theoretical knowledge on the current forms of technology that are being used in professional football.

2.3.4.1 Heart Rate Monitoring

One of the earliest examples of the measurement of the internal load is HR monitoring. It has been seen that HR monitors using chest straps that contain electrodes provide valid and reliable results. As technology has progressed, wrist-based HR monitors have become a popular choice (Cardinale and Varley, 2017). A study by Proietti *et al.*(2017) agrees that heart rate monitors have been widely used to monitor players. This article went on to state that performance gains were observed when heart rate was monitored daily. A study by Flatt, Esco and Nakamura (2017) also confirms the widespread use of resting heart rate as an objective data metric for monitoring players. Wrist-based HR monitors use photoplethysmography to detect HR. These days, muscle oxygenation is measured using the widely accepted near-infrared spectroscopy (NIRS). The disadvantage of this technology is that only some devices have been proven to be valid. As technology continues to advance, embedded devices become smaller in size and thus allow for more practical applications in measuring internal load (Cardinale and Varley, 2017).

2.3.4.2 Virtual Reality (VR)

A sport like football involves many interceptive movements. A player's performance can be measured against how accurately they predict where the football will land. This prediction can provide a competitive edge. Previous research has shown that using a consistent environment may prove beneficial when analysing a player's visual perception. Two methods can produce this consistent environment. The first being video-based and the second being virtual reality (VR) (Vignais *et al.*, 2015).

The introduction of VR technology has helped to address the issues with video-based methods. In the virtual environment, the researcher will control what visual information is being displayed. The player will then react according to what is displayed. The researcher can modify the displayed information at any time and observe how the player reacts. The head movements of a player are continually tracked to update their surroundings. The player can then collect visual information from various angles, which creates a real-life feeling. The player can then make improved decisions as compared to the video-based method (Vignais *et al.*, 2015). An article by Marcelo Pires and Vítor Santos (2018) discusses how VR technology has had a significant impact on player performance during training sessions. A study by Yamchi *et al.* (2021) found that the use of VR technology in the training of athletes with functional ankle sprains significantly increased the performance of these athletes. Thus, VR technology can potentially be used for the rehabilitation of professional footballers. Previous VR research in football has investigated how adding spin to the football during a free-kick routine will affect a player's prediction of where the football will land. VR systems can be validated by comparing a player's reactions in real life with their reactions in the VR system (Vignais *et al.*, 2015).

VR systems may improve on the shortcomings of video-based systems, however, there are disadvantages. The first being the cost of implementing a VR system. The display fidelity of the initial image may be reduced when using a VR system. The use of 3-D glasses may cause viewing angle issues and the weight of head-mounted displays may be problematic. Haptic feedback systems that enhance the VR system by allowing the player to feel physical contact are costly and impractical to implement for a sport that requires rapid movement. The real-life pressure of limited time experienced by players may also prove difficult to simulate in a virtual environment (Vignais *et al.*, 2015).

2.3.4.3 Global Positioning System (GPS) devices

It has become common to combine Global Positioning Systems (GPS) and Heart Rate (HR) to monitor player performance during training and matches (Morgans *et al.*, 2014). An article by Principe *et al.* (2020) agrees with this and states that ever since 2015, these wearable devices have become vital tools for football clubs. These devices are used to obtain data about acceleration, position, and velocity. From this data, the external load can be quantified (Cardinale and Varley, 2017). Various graphical and numerical reports are produced for the coaching staff to analyse. During training, these reports can be produced in real-time. From this data, coaches can alter training plans according to what works best for individual players. It is evident that technology has added another dimension to sport tactics (Morgans *et al.*, 2014).

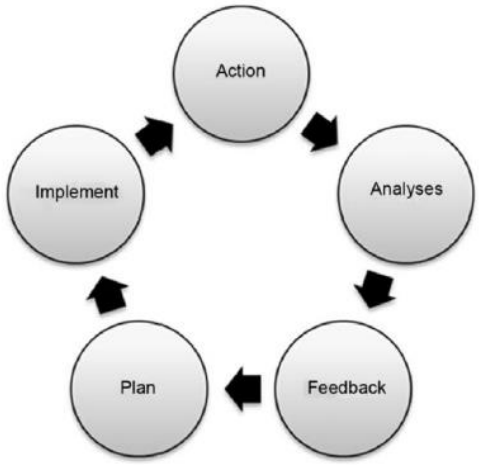


Figure 5: The feedback cycle used in football training. Source: (Morgans *et al.*, 2014)

The external load of athletes is most monitored using inertial sensing devices such as gyroscopes, accelerometers, and magnetometers. Accelerometers may provide more valid results about external load as compared to GPS devices. The reason for this is that accelerometers consider external load from movements such as foot impacts and collisions whereas these movements are not considered by GPS (Cardinale and Varley, 2017). Other potential reasons for unreliable GPS results are poor satellite connection, poor data processing or unreliable devices (Principe *et al.*, 2020). External load from

indoor sports can also be calculated using the above devices in parallel with magnetometers and gyroscopes (Cardinale and Varley, 2017).

Two methods are used to measure distance by utilising GPS data. The first method being positional differentiation and the second one being the integral of the Doppler-shift velocity. GPS devices calculate velocity through the Doppler-shift method or through the derivation of the change in distance over time. Research has shown that the Doppler-shift method is more precise with a lower percentage error. More focus is placed on the distance covered by a player at high speeds as well as the total distance covered (Cardinale and Varley, 2017).

Research has shown that acceleration consumes more energy than moving at a constant velocity. Other actions such as tackling and changing direction, both of which are very common in football, are also energy-intensive. GPS velocity data is used to derive the acceleration. The process of calculating acceleration involves two steps. The first step involves the time interval used when deriving the acceleration from velocity. The second step involves filtering the calculated acceleration, which is significant because of the magnification in error that can occur when the acceleration is derived from the velocity. The filtering techniques utilised must remain constant to ensure that no unnecessary errors are encountered (Cardinale and Varley, 2017).

As indicated earlier, accelerometers can also be used to calculate the external load. These devices may even provide more accurate results as compared to GPS devices. The most common way in which the external load is measured is by calculating the sum of a player's acceleration in the three planes. This measurement is conducted using a triaxial accelerometer. Sports technology company Catapult used a metric called *PlayerLoad* to measure external load. *PlayerLoad* is measured using the following calculation:

$$(Instantaneous\ \Delta\ in\ a\ in\ x, y, z)/100$$

where Δ is the rate of change, a is acceleration and x, y, z are the x, y, and z planes.

External load calculated by accelerometers provide player-specific data, therefore this data needs to be compared to a player's historical data rather than between different players.

When dealing with wearable devices, it is extremely important to understand the validity and reliability of individual devices. An article by Wilson (2021) discusses how the data collected by various sports tracking device businesses are not comparable in terms of reliability and validity. It is advised that one device is utilised during measurement as the accuracy and reliability of that device will be known, thus allowing the coaching staff to consider any changes in measurements as valid results (Cardinale and Varley, 2017). GPS data has been shown to have a lower accuracy at higher velocities. An increase in error is also witnessed for actions that require swift acceleration such as explosive sprinting or a rapid change in direction, both of which are fundamental football movements (Cardinale and Varley, 2017).

Data collection is an integral part of accurate measurements. Software updates may affect calculation algorithms, thus devices may not be upgraded until the end of the season. To achieve the best results, measurements need to be taken over a long period. Devices may be upgraded during this period (Cardinale and Varley, 2017). An article by Malone *et al.* (2020) stresses the importance of consistency with the hardware and software used during the acquiring and processing of GPS data. The ability to re-process previously collected data according to new algorithms will greatly increase the insight into the change in a player's performance (Cardinale and Varley, 2017).

A study by Ehrmann *et al.* (2016) states how GPS has become a key tool in finding the balance between training load and recovery to maximise performance gain and reduce the risk of OTS. A study by Principe *et al.* (2020) agrees with this and states that performance is linked to adequate recovery time between training and matches. In a study by Ehrmann *et al.* (2016), two GPS variables were used to predict soft tissue injury. They were average new body load and average meters per minute. An increase in average meters per minute leading up to an injury showed a direct relationship between an increasing intensity and injury. It was also found that increasing the training load also increased the risk of injury. Coaches may allow for player recovery by decreasing training time and keeping training load stable without decreasing intensity. This will increase the average player intensity per training session. This hurts player recovery which leads to an increased risk of injury. Coaches may also reduce the time for breaks between training exercises. Even if the training intensity is not increased, the decrease in break duration leads to an increase in the average intensity per training session which has adverse effects on player recovery

(Ehrmann *et al.*, 2016). A football player in one of Europe's top-flight leagues on average misses 12% of a season because of injury, thus detrimentally affecting their club (Ehrmann *et al.*, 2016).

Due to the extremely competitive nature of professional football, there are situations where coaches are forced to field a player that is carrying an injury. With GPS data available, the coach and staff may be able to make a more informed decision as to whether the risk is worth taking. Two factors should be considered when dealing with injuries:

1. Non-modifiable risk factors: Injury history, age etc.
2. Modifiable risk factors: Meters covered per minute etc.

It can be seen from this study that GPS data provides extremely valuable insight when dealing with injury prediction in football. GPS data gathered should also be used to predict OTS.

2.3.4.4 Electromyographic (EMG) Sensors

Sports attire containing Electromyographic (EMG) sensors have been developed to measure the activity of a player's muscles during training. As mentioned earlier, sensors on the skin can also be used to monitor the muscles (Cardinale and Varley, 2017). A study by Worsey *et al.* (2020) showed how EMG sensors were used to measure the muscle activity in the neck during the process of heading a football. It was discovered that using the correct heading technique reduced the force experienced by the head during the heading of a football. EMG can potentially be used to reduce the impact that various other football movements have on the body, thus reducing injury risk. A study by It has proven to be difficult for researchers to test this technology over an extended period as the equipment used is impractically large and would hamper the mobility of players (Cardinale and Varley, 2017). A study by (Pedersen *et al.*, 2021) states that due to the contribution of neighbouring muscles, EMG sensors can only provide an estimated measurement of muscle activation. The study also mentions that the tendency of the sensors to move during dynamic contractions can impact the measurement.

2.3.4.5 Drone Technology

During a football match, coaches and spectators tend to view the game differently. Spectators tend to focus on what is transpiring around the football. The coaches also need to be aware of what is going on away from the ball. Modern-day football has become an extremely complex sport because of the multitude of tactics utilised to get the upper hand over the opponent. Teams have specialised staff focusing on the style of play and formation (Islam, 2020). The five key moments that occur during a football match are listed below:

1. **Own ball possession** – This is when your team is in possession of the football and most likely in control of the pattern of play. Most of the time, teams in possession will be stringing passes together while trying to attack the opposition's goal.
2. **Opponent ball possession** – This is when your opponent is in possession of the football. The opponent will most likely be attacking your goal. The defending team will have to try and win back possession of the ball and prevent the attacking team from scoring a goal.
3. **Negative transition** – This happens when the football changes possession from your team to the opponent. Usually, this will result in the opposition starting an attack which will require defending from your team.
4. **Positive transition** – This happens when the football changes possession from the opponent to your team. Usually, this will result in your team preparing to attack the opposition's goal.
5. **Set-plays** – This is when the game is restarted from a dead-ball e.g. corners and freekicks. Freekicks are awarded to the opposition when one of their players is fouled. Corners are awarded when the football is kicked over the goal line (the lines on either side of the goalposts which lead to the corner flags)

The above moments are made up of a group of players interacting either with or against each other. Utilising drone footage may provide the coaches with a better viewing angle to analyse these five moments (Islam, 2020).

A drone is essentially an unmanned aerial vehicle that is controlled remotely from the ground (Hilton, 2020). The drones used in football training are equipped with advanced

sensors such as speed, distance, thermal, image and GPS. The drones are controlled using radio waves via Wi-Fi. Drones have become popular tools in sports training. Athletes use a variety of tools to extract the best possible performances from themselves. American football teams have been using drone data to enhance player movement and technique. When it comes to professional sports, every little improvement is significant (Islam, 2020).

Aerial views provide a better view of the whole game. The coach can analyse what is happening around the ball as well as what is happening away from the ball. One important statistic that players are measured on is how well they use space. The drone can track the player as well as the spaces around the player. A player's positioning can be monitored during attack and defence to determine if the formations are maintained (Islam, 2020).

The formation of the team is affected by various runs. These runs are used to create space. Some examples are overlapping runs, dummy runs, and blind-side runs. However, space is not always created by running. Drone footage is also used to determine how well attacking players fit into the defensive formation during an attack from the opposition and vice versa (Islam, 2020).

An article by Hilton (2020) describes how drones can also be used to monitor injuries. The drone records video footage of the events before and after an injury occurs. This video footage can be used by the coaching staff for further injury analysis.

2.3.4.6 Video Analysis

Visual analysis has become a very popular technique of match data analysis. In video analytics, video recordings are analysed by video analysts to provide insights to the coaching staff. These insights can be used by football clubs for player scouting, strategic decisions as well as statistical analysis (Vanderplaetse and Dupont, 2020). Modern-day video analytics involves using video data to produce abstract visual representations of match events (Stein *et al.*, 2018). These match events include kicks, offsides, passes and goals among others (Khan *et al.*, 2018).

The major benefit of utilising video-based methods is that it is easy to implement. Various techniques have been used to analyse visual perception using this method. The first technique is calculating the response time of the player to the video clip. The second technique involved stopping the video clip at crucial moments such as the moment a ball is kicked in football. This shows how the player uses the moments before the video is stopped to predict what will occur after and react (Vignais *et al.*, 2015).

Video-tracking systems (VTS) are used to collect objective data from players during matches. This data contains information about the various actions a player performs such as accelerations and decelerations, change of direction and high-speed running among others. The main advantage of VTS is that players don't have to wear any devices as they do with GPS (Beato and Jamil, 2018).

There are however disadvantages to the video-based method. The first is the fact that the video is two-dimensional. This does not allow the player to get a three-dimensional perspective as in real life. The second disadvantage is only having one viewing angle whereas, in a real-life situation, the player may change their position to extract more visual data from the environment (Vignais *et al.*, 2015).

2.3.4.7 Summary of Theme 4

Table 10: Theme 4 summary of findings

Theme 4 presented academic literature on various technologies used in football training. HR chest straps have been used for a while because of the validity and reliability of results. VR systems are used to develop a player's reactions by placing them in virtual match situations. One of the advantages of GPS devices is the ability for technical teams to acquire immediate results during training. EMG sensors have been developed to monitor muscle activity, however, this technology is still not practical. Drone Technology provides better viewing angles for technical staff to analyse player and team performances. Video Analysis is easy to implement and allows technical teams to pause the video at critical moments to conduct further analysis.

2.4 CONCLUSION

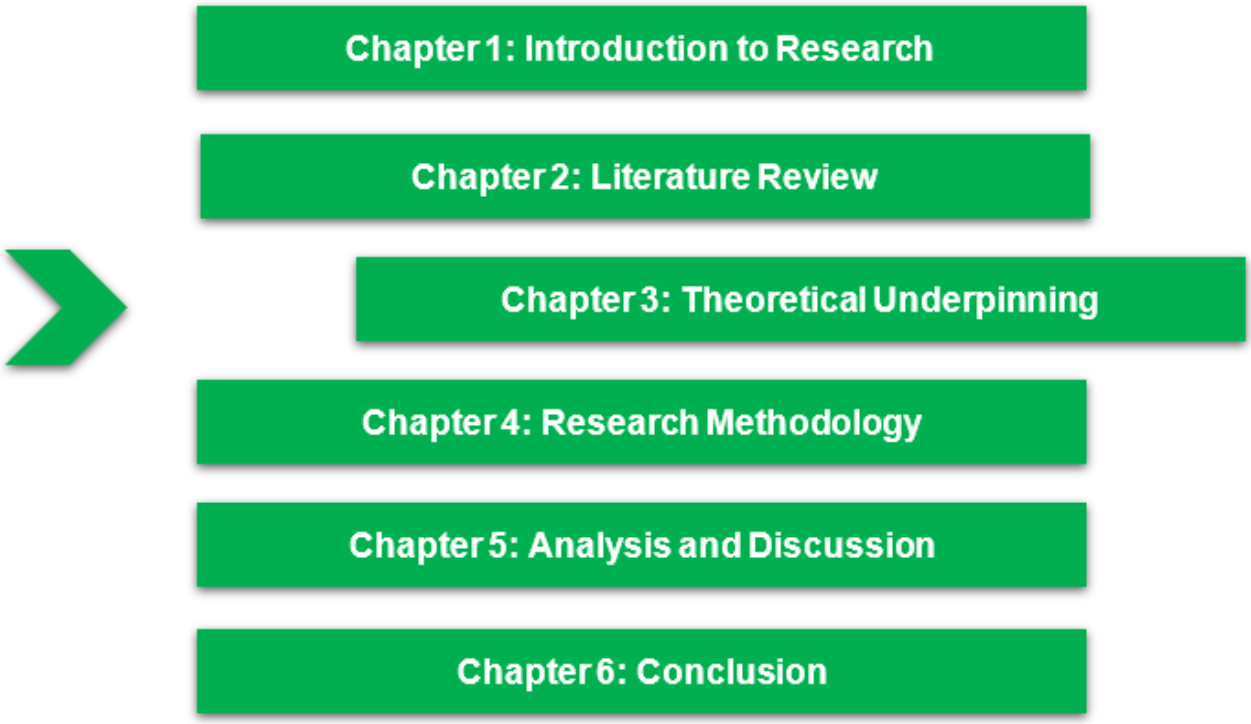
This chapter provided insight into the various themes that deal with OTS. The researcher was able to become familiarised with theory relating to OTS, thus preparing for the rest of the research study.

Table 11: Summary of Chapter 2

Theme 1: Overtraining Syndrome	The background of OTS was discussed and possible causes were outlined. Preventative measures were also looked at.
Theme 2: Previous cases of OTS	Previous cases of OTS were usually the cause of a busy schedule where players were forced to play more and have less rest.
Theme 3: Football training methods	It was seen that most training methods make use of small/large group training. Each of these types of training brings its benefits.
Theme 4: Football training technology	Data collection using various technologies has provided a new dimension to sports analysis. The coaching staff can extract the best results from their players by thoroughly examining these reports.

Chapter 2 has provided background theory on themes relating to OTS. The theoretical knowledge acquired during this chapter will provide a good platform for the researcher to complete the chapters ahead. The next chapter will provide a detailed structure for the research design of this study.

3 THEORETICAL UNDERPINNING



3.1 INTRODUCTION

During this chapter, possible theoretical frameworks will be discussed. A framework will be chosen and will act as a guideline to conduct this research study. The various theories discussed in this chapter include Task-Technology Fit (TTF), Technology-to-Performance Chain (TPC) and Technology Acceptance Model (TAM).

3.2 TECHNOLOGY ACCEPTANCE MODEL

The Theory of Reasoned Action (TRA) was used to create the Technology Acceptance Model (TAM). TRA states that behaviour is dependent on intentions which are dependent on attitudes which are dependent on beliefs (Hu *et al.*, 1999). TRA was modified to suit the Information Technology landscape. Past research has shown TAM to successfully predict technology use. TAM has continued to evolve over the years with many researchers making modifications to suit their needs. One of TAM's biggest downfalls is that it does not

consider external variables. Previous research studies have added variables such as “perceived playfulness”, “perceived user resources”, “perceived risk” and “perceived enjoyment” to TAM (Galib, Hammou and Steiger, 2018).

TAM has been tested with students as well as employees as the user group. Results from both these types of tests have validated TAM’s ability to explain technology use. The two measurements “perceived usefulness” and “perceived ease of use” has been thoroughly dissected to determine validity. These tests have suggested high validity and reliability (Hu *et al.*, 1999).

It is noted that TAM provides a very general structure which can be a disadvantage when attempting to research a specific entity. This is the reason researchers have modified TAM to suit their research study as mentioned above (Lu *et al.*, 2003).

The main concept behind TAM is the attempt to predict the likelihood that a technology system will be used. TAM is used to gain a general understanding of how individuals feel toward a technology system. TAM comprises several components. Each component contributes to the prediction of whether a system will be used. The two main components being the outlook an individual has on how easy a system is to use and whether using the system will improve or maximise performance (Mathieson, 1991).

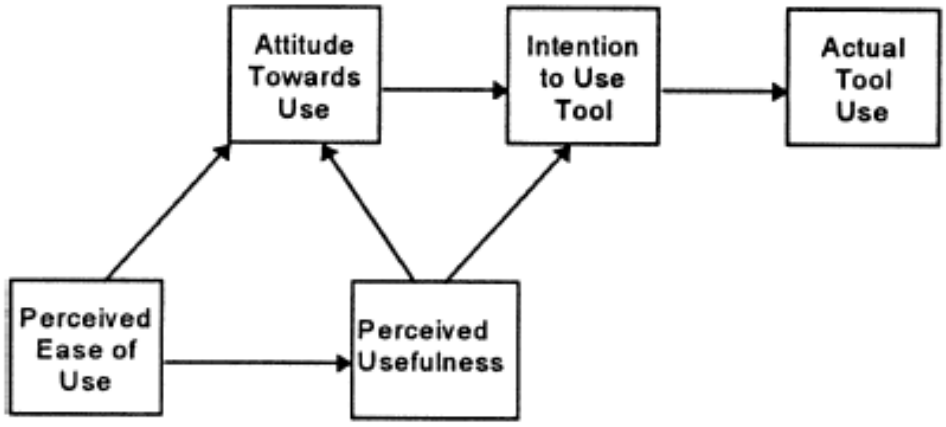


Figure 6: A version of the TAM model. Source: (Dishaw and Strong, 1999)

TAM is based on the idea that the intention to use a tool directly influences actual tool use (Dishaw and Strong, 1999). As seen in **Error! Reference source not found.**, the perceived ease of use has a direct impact on the perceived usefulness. TAM also takes into account that the intention to use a tool is dependent on the user (Dishaw and Strong, 1999).

TAM focuses more on the attitudes of individuals towards IT. TAM is known to be weak on actual use, and strong on intentional use. TAM does not show how well the technology addresses a specific task's requirements. As a result of TAM not being task-specific in nature when measuring performance, results have been inconsistent when testing technology implementation (Dishaw and Strong, 1999).

Table 12: Summary of Technology Acceptance Model

Aim	To predict the likelihood that a technology system will be used
Inputs	Perceived Ease of Use, Perceived Usefulness
Outputs	Actual Tool Use
Perceived Ease of Use	The outlook an individual has on how easy a system is to use
Perceived Usefulness	Will using the system improve or maximise performance

3.3 TASK-TECHNOLOGY FIT

The Task-Technology Fit (TTF) theory focuses on how an individual's performance is affected by the use of technology (Michael L. Irick, 2008). An article by Goodhue and Thompson (1995) states that the individual, the task and the technology used need to be closely linked to produce the best results and improve performance. TTF consists of multiple parts. TTF is based on the interaction between the task, the individual performing the task and the technology used by the individual to perform the task. The task and individual determine what technology is utilised. The better the performance, the more

likely the technology will be used or recommended in future (Goodhue and Thompson, 1995).

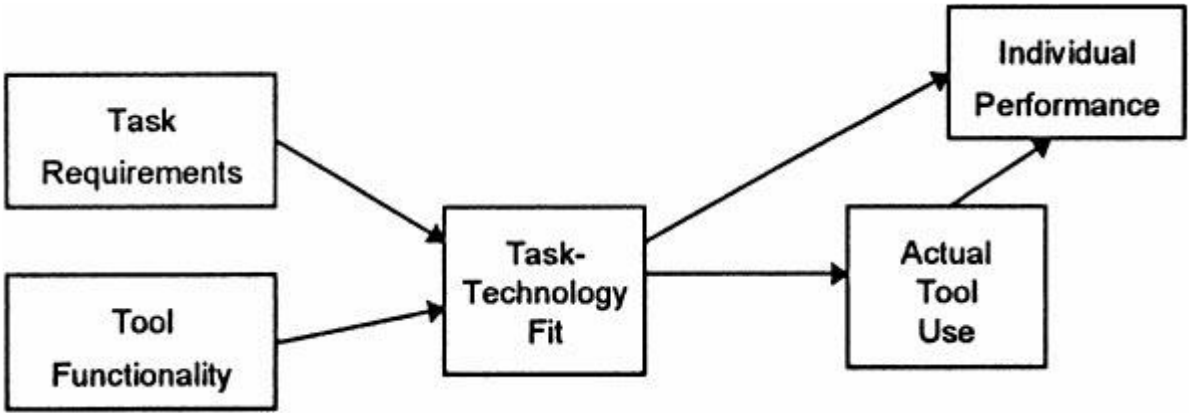


Figure 7: A version of the TTF model measuring individual performance. Source: (Dishaw and Strong, 1999)

TTF focuses more on the results of an end-user using the technology (Dishaw and Strong, 1999). The technology utilised is dependent on the requirements of the task. Users with extensive experience have the skill to decide which type of tool to use to gain the most value. Figure 7 depicts a version of the TTF model. It is important to note that this is not the only TTF model. Figure 7 shows two outcome variables, Individual performance, and actual tool use. TTF models developed earlier did not depict actual tool use as one of the outcome variables. The TTF models suggest that users focus solely on the benefits provided by a certain technology when deciding which technology to use. The users do not consider their personal views about a certain technology when deciding which technology to use (Dishaw and Strong, 1999).

Many TTF models include individual ability as one of the inputs. Previous testing of TTF models produced the following results:

- The Task-Technology fit was negatively affected when computer literacy was tested as an individual ability
- Utilisation was positively affected when experience with a certain technology was tested as an individual ability

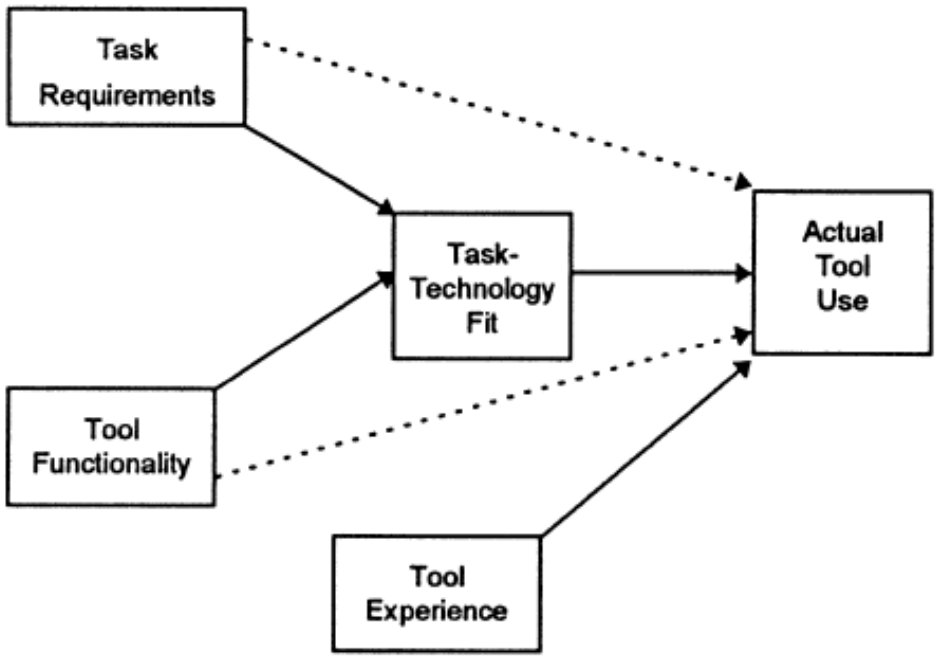


Figure 8: A version of the TTF model with tool experience as an input. Source: (Dishaw and Strong, 1999)

Figure 8 depicts the TTF model with actual tool use as the only outcome variable. Individual experience in the form of tool experience, task requirements and tool functionality all have a direct influence on actual tool use. The TTF model can be altered according to what is being investigated (Dishaw and Strong, 1999).

TTF focuses more on the requirements of a specific task. Looking at this, the strong task-specific characteristic of TTF will provide a platform with which to develop a technological system specific to the task of providing a means for players to avoid OTS (Goodhue and Thompson, 1995).

TTF does not focus on attitudes and beliefs towards using technology, which is the foundation of TAM (Dishaw and Strong, 1999). TTF will provide insight into what coaching staff feel towards current training technology, what impact this technology has on a player's performances and how this technology can be improved. TTF is suited more to this research problem than TAM (Goodhue and Thompson, 1995).

Table 13: Summary of Task-Technology Fit Theory

Aim	The TTF model focuses on the results of an end-user using the technology and whether a certain technology is used
Inputs	Task Requirements, Task Functionality, Tool Experience
Outputs	Actual Tool Use, Individual Performance
Actual Tool Use	The task and individual determine what technology to utilise
Individual Performance	The better the performance, the more likely the technology will be used/recommended in future

3.4 TECHNOLOGY-TO-PERFORMANCE CHAIN

Goodhue and Thompson (1995) proposed an extension of the TTF model which incorporates a utilisation focus into the model. Utilisation is made up of factors influencing an individual's choice such as beliefs and social norms. The utilisation of the task is influenced by factors such as personal beliefs and social norms. If utilisation occurs, performance is measured, and feedback is provided. This proposed model is called the Technology-to-Performance Chain (TPC). This model provides a means to gather qualitative and quantitative data (Goodhue and Thompson, 1995).

TPC proposes that TTF is dependent on the task, technology, and individual characteristics. Utilisation is dependent on TTF and Performance is dependent on utilisation. Thus, Performance is indirectly dependent on TTF (Goodhue and Thompson, 1995).

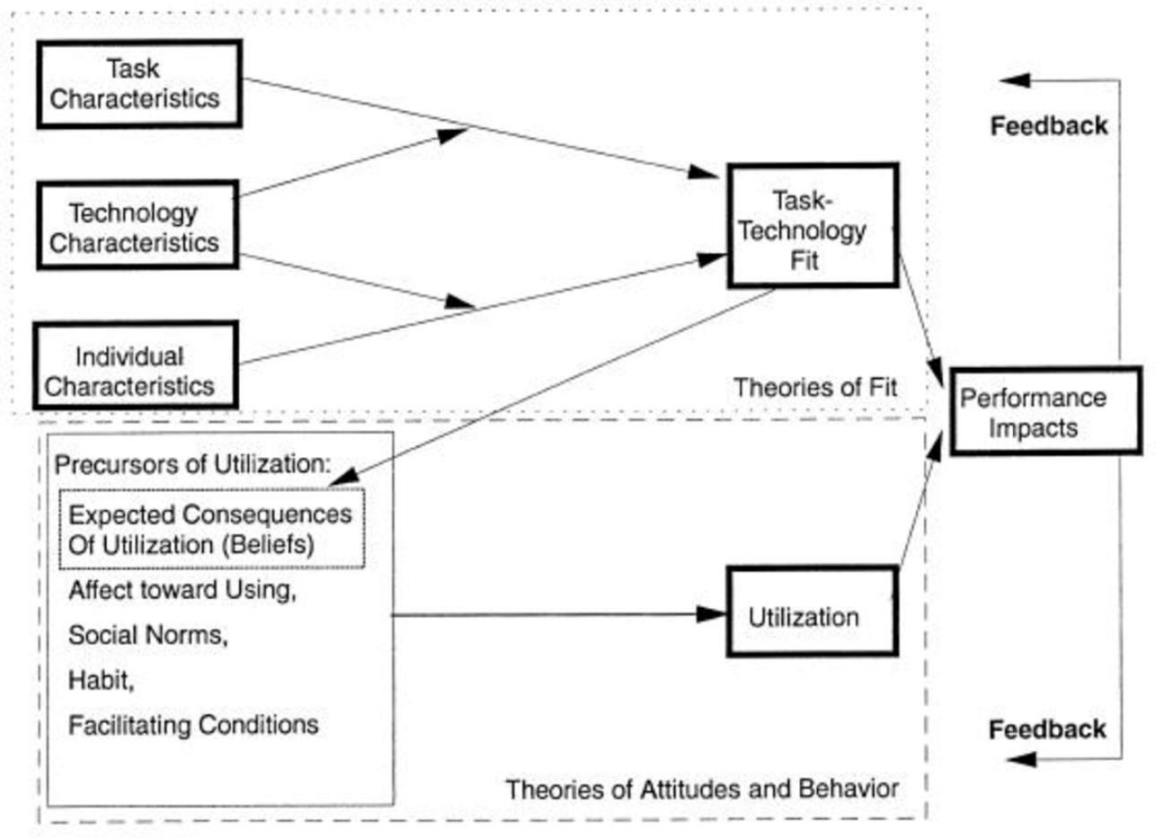


Figure 9: An extension of the TTF model to create the TPC model. Source: (Goodhue and Thompson, 1995)

TPC provides a framework with which to structure research questions and objectives. The research questions of this study will provide answers to each building block in the TPC model above. These answers will be used for the design of the information system.

- The **task characteristics** block will be answered by training-specific questions and what the requirements of the technical staff are.
- The **technology characteristics** block will be answered by current training technology questions such as the current technology utilised and the technology required.
- The **individual characteristic** block will be answered by coaching-specific questions such as the current technical skillset.
- The **utilisation** block will be answered by social and psychological questions to determine how and why a technology is used for specific tasks.

- The **performance** block will be answered by gathering qualitative data from coaching staff to determine the performance of a technology.

Analysis of the performance block in the TPC model will provide great insight into whether the implemented technology is working. A player's performance will be examined to determine the correlation between the type of technology used and the performance gained. The feedback loop will provide a way to refine the technology according to performances.

Feedback returned to the TPC model plays a vital part in refining the proposed technology. The researcher can rework the solution with the coaching staff repeatedly until it is efficient and effective. Analysing the collected qualitative data can contribute significantly to the field of football training technology as OTS is a common occurrence. Other sporting codes may also benefit from the research as OTS occurs in many sports.

Further expanding on the strengths of TTF, the TPC model proposed by Goodhue and Thompson (1995) has all the necessary characteristics to address this research problem. The TPC model consists of two main components, the Utilisation Focus, and the Fit Focus. The utilisation focus includes components from TAM and the Fit Focus includes components from TTF. Strengths from both TAM and TTF are combined to create the TPC model. This will allow the researcher to develop a dynamic solution. Therefore, the choice of theory for this research study will be TPC (Goodhue and Thompson, 1995).

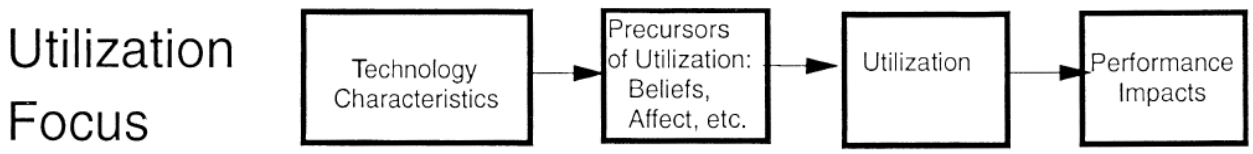


Figure 10: Utilisation focus of TPC. Source: (Goodhue and Thompson, 1995)

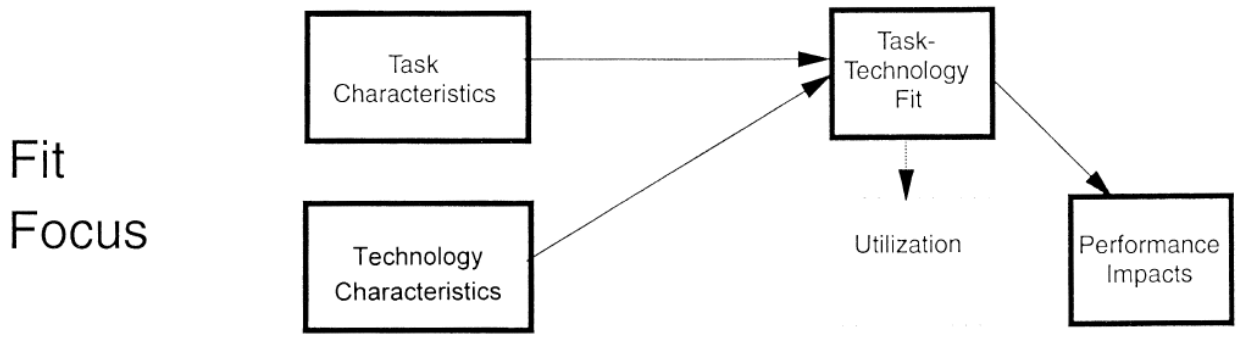


Figure 11: Fit focus of TPC. Source: (Goodhue and Thompson, 1995)

Table 14: Summary of Technology-to-Performance Chain

Aim	Utilisation is incorporated into the TTF model to determine the influence of factors such as social norms and beliefs on performance
Inputs	Task Characteristics, Technology Characteristics, Individual Characteristics, Precursors of Utilisation and Utilisation
Outputs	Performance
Task Characteristics	A description of the task
Technology Characteristics	A description of what technology is used
Individual Characteristics	A description of what skills the user possesses
Precursors of Utilisation	This includes personal beliefs and social norms
Utilisation	Whether a certain technology is used
Performance	Measurement of the success rate of using a certain technology

3.5 SUMMARY OF COMPARISON OF RESEARCH THEORIES

Table 15: Comparison of TAM, TTF and TPC

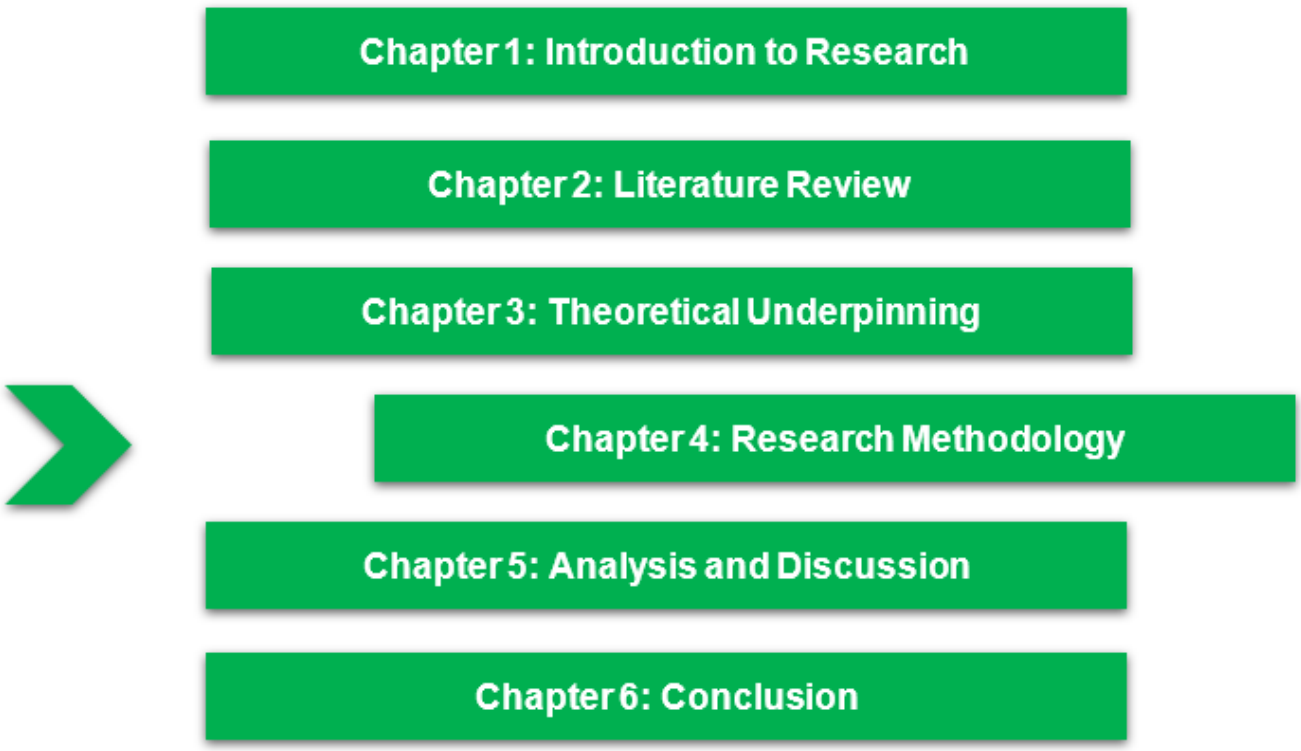
	TAM	TTF	TPC
Aim	To predict the	The TTF model	Utilisation is incorporated into

	likelihood that a technology system will be used	focuses on the results of an end-user using the technology and whether a certain technology is used	the TTF model to determine the influence of factors such as social norms and beliefs on performance
Inputs	1. Perceived Ease of Use 2. Perceived Usefulness	1. Task Requirements 2. Task Functionality 3. Tool Experience	1. Task Characteristics 2. Technology Characteristics 3. Individual Characteristics 4. Precursors of Utilisation and Utilisation
Outputs	1. Actual Tool Use	1. Actual Tool Use 2. Individual Performance	1. Performance

3.6 CONCLUSION

During this chapter, three theories relating to technology implementation were discussed. The theories were Task-Technology Fit, Technology Acceptance Model and Technology-to-Performance Chain. A comparison of theories was conducted to select the best-suited theory. It was seen that TTF was more suited to this research study as opposed to TAM. The TPC model is an extension of the TTF model which includes an aspect of attitudes and behaviour. This allows a more holistic approach to assessing the performance of a technology. As a result of this, it was decided that the TPC model would be best suited for this study.

4 RESEARCH METHODOLOGY



4.1 INTRODUCTION

The previous chapter focused on the theoretical underpinning of the research study. This chapter will provide insight into the research methodology that will be utilised for this study.

4.2 A MODEL FOR RESEARCH CHOICES

The “Research Onion” was created by Saunders, Lewis and Thornhill (2009) to provide a means for researchers to make research choices. This model was utilised in this research study.

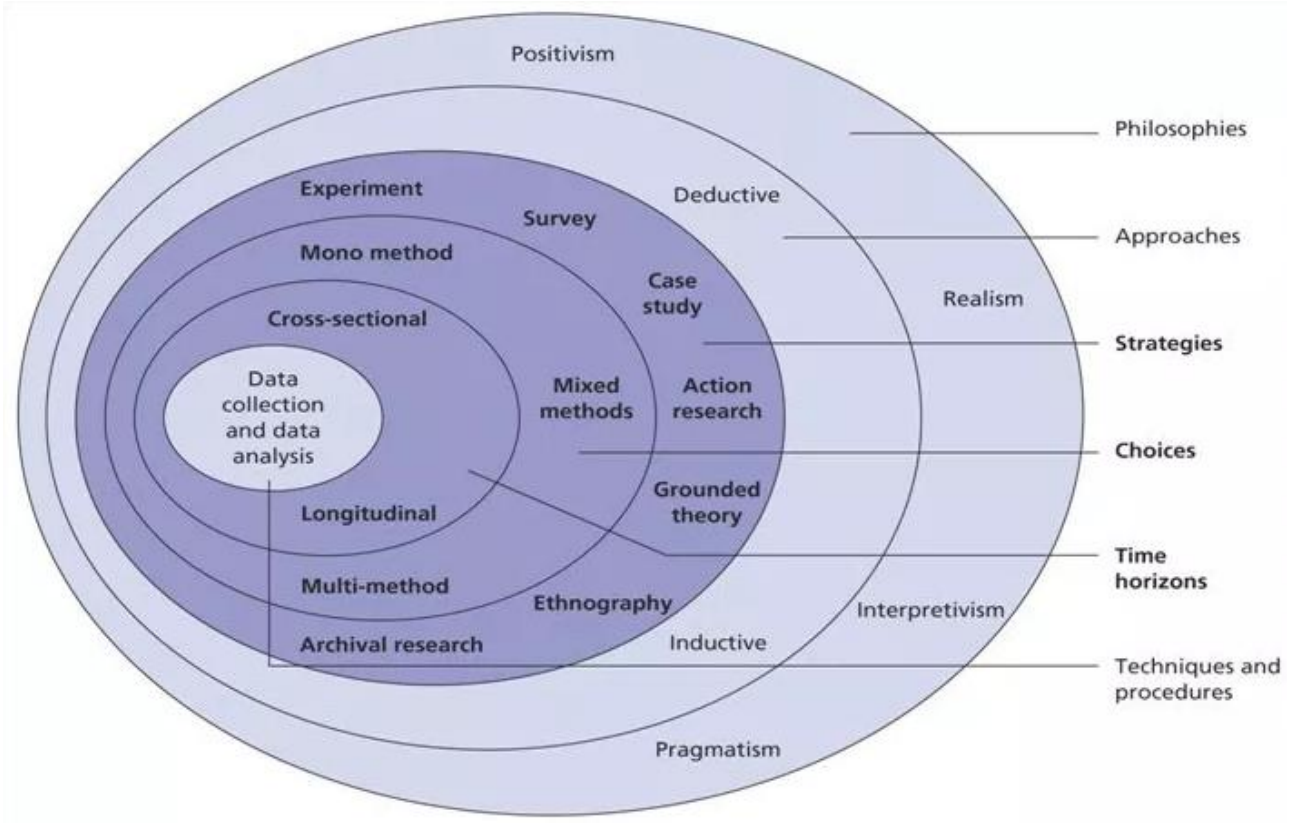


Figure 12: The Research Onion. Source: (Saunders, Lewis and Thornhill, 2009)

In Figure 12, starting from the outermost layer (Research Philosophy), the researcher will make their way towards the innermost layer (Data Collection and Data Analysis). The layers of the Research Onion are discussed in order below:

Philosophies: How a researcher views the nature and construction of knowledge is known as research philosophy. Interpretivism, positivism, pragmatism and realism are the four main research paradigms (Saunders, Lewis and Thornhill, 2009).

Approaches: According to Saunders, Lewis and Thornhill (2009) the two major research approaches are the deductive research approach and the inductive research approach.

Strategies: A plan detailing how the researcher will attempt to gather data in such a way that will answer research questions. There are seven main research strategies: Archival

research, Ethnography, Grounded theory, Action research, Case study, Survey and Experiment (Saunders, Lewis and Thornhill, 2009).

Choices: Data collection and analysis can be either quantitative, qualitative or both. The researcher may decide to choose one method or combine methods. There are three main methods: multi-method, mixed methods and the mono-method (Saunders, Lewis and Thornhill, 2009).

Time Horizons: This describes how long the researcher wishes to conduct the study. The two main time horizons are either longitudinal or cross-sectional (Saunders, Lewis and Thornhill, 2009).

Techniques and Procedures: This describes how the researcher will conduct their data collection and analysis (Saunders, Lewis and Thornhill, 2009).

As shown in Figure 12, each layer of the research onion becomes dependent on the previous layer. This allows a link to form between layers and in doing so builds a framework to conduct the study.

4.3 RESEARCH DESIGN

According to Saunders, Lewis and Thornhill (2009) research design is the method by which the research questions will be answered.

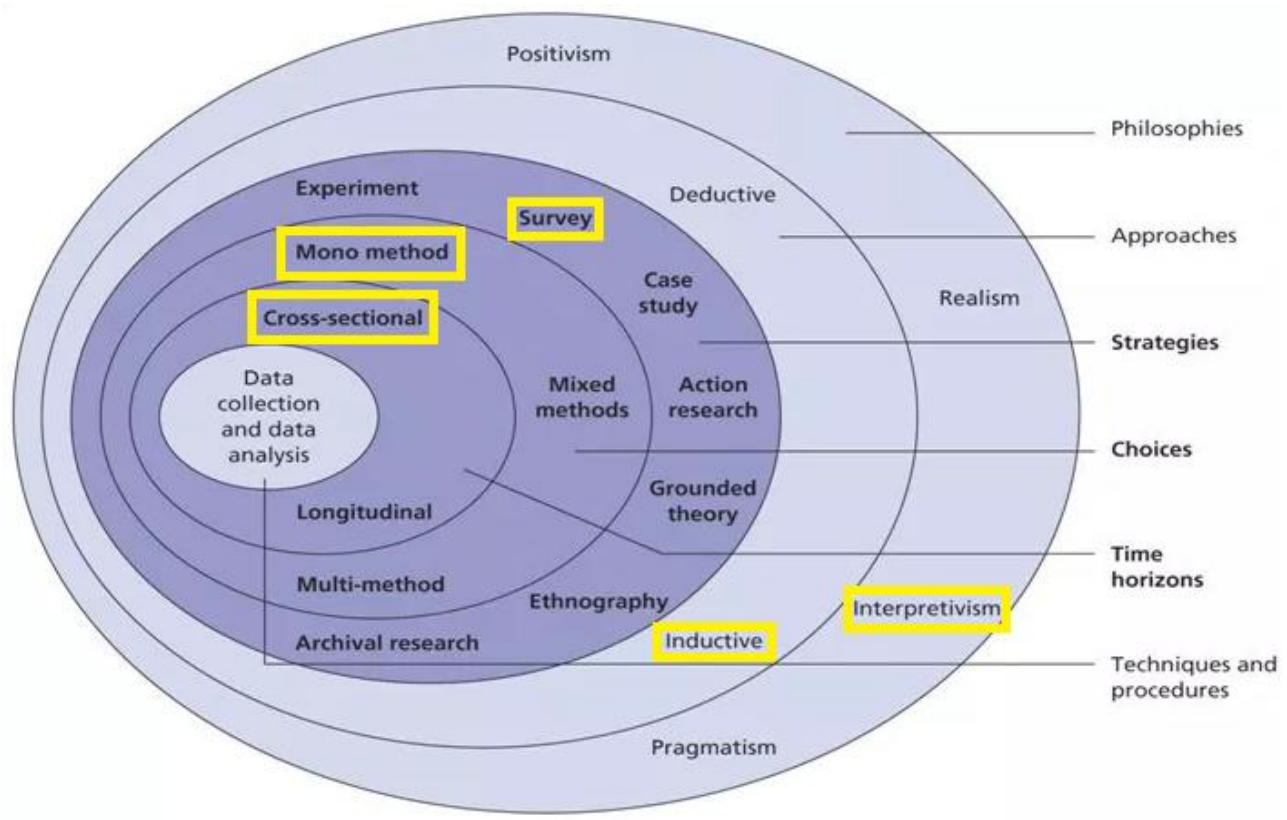


Figure 13: Research Onion with selected choices. Source: (Saunders, Lewis and Thornhill, 2009)

4.3.1 Research Philosophy

How a researcher views the nature and construction of knowledge is known as research philosophy (Saunders, Lewis and Thornhill, 2009). According to May (2011), the type of knowledge that the researcher is investigating has a direct influence on which philosophy is adopted. Interpretivism, positivism, pragmatism and realism are the four main research paradigms (Saunders, Lewis and Thornhill, 2009).

4.3.1.1 Positivism

The main theme behind positivism is the idea that reality is objective and independent of the researcher's beliefs or personal experiences (Chen and Hirschheim, 2004). Most of the time the research objectives are not linked to the researcher. Positivists believe that human knowledge is entirely constructed of a single reality (Onwuegbuzie and Leech,

2005). Inquiry into the research problem is not value-driven and reality is only known through theories and frameworks (Weber, 2017).

Research methods are mostly quantitative in nature (statistical and analytical) (Weber, 2017). The sample size of data acquired from the research is usually large and probabilistic (Onwuegbuzie and Leech, 2005). Weber (2017) further describes how research findings should be replicable and used to determine the validity and reliability of the research. Deductive reasoning is used to conduct the study as the researcher proposes a theory/hypothesis and then goes about testing this theory/hypothesis (Chen and Hirschheim, 2004).

Positivism does share some similarities with Interpretivism in that both paradigms analyse data analytically once observations are completed. Conclusions based on these observations are then made.

4.3.1.2 Interpretivism

The main theme behind interpretivism is the idea that reality is subjective and dependent on the researcher's beliefs, past experiences and previous social interactions (Chen and Hirschheim, 2004). The research objective is tied closely to the researcher's beliefs or past experiences. Interpretivists believe that human knowledge is composed of multiple interpreted interactions (Onwuegbuzie and Leech, 2005). Inquiry into the research problem is influence by the researcher's value system (Weber, 2017).

Research methods are mostly qualitative in nature (hermeneutical and phenomenological) (Weber, 2017). The acquired data sample size is usually small and non-probabilistic (Onwuegbuzie and Leech, 2005). Research findings are unique and non-replicable as they are interpreted by the researcher's own life experience, thus impacting validity (Weber, 2017). Inductive reasoning is used to conduct the study as the common themes and trends that are discovered from the analysis of collected data are then used to construct a theory (Onwuegbuzie and Leech, 2005).

4.3.1.3 Pragmatism

Pragmatism places a heavy emphasis on human action. Human action is used to validate an interpretation. This highlights the objective perspective of acquiring knowledge. The knowledge gained from other people's experiences plays a part in the views we have about the world. This highlights the social impact of acquiring knowledge. Thus, we can say that pragmatic researchers combine both a subjective as well as an objective perspective (Goldkuhl, 2004).

Pragmatists believe that knowledge is constructed from personal experiences. Knowledge is a combination of an individual's actions as well as what is learned from another individual's experiences (Goldkuhl, 2004). Knowledge is gained through the repetitive process of assessing beliefs through actions (Morgan, 2014). A pragmatist conducts an ongoing process of communication to acquire cultural knowledge. This acquired knowledge is then assessed to determine the value and potential concerns (Giacobbi, Poczwardowski and Hager, 2005). Knowledge should be considered valid if the above processes are carried out.

Pragmatic researchers focus on the analysis of actions during their research. A pragmatic researcher studies human actions to gain an understanding of the social world. The pragmatic researcher acts as the link between an idea and the investigation as to whether that idea can be implemented practically (Goldkuhl, 2004). The pragmatic researcher aims to combine the strengths of both quantitative and qualitative research methodologies to tackle research problems (Onwuegbuzie and Leech, 2005).

Pragmatic research aims to utilise the strengths of both qualitative and quantitative research techniques to gain a much deeper understanding of the social world. As a result of this, pragmatic research brings forward a much more creative way of solving research problems. Pragmatic research encourages researchers from different philosophical backgrounds to combine their expertise by working together (Onwuegbuzie and Leech, 2005).

The formulation of research questions is influenced by the researcher's interest in the actions of the social world. Thus, the research questions will be mainly concerned with all

aspects surrounding the action. Pragmatic research involves utilising both quantitative and qualitative research methodologies. Quantitative methods complement qualitative methods and vice versa. For example, qualitative techniques can be used to analyse quantitative data and vice versa (Onwuegbuzie and Leech, 2005).

4.3.1.4 Paradigm selection and motivation

The main aim of this investigation is to investigate the adoption of technology for the measurement and management of factors related to the risk of overtraining syndrome in football. As mentioned earlier, OTS is an amalgamation of both psychological and physical factors. The interpretivism paradigm will be used to gain an understanding of how footballers, coaches and trainers perceive their reality. Qualitative methods can be used to acquire an understanding of how players, coaches and trainers feel towards the physical and psychological factors associated with training and match performance and how technology can improve this.

The nature of interpretivism allows the researcher to gain a holistic understanding of OTS and thus construct a better technological solution to the problem. The nature of interpretivism allows us to gain a thorough understanding of the inner workings of the entire player process from training to match day performance to recovery. The subjective nature of interpretivism will provide many different types of answers to interview questions. This allows the researcher to gain a multidimensional view of the current problem of OTS in professional football. This holistic understanding of OTS will form the basis with which to construct a solid technological solution to the problem.

4.3.2 Research Approach

According to Saunders, Lewis and Thornhill (2009), the two main research approaches are the deductive research approach and the inductive research approach. The deductive research approach involves the researcher developing a new theory/hypothesis and then testing this theory/hypothesis with a newly developed research strategy. The inductive research approach involves the researcher acquiring data, analysing this data, and then developing a theory by using the results of the analysis. The deductive approach involves applying reasoning from a general to a specific standpoint (Gulati, 2009). The inductive

approach involves applying reasoning from a specific to a general standpoint (Bryman and Bell, 2008).

According to Saunders, Lewis and Thornhill (2009), a deductive approach should be applied in cases where the topic has been well documented and has numerous resources. As a result of the low quantity of literature on OTS in football, following a deductive approach would not be conducive. Due to a low number of professional coaches and trainers available, the inductive approach is favoured. Therefore, it was decided that an inductive approach would be used for this research study.

4.3.3 Research Strategy

The research strategy describes a plan of action of how the researcher will answer research questions (Saunders and Lewis, 2012). Saunders, Lewis and Thornhill (2009) list the following seven research strategies: Archival research, Ethnography, Grounded theory, Action research, Case study, Survey and Experiment. The type of research strategy chosen depends on the research being done. The research objectives/questions, as well as the time and money available, influence the type of research strategy that the researcher adopts (Saunders, Lewis and Thornhill, 2009).

As a result of the selection of interpretivism as the paradigm and induction as the research approach, for this research study, coaching staff from football clubs will be interviewed to identify potential causes of OTS. Thus, it was decided that a strategy involving collecting data through interviews would provide the means necessary to successfully conduct this research study.

Interviews are the data collection technique of choice when there is little existing theory on the research topic (Gill *et al.*, 2008). The dynamism and flexibility of being able to gather data at any time from interviews make it the perfect type of data collection technique for this study (Patton, 2015). The interview research strategy will be further discussed in section 4.4.1.

4.3.4 Research Choices

Data collection and analysis can be either quantitative, qualitative or both. The researcher may decide to choose one method or combine methods. Saunders, Lewis and Thornhill (2009) state that there are three main methods: multi-method, mixed methods, and mono-method:

- **Mono-Method**: Makes use of either a quantitative or qualitative approach.
- **Multi-Method**: Makes use of more than one qualitative or more than one quantitative approach.
- **Mixed-Method**: Makes use of a combination of both quantitative and qualitative methods.

For this study, a qualitative mono-method approach will be used. As mentioned earlier, the use of a qualitative approach will allow the researcher to gain a deep understanding of the research problem. The mono-method approach works well with a research strategy that involves collecting data through interviews.

4.3.5 Time Horizons

This describes how long the researcher wishes to conduct the study. The two main time horizons are either longitudinal or cross-sectional (Saunders, Lewis and Thornhill, 2009). A cross-sectional study provides a view of phenomena in a single instance of time whereas a longitudinal study provides multiples views of the same phenomena (Blumberg, Cooper and Schindler, 2008; Flick Uwe, 2012). For this study, time to conduct the research is seen as a potential limitation, thus the cross-sectional study would be the best choice.

4.3.6 Techniques and Procedures

The mono-method approach, the interview research strategy involving semi-structured interviews will be used during this research study. Section 4.3.3 discusses how Interviews are the data collection technique of choice when there is little existing theory on the research topic. As discussed in section 4.3.4, the qualitative mono-method approach

allows the researcher to gain a deep understanding of the research problem. Section 4.4.1 mentions that semi-structured interviews will be used as they allow the researcher to use open-ended and closed-ended questions.

4.4 DATA COLLECTION AND ANALYSIS

Saunders, Lewis and Thornhill (2009) state that data may be gathered using many different techniques, with two common techniques being interviews and questionnaires. The method of data collection directly influences the validity and reliability of the research results. Data can also be grouped into primary and secondary data. Primary data is acquired directly from the source whereas secondary data is made up of previously analysed data (Bryman, 2012).

For this research study, interviews were chosen as the method of data collection.

4.4.1 Interviews

When the purpose of a discussion between two people is to acquire data that is reliable and valid to provide answers to research questions, this process is called a research interview (Saunders, Lewis and Thornhill, 2009). Mathers, Fox and Hunn (1998) described the following three interview types:

- **Unstructured/In-depth**: The interviewer does not have a plan as to what questions will be asked, they simply adapt the questions according to the responses of previous questions.
- **Semi-structured**: Questions are open-ended giving both parties the flexibility to focus more on certain topics.
- **Structured/Standardised**: A strict plan is followed as to what questions are asked making this similar to a questionnaire.

Semi-structured interviews can be a combination of both open-ended and closed-ended questions, thus ensuring interviews maintain their focus on the topics at hand and providing a platform for interviewees to provide their detailed insight on certain topics. As a

result of this flexibility, the interviewer can adapt their questions according to the interviewee's response (Klenke, 2017).

This research study will aim to conduct face-to-face semi-structured interviews to gather data. Face-to-face interviews provide the optional luxury of audio or video recording to capture the tone and facial expression for improved analysis (Saldanha and Zanettin, 2016).

Figure 14 depicts the seven stages of the interview process as described by (Kvale and Brinkmann, 2009):

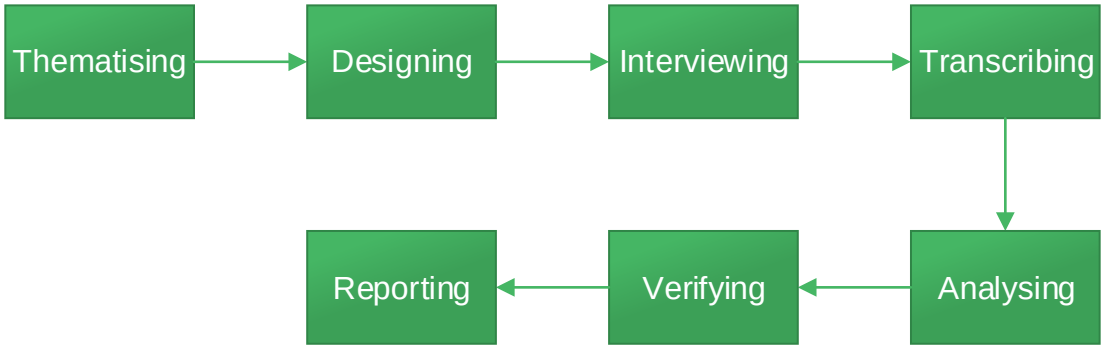


Figure 14: Seven stages of the interview process. Source: (Kvale and Brinkmann, 2009)

1. **Thematising**: The main objectives and desired outcomes of conducting the interviews need to be determined before the interviews begin.
2. **Designing**: Acquire the necessary knowledge needed to conduct the interviews before the interviews begin.
3. **Interviewing**: Conduct the interviews in a way that will provide the desired information.
4. **Transcribing**: Gather all the interview material in a way that simplifies analysis. This can include converting audio to written text.
5. **Analysing**: Determine what types of analysis techniques will be applied such as thematic analysis.
6. **Verifying**: Use the results to determine whether the research study is valid and reliable. The results will be compared to existing literature to find any correlations.
7. **Reporting**: Produce a scientific document that clearly explains the details of the results while ensuring that the correct ethical standards are implemented.

4.4.2 Data Collection Framework

For this study, a qualitative mono-method approach will be used. As mentioned earlier, the use of a qualitative approach will allow the researcher to gain a deep understanding of the research problem. The mono-method approach works well with a research strategy that involves collecting data through interviews.

To acquire the desired data, a framework needed to be developed. This framework would need to make use of interrogatives e.g. How the data would be collected? The Zachman Framework was chosen as a guideline as this framework contains six well-defined interrogatives (Zachman, 2003). The data framework for this research study is outlined in Table 16.

Table 16: Data Collection Framework

Interrogative	Details
What? (Data)	Data would be acquired through semi-structured interview questions.
How? (Function)	Open-ended and closed-ended questions were used.
Where? (Location)	Due to the COVID-19 pandemic, all interviews were conducted via online meeting platforms.
Who? (People)	Four individuals from Premier Soccer League (South Africa) football clubs and one individual from an English Football League Championship (United Kingdom) football club were interviewed.
When? (Time)	Interviews were scheduled according to the availability of both the interviewee and interviewer.
Why? (Motivation)	The motivation behind the interviews was to gain insight into the current situation involving OTS in football and how technology can have a positive impact on reducing the risk of OTS.

Table 16 shows how the Data Collection Framework was developed with a detailed description of each interrogative.

4.4.3 Data Collection Challenges

Table 17 describes some of the challenges faced with data collection during this research study.

Table 17: Data Collection Challenges

Action	Challenges
Participants	• The research topic is a very specific area of research and not many professionals were available • The highest level of football in South Africa only has 16 teams • Some professionals were busy and some professionals were not open to partake in the research study
Interview Guide Design	• Formulating questions that would provide answers to all research questions • Formulating questions that are open-ended to potentially gain extra information from participants
Pilot interview	• The interview guide had to be refined after the pilot interview to remove questions with possible duplicate answers
COVID-19	• Interviews had to be conducted over the internet because of lockdown restrictions • Difficulty reaching out to potential participants
Scheduling interviews	• Schedules of both the researcher and participants were full • Time slots that were found were sometimes cancelled which resulted in delays of several days to weeks
Conducting interviews	• Some challenges with online meeting apps and internet connections which affected the quality

	of interviews • As a result of COVID-19, all interviews were conducted over the internet which is less desirable than face-to-face interviews

4.5 RESEARCH ETHICS

According to Cresswell (2003), ethical considerations need to be taken into account before the research study begins, during the research study and after the research study. Cresswell (2003) suggested the following methods to ensure ethics are adhered to during each stage of the study:

- **Before the research study**: A request needs to be made to the board to undertake the research study.
- **Commencing the study**: There needs to be full transparency regarding the research study between the interviewer and the interviewee. Consent needs to be attained from the interviewees and respect needs to be upheld during the entire process.
- **Collection of data**: Provide details about how and why the collected data will be used. This is discussed in Sections 5.1 and 5.2.
- **Analysis of data**: Ensure that privacy is maintained, and all aspects of findings are reported.
- **Reporting/Storing of data**: Ensure that anonymity is maintained, and results are truthfully reported without any falsification.

4.6 PILOT STUDY

The first interview conducted during this research study was used as a pilot interview. The responses to the interview questions were used to optimise the interview questions in the interview guide. Optimisations were made in the following ways:

1. Interview questions where possible duplication of responses could occur were removed.
2. The number of interview questions was decreased by combining and restructuring interview questions.

The pilot study, as well as each new interview, were used to improve the researcher's interviewing techniques. These techniques were improved in the following ways:

1. A brief introduction was used at the beginning of every interview explaining the intention of the interview and providing an opportunity for interviewees to ask any questions. This was done to provide transparency and ensure interviewees feel comfortable.
2. The researcher used a relaxed tone to ensure interviewees were comfortable.
3. As the researcher conducted more interviews, common themes were found, and the researcher could build on these themes by asking specific follow-up questions.
4. The researcher improved their time management skills during interviews by determining when to move on to the next question or when to use follow-up questions.
5. Time management was also improved by noting whether an interviewee had already provided an answer to an upcoming question.

4.7 CONCLUSION

During this chapter, the research design of this study was constructed using the Research Onion by Saunders, Lewis and Thornhill (2009). Motivations were provided for the selection of the various parts of the research design. Table 18 provides a summary of the research design that was constructed in this chapter.

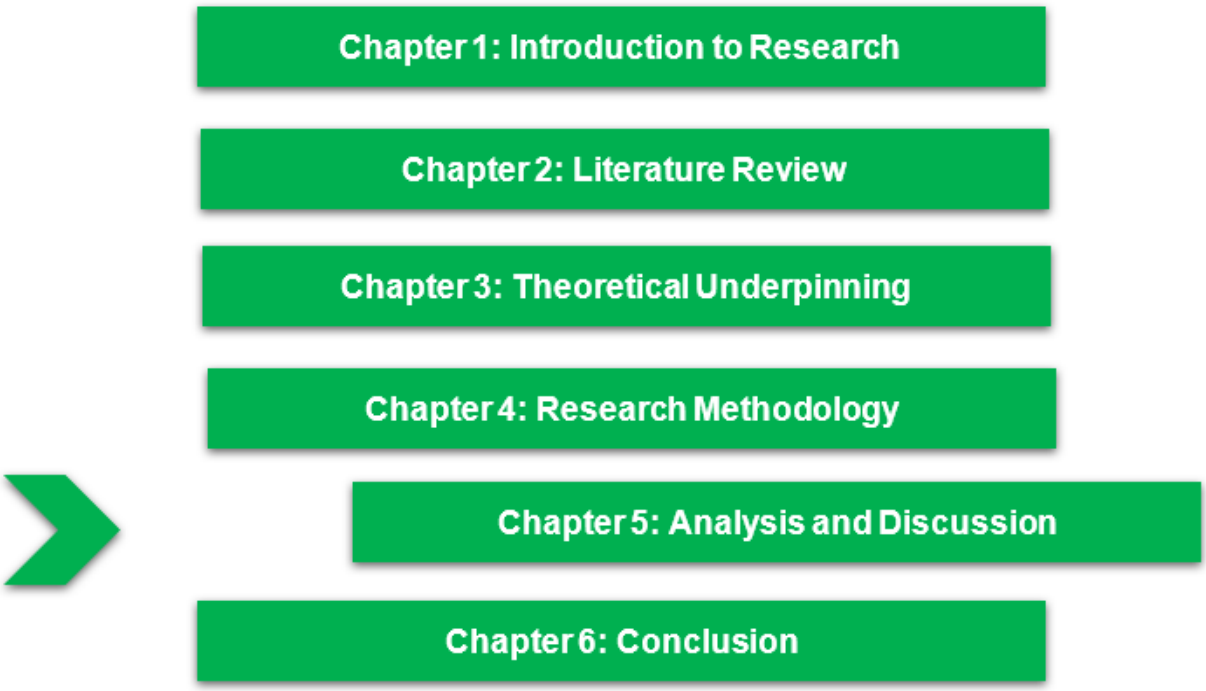
Table 18: Research Design Summary

Research Philosophy	Interpretivism
Research Approach	Inductive
Research Strategy	Interview

Research Choice	Mono-Method
Time horizon	Cross-sectional
Data Collection Method	Interviews

This chapter provides a basis for the next chapter where the analysis of research findings will be discussed.

5 ANALYSIS AND DISCUSSION



5.1 INTRODUCTION

During this chapter, responses acquired from conducting interviews will be analysed and presented. The researcher's interpretation will be utilised to analyse the interview data. The research questions and objectives defined in Chapter 1 were used to formulate interview questions. The findings of this research study will be organised according to respective research objectives and questions.

Due to the low number of potential interviewees, the researcher attempted to contact international sport scientists, with only one successful outcome. The researcher believed that this would add an international perspective to the research study.

There are only 16 football clubs in the highest tier of South African football. Most of these clubs have only one sports scientist that also plays the role of head of performance or vice versa. After reaching out to many clubs, the specialists were not interested in divulging any sensitive information that could affect their competitive edge.

For this research study, five coaching professionals were interviewed. Four individuals from Premier Soccer League (South Africa) football clubs and one individual from an English Football League Championship (United Kingdom) football club were interviewed. This number was deemed to be appropriate for three reasons:

1. After conducting the first three interviews, it was seen that information acquired was saturated with interviewees providing similarly themed responses.
2. A low number of available resources in the premier level of football in South Africa.
3. A total of four coaching professionals out of the 16 teams from the Premier Soccer League (South Africa) were interviewed. This represents 25% of the potential resources.

All interviews were conducted via an online meeting platform due to the regulations of the COVID-19 pandemic. All interviews were recorded after receiving permission from the interviewees. Responses from interviewees have been edited without changing the meaning of the responses. This has been done to improve readability. Thematic analysis has been used to structure interview responses according to specific themes.

5.2 PARTICIPANTS

5.2.1 Job Roles

All the participants were part of the coaching staff of their respective clubs. Coaching staff work closely with the football players and would be extremely knowledgeable about OTS. Specific job roles are listed below:

Table 19: Job roles of participants

Participant no.	Job Role
1	Head Strength and Conditioning Coach
2	Sport Scientist
3	Head of Sport Science
4	Head of Performance

5	Lead Sport Scientist

In the following sections, each sub-research question and sub-research objective will be discussed along with their respective interview questions and answers.

5.3 ADDRESSING SUB-RESEARCH QUESTION 1

Sub-research objective 1 is **"To investigate previous cases of overtraining syndrome and their underlying reasons".**

This sub-research objective aims to identify any similarities amongst previous cases in the attempt to find common root causes of OTS in football.

This sub-research objective is used to formulate the sub-research question: **What are the underlying causes of previous cases of overtraining syndrome and can any similarities/themes be uncovered?**

From this sub-research question, the following interview questions were formulated:

5.3.1 Explain similarities between previous cases of OTS such as causes, symptoms or recovery times? Please elaborate.

This question was formulated to try and find any similarities between previous cases of OTS and compare this with previously documented cases of OTS. Table 20 thematises the responses to this question and provides an interpretation of these responses.

Table 20: Previous cases of OTS

Raw Data	Theme	Interpretation
"Performance was plateauing and eventually declining" – Participant 1 **"The most important symptom everyone focuses on is a decrement**	Plateauing and deteriorating performance.	A decrease/plateau in performance was an indicator of OTS.

in performance or plateau in performance. This is where players seem to not develop, not improve, become stale in their performance or even start to underperform." – Participant 2		
"We pick up patterns like some of the guys are giving poor recovery scores when the previous day was not a high loading day. From there we can start to see that they are not recovering well and they often present niggles[2]." – Participant 3 **"If everyone is running 5km and someone perceived it to have always been a certain difficulty and then suddenly after two or three weeks that perceived difficulty increases, there's an imbalance between their recovery process and their performance process. They are perceiving their output to be more difficult than what it used to be or what it should be." – Participant 4** **"I have found that it is inadequate rest within a microcycle[3]." – Participant 5**	Poor levels of rest or recovery.	Rest and recovery are extremely important and if players do not get enough rest and allow their bodies to recover, they are at a higher risk of OTS.
"What also causes OTS within football is a workload or training load that is too high or training too much too	Too much training too frequently.	Players that train too much or too frequently have an increased risk

[2] A discomfort, pain, or the inability to execute a previously honed skill. Source: (Tee, 2020)
[3] The smallest unit within a mesocycle; usually a week of training. Source: (Holmes, 2007)

frequently.” – Participant 5		of OTS.

Table 20 shows that all the participants can attribute OTS to some sort of physical parameter. More interviewees suggested that poor rest or recovery contributed the most to previous cases of OTS. Other similarities seen were players who train too much, too frequently or too much too frequently have an increased risk of OTS. This correlates with Pankanin (2018), who suggests that increasing the training load and not increasing the resting period will harm players. Kreher and Schwartz (2012) stated that when the amount of training is increased, the amount of recovery needs to be increased as well. A decrease or plateau in performance levels was seen to be an indicator of OTS which is what was seen by Pankanin (2018) as a symptom of OTS. Three themes were found from the answers to this research question.

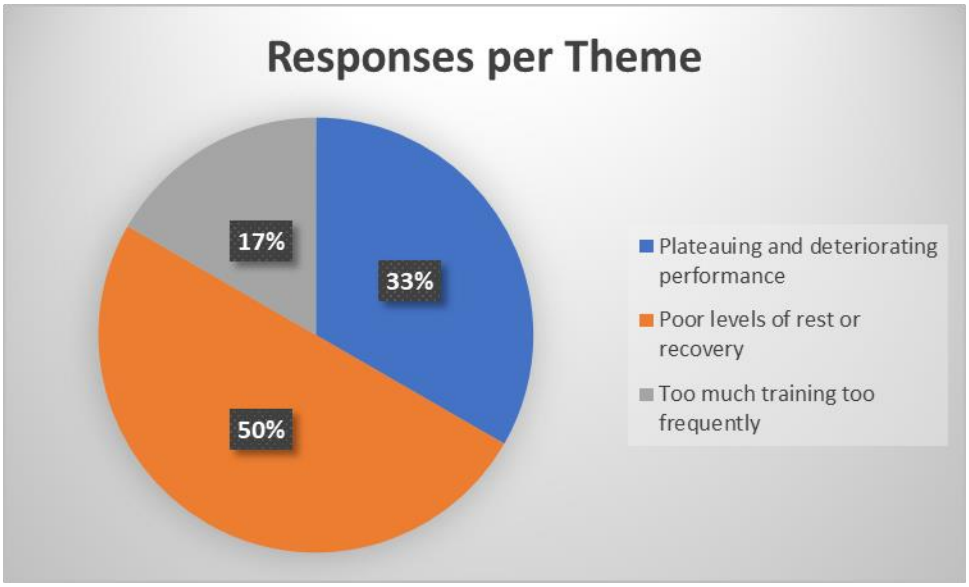


Figure 15: Interview question 5.3.1 Responses per Theme

Figure 15 shows that **Theme 2: Poor levels of rest or recovery** had the most responses from participants while **Theme 3: Too much training too frequently** had the least responses from participants. Participant 1 and participant 2 mentioned how a player’s performance that is declining or not improving is a warning sign for OTS. Participant 3 and participant 4 used the subjective scores completed by the players to detect patterns of changing rates of perceived exertion. Players start to feel that training sessions are more difficult than they are due to inadequate rest and recovery. When a player trains too much

or too frequently, they are reducing their recovery time and placing extra strain on the body, which can lead to OTS.

5.3.1.1 Summary of findings for interview question 5.3.1

Table 21: Interview question 5.3.1 summary

According to the responses acquired in the interview question above, the main similarities between previous cases of OTS are inadequate rest and recovery, amount and frequency of training and a decrease/plateau in performance. The most popular similarity of previous cases of OTS was poor rest and recovery which had a response rate of 50%.

5.3.2 Explain what types of players were affected and with what types of injuries?

This question was formulated to try and find any similarities amongst players with regards to player attributes and injury types. Table 22 thematises the participant responses to this question and provides interpretations of the responses.

Table 22: Player types and injuries

Raw Data	Theme	Interpretation
"Previous cases of OTS were not position-specific." – Participant 2 **"I would expect one of our explosive strikers[4] to have more hamstring issues, but I wasn't able to find any patterns between age or positions." – Participant 3**	OTS is not position-specific.	Previous data has not shown a relationship between player position and OTS.
"A player entering the first team from the youth academy has a higher risk of OTS. Susceptibility ages between	OTS is linked to age.	Players at the early stages and later stages of their careers are

[4] A player who focuses more on attacking and scoring goals and less on defending

17, 18 and 19 when the adjustment period hits for many players transitioning from school environments into professional footballing careers as well as players above the age of 30 who are not necessarily looking to retire but have had a good 10-15-year career and are expected to perform at the level of a 22-year-old." – Participant 2 **"When you can look at OTS from an emotional/cognitive perspective, that might be more associated with players that are older" - Participant 4**		susceptible to OTS.
"The biggest pattern when it came to injuries this season was a lot of contact injuries and not a lot of soft tissue injuries that we could have prevented. We got a lot of contact injuries where it was a bad tackle or a tackle where the player landed wrong and hurt his knee in the process."– Participant 3 **"When we are looking at overuse injuries it is generally tendons and ligaments. Soft tissue injuries (muscle-based) injuries do occur, but we get a good inclination when a player is training too much and starts developing tendon issues." – Participant 4**	Players are affected with contact and non-contact injuries.	OTS injuries are generally soft tissue and non-contact injuries which can be caused by the body's stress responses to a high training load.

"Stress responses in your back, tendinopathies[5] in the knee and fractures (non-contact injuries) which are stress responses in the bone due to a high workload with little time to adapt and reform before having to work again" – Participant 5		
"Reflecting on our season, training status is important. Players that are not in the best shape tend to burn out quicker than players that are in a better physical state or physical capacity" – Participant 4	OTS is linked to the physical state of a player.	A player that is in a better physical condition is less susceptible to OTS.
"Something that I've always experienced with our philosophy of being a pressing team and the way we play is a relationship between fullbacks[6] and groin injuries. That is a popular one because of the style of play where the fullbacks have to do sprinting, high-speed running and a high number of accelerations and decelerations. In other positions, it differs as they might have to do only one of these two movements." – Participant 5	OTS is position-specific.	Fullbacks with groin injuries are the most common OTS position-injury combination. This is due to the type and amount of work they perform.
"I wasn't able to find any patterns between age or positions." – Participant 3.	OTS is not linked to age.	Previous data has not shown a relationship between player age and OTS.

[5] A failed healing response of the tendon. Source: (Physiopedia)
[6] A defensive player playing on either the left or right side of the central defenders.

From the responses in Table 22, six themes were uncovered. The responses to this interview question showed the following contrasting views:

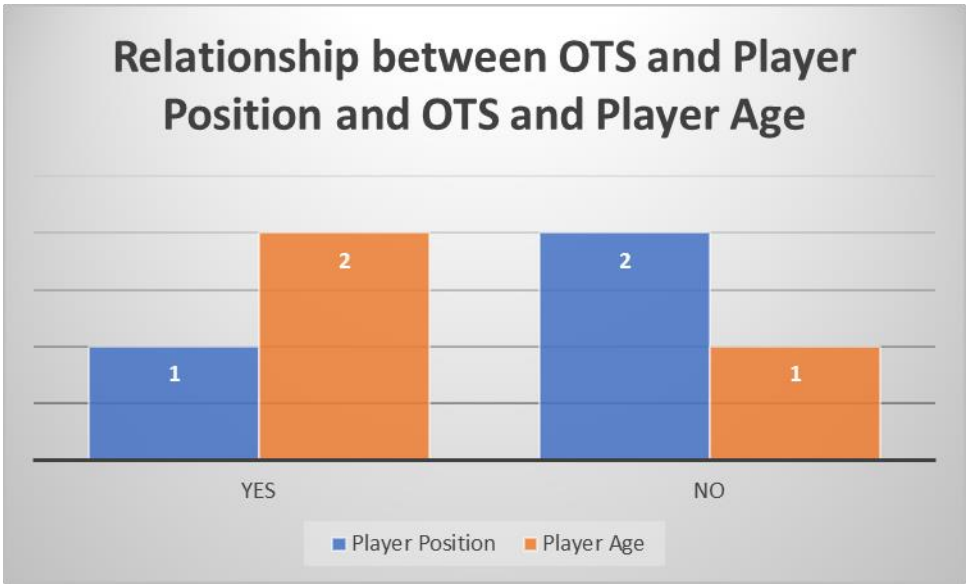


Figure 16: Interview question 5.3.2 Contrasting views on OTS link to player position and player age

Figure 16 shows the varying responses on the relationships between OTS and Player Age and OTS and Player Position. Some participants agreed that OTS was linked to Player Age and Player Position whereas other participants agreed that OTS was not linked to Player Age and Player Position.

Participant 2 mentioned how players in the early and later years of their footballing careers were most susceptible to OTS. This is due to players making the jump from the junior levels to the senior levels of football which is more physically demanding of the body. Players that are in the later years of their careers are more susceptible to OTS as their bodies take longer to recover.

Participants 2 and 3 discussed how OTS was not linked to Player Position. This contrasts with Verardi *et al.* (2014), who state that footballers playing different positions are prone to different levels of stress. It was also stated by Ade, Fitzpatrick and Bradley (2016) that footballers in different positions run at different intensities, run for different durations and complete different types of movements. Morgans *et al.* (2014) also suggested that the match-movements differs between the different playing positions.

Participant 5 mentions how fullbacks have a higher risk of OTS as a result of the higher amounts of sprinting they are required to perform. This correlates with Riccardo and Ciro Hosseini (2017), who state that fullbacks complete the second-highest amount of sprinting distance behind attackers. A study by Silvestre *et al.* (2006) mentioned how defenders complete the second-highest number of total sprints and the highest number of sprints under five yards.

There is evidence that shows that OTS can indeed be related to Player Age or Player Position, however, due to the varying responses of the participants, the link between OTS and Player Age and OTS and Player Position is inconclusive.

Participants 4 and 5 discussed how the most common OTS injuries were soft tissue and non-contact injuries which are caused by the body's stress response to a high training load.

Participant 4 mentioned players that who are in a better physical condition have a lower risk of OTS.

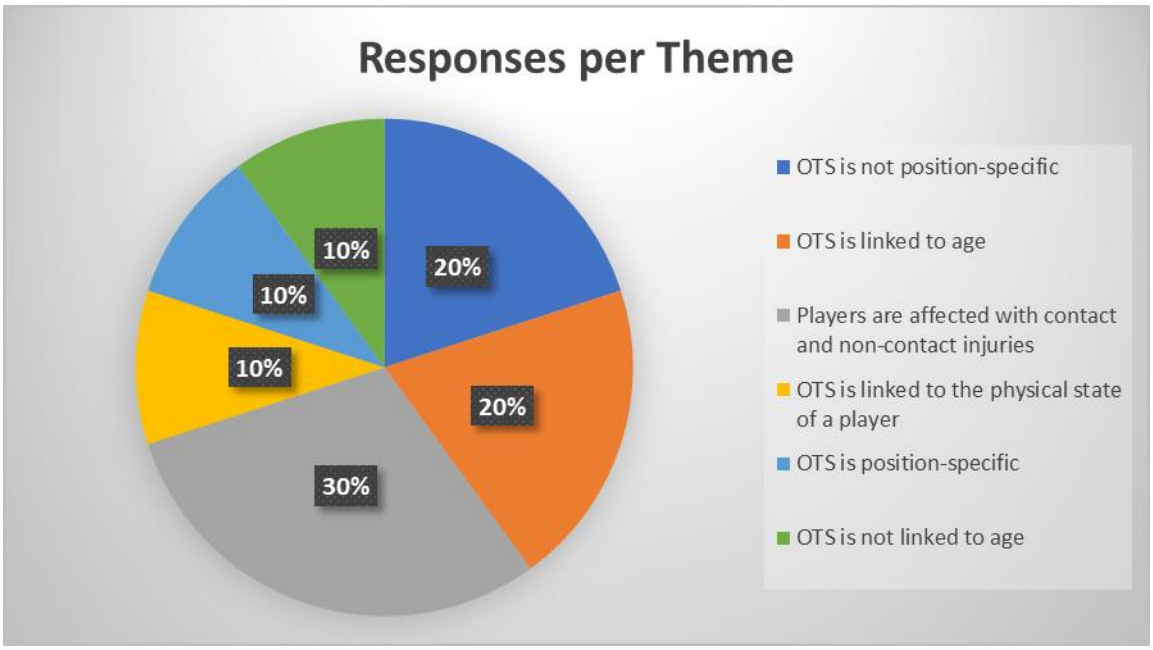


Figure 17: Interview question 5.3.2 Responses per Theme

Figure 17 shows that **Theme 3: Players affected with contact and non-contact injuries** had the most responses.

5.3.2.1 Summary of findings for interview question 5.3.2

Table 23: Interview question 5.3.2 summary

According to the responses acquired in the interview question above, there are contrasting views on the relation between Player Age and OTS as well as the relation between Player Position and OTS. Previous cases of OTS had shown non-contact as well as contact injuries, but the most common injury types were soft tissue and non-contact injuries. It was also seen that a player in a good physical condition was less at risk of OTS.

5.4 ADDRESSING SUB-RESEARCH QUESTION 2

Sub-research objective 2 is **"To determine all non-physical related contributing factors to overtraining syndrome".**

This sub-research objective plans to gain a holistic view of all elements involving a football player and OTS.

This research objective is used to formulate the sub-research question: **What are all the non-physical related factors contributing to overtraining syndrome in football players?**

From this sub-research question, the following interview questions were formulated:

5.4.1 Describe how playing styles (team/player), player physical and mental attributes are related to overtraining syndrome.

This question was formulated to gain insight into whether certain player and team attributes contribute to OTS.

Table 24: Playing styles, player physical and attributes

Raw Data	Theme	Interpretation
"High-pressing[7] formations are very popular in football at the moment. A lot of teams are obsessed with high-pressing. This increases the physical load of the player in both physical metrics as well as perceived exertion." – Participant 2 **"It depends on the style of play that the coach wants to impose. Under our previous coach, he liked to have a lot of the ball and as soon as you lost the ball, it was a very high-pressing, high-intensity game, so that demanded quite a bit physically from the players to be able to push and hit the standard that he was looking for. There are also playing styles where the players are instructed to sit in a low block[8] and wait for the opposition to come towards them. It is not as physically taxing, so I would assume that type of playing style would take less time to recover from. If you are trying to play this high-pressing high-intensity game and if you have got a lot of matches in quick succession, it could take a toll physically as the players cannot recover properly in**	Playing styles play a big part in OTS.	The "High Pressing" playing style is currently the most popular and requires a high amount of work from the players which can lead to OTS.

[7] Chasing after the opposition to reduce their time on the ball in their own half with the objective of regaining possession of the ball.
[8] A defensive system where players defend very deep in their own territory. There is less movement compared to the high-pressing system

time. This will contribute to players acquiring OTS." – Participant 3 **"If a coach is wanting to play in a certain way or a certain formation and is asking a certain player to work or produce certain outputs and he isn't at that level then it might push him more than if he played in a position that's less demanding physically. The players might be able to perform better in a position that's less physically demanding than if they had to be more explosive, run more or sprint more. If the player doesn't have that capacity, it means they might acquire OTS a lot quicker" – Participant 4** **"Any energetic style. A style quite popular at the moment in football is pressing and going after the opposition. This requires lots of energy depending on how long you're going to do it. To be able to do that during matches you have to be able to replicate that in training. You increase the risk of OTS when you have to perform high-intensity work or a high volume of work" – Participant 5**		
"This can be associated with resilience in the player alone. The educational aspect contributes to	Mental attributes and OTS are related.	The mental state of a player has a direct effect on their physical well-

whether they are conscious enough to recover in their own time as well as seek recovery assistance. There is a large amount of discipline that goes with it. Naturally, players do have a social life and private life. These include players getting married very early due to having very well-off incomes at such a young age and players becoming parents. The period where the partner is pregnant is normally a very critical stage where players are stressed, and this is evident in their performances. Other factors are financial problems, the stress of current South African affairs like Loadshedding, protests on the roads and now the lockdown as well." – Participant 2 **"Mental state is such a big part of football that is overlooked by a lot of people. You can have GPS data and say, 'Oh look he is covering this much distance', or you can just have your subjective data and say, 'He has a Rate of Perceived Exertion (RPE) of this'. What we like to do is combine the two. It is so important to get that subjective data, particularly in the mornings when players come to training. Players fill in a questionnaire about how they slept, how they are**		being as well as their performance. Therefore, a poor mental state will increase the chance of OTS.

feeling and any other issues. We use that to track mental state. We also use it as a conversation starter, e.g. Players have reported that they have slept poorly and are having certain issues. We put an arm around their shoulder, so they have someone to talk to about the issues they are having."– Participant 3 **"In terms of the emotional side, being aware of your socio-economic status is important. The number of people in the household, access to transport, dependencies, number of children and educational status are factors that pour stress into the stress bucket." – Participant 4** **"I think teams that go for the low-block have to be mentally tough as you know you're stepping onto a pitch with the opposition being physically fitter than you and attacking for 90 minutes. You are going to need the mental capacity to concentrate and know you cannot make any mistakes. You have probably gone nine months of doing that and it is tough, especially when the pressure increases. By the long end of the season, everyone is going to be mentally tired." – Participant 5**		

Table 24 shows the two themes that were uncovered. Theme 1 shows that the playing style of a football team depends on a coach and is related to OTS. The “high-pressing” playing style is currently very popular. This playing style is physically demanding, and players must work harder compared to other playing styles. This increased workload can contribute to OTS. Theme 2 discusses how various factors such as social life, family life and educational commitments affect a player’s mental health. This in turn increases their risk of OTS. This correlates with Pankanin (2018), who stated that personal stress should be eradicated and a player’s emotional state should be closely monitored to reduce the risk of OTS. This also associates with Kreher (2016), who mentioned how stress releases cortisol which has adverse effects on the body and will affect performance.

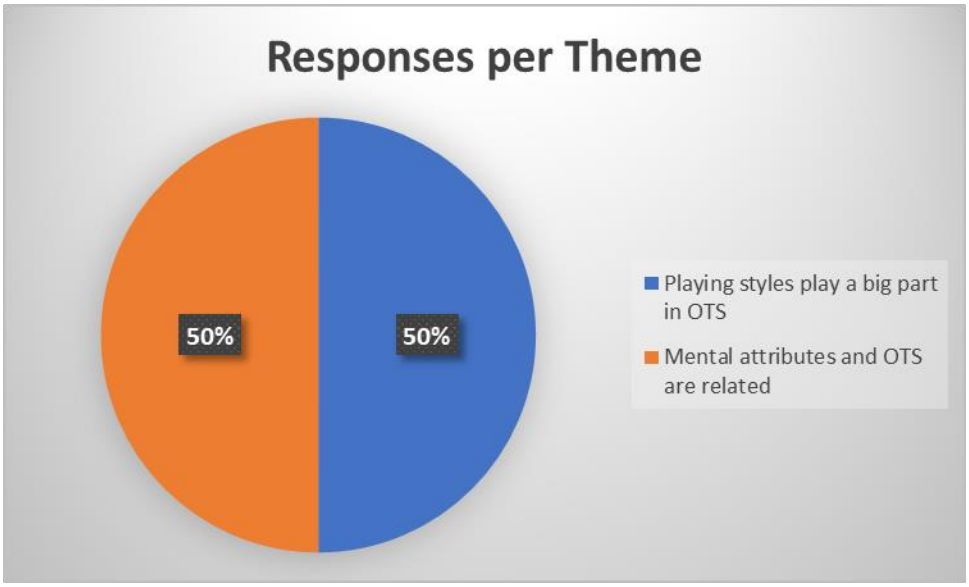


Figure 18: Interview question 5.4.1 Responses per Theme

Figure 18 shows an even distribution of responses between **Theme 1: Playing styles play a big part in OTS** and **Theme 2: Mental attributes and OTS are related.**

5.4.1.1 Summary of findings for interview question 5.4.1

Table 25: Interview question 5.4.1 summary

According to the responses acquired in the interview question above, two equally important themes were uncovered. The first theme suggested that playing styles can contribute to OTS. The second theme suggested that a player’s mental state can increase

their risk of OTS.

5.4.2 Explain how a player's form plays a part in overtraining syndrome?

This question aims to identify whether a player's form can increase their risk of OTS.

Table 26: Player Form

Raw Data	Theme	Interpretation
"Some players are looking for that step into Europe and are also very willing to work with a sports scientist and their conditioning coach to look after themselves whereas other players are satisfied with being in form[9] and either become complacent and comfortable or neglect the fact that they now need to recover and look after their bodies." – Participant 2 **"I see in form players that are in the gym working harder and running harder. I see players that are out of form doing the same trying to find that magic touch and it does not come to them. I also see players in form that are not working as hard and they can still perform, and they feel fresher because of it. Maybe they've found something at this moment in time that may not last forever, but it gets their performance on the pitch to its peak.**	Hard work is not dependent on a player's form.	Both in form and out of form players were seen working hard. In form players could be working hard to maintain their form, and out of form players could be working hard to try and find their form. The opposite is also true where an out of form player does not work hard, or an in form player feels they do not need to work as hard.

[9] Describes a player that is performing well. Source: (Lexico)

You also see players that are out of form and not training hard. They are the ones we put pressure on because they are not doing well out there and they are not doing anything on the training pitch or in the gym to change that. Some lucky players do not put in that much work and still perform. There are players that are unfortunate who put in the work but cannot find that form. There are players that are putting in the work which may increase their risk of OTS but that's how they get their form."– Participant 5 **"Some players who are not getting into the team couldn't care less. They are happy to receive their salaries or they have the belief that the coach has an issue with them. I have seen other players who have the mindset to work harder and prove themselves." – Participant 3**		
"In the case where there is overloading[10] in the training week or the training block, you would find that there are typically changes in mood states or injury niggles that creep in. If it does get to the point where the load is too much and you see a decline in their form, that training	OTS can lead to a decrease in form.	OTS can adversely affect a player's form as they may acquire injuries that will affect their playing time and thus their form.

[10] A principle dictating that in order to improve, athletes must continually work harder as their bodies adjust to existing workouts. Source: (sports-training-adviser)

block is essentially not beneficial because they have seen a decline in form rather than an improvement in fitness" – Participant 1		
"I find they have a lower chance, however being in form can be abused. A player that's performing extremely well will be expected to perform for a long period and will be in the starting 11 week in, week out. Form does affect OTS, but I find and from what I've seen in research, players in form have a lower risk of injury and overtraining." – Participant 2	Players in form have a lower risk of OTS.	In form players have been known to have a lower risk of OTS.
"I can't say that I've seen anyone out of form getting into that OTS zone, mainly because if they're out of form, they don't play as often and when you don't play as often you don't reach those high loads from training." – Participant 3	Out of form players have a lower risk of OTS.	As a result of less match time, out of form players are less prone to OTS.
"What I have seen is guys who are in form wanting to play more and it's a difficult conversation. We have a player with us who was scoring a lot of goals, but he was coming back from a neural issue in his hamstring. In his return to full fitness, he was only supposed to play 50 minutes of this match, but because he scored two goals he wanted to keep pushing and keep going and he started feeling issues with the hamstring that we	In form players have a higher risk of OTS.	As a result of good performances, in form players tend to play more minutes, and this can lead to OTS.

worked on the previous four weeks to get over. You are performing well so you want to maintain that high. If players are out of form, they are not chosen to start as many matches. This reduces their total load." – Participant 3 **"It does happen, and it has happened to us as well. A player is playing well, therefore the coach wants to play him more and they start to neglect other factors that are around them. We've had various instances throughout this season where a player was only supposed to play 30,40 or 60 minutes in a match, but because he was playing well, you make that decision in the moment for him to see out the rest of the match and then he goes on to pick up an injury in two weeks." – Participant 4**		

Five themes were found as shown in Table 26. There were contrasting ideas with regards to in form and out of form players and their risk of OTS. Figure 19 depicts these results.

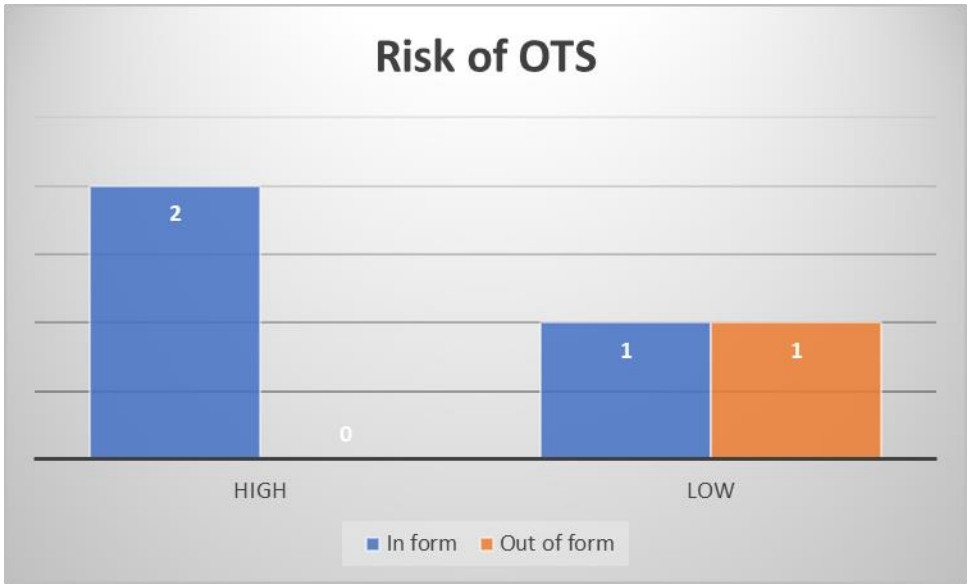


Figure 19: Risk of OTS for In form and Out of form players

Figure 19 shows that more participants agreed that in form players have a higher risk of OTS. This can be attributed to the fact that in form players tend to play more minutes of a football match, meaning their bodies are working more and recovering less. Figure 19 also shows that one participant agreed that out of form players have a lower risk of OTS. This can be attributed to the fact that out of form players play fewer minutes of the match, meaning they are less prone to overtraining injuries. None of the participants mentioned that out of form players have a higher risk of OTS.

Other important ideas uncovered by this interview question were:

- The amount of work a player puts in during training is independent of their form – hard-working players tend to work hard regardless of their form status. These players may work hard to maintain their form or work hard to find their form.
- A player's form is adversely affected by OTS – A player that has OTS will not train at high-intensity or play matches, thus their form will be lost.

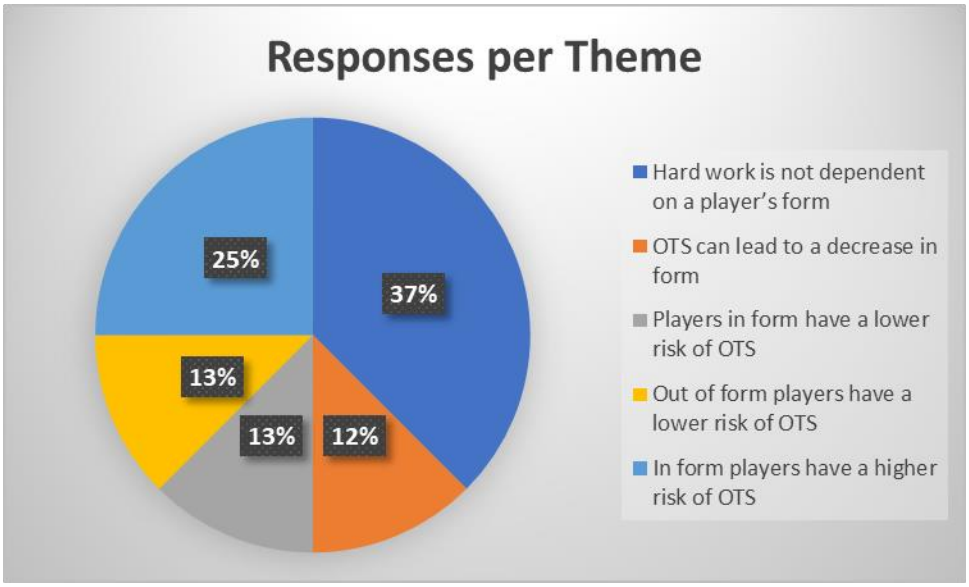


Figure 20: Interview question 5.4.2 Responses per Theme

Figure 20 shows that **"Theme 1: Hard work is not dependent on a player's form"** had the highest response rate.

5.4.2.1 Summary of findings for interview question 5.4.2

Table 27: Interview question 5.4.2 summary

According to the responses acquired in the interview question above, various ideas were uncovered. A player's form is not an indication of the amount of effort that the player will invest in training sessions. There are contrasting views around the influence of a player's form on their risk of OTS. A player's form is negatively affected by OTS because of a reduction in playing time due to injury.

5.4.3 How does a player's personal lifestyle play a part in OTS? Please motivate.

This question aims to identify how a player's personal lifestyle can play a part in OTS.

Table 28: Player Personal Lifestyle

Raw Data	Theme	Interpretation
"High profile athletes have a lot more sponsor obligations whether it's with the club or community interaction. They are being mentally fatigued and when you have a personal life where things are not all right at home, you have to put on the appearance that you're on top of your game and everything is good in your life. This is mentally taxing and affects recovery. Athletes who perform negatively take longer to recover from the training load or competition load compared to athletes who perform well. This has been linked to mental stress and actual anticipation of the next event." – Participant 1 **"We're in an age of social media where your social media presence is just as important as your on-field performances. We have seen a few cases where guys have become very involved with off-field antics of social media work and going out to certain events outside of football. The biggest effect of this that I have seen from our players is sleep. They are not sleeping**	Personal lifestyle plays a significant role in OTS.	A player's lifestyle contributes significantly to their risk of OTS. Any off-field activities that result in poor sleep and poor nutrition negatively affects the recovery process of the player. Good recovery is vital in lowering the risk of OTS.

properly after training because of their off-field behaviours, and they are not getting the right nutrition. If you are not getting the right sleep and the right nutrition you are not going to recover adequately. Combining this with tougher training leads to a downward spiral." – Participant 3 **"Social life influences the recovery process. If a player is out and about, not sleeping, not eating well, not recovering and not drinking enough fluids, his ability to recover is hampered. The more blunted or dented the recovery process is, the longer it takes for you to get back to baseline[11] and be able to train hard and push yourself. If you are continuously not recovering well because of your social life, social circumstances or social decisions, it's a small decline over time in terms of your physical performance till it gets to the point where you are either physically unable to train because of your recovery status or you are just emotionally unable to push yourself in training or matches." – Participant 4** **"We talk about good professionals and bad professionals. You have got**		

[11] Information that is used as a starting point by which to compare other information. Source: (Merriam-Webster.com Dictionary)

players that will sleep correctly, eat correctly, and do everything the support staff requires of them. You have got players that will do the complete opposite and get away with it. They could play video games till 4 am, pitch up to training and have the talent to be the best player. A lack of sleep and too much workload leads to OTS which can cause significant injuries." – Participant 5		

Table 28 shows that the player's personal lifestyle influences their risk of OTS. It was seen that players who lose recovery time due to social activities which contribute to poor sleep, poor recovery and poor nutrition have an increased risk of OTS. A player may have a stressful personal life which can also increase their risk of OTS. This correlates with Pankanin (2018), who said that following the correct diet, hydrating and having a personal life that does not hamper sleep quantity and quality are ways to reduce the risk of OTS. A study by Meeusen *et al.* (2013) mentions how a lack of sleep and stressful personal lives builds on the stress of physical training. This study also mentions the importance of good levels of sleep, hydration and nutrition to reduce the risk of OTS.

Cadegiani, Kater and Gazola (2019) discuss how sleep quality is more important than sleep duration in terms of the risk of OTS. Sleep hygiene should be practised which entails turning off electronic devices such as televisions and smartphones before bedtime. Carter, Potter and Brooks (2014) mention how sleep plays a vital role in repairing the body. This article also states that as the intensity of training increases, the importance of good quality sleep increases. Insufficient levels of sleep harm a player's mood state, cardiovascular performance and reaction times, which in turn will affect the player's performance. Carter, Potter and Brooks (2014) also state that without the correct levels of nutrition, the player will not have the required micro and macronutrients to recover well. Poor recovery will lead to poor performance and eventually OTS.

An article by Lastella *et al.* (2018) further emphasises the importance of sleep as a recovery method by stating that sleep is the best form of recovery for athletes. The article discusses how high training loads have been known to negatively affect sleep quality. It was also mentioned that an underperforming athlete may become increasingly stressed which will adversely affect their sleep quality.

5.4.3.1 Summary of findings for interview question 5.4.3

Table 29: Interview question 5.4.3 summary

According to the responses acquired in the interview question above, the theme uncovered was that a player's lifestyle and emotional well-being influences their risk of OTS. A personal lifestyle that hampers the sleeping patterns and nutrition of a player will cause poor recovery which will lead to OTS.

5.5 ADDRESSING SUB-RESEARCH QUESTION 3

Sub-research objective 3 is **"To understand the current training methods and recovery processes utilised in modern-day professional football teams".**

This sub-research objective aims to determine the relationship between training, recovery, and OTS.

This sub-research objective is used to formulate the sub-research question: **What are the current training methods and recovery processes of footballers and how do they influence the player's risk of overtraining syndrome?**

From this sub-research question, the following interview questions were formulated:

5.5.1 Explain what training methods are currently used and for what purpose?

This interview question aims to gather information on what types of training methods are currently used in football.

Table 30: Training Methods

Raw Data	Theme	Interpretation
"We split our week into development and performance. The first two days are very much development, and we will have a big day that works aerobically in big spaces as well as a second day that works in tight areas. What that does relative to OTS is we are not working one energy system of the body every day. We will have a day off and we will go into the performance part where we will have very light match preparation. We will play the match which is very important in terms of performance. The third element of the performance portion, the sixth day of the week, we would work with anyone who's not played a significant part in that match, so they get their work in for the week. Sometimes match starters will go out which is unusual, but it is just finding the balance to ensure that they're getting enough rest and recovery." – Participant 5	Development and Performance.	The training week is split into development days and performance days to target specific areas.
"There is a wide variety of training methods that depends on the head coach and what they want to cover in training. Some coaches will stick to their guns and have a stronger say in what they do in the week and other coaches will allow the technical staff	Training methods depend on the coach.	The coach determines what training methods are used as this will complement the philosophy of the coach.

members to provide input so that training is more holistic. The strength and conditioning coach and sports scientist will add in mobility, regeneration, active recovery, or strength sessions. The physiotherapist will add in injury prevention and rehabilitation." – Participant 1 **"I've worked with a variety of coaches, so there have been different training methods." – Participant 5**		
"We follow a tactical periodisation model which essentially comes down to us having themes or outcomes for every day we train. Every day looks different physically, technically and tactically. This allows us to have certain days where we do more or push the players more. This allows us to have recovery sessions/recovery periods throughout the week to ensure that we have freshness by the end of the week when the guys need to play the match." - Participant 4 **"The team follows a tactical periodisation model in the sense that we periodise week to week, match to match. The post-matchday is usually either an off-day or an active recovery day. The best type of training method**	Tactical Periodisation Model.	Various training methods are used with a particular focus on a tactical periodisation training model.

I would like to see in modern football and which I've seen to be the most effective is a holistic approach. A holistic approach integrates the tactical, physical and mental aspects of football. What you are trying to do each week is balance out these three aspects to achieve optimal readiness for the upcoming match day. Tactical periodisation includes a recovery phase post-matchday, a loading phase (two to three days) and a tapering phase before the following matchday. Those three phases allow us to physically work the players, recover the players and prepare the players. The tactical objectives also relate to and complement the physical objectives e.g. if we are working on sprint distance for the day and we want to increase the intensity, we will open up the spaces and we will do 7v7 (7 players on either side) and a pitch size of 40mx30m. Players can hit their top speeds more during these sessions." – Participant 2 **"We try to look at the athlete as a whole and we try to train athletes holistically. We do a lot of physical work during training to ensure we get the maximum velocity runs, the endurance work and the correct**		

amounts of distance covered. We also try to do a lot with the ball. Essentially this is combining the technical, tactical and physical aspects. This is a form of the tactical periodised plan. We do a lot of prehabilitation and activation for the session. On an individual basis, we will have little prehabilitation exercises for each of the players to do for about 15-20 minutes before they start the session. This could be work with the rubber bands, mobility work, core activation or glute activation. Another form of training that we do is specifically for players who struggle with mobility. We get them to do yoga classes to work on mobility." – Participant 3 **"The field sessions are priority where you would have technical, tactical or conditioning sessions. For technical sessions, it is more about the individual's and team's playing skills. Tactical sessions are more about the style of play and tactical awareness. These are topics that players need to cover during the training week looking forward to that opponent in the match week. For the conditioning sessions, it is essentially ensuring that the athlete is conditioned or maintaining a condition for the**		

season. Essentially this is the biggest loading session. With regards to the strength work, you would have your actual strength sessions which depend on your training week or your match week, how many sessions you can fit in the week and if the coach believes in it. With regards to affirmation sessions, it is something that can be a combination of injury rehabilitation or prehabilitation. Mobility sessions are also a part of your injury prehabilitation and are done to ensure the footballer is ready for the training session or match." – Participant 1		
"The two most important forms of recovery are sleeping and eating well. After those, comes active recovery modalities which might be getting into the pool, getting on a bike, foam rolling, stretching or going for a light jog. The most important things which aid recovery are diet, nutrient intake, hydration and adequate sleep." – Participant 4 **"For recovery, there's the team approach as well as the individualised approach. Active recovery helps recover the players much quicker. We can also include a passive recovery day or a day off. This works very well**	Recovery Methods.	Various recovery methods are used with sleep and correct diet being emphasised as extremely important.

for the mental side as players can be with their family and friends. We incorporate ice baths, massages, hyperbaric chambers[12] and we use a system called kinematics which manipulates the muscles mechanically. We also advise players who want to do post-training and need an extra step of recovery. This can be either an extra day off for older players, yoga or flexibility sessions." – Participant 2		

The four themes that were uncovered are shown in Table 30. According to the findings, two main training models are used. These models are discussed below. The first model being **Development and Performance** and the second being **Tactical Periodisation.** This correlates with Morgans *et al.* (2014)**,** who discussed the Periodisation framework and how it is used to vary the training loads that players are exposed to.

Model 1: Development and Performance

Day 1: Aerobic work in big spaces.
Day 2: Work in tight areas.
Day 3: Day off.
Day 4: Very light match preparation.
Day 5: Matchday.
Day 6: Working with any players that have not played a significant portion of the match.

Model 2: Tactical Periodisation

Technical: Individual and team playing skills.

[12] A steel vessel in which atmospheric pressure can be raised or lowered by air compressors, used to treat divers or pilots afflicted with aeroembolism and to provide high-oxygen environments for certain medical treatments and operations. Source: (Collins Dictionary)

Tactical: Style of play, tactical awareness, and topics that they need to cover in the training week looking forward to that opponent in the match week.
Conditioning: Ensuring that the athlete is conditioned or maintaining a condition for the season. This is the biggest loading session.
Strength: Actual strength sessions depending on your training week or your match week.
Affirmation: Combination of injury rehabilitation or prehabilitation which can include mobility sessions.

Participants 2 and 4 mention how their training plans are broken up into a weekly plan with each training session targeting different areas. This correlates with Lacome *et al.* (2018), who discuss how fitness components are distributed throughout a week rather than in a single training session. This method allows players to have a much more focused training session and reduces the risk of OTS as the same areas are not trained every day.

All the participants mentioned how their training sessions include tactical or technical aspects that focus on match-related situations. These situations can be small-sided games e.g. training matches with seven players on either side or training exercises that include technical work with the football. This correlates with Lacome *et al.* (2018), who mention how training has adopted a more integrated approach that focuses on match-related situations with the football rather than pure physical training. Training sessions such as these can develop players technically and tactically.
Participant 2 discussed how the use of a 7v7 small-sided game can combine tactical and physical objectives. This correlates with Owen *et al.* (2014), who state that small-sided games have become a popular training method as a result of their ability to develop players tactically, physiologically and technically.

It was discovered that various recovery methods are also used such as swimming, cycling, foam rolling, stretching and going for a light jog. The most important recovery methods are eating, nutrient intake, hydration, and adequate sleep.

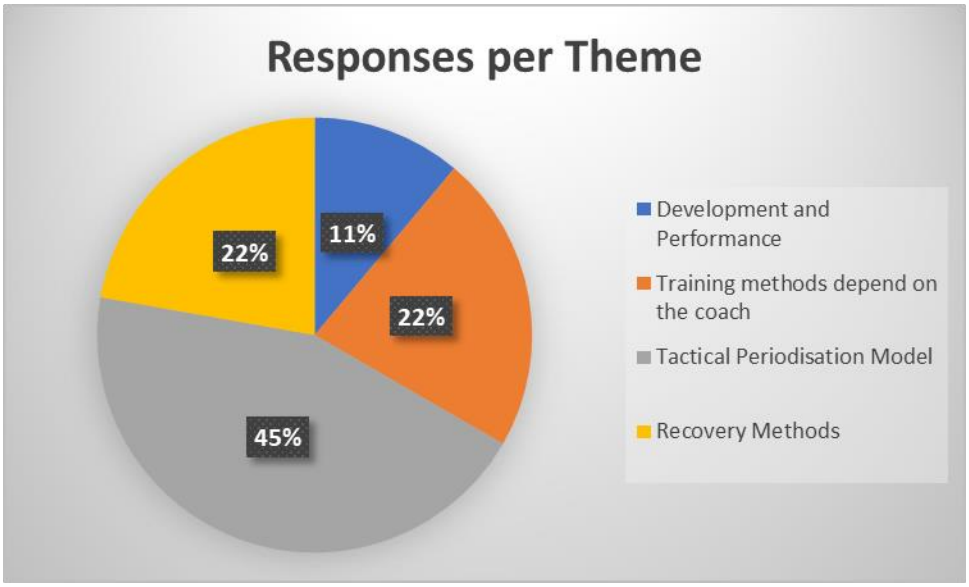


Figure 21: Interview question 5.5.1 Responses per Theme

Figure 21 shows that **Theme 3: Tactical Periodisation Model** had the most responses. This shows the popularity of the tactical periodisation model among football professionals.

5.5.1.1 Summary of findings for interview question 5.5.1

Table 31: Interview question 5.5.1 summary

Two training models are used, namely Development and Performance and Tactical Periodisation. High attention is also given to recovery with the most important recovery methods being sleep and diet.

5.5.2 What technology-driven training methods are currently used? Please elaborate.

This question aims to gain insight into the current technology used in football training.

Table 32: Technology-driven training methods

Raw Data	Theme	Interpretation
"The outfield players wear GPS units where you can track distance	GPS Monitoring.	GPS is an integral part of the technology used

covered, speed achieved, accelerations and decelerations. Using these metrics, you can get a general idea of the amount of work performed during a session and match." – Participant 1 **"We use video analysis and GPS monitoring. Each player is assigned a GPS unit and we look at metrics such as distance, sprint distance, metres per minute and relative distance. The GPS unit and our Acute Chronic Workload Ratio are separate. Some companies do offer them integrated, however, we have chosen to use the separate method which gives us two different perspectives." – Participant 2** **"The biggest one in terms of technology is the GPS that we use to record the players. They have it on for every training session and every match. We track different parameters like max velocity, total distance, meters per minute, number of accelerations and number of decelerations. We've got a couple of different methods of analysing this data we get from the GPS unit as well as the subjective data." – Participant 3** **"On the field, we use GPS technology**		in football training and matches.

and we use that in conjunction with our tactical periodisation. There will be certain days where certain physical outcomes, certain technical outcomes and certain tactical outcomes are the themes." – Participant 4 **"From a physical point of view, we've got live GPS and HR monitoring whilst they're training and during matches." – Participant 5**		
"We use video analysis to analyse our playing style. We record training sessions as well as match days. This assists with the tactical style that we play which also influences the conditioning of the players e.g. the high-pressing approach will naturally be much more strenuous on the body." – Participant 2 **"Video footage is used from a technical or tactical perspective. Technical and tactical driven statistics come from video footage." – Participant 4**	Video Analysis.	Video Analysis is used for the tactical analysis of the team.
"From a physical point of view, we've got live GPS and HR monitoring whilst they're training and during matches." – Participant 5	Heart Rate Monitoring.	Heart Rate monitoring is also used to track physical metrics.
"We've had force decks (force platforms) which measure players' jumps. We have a watt bike which we	Alternative technologies.	Alternative technologies are used to target specific areas of the

use for neuromuscular tests. We have a groin bar. Around that, we use an Isometric Mid-Thigh Pull[13] which is just another indicator of whether the players are developing and improving. This creates a debate of why they're not developing or improving." – Participant 5		body.
"We use load monitoring which makes use of acute chronic workload ratios and perceived exertion. For the load monitoring device, we use a tablet inside the changerooms where players can record their scores. This program is also available on their phones so they can access it post-training as well. At the beginning of every day, players can log in online and submit questionnaires and surveys on their wellness and mental health state." – Participant 2 **"We have a monitoring system for subjective monitoring. Players will complete an RPE score out of ten about how intense they felt that session was. Players complete this on a tablet after each session. We'll combine that with the total time of that session to get a session load for each player in arbitrary units and then track those patterns over time to try**	Subjective Monitoring.	Subjective monitoring is a vital aspect of managing the mental state of football players.

[13] The Isometric Mid-Thigh Pull is a maximal strength test done with force analysis hardware and a barbell placed equidistant between the athlete's knee and hip. Source: (Valle, 2018)

and keep the players in a safe zone of periodised planning." – Participant 3 **"We have an athlete monitoring system. We collect data from players via an app on the player's phone. They submit their wellness scores/ wellness reports, complete their muscle-skeletal screens, which are small tests they do once or twice a week, as well as submit their subjective ratings of the sessions using the app." – Participant 4** **"Every morning the players fill out a survey, not only in terms of their muscle health and how their muscles are feeling but also in terms of how they are feeling mentally and nutritionally. We use this data to decide that if these guys are feeling bad and if their scores are bad we need to reduce the pressure them." – Participant 5**		
"Information is captured and analysed to have a look at what the data says. That can give you an idea of whether the footballer is performing within their capacity or performing a lot lower than what they should be. This can be used to identify if a footballer is struggling with an injury or niggle. For example, if a player is	Data Analysis.	Various tools are used for data analysis. The newly acquired data is compared to baseline data to try and find any anomalies which could flag potential warning signs.

complaining about hamstring tightness and we see that they aren't sprinting at all around the speeds that they should be, you can get a general idea that something is not right with regards to that player's physical capacity. I handle the GPS data, so that is something I have had to upskill myself in. The data does not tell you the quality of the pass and the decision making. A lot of distance covered does not mean the player had a good match. You must ask the question as to why the player covered so much distance. They may not be understanding the tactics and might be running for no reason." – Participant 1 **"We look at weekly percentage changes and we try and keep players within two standard deviations above or below their average load for the season. When we find those spikes, we start to pick up those niggles. We have luckily had the GPS units for two seasons now, so each player has a profile. We've got their baseline and their matchday data. We use GPS data to compare certain matches and certain training sessions particularly with players coming back from injury. We use GPS data to determine**		

whether the player has reached 60% of their pre-injury matchday values. From this, we decide whether to put them back into playing situations. GPS and subjective monitoring that we have built on Excel are the two biggest tools for us. GPS is used on matchdays and in training. The players are quite competitive and want to know when the results will be available to see who performed better. It is important having buy-in from players and the coach. The coach is the first to ask for the match stats. You plug in the GPS device to the computer and it produces some visualisations which you can export to Excel for further analysis. RPE data is collected via tablet and goes straight to Google Drive. We have built a monitoring system on Excel, so I export data from Google Drive into Excel. Different players' loads go into their respective tabs and there's also visualisations. There is a lot of information available to you, but I think it's important as a sports scientist to make sure that you are giving the essential information to the coaches. Coaches want to see the five or six parameters that are the most important. We do a lot of our predictions from our subjective data.		

The most important objective data metrics would be total distance (weekly patterns), amount of sprint distance (distance covered over 24km/h), the number of accelerations and decelerations and meters per minute. The guys that are covering a lot of meters per minute are at a higher risk of injury." – Participant 3 **"We may have feedback that the session was a lot harder than what we expected it to be and that influences our decision for the next day or the next week to ensure that we don't increase the risk of OTS. The monitoring system is made up of a cloud-based storage system whereby we collect, arrange, store and analyse information. Another sports scientist and I work with the data and feedback to the coaching staff and players." – Participant 4** **"We have baseline data for all players. If their results drop, there must be a reason. The first reason is usually fatigue. Sometimes these guys score the same or worse. Low scores are valid when it was a difficult week. It is a cause for concern when scores are low after an easy week. If scores stay consistently low or stagnate and you**		

are not achieving the desired development, it raises a major red flag."– Participant 5		
"From the information gathered, we determine what recovery time should be. When there is high-speed running your soft tissue is placed under a lot of stress. When there is a lot of distance covered, the legs will typically feel quite heavy or tired. If a footballer is constantly drilled with long-distance running and high-speed running, they will eventually pick up a niggle and that niggle will turn into an injury where there would be time off from training. At that point, they would eventually recover, but they would be reluctant to go back into those high loads of running." – Participant 1 **"Match related data brings much more interest from the players. This data is readily available in public areas for players to view. I would say 50% of the squad is interested in this data. There are other types of data that we make available to players. This can be their testing data or their muscle-skeletal data which they may have a personal interest in. Sometimes you will get players asking for data from a certain session e.g. the amount of**	Application of data insights.	After the data is analysed, it is used for certain processes. These processes include planning training sessions and recovery sessions, managing players and providing insightful information to players about their performances.

running they did or the number of sprints they completed. That generally tends to tie in with players that are formally educated." – Participant 4 **"Before training, we conduct these surveillance tests to see if players are feeling down, if their baselines are down or if they are fatigued. Training may have to be changed depending on the surveillance results. For example, if everyone is tight in their groins, we won't go into tight spaces, but we may open up the spaces. The types of feedback we focus on the most is player scores that are higher than usual and Bi-lateral differences (comparing the left and right side of the body). Analysis of surveillance results is always based on the context. For example, if we did a counter-attacking day which is heavy eccentric work or we've done eccentric work in the gym and everyone's hamstrings are sorer than usual, it's an expected result. The decision will then be to go into tighter areas or smaller sided games where there are fewer sprinting actions, more accelerations, more decelerations, and more mechanical work. We would not go into mechanical work if the players' groins**		

were sore. You must be reactive to look after the player or squad. You must be dynamic when planning training sessions." – Participant 5		

Table 32 shows that seven themes were uncovered for this interview question. GPS remains an integral part of the technology used in football training and matches. This correlates with Morgans *et al.* (2014), who said that it has become common to use GPS to monitor player performance during training sessions and matches. It was stated by Ehrmann *et al.* (2016) that GPS has become an important tool for finding the balance between training load and recovery. GPS provides great insight into the physical states and performances of players. Cardinale and Varley (2017) state that external load can be calculated using acceleration, position, and velocity data from GPS units.

Video Analysis focuses more on the team. Hughes and Bartlett (2002) mention that Video Analysis can be used to analyse individual player performance as well as the performance of the team. By using video analysis, the team can analyse the tactical aspect of their game. Heart rate monitoring is also used by some teams to gain insight into the physical condition of players. This correlates with Cardinale and Varley (2017), who state that heart rate monitors using chest straps provide valid and reliable results. Various other technologies are used to target specific areas of the body such as force decks (force platforms) which measure players' jumps and the watt bike which is used for neuromuscular tests.

Subjective monitoring is vital in managing football players. This correlates with Piesik *et al.* (2017), who state that a diagnosis of OTS can be made using subjective assessments of symptomatic athletes. Pankanin (2018) mentioned how a player's mental state should be closely monitored to swiftly identify drastic changes. Players can communicate how they are feeling in general as well as in response to training. These responses are captured on digital devices. The technical staff can use this feedback to plan training sessions as well as prevent possible injuries. Various tools are used for data analysis. The newly acquired data is compared to baseline data to try and find any anomalies which could flag potential warning signs. After the data is analysed, it is used for certain processes. These

processes include planning training sessions and recovery sessions, managing players and providing insightful information to players about their performances.

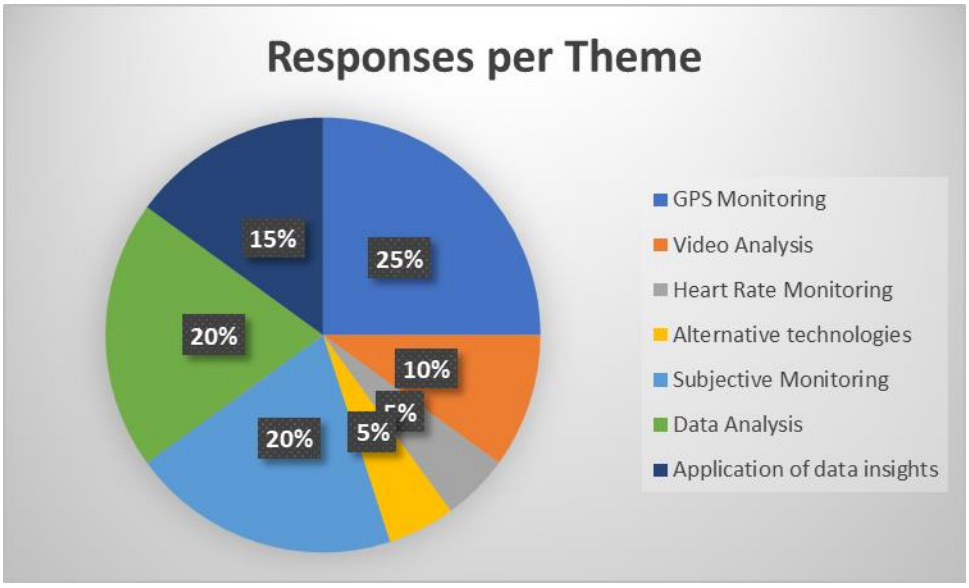


Figure 22: Interview question 5.5.2 Responses per Theme

Figure 22 shows that **Theme 1: GPS Monitoring** had the most responses**.**

5.5.2.1 Summary of findings for interview question 5.5.2

Table 33: Interview question 5.5.2 summary

Interview question 5.5.2 has shown that the most popular technologies used for physical monitoring are GPS, HR, and Video Analysis. The importance of Subjective monitoring has been uncovered in the responses of interviewees. The data acquired from these tools are analysed in various ways and the data is used for planning training and recovery sessions, managing players, and providing insight to players about their performances.

5.5.3 How does technology play a part in player management, such as during training, during matches, during injury periods, during recovery? Please explain.

This question was formulated to acquire information on how technology is used for player management.

Table 34: Technology in Player Management

Raw Data	Theme	Interpretation
"Technology gives us a completely different perspective whereas beforehand it was very focused on communication between the coach and the player. Now we have objective data to monitor and compare players, not just with one another but also with benchmarks across the world." – Participant 2	Technology provides an objective way to monitor players.	Objective data acquired from technological devices provide the technical staff with another dimension of monitoring the condition and performances of players.
"Technology allows us to individualise our perspective on the players. We create player profiles which can be used by the coach to achieve the desired tactical objectives." – Participant 2 **"The player survey is good as it works off their profiles. The scores are a rating of 0-10 on soreness of muscles with 0 being no soreness and 10 being you are injured. For example, some players will rate hamstrings a 4 the day after training and some players would say it is a 1. A 4 rating might be normal for that player, but the player who scores a 0 every day and then scores a 1 will raise a red flag. We use individual thresholds. If a player is above a standard deviation of what they usually are, it prompts me. I always speak to every player in**	Technology provides a means to individualise perspectives on players.	Each player has their profile which continually updates after the latest performance.

the morning in prehabilitation when they are in the gym and I ask how they are feeling from a physical and personal point of view. The responses from players help us plan training. For example, if everyone's hamstrings are very sore, we will not go into a counter-attacking session. The surveillance is great because it tracks how the players are performing longitudinally."– Participant 5		
"Technology has given us an element of a personalised approach in the sense that players can now access information on their phones, provide information via their phones as well as submit anonymous information."– Participant 2	Technology has provided a means for players to submit true anonymous data in their time.	Players can provide true feedback without worrying about being victimised.
"The Premier League runs the academies in England. Everyone has to use their player management app where you track your players' welfare from the training sessions that they do. Players get a players' clock in terms of how much training they do and what training they do. Each player has a profile they log in to." – Participant 5	Some leagues already have player management apps.	The Premier League in England already has a player management app.
"In the past, a big hurdle of ours would be the players manipulating their responses to a coach or sports scientist depending on their agenda e.g. if they were not willing to play in a	Technology provides objective data which prevents sole dependency on potentially false	Objective data provide more reliable information.

match or if they were too eager to play, they would give false recovery scores. Now we can prevent that deception." – Participant 2	subjective data.	

Table 34 shows the five themes that were uncovered. Objective data acquired from technological devices provide the technical staff with another dimension of monitoring the condition and performances of players. Each player has a profile. Each new performance is measured relative to this profile to provide individualised insights. This applies to both objective and subjective player data. Players can provide true feedback without worrying about being victimised. Players tend to be more truthful with their responses when they can submit responses from their devices in their environments. This relates to Ehrmann *et al.* (2016), who states that there have been cases where players continued to train with an injury without informing the coaching staff.

The Premier League in England already has a player management app where training session data can be tracked by technical staff. Objective data provide more reliable information with regards to physical performance and physical condition. The technical staff can use this data to decide whether players are ready to play or not without solely relying on whether the player feels they are ready to play or not. This correlates with Ehrmann *et al.* (2016), who said that with GPS data the coach and technical staff may be able to make more informed decisions regarding fielding players carrying injuries.

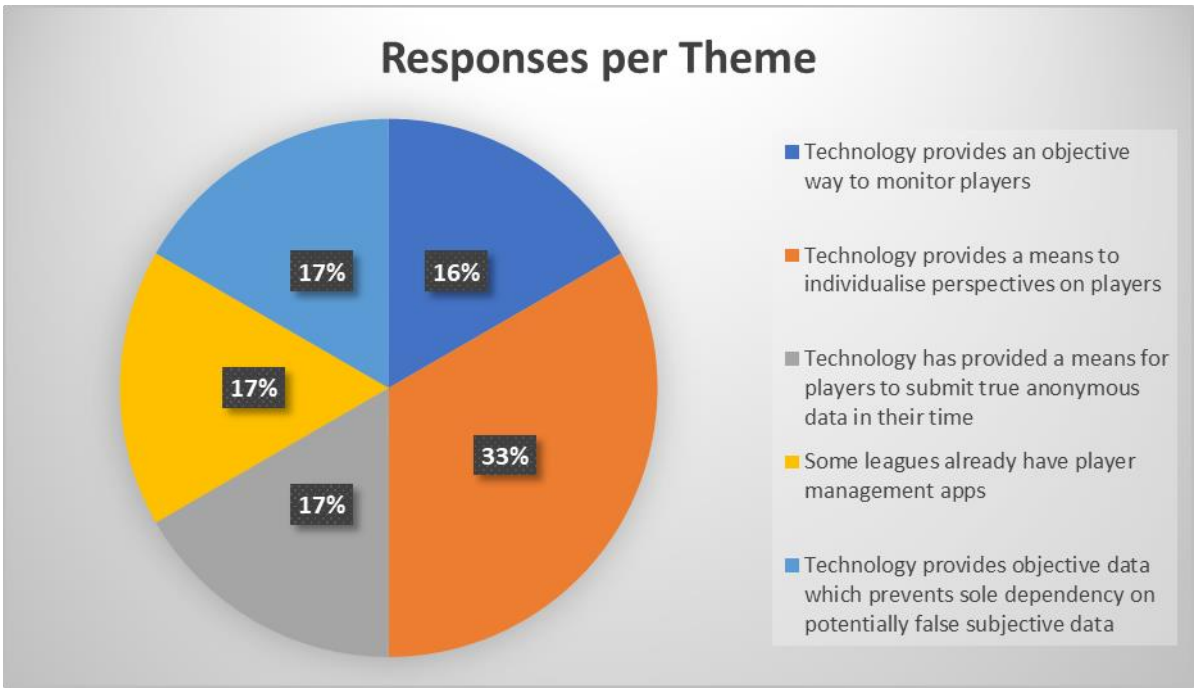


Figure 23: Interview question 5.5.3 Responses per Theme

Figure 23 shows that **Theme 2: Technology provides a means to individualise perspectives on players** had the most responses.

5.5.3.1 Summary of findings for interview question 5.5.3

Table 35: Interview question 5.5.3 summary

The most popular technologies used for physical monitoring are GPS, HR, and Video Analysis. Technology allows players to submit anonymous information without feeling victimised. Objective and subjective data obtained from technological devices are used by the technical staff to build a profile for each player which contains baseline values for each metric. The latest performances are measured according to these baselines to flag any outliers. The technical staff can use these profiles to manage the physical and mental conditions of the players.

5.6 ADDRESSING SUB-RESEARCH QUESTION 4

Sub-research objective 4 is **"To identify and analyse the current training technology encompassing a football player".**

This sub-research objective aims to look for existing gaps and possible improvements concerning the technology used to assist football players during training.

This sub-research objective is used to formulate the sub-research question: **What current training technologies are used by football players and how are these technologies used to address overtraining syndrome?**

From this sub-research question, the following interview questions were formulated:

5.6.1 Explain what training technology is used and the pros and cons?

This interview question intends to uncover the advantages and disadvantages of each type of technology used in football training.

Table 36: Pros and Cons of Technology used

Raw Data	Theme	Interpretation
"We are currently only using GPS units as training technology. The pros are that you can get a good indication of the training load players are completing in a week. For example, if you think players are not running enough, you can have a look at the data and see if they are running as much as the other Central Midfielder or the opposition Central Midfielder (if you are comparing a 11v11 during a training session). You can have immediate feedback as you can do	Pros of GPS.	GPS provides immediate and objective data during training which allows coaches to view immediate feedback of training exercises.

live tracking during a training session. You can determine the work rate in the form of the rate at which distance is covered (distance covered per minute) and you can get an idea of their high-intensity running. This will give you a better idea of how much stress the soft tissue is dealing with." – Participant 1 **"The current training technology we use is GPS monitoring of the players. Metrics such as distances and sprint distances are tracked. This is our most valuable technological resource." – Participant 2** **"We know the baselines of what the game requires. We know what is required from players and we know what certain playing philosophies require. We can plan our training in and around that." – Participant 5**		
"The cons of GPS would be just looking at the numbers and ignoring everything else. For example, if a player covers half the distance compared to what the opposition player covers in the 11v11 training session and they say they are completely tired and you disagree because the data shows they didn't run as much as the other player, you	Cons of GPS.	Technical teams should not limit player growth based on data.

could be ignoring red flags with regards to them feeling physically fatigued, mentally fatigued or sick. There could be a reason for why they did not cover as much distance." – Participant 1 **"For me, the biggest con is that sometimes certain people or coaches become too obsessed with the physical data and have these certain ideals like the team should run 110km in total during a match. We will say we won the match 3-0 and we had 75% ball possession, therefore the players were not able to reach 110km total distance. It is a big part of our job to make sure that coaches are looking at the data in the correct context." – Participant 3** **"A negative of GPS is that it creates boundaries. For example, if someone says you should not do more than 2km of high-speed running a week and if the player does that in the first two days, do you not let the player do more? What if the player can genuinely handle that? Just because the data recommends a limit, you should not put a ceiling on there. Do we never have that shock factor? Do we never push players beyond their**		

limits at the appropriate moments? A massive risk to sports science is when data provides a ceiling and people do not want to go above that. Data is great for quantifying, understanding and developing but it shouldn't inhibit development." – Participant 5		
"Other methods that I'm aware of and would personally like to incorporate at the club is heart rate variability (monitoring the heart rate of players). An additional one could be attachments for football boots that monitor the velocity and movements of players feet relative to their bodies. This can record contacts on the ball, pressure and pushes off the ground, impacts and other movements. There are a few technologies out there that actively track the movements of players without physical GPS units on the players, but rather using cameras. The benefit of this is that they can track the ball relative to the player as well as the player's movements relative to their teammates and opponents. Other technologies that we would like to get involved with is tracking of lactate data to achieve lactate thresholds and monitor lactate levels." – Participant 2	Additional football technologies.	There are current technologies that provide a different perspective on football data analysis.

"There's more technology that I would like. A NordBord (calculates differences between the right and left side of the body) which measures the amount of hamstring activation." – Participant 3		
"Unfortunately, with technology, you cannot pick up on the personal or human aspect of how someone responds to the questions. Some things that a couple of articles have pointed out is that you can ask a question online, you can get GPS data, you can have players jumping up and down to determine neuromuscular fatigue but at the end of the day if you ask players how they are feeling and they give you an honest answer, that would give you a lot more information than all the gadgets used in monitoring programs."– Participant 4	Cons of technology.	Technology does not provide a personal connection with players.

Table 36 indicates that four themes were uncovered. GPS provides objective data and a means for technical staff to view immediate statistics from GPS units during training. This correlates with Morgans *et al.* (2014), who stated that reports from GPS data can be produced in real-time for the technical team to analyse. This allows the technical team to tweak training sessions to get optimal performance from footballers without overworking them. This correlates with Ehrmann *et al.* (2016), who states that GPS provides a way to balance training load and recovery by optimizing performance gain and minimizing the risk of OTS.

If technical teams are solely focused on the data from GPS units and do not allow footballers to be pushed further than their limits, this could hamper the development and improvement of players. The participants mentioned how there are current technologies that provide a different perspective on football data analysis. These technologies include devices for football boots that monitor the velocity and movements of players feet relative to their bodies, devices that track lactate data, cameras that can track players and NordBords. These technologies could be used together with existing technologies to further reduce the risk of OTS. Technology does not give you that personal connection with a player that may provide more insight into how a player is feeling.

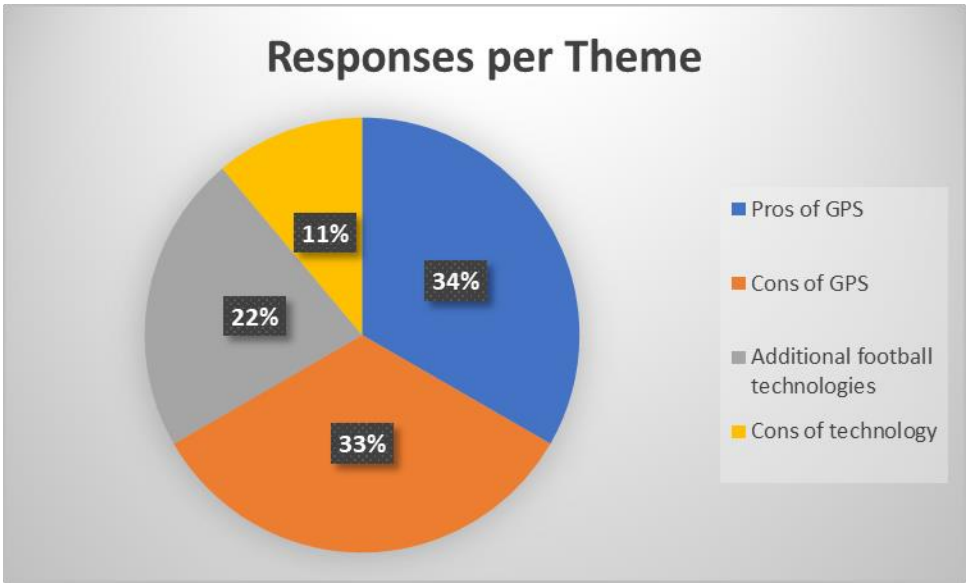


Figure 24: Interview question 5.6.1 Responses per Theme

Figure 24 shows **Theme 1: Pros of GPS** and **Theme 2: Cons of GPS** had the most responses.

5.6.1.1 Summary of findings for interview question 5.6.1

Table 37: Interview question 5.6.1 summary

The pros of GPS are the objective data that can be used against baseline data to determine whether players are improving as well as the immediacy of acquiring GPS data during training sessions which allows coaches to see if the desired outputs are being achieved instantaneously. The cons of GPS included coaches that base too much of their decision making on data alone and in that way end up stunting player growth.

5.6.2 How does the current technology help with overtraining? Please motivate.

This question aims to uncover how current technology assists in reducing the risk of OTS.

Table 38: Current Technology and OTS

Raw Data	Theme	Interpretation
"We like to achieve and create normative data for each player. This data is compared to performances at training and during match days. This not only helps us but also the players. The players have another perspective with which to judge their performances e.g. when they felt they had a very bad physical performance, we show them the objective data that shows they ran more than usual in some areas or underperformed in other areas. Not only does it allow us to create a completely different perspective, but it also allows us to narrow down the shortcomings of a player." – Participant 2 **"There's no golden bullet to OTS and it's quite diverse and broad. There are many different avenues and channels that influence OTS and that is where we look to collect information from. Different information sources give us the best possible understanding of the demands that the players must cope with. On the field, we use GPS to**	The role current technology has in reducing the risk of OTS.	Current technology allows baseline data to be created for both objective and subjective data. Every new set of collected data is then compared to this baseline data to flag anomalies.

quantify the external load placed on the players. We determine, set, and then manipulate the load according to what our desired outcomes are and where we want to be in terms of our loading schedule and loading pattern whether that is weekly, bi-weekly, monthly etc. It ensures that if we are loading, we are loading optimally and correctly and if we are de-loading, we are de-loading optimally and correctly. Our Athlete Monitoring System is more than just subjective data. It is a player's internal response to training, how difficult they thought the training was, their subjective rating of their fatigue, their subjective rating of their tiredness and their subjective rating of their emotional state. If there is any muscle soreness, players report this which then drives our decision-making process. Training load is a representation of the work completed. There are two main measures of training load. One is internal training load which is the individual's internal response to a stimulus and the other is external training load which is the amount of work completed." - Participant 4 **"Technology quantifies the current state of players using various metrics.**		

You are looking weekly, monthly, across your season and seeing that players need to peak in November and again in February or March when the back end of the season is approaching, and the title is up for grabs. If you can plan your season in a way where you have got peaks and troughs, adequate rest and recovery and adequate periods of hard work, you will avoid OTS because you've periodised in a way." – Participant 5		

Table 38 shows that one theme was uncovered. Current technology allows baseline data to be created for both objective and subjective data for each player. This correlates with Cardinale and Varley (2017), who state that the external load of each player should be monitored as many variables contribute to the risk of injury. Every new set of collected data is then compared to this baseline data to flag anomalies. The technical staff will then analyse this data further to determine the severity of these anomalies. If the data is showing that a player is heading towards OTS, the technical staff can intervene. This correlates with Cardinale and Varley (2017), who state that after analysing the data, the technical staff can create player-specific training programs. Objective data is looked at together with Subjective data to determine if player responses are in sync with the amount of work they have done. If not, those players will be monitored further.

5.6.2.1 Summary of findings for interview question 5.6.2

Table 39: Interview question 5.6.2 summary

Objective and Subjective data are analysed and compared to baseline data to find any outliers. Each player is looked at individually and interventions are made if the risk of OTS is increasing. Subjective responses should be in sync with Objective work done.

5.6.3 How can the current technology be improved to assist with overtraining? Please motivate.

This interview question aims to find out how current technology can be improved to lower the risk of OTS.

Table 40: Improving current technology

Raw Data	Theme	Interpretation
"Some sports scientists try to use too much technology but keeping things simpler is a lot easier because you don't want to overburden the footballer with all of these gadgets and have them believe that every single movement needs to be analysed."– Participant 1	The effect of too much technology on players.	Too much technology may make things too complex and could be stressful for players.
"A massive challenge, especially in South Africa is the application of GPS metrics and data in the sense that it takes a lot of time to analyse and process the data, especially for one sports scientist. This process of uploading, downloading and analysing should be simpler and more efficient." – Participant 2	Simplify the use of data.	The analyst should focus all their time on data analysis and not data processing.
"The club's data should stay confidential and that's very difficult because there is no guarantee that the data will not be leaked. There's a data security aspect to it." – Participant 2	Data Security.	Data analysis platforms should ensure the best security protocols are in place.
"A lot of companies offer their load monitoring formulae for GPS whereby they utilise the player's age, height, weight, and physical stats relative to	Club specific data solutions.	Each club should have its own tailor-made data solutions.

past performances. The problem with this is that each company has its own formula which makes the validity of the formula questionable."– Participant 2 **"The biggest frustration is that we have this wealth of data and we don't have a system that does its justice. Some of these companies are asking for our data so they can provide insight but there is little freedom in terms of personalisation. When you use a platform from a third-party company, it is never exactly how you would prefer it. There may be something new we want to implement and for the technology professionals, it takes months of development. We have not got those resources. We need to work towards that." – Participant 5**		
"A lot of the GPS companies are hoarding their information and results and aren't working with one another to achieve something a bit more universal and accessible." – Participant 2	GPS data collaboration.	There needs to be some sort of collaboration with GPS research and development.
"A better way to measure emotional stress and internal stress. People have looked at using HR variability to measure internal training status and brainwaves have been analysed to	New Technology Requirements.	There is a need for a way to measure internal stress such as emotional stress, a system that combines

determine stress levels. Having a better way to quantify internal stress or internal fatigue is probably your biggest go-to at the moment." – Participant 4 **"We have to get this data and make a call. The data comes through and the system may say "The player should not train" or "The player is at risk of overtraining", but the player may say "No, I am going to play, there's no reason why I shouldn't play". There is a risk that the player will get injured. It comes down to you making a human decision on whether the risk is worth taking." – Participant 5**		subjective and objective data and generates results like player readiness etc.
"The most frustrating thing would be manpower. I was trying to do all of this on my own as well as plan the different parts of training for the first two years in charge of this team, which is a very difficult job for one person. I had to fight to get another sports scientist involved and luckily with the backing of the coach we were able to do that. It is now a lot more efficient and we can look at a lot more. Some teams don't value the data as highly or don't have the manpower to do as much as they could be doing with the data." – Participant 3	Manpower is required to unlock the potential of data.	Specialist data analysts would be able to gain more insight from the vast data available.

“We have all this data. We have many years’ worth of data. We are picking up the obvious trends and the things that stand out to us. I have got 20 players and 40000 metrics I look at every week. When you look at all this information, some things stand out, some things don’t and sometimes the stuff that doesn’t, you need it to as it’s important and it may show you a picture before something happens. It’s easy enough when someone gets injured and you’re looking back, and you realise you didn’t pick up on them doing X amount of sprinting distance on consecutive days. If you are looking at 20 players and 40000 metrics a week, you are going to miss stuff. It is that human error that creates the need for a Data Analyst/Data Scientist. We’re introducing people into the sport that are better than us with computers and analytics to help us fully understand the dataset.” – Participant 5		

Seven themes were uncovered as shown in Table 40. Too much technology may make things too complex. This correlates with Cardinale and Varley (2017), who state that some teams do not implement player monitoring systems as they believe these systems will not have a significant impact on improving training regimes. This could potentially cause extra stress for players. Choosing one or two technologies may be a better approach as analysis can be focused on the data acquired from these technologies. The processing of data

should be a seamless process. The analyst should focus all their time on the actual analysis of the data, not the processing.

Using third parties to process and analyse data may pose a security risk. If vital data is leaked, the football club may lose its competitive edge. Data analysis platforms should ensure the best security protocols are in place. Each club should have its own tailor-made data solutions to create metrics with ease, analyse data in a way that suits them and have algorithms built according to how their data looks. There needs to be some sort of collaboration on GPS research and development.

There is a need for a way to measure internal stress such as emotional stress. This correlates with (Cardinale and Varley, 2017), who state that internal load monitoring provides insight into how to improve player-specific training programs to produce the best results. There is also a need for a system that combines subjective and objective data and generates results like player readiness etc. Football clubs should consider expanding teams, especially in the data department. This would prove beneficial as specialist data analysts would be able to gain more insight from the vast data available.

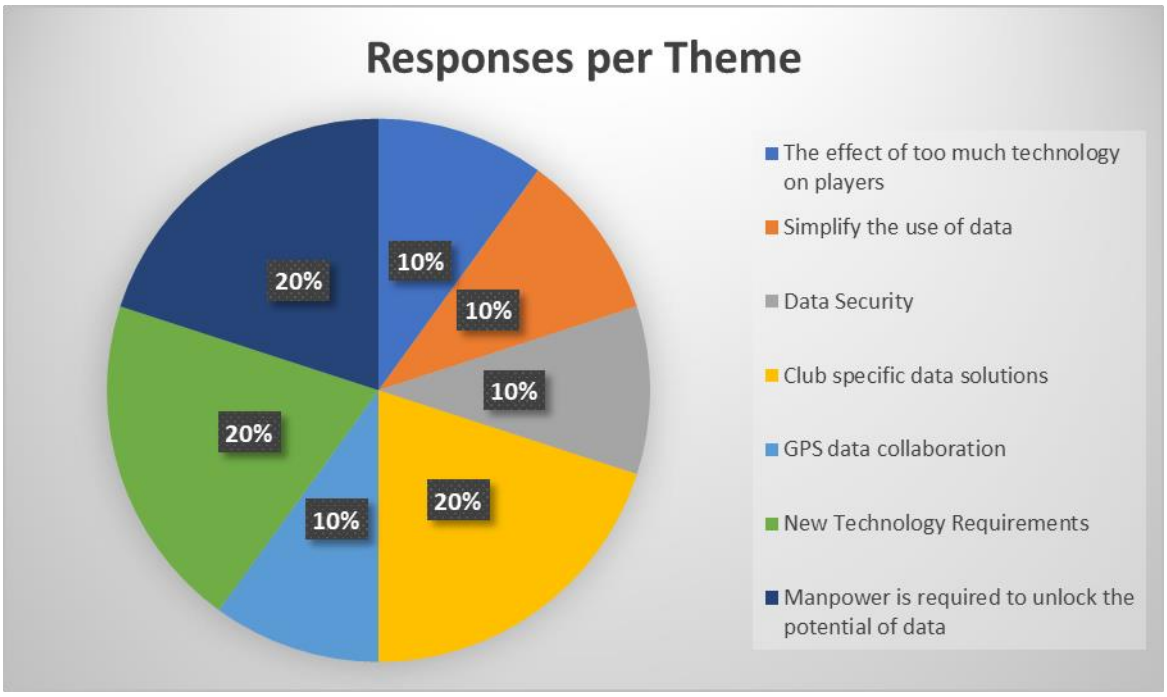


Figure 25: Interview question 5.6.3 Responses per Theme

Figure 25 shows that **Theme 4: Club specific data solutions**, **Theme 6: New Technology Requirements** and **Theme 7: Manpower is required to unlock the potential of data** had the most responses.

5.6.3.1 Summary of findings for interview question 5.6.3

Table 41: Interview question 5.6.3 summary

Too much technology can cause extra stress for players. Choosing one or two technologies may be a better approach as analysis can be focused on the data acquired from these technologies. Specialist data professionals should be hired by football clubs to build club-specific data solutions which will then allow the technical staff to focus more time on analysing data and not processing data. There is a need for a way to measure internal stress such as emotional stress and a need for a system that combines subjective and objective data.

5.6.4 Please describe how training data is used and how it can play a role in preventing overtraining syndrome?

This question aims to uncover how training data is used to prevent OTS.

Table 42: Training Data

Raw Data	Theme	Interpretation
"We have two data analysts, one for video analysis (he also fills the role of an assistant coach), and then we have the physical performance analyst, being myself, however, I am also the conditioning coach. Ideally one would employ a person purely for data analysis, however financial constraints and time constraints are a factor." – Participant 2	Shared responsibilities.	Currently, the sports scientist also plays the role of a data analyst.

"Luckily, I'm quite handy with Excel so I create the elaborate databases that we use throughout the club in the first team and down through the academy." – Participant 5		
"Luckily, each company does offer a platform that helps us portray the data simply, which is a massive benefit. We are always in communication with them if there are other metrics we would like to see or if we would like to see metrics relative to one another. I have a basic knowledge of different programming languages. It is specific to what I am trying to achieve as a physical performance analyst with the data I work with. I use Microsoft Excel and Python." – Participant 2	Data Analysis Tools.	Third-party data analysis tools are used as well as in-house developed tools.
"The responses to technology I've received in the past can range from evasive, whereby a player now finds that he is being exposed by objective data and does not buy into the technology, towards curiosity, whereby the players have a genuine interest in the data and feel that it is a benefit to their performances. Another response I have received is complete ignorance of the data. I found with younger players I was able to educate them over time on the benefits of technology. The portrayal of the data	Players' response to technology.	The response players have to the use of technology in football varies. Some players prefer it whereas some players do not.

to the players plays a massive role, so there is an educational aspect to it. Luckily, a lot of experienced players have had access to technology over the past 5-10 years and are very familiar with it. One bad experience from one bad sports scientist who overvalued a specific data metric in the sense that they overemphasised its importance may have had a bad effect on a player. We need to keep reminding the players that it is only a perspective and an opinion among many within the holistic approach to their performance." – Participant 2		
"We will try and find surveillance techniques that will enhance our practice. One example is players going near their max speed every four days to avoid hamstring injuries. All the data goes into a big Excel file and it shows you they have hit that target. If they did not hit that target, the next day you go out and try again to reach the target. If they are not hitting targets, then why not? Is this player fatigued? Does this player have OTS? Is he carrying an injury? Why are we not getting the results we are trying to achieve? High-speed running which we class at the club as anything above 5.5m/s, total distance covered and maximum speed are the most	Analysis of training data.	Training data is analysed by the Sports Scientist to determine if any players are reaching OTS.

important metrics. If you cover too much distance during your training week, you are going to overtrain much quicker." – Participant 5		

Table 42 shows the four uncovered themes. Currently, the sports scientist also plays the role of a data analyst. This is not ideal as time is lost by performing data-related tasks. Third-party data analysis tools are used as well as in-house developed tools using Microsoft Excel. Some players buy into the idea of football technology whereas some players do not, possibly due to previous bad experiences. Participant 5 mentions that during the analysis of training data, the sports scientist will ask questions such as:

- Why is the player not hitting their targets?
- Is the player fatigued?
- Does this player have OTS?
- Is the player carrying an injury?
- Why are we not getting the results we are trying to achieve?

From asking these questions, informed decisions can be made to either intervene in potential OTS cases or start the recovery process for players who have already acquired OTS.

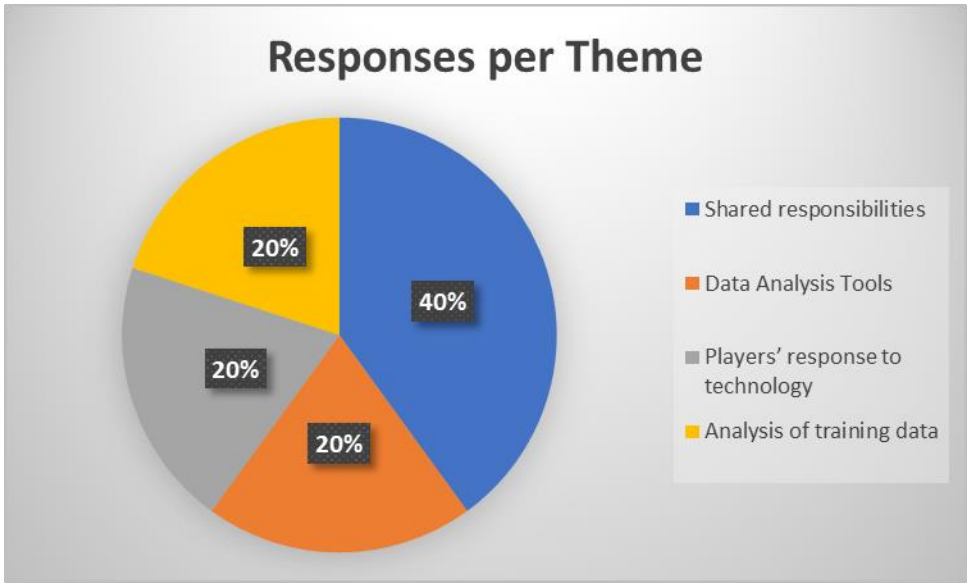


Figure 26: Interview question 5.6.4 Responses per Theme

Figure 26: shows that **Theme 1: Shared responsibilities** had the most responses.

5.6.4.1 Summary of findings for interview question 5.6.4

Table 43: Interview question 5.6.4 summary

Sports scientists also play the role of Data Analysts. Microsoft Excel is a popular tool used by clubs for data analysis. The Sports Scientist uses the training data to uncover whether players are performing adequately, are in a good physical condition or are on the verge of OTS.

5.6.5 What could be developed to monitor and control overtraining syndrome? Please motivate.

This interview question aims to identify possible solutions that could be developed to reduce OTS.

Table 44: Potential Technological Solutions

Raw Data	Theme	Interpretation
"With the use of technology, you're looking for something that follows an	Human interaction is more vital than	Human interaction with players is still seen as

almost predictable algorithm. When working with an athlete, you must remember that they are a human first and an athlete second. With that human aspect, you can have someone that is on top of the world one day and then down in the dumps the next day. It is difficult to say "I'm going to have a look at how you're running and then I'm going to tell you if you're overtraining" because some athletes are natural competitors, so if they are down in the dumps they can still perform well and you wouldn't be able to notice that they aren't coping with whatever's happening. It is very difficult to try and use technology to pick out the human context of monitoring. Technology should only be used to guide you so you can have a clear and well planned out structure for your training week. Based on what the technology is saying you can decide whether you need to make drastic changes or minor tweaks. If you see that a player is not coping but the technology indicated they are coping, you'd have to follow what you see and through communication, you can acquire a lot more information compared to technology." – Participant 1	technology.	more important than data from technology.
"What can be developed and	Understanding	The coaching staff and

improved is the social relationship between technology, player and coaching staff. You need buy-in from all three so that the effective application of the technology is present, the effective retrieval of the technology is present as well as the validity and reliability of data. Currently, there is a bit of miscommunication and it may lead to flagging false positives and false negatives." – Participant 2	amongst coaching staff, players, and technology.	players need to be fully educated on the technology used and how this fits in with the philosophy of the football club. The coaching staff and players need to be on the same page in terms of what is the desired outcomes of using technology.
"No one taught me GPS technology in my undergraduate or postgraduate year. I had to teach myself through online courses and YouTube tutorials. Companies that do provide GPS technology are lacking the educational aspect for sports scientists in terms of the application of the technology. As sports scientists, we are actively searching for platforms to learn from and we do have access to them via webinars and YouTube, however, it is not in layman's terms. The coach must familiarise themselves with the technology in coaching courses. These educational courses are not available in South Africa. I have done a license in Germany and they are only touching on it now for the coaches. For the players themselves,	Technology education.	Sports Scientists must teach themselves how to use the technology.

the lack of technology in academy systems due to high financial costs also creates an un-familiarised approach when they do enter a professional environment." – Participant 2		
"We can improve on the simplicity in such a complex and dynamic data system. When I retrieve data from a training session or match day, I am bombarded with up to 100000 data points. The ability to make sense of that can be very difficult and at some point, feels like a maze."– Participant 2	Simplicity is imperative.	User experience needs to be taken into account when developing analytical tools.
"Muscle oxygen saturation parameters are now also being included in the higher end sports watches and that will give you a good idea of what your muscle oxygen level is. It is important to have proper monitoring protocols in place so you can focus on important metrics instead of saying you can measure 67 parameters but only three are relevant to how a player is responding to training. HR reserve, resting heart rate, heart rate and neuromuscular fatigue are the most important metrics to look at." – Participant 1 **"Distance, sprint distance from a specific speed, high-intensity sprint**	Information System Ideas.	The general response from participants is that a holistic approach is required. The information system should integrate all sources of data such as objective and subjective and use this data to generate outcomes for the technical staff.

distance above 30km/h, meters per minute (relative distance) and distances within specific velocity zones (for both accelerations and decelerations) are the most important metrics to look at. Systems are more useful when you compare data relative to the player's previous performances, relative to the performances of other players in the session as well as relative to long-term performances."– Participant 2 **"An app that houses your subjective and objective data in one and gives you an athlete readiness score. It should consider all of their GPS baselines, what they hit the previous day, their RPE score for the previous day and give you that red light "athlete can't push today" or green light "athlete can push today". The app should combine and analyse objective and subjective data so that you can make quicker informed decisions and spend more time planning the actual training sessions. Another big thing would be technology in the recovery processes. I think a lot of the technology is used to monitor training and gauge whether a player is spiking or is in a safe zone. I do not know how much technology**		

has been implemented into recovery. Recovery is a very big part of preventing the player from overtraining. For recovery, we have just got the wellness questionnaire data and Rate of Perceived Freshness (RPF) scores that players fill in. This is why I like combining subjective and objective data e.g. if players are hitting 60% of their baseline, but giving an 8/10 RPE, it raises a flag. This shows that the player is not fully recovered and is not able to achieve parameters they were achieving before the injury." – Participant 3 **"Our biggest task is to quantify demands, the response to demands or the response to a stimulus. We are fine with measuring what the players do. We need to improve in measuring how the players respond to what they do in terms of their subjective responses to stress and seeing those adaptations more frequently such as cognitive load and cognitive fatigue. When working with big squads, time and efficiency are two very important factors that you need to consider. Whatever you do, it needs to be quick and scalable." – Participant 4** **"We know GPS can figure out the**		

physical aspect. If we had better software and people that understood this software, we could get the tactical aspect. If you could get that GPS unit inside the boot so it was less invasive or under the soles of the feet where it could measure forces going through, a whole new dimension of calculations could be created using forces on the sensor, forces on the ball and forces received. If you could measure forces going through the knees, how much force you are absorbing and how much force you're exerting, you could get a system where we have physical data, technical data, tactical data and the relationships between them all. The very best clubs are combining their tactical, technical, and physical data in a way that is getting them great results. When you're bringing in new players, you understand their shortfalls and their strengths, so you don't have to do more than what's required with that player to integrate them into your squad. The four elements that we look at are physical, technical, tactical and psychological. It is about integrating all four of these elements into one platform as they all relate."– Participant 5		

Five themes were uncovered as seen in Table 44. Some professionals feel that human interaction with players is more important than data from technology. The coaching staff and players need to be fully educated on the technology used and how this fits in with the philosophy of the football club. The coaching staff and players need to be on the same page in terms of what is the desired outcomes of using technology. Sports Scientists must teach themselves how to use the technology. User experience needs to be considered when developing analytical tools.

Some of the most valuable metrics that should be included in a player monitoring information system are:

- **Heart rate reserve** - The difference between the resting heart rate and the measured heart rate (Dr Ananya Mandal, 2009)
- **Resting heart rate** - The rate at which the heart beats while at complete rest
- **Heart rate** - The rate at which the heart beats (Burngardner, 2019)
- **Neuromuscular fatigue** – A decrease in a muscle's ability to produce a force or power as a result of exercise (Boyas and Guével, 2011)
- **Distance** – The length between two points
- **Sprint distance from a specific speed** – The total distance covered while sprinting from a certain speed
- **High-intensity sprint distance above 30km/h** – The total distance covered while sprinting above 30km/h
- **Meters per minute (Relative distance)** – The total number of meters covered in a single minute
- **Distances within specific velocity zones** – The total distance covered at a velocity within a specified velocity zone
- **Cognitive load** – The information capacity of the working memory (Tools)
- **Cognitive fatigue** – The perceived shortage of mental power (Wylie *et al.*, 2017)

Participant 3 mentions how having an app that combines and analyses objective and subjective data would be extremely beneficial. Participant 4 mentions the need to be able to measure the players' subjective responses to stress, such as cognitive load and cognitive fatigue. Participant 5 mentions that the four elements namely physical, technical,

tactical and psychological (subjective) should be integrated into one platform. It is evident that the general response from participants is that the information system should integrate all sources of data like objective and subjective and use this data to generate suggestions and ideas for technical staff. The ideal Player Monitoring Information System would consist of the following features:

- Data from the four elements of football (physical, technical, tactical, and psychological
- Recovery Analytics
- Integration between the Objective and Subjective data to provide holistic player analysis

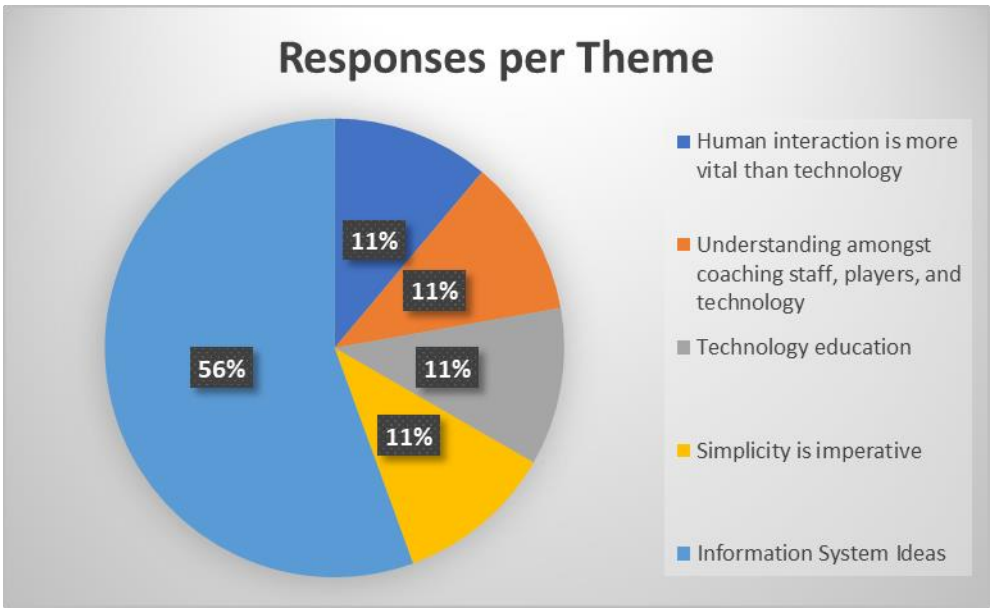


Figure 27: Interview question 5.6.5 Responses per Theme

Figure 27: shows that **Theme 5: Information System Ideas** had the most responses (50%).

5.6.5.1 Summary of findings for interview question 5.6.5

Table 45: Interview question 5.6.5 summary

Some coaches still feel that human interaction is more important than data. Technical staff and players should be educated on how technology fits in with the philosophy and goals of the football club, so everyone is on the same page. There is a current need for player monitoring systems that combine subjective and objective data to provide new perspectives into the physical and mental state of players.

5.7 PLAYER MONITORING INFORMATION SYSTEM

The main finding from this research study is that there is a need to create a holistic view of a football player by integrating subjective (mental) and objective (physical) data. Subjective data is the player's internal responses to training e.g. their perceived difficulty of a training session. Objective data comes from devices used by players that track the player's physical performance metrics such as sprint speed and heart rate. Currently, most technical teams compare subjective and objective data to try and find correlations between training load and how the athlete responds to this training load. This is done mainly by using GPS and HR data (Objective data) and Player Questionnaires (Subjective data) to gain insight. One of the biggest challenges of this is that these two datasets live on different platforms or are not properly integrated. This causes teams to lose valuable insight.

Subjective and Objective data will provide data on two out of the four dimensions of football. The other two dimensions are Tactical and Technical. The four dimensions surrounding a footballer are shown in **Error! Reference source not found.**. Tactical data is provided by the coaching staff and Technical data will come from Video Analysis. An ideal solution would encompass all four dimensions of football.

Figure 28: The four dimensions of footballer well-being

As discussed in section 3, the TPC theory was chosen due to the strong holistic approach with which the theory utilises to assess the performance of a technology. The TPC theory was utilised to design the information system in Figure 29. The designing process is explained below:

Aim	Utilisation is incorporated into the TTF model to determine the influence of factors such as social norms and beliefs on performance – **The participants believed that there is a need to integrate objective and subjective player data**
Inputs	Task Characteristics – **The technical staff require an information system to view integrated objective and subjective player data** Technology Characteristics – **Data is fed into the information system via internal and external data sources. Some of these data sources are currently used by football teams e.g. GPS devices** Individual Characteristics – **The technical staff are well equipped with the technical skills to navigate technical systems**

	Precursors of Utilisation and Utilisation – **The technical teams currently believe in the importance of technology in sport**
Outputs	Performance - **Measurement of the success rate of using a certain technology**

The information system in Figure 29: describes a high-level potential solution for integrating subjective, objective, tactical and technical data into one platform.

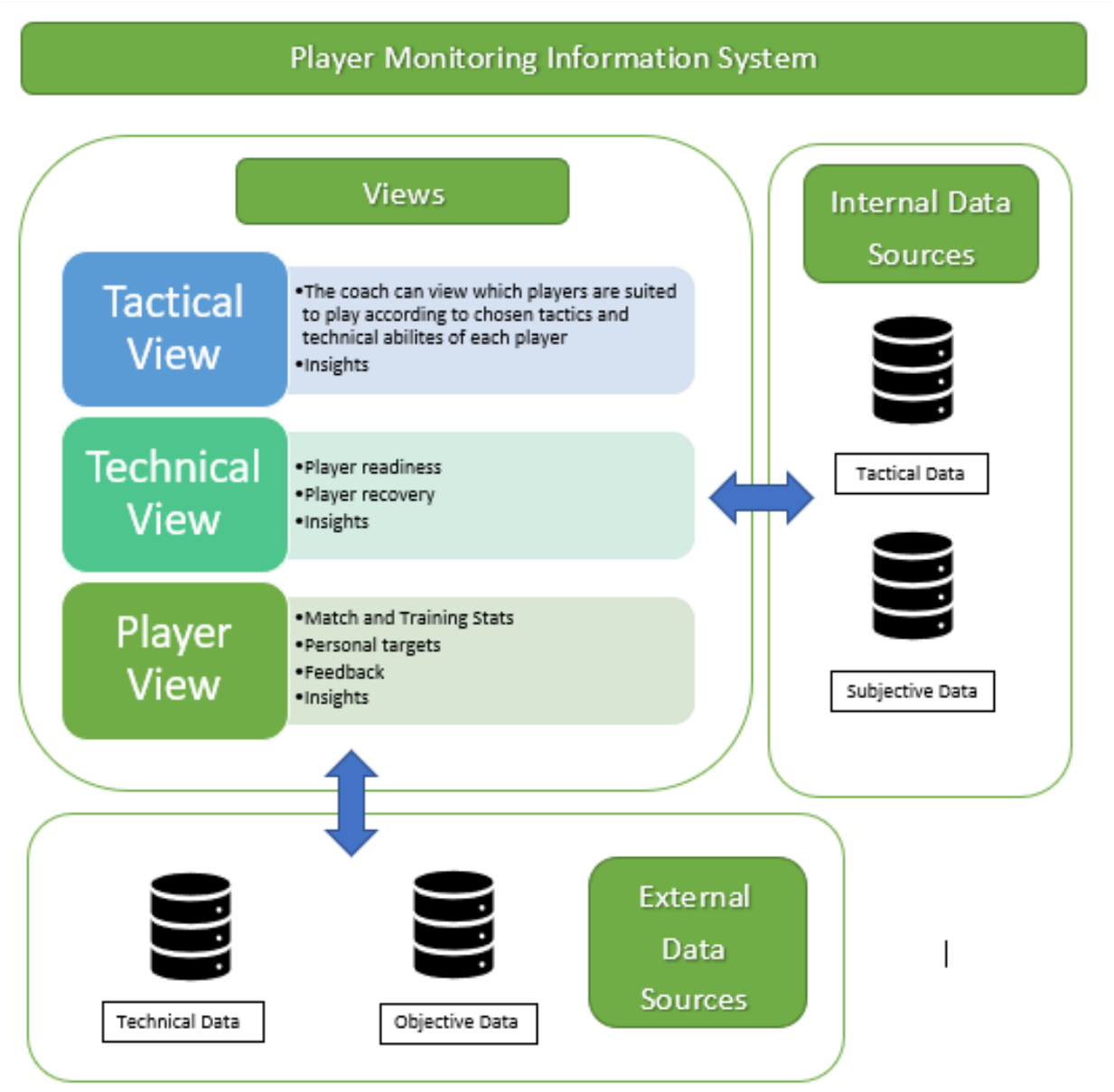


Figure 29: Player Monitoring Information System

The Player Monitoring Information System shown in Figure 29: is discussed in detail below. This information system is only a proposed solution and has not been tested.

5.7.1 Views

The user interface of the monitoring system will be composed of three different views. Each view will be access-controlled according to specific user rights. These views are further discussed in the sections below.

5.7.1.1 Tactical

A view for coaches to input tactical data, to view players that match certain tactics as well as to view system-generated/user-created insights. Algorithms will use objective data, technical data, and tactical data to bring forward players that match selected tactics.

5.7.1.2 Technical

A view for the technical team to view various flags such as player readiness, player recovery status as well as system-generated/user-created insights. Algorithms will use subjective data, objective data, and technical data to provide insight into the condition and performance of players. This view will provide insights into why players are not hitting targets, possible fatigue, whether players have an increased risk of OTS, the possibility of injuries and why the training staff are not achieving their desired results in terms of player performance.

5.7.1.3 Player

A view for the player to submit their subjective scores, view their own match/training stats, track their targets, provide feedback to the coach/technical staff and view system-generated/user-created insights. Algorithms will use Objective and Technical data to provide insight into personal performances.

5.7.2 External Data Sources

- **Technical Data**: Video Analysis data
- **Objective Data**: GPS and HR data

5.7.3 Internal Data Sources

- **Tactical Data**: Provided by the coach through their Tactical View
- **Subjective Data**: Provided by the player through their Player View

5.7.4 Supporting Technologies

Various forms of technology will contribute to the seamless performance of the Player Monitoring Information System. These technologies will be discussed for each block of this information system.

5.7.4.1 Views

The Views block is the frontend[14] of the system which will run on an application. This application can be developed for use on various operating systems. Mobile operating systems would include Android[15] or iOS[16]. Desktop operating systems would include Windows[17] or macOS[18]. Information is displayed using the data stored in the data storage facility mentioned in section 5.7.4.2. Various algorithms will exist in the backend to process the data and calculate the necessary metrics. Various members of the football club will use this interface to perform the tasks mentioned in section 5.7.1. The application will require an internet connection for full functionality.

5.7.4.2 Internal Data Sources

Internal data will come from the coach and players. The coach and players will input their data by using the application mentioned in section 5.7.4.1. This data is stored in a cloud-based data storage facility e.g. Google Cloud Platform. A cloud-based solution provides advantages such as maintainability of resources, reliability, cost-saving, performance and security.

[14] The part of a software program that the user interacts with. Source: (Techterms)
[15] Mobile operating system developed by Google. Source: (Techterms)
[16] Mobile operating system developed by Apple. Source: (Techterms)
[17] Operating system developed by Microsoft. Source: (Techterms)
[18] Operating system developed by Apple. Source: (Techterms)

5.7.4.3 External Data Sources

External data comes from devices used during training and matches. Examples of this data are video footage, GPS and HR data. GPS and HR data could be acquired from devices such as GPS vests or HR chest straps. Video footage comes from video cameras set up at training. GPS and HR data is stored in real-time into the respective device manufacturer's servers. The player monitoring system would access the data on these servers via API[19] integration. Video footage can be live-streamed to the data storage facility mentioned in section 5.7.4.2. The monitoring system can then acquire video footage from this data storage facility. A data flow diagram of the player monitoring system is shown in Figure 30: .

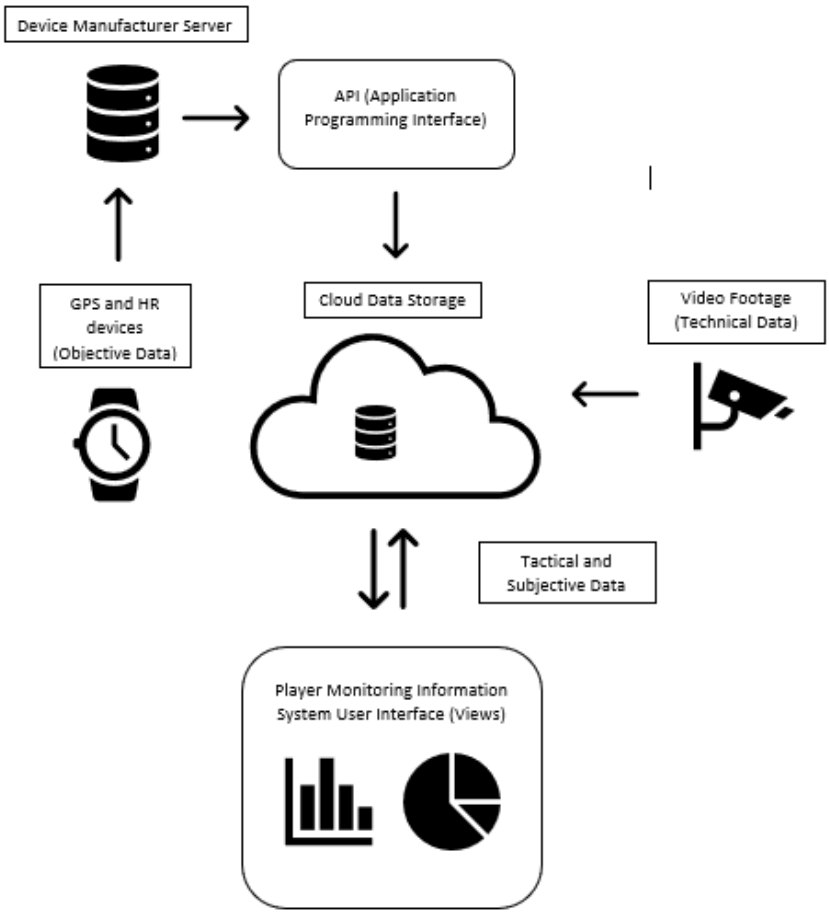


Figure 30: Data Flow Diagram

[19] Application Programming Interface enables the transmission of data between two software systems. Source: (altexsoft, 2019)

Several metrics from the data sources shown in Figure 30: already exist, but more research is required to determine how these metrics can be integrated to present a holistic view of a football player's wellbeing with the goal of preventing OTS.

5.8 CONCLUSION

During Chapter 5, the responses to the interview questions that were formulated using the research objectives were discussed. A Player Monitoring Information System was introduced and described in section 5.7. The insights from this chapter are discussed in Table 46.

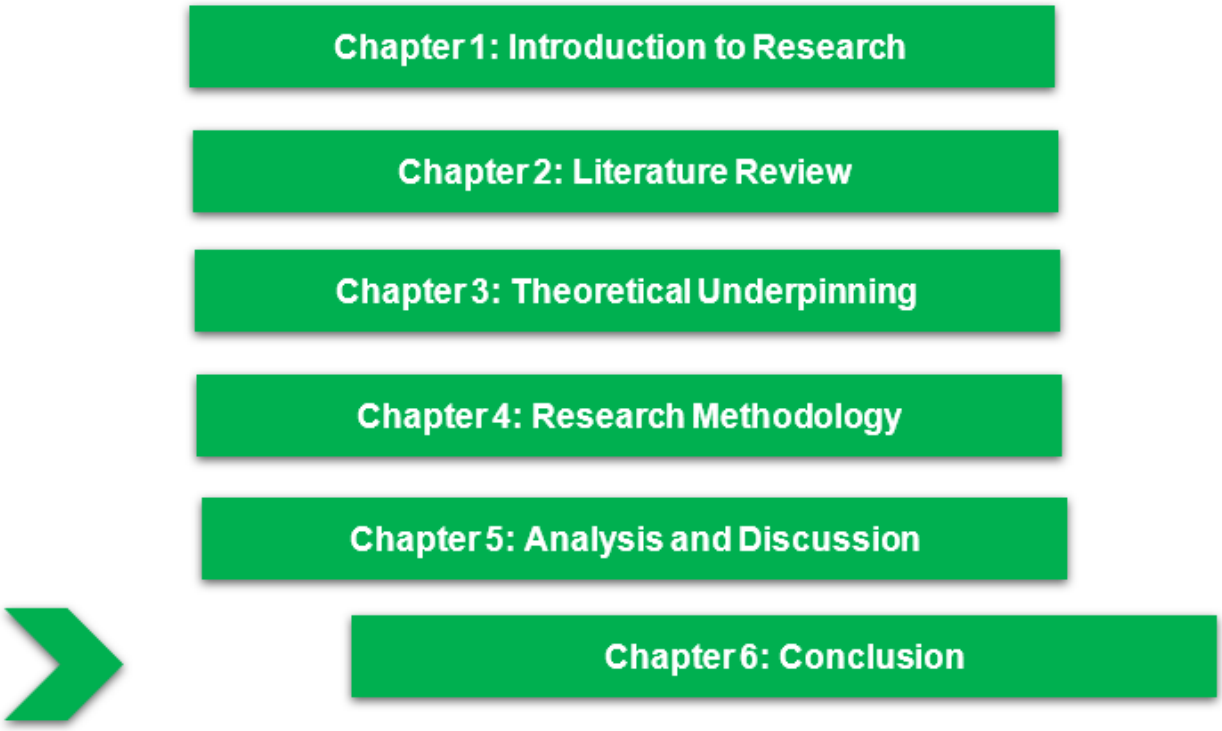
Table 46: Summary of Research findings

Previous Cases of OTS	• There are contrasting views around whether OTS is linked to Player Age and whether OTS is linked to Player Position. • Previous cases of OTS had shown non-contact as well as contact injuries. • The most common injury types were soft tissue and non-contact injuries. • A player in good physical condition was less at risk of OTS.
Non-physical related OTS factors	• Player personal lifestyle relates to OTS. • A personal lifestyle that hampers the sleeping patterns and nutrition of a player will cause poor recovery which will lead to OTS.
Current training methods	• Two training models are used, namely Development and Performance and Tactical Periodisation. • High attention is also given to recovery with the most important recovery methods being sleep and diet. • Objective (physical) and subjective (mental)

	data are used by the technical staff to build a profile for each player which contains baseline values for each metric. • The latest performances are measured according to these baselines to flag any outliers. • The technical staff can use these baseline player profiles to manage the physical and mental conditions of the players.
Current training technology	• Some coaches still feel that human interaction is more important than data. • The most popular technologies used for physical monitoring are GPS, HR, and Video Analysis. • Technology allows players to submit anonymous information without feeling victimised. • Technical staff and players should be educated on how technology fits in with the philosophy and goals of the football club, so everyone is on the same page. • There is a current need for player monitoring systems that combine subjective and objective data to provide new perspectives into the physical and mental state of players.

Chapter 5 provided a detailed discussion of the findings from the research investigation. The main finding from this research study is that there is a need to create a holistic view of a football player by integrating subjective (mental) and objective (physical) data. The Player Monitoring Information System depicted in Figure 29: shows how a holistic view can be created by integrating various data sources on a single information system. The conclusion of the research study will be presented in Chapter 6.

6 CONCLUSION



6.1 INTRODUCTION

In the previous chapter, data collected from interviews were analysed and discussed. During this chapter, the researcher will discuss the findings from the research study. The contribution made to the body of knowledge and recommendations for future investigations will also be discussed during this chapter.

6.2 ADDRESSING RESEARCH QUESTIONS

The main research objective was defined in Chapter 1 as:

"To investigate the adoption of technology for the measurement and management of factors related to the risk of overtraining syndrome in football."

The main research question was then defined in Chapter 1 as:

“How can technology be utilised in football to reduce the risk of overtraining syndrome?”

The following **sub-research objectives** were then defined:

1. To investigate previous cases of overtraining syndrome and their underlying reasons.
2. To determine all non-physical related contributing factors to overtraining syndrome.
3. To understand the current training methods and recovery processes utilised in modern-day professional football teams.
4. To identify and analyse the current training technology encompassing a football player.

To answer these sub-research objectives, the following **sub-research questions** were defined:

1. What are the underlying causes of previous cases of overtraining syndrome and can any similarities/themes be uncovered?
2. What are all the non-physical related factors contributing to overtraining syndrome in football players?
3. What are the current training methods and recovery processes of footballers and how do they influence the player’s risk of overtraining syndrome?
4. What current training technologies are used by football players and how are these technologies used to address overtraining syndrome?

Starting with these sub-research questions, the researcher would be able to answer the main research question. The following sections discuss findings from the investigation which answer each sub-research question.

6.2.1 What are the underlying causes of previous cases of overtraining syndrome and can any similarities/themes be uncovered?

This sub-research question was formulated to gain insight into previous cases of OTS and to uncover whether there were any similarities amongst previous cases.

According to academic literature, in previous cases of OTS, players have displayed various symptoms. These symptoms include fatigue, performance decline, negative attitude towards training and muscle and joint pain, among others. Possible triggers of OTS included monotony of training, increasing the amount of training without increasing the amount of recovery time, poor diet, and personal emotional problems, among others. The academic literature also mentioned how most OTS injuries occurred in the lower leg areas such as the knees and ankles, although some literature did mention injuries in other areas such as hamstring strains, calf strains and groin strains. There were differing ideas on when these injuries took place. Some literature mentioned that these injuries mainly took place during training sessions in the preseason period as training is more intense during the preseason as compared to the competitive season. Other literature mentioned that most of these injuries took place during the competitive season.

The research investigation discussed how previous cases of OTS were caused by poor rest or recovery, training too much, training too frequently or training too much too frequently. The most common symptom of OTS was a decrease or plateau in player performance levels. The research investigation uncovered that OTS is linked to a player's age, but not linked to their playing position. The most common injuries were soft tissue and non-contact injuries. It was seen that a player with a good physical condition was less at risk of OTS.

There were correlations between the academic literature and the research investigation. Both the academic literature and the research investigation agreed that increasing the training load without increasing the resting period will have a negative effect on players. It was also agreed that a decrease or plateau in player performance is seen as a symptom of OTS. There were also contrasting views. The academic literature suggested that OTS is linked to player position whereas the research investigation suggested that OTS is not linked to player position.

6.2.2 What are all the non-physical related factors contributing to overtraining syndrome in football players?

This sub-research question was formulated to gain insight into factors contributing to OTS that are unrelated to training.

The academic literature discussed how football players are humans at the end of the day and will experience human-related problems. These problems can affect the emotional and mental state of the player, thus increasing the player's risk of OTS. The risk of OTS can also be due to the characteristics of a player. A player can be a natural perfectionist. However, the continual desire to improve one's performance can lead to OTS. The academic literature also discussed how an increased number of competitive matches causes increased muscle soreness and reduces recovery time, both of which can increase the risk of OTS. It is stated in the literature that sleep is an essential part of muscle growth and recovery. When a player experiences interruption in sleeping patterns, their risk of OTS is increased. Football players can also be stressed due to various reasons. Stress releases cortisol in the body which negatively affects the mind and body, thus negatively affecting performance.

The research investigation discussed how a player's social life, family life and educational commitments can affect their mental health, thus increasing their risk of OTS. The idea of player form was also discussed. The investigation showed that the amount of work a player puts in is independent of their form and a player's form is adversely affected by OTS. It was seen that players who lose recovery time due to social activities which result in poor sleep, poor recovery and poor nutrition have an increased risk of OTS.

There were correlations between the academic literature and the research investigation. It was agreed that if a player's sleeping patterns were disrupted for whatever reason, their risk of OTS would increase. It was seen that stress caused by personal factors such as social life, family life and educational commitments can also increase a player's risk of OTS.

6.2.3 What are the current training methods and recovery processes of footballers and how do they influence the player's risk of overtraining syndrome?

This research question was formulated to gain insight into current training methods and recovery processes of football clubs and how they contribute to a player's risk of OTS.

The academic literature discussed how training load responses are used to tailor training programs. The topic of training load has become a popular research area as technical teams continually aim to increase player performance and prevent OTS. Training load can be broken up into external load, which is the physical work done by the player and internal load, which is the impact on the player's physiological systems. The academic research discussed the importance of utilising training methods that improve the strength and flexibility of the player, which in turn improves their passing and shooting. Plyometric training is used to increase a player's explosiveness and speed. The Periodisation framework was discussed which entails varying the training load by varying the volume, intensity, or frequency of training. It was also discussed that training should be player-specific as each player reacts differently to different training methods. Training drills are created according to various player-positional characteristics such as playing position, pitch location, combination-play, and possession status.

The research investigation discussed two training models currently used by football clubs. The first one being Development and Performance and the second one being Tactical Periodisation. Various recovery methods were also discussed, and it was found that diet and sleep are the most important. The research investigation showed that GPS, HR, and Video Analysis are currently the three most popular technologies used by football clubs. It was seen that subjective monitoring is vital in player management. Various data tools are used to compare results to baseline data for each player. From this analysis, technical staff can plan training and recovery sessions. Objective data provide reliable information about physical performance and physical condition.

There were correlations between the academic literature and the research investigation. It was agreed that the Tactical Periodisation Model is a popular training model used by football clubs. It was agreed that training should be player-specific. This is done by analysing data for each player.

6.2.4 What current training technologies are used by football players and how are these technologies used to address overtraining syndrome?

This research question was formulated to gain insight into what current football technology is utilised, the benefits of this technology as well as how this technology can be improved to address OTS.

The academic literature discussed the following technologies currently used in football:

- Heart Rate Monitoring
- Virtual Reality
- GPS
- Drone technology
- Electromyographic (EMG) Sensors
- Video Analysis

Heart Rate monitors using chest straps were seen to have more reliable results as compared to wrist-based HR devices. Virtual Reality improves the player's reactions and decision making; however, the cost of these systems remain an obstacle. GPS devices provide baseline objective data for each player which allows the technical team to track improvements in performance levels. GPS also provides immediate access to training data which allows technical staff to tweak training programmes accordingly. Drone Technology provides coaches with new viewing angles which provide new perspectives into the various movements of the players as well as the team. Video Analysis is used by the coaching staff to analyse various performance indicators for the team as well as the players. Video Analysis can also be used to improve player reactions and decision making, however, its 2D nature is a disadvantage when compared with Virtual Reality systems. Video Analysis focuses more on the technical aspect of football.

The research investigation discussed how objective GPS data can be used to create baseline data from which each new performance will be compared to. The immediacy of acquiring GPS data during training sessions was also seen as a benefit as technical staff can tweak training sessions accordingly. The research investigation also showed that

coaches should not place too much importance on objective data as that may create ceilings that stunt player growth. It was seen that subjective data is used with objective data to flag outliers for each player. Subjective responses should be in line with objective work done. It was seen that too much technology encompassing a player may become stressful. Specialist data professionals should be hired to build and maintain club-specific data solutions, as currently, many sports scientists play the role of a data analyst as well. This will allow the technical staff to focus more on analysing data and not processing data. These specialists would have the skills to unlock more insight from the available data. The research investigation uncovered the current need for a player monitoring information system that combines subjective and objective data to provide a holistic overview of each player's physical and mental wellbeing as well as provide insight into how the recovery process for each player should be handled.

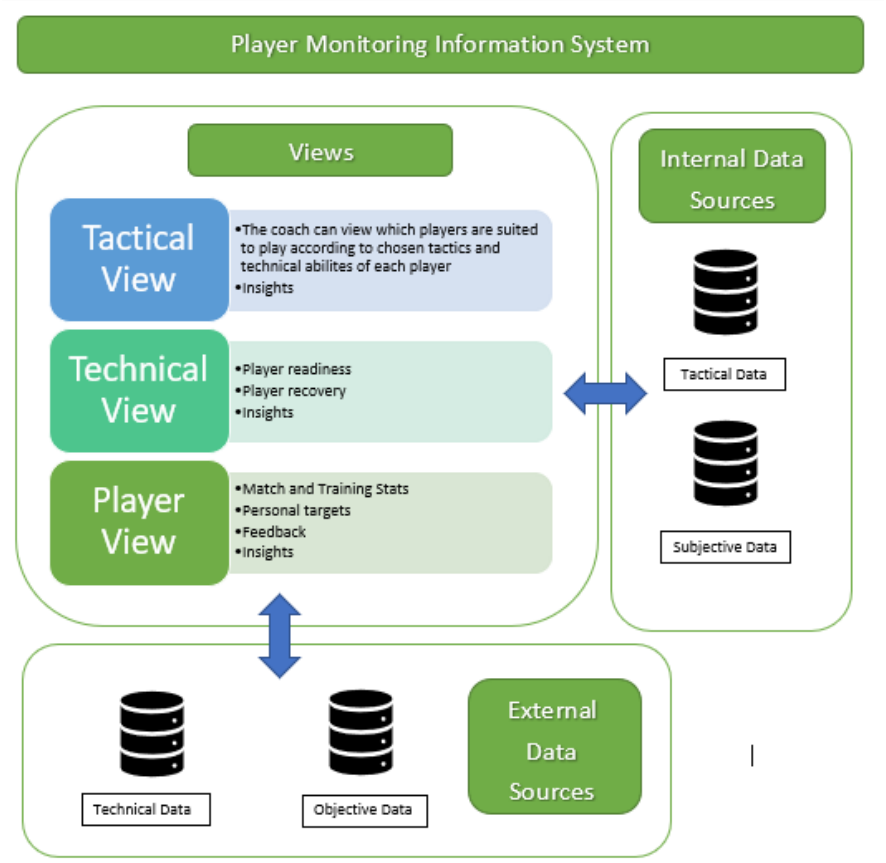
There were correlations between the academic literature and the research investigation particularly around the benefits of GPS technology. It was agreed that GPS provides valuable objective data from which baseline metrics are created per player. Each new set of performance data is compared to this baseline data to determine whether performance is improving. It was also agreed that another valuable trait of GPS technology is the ability to extract data immediately. During training sessions, the technical staff have access to immediate GPS data which allows them to fine-tune training exercises accordingly.

Using the answers to each of the sub-research questions above, the main research question is answered in section 6.2.5.

6.2.5 How can technology be utilised in football to reduce the risk of overtraining syndrome?

The main finding from this research study was that there is currently a need for a way to fully integrate the subjective and objective data of football players to gain a holistic view of a footballer’s well-being. In section 5.7, a high-level player monitoring information system was introduced that combines data from the four dimensions of footballer well-being shown in **Error! Reference source not found.**. This data includes subjective, objective, technical and tactical data.

The Player Monitoring Information System first described in Figure 29: is shown below:



This model describes a high-level solution to the main research question. The player's internal responses to training (subjective data), the player's physical performances (objective data), the tactics that a coach utilises (tactical) and the player's technical performance (technical data) are all integrated into one platform to generate insights on a player's holistic well-being. Insights are available to players, coaches and technical staff through the respective player, tactical and technical views. Using these insights, the technical staff are more enabled to track any OTS warning signs. The technical staff can use these warning signs to proactively prevent OTS.

6.3 ASSUMPTIONS

1. All participants will answer all interview questions with complete honesty and transparency.
2. The interviewed coaching staff will have detailed knowledge regarding their training methods, recovery processes and their impact on OTS.

3. The interviewed coaching staff will have encountered previous cases of OTS and have a solid understanding of the condition.
4. South African football clubs place great importance on the physical well-being of their football players.
5. South African football clubs have an interest in utilising and investing in technology to benefit their footballers and the club.

6.4 LIMITATIONS

1. Due to the highly competitive nature of professional football, clubs may not want to disclose vital information as they may lose their competitive edge.
2. Data will be collected from interviews which will be conducted at football clubs in South Africa.
3. Conclusions drawn will provide insight into the specific clubs interviewed only and not the entire South African football landscape.
4. Due to the busy schedule of professional football clubs, there may only be limited time available for data collection, which may impact the amount and type of data collected.
5. The specific football clubs where research is conducted may not have implemented any training technology, and thus may not have any data available on the impact of training technology on OTS.
6. The coaching staff at researched clubs may not have had previous experience with OTS.
7. Due to the low number of available resources in the premier level of football in South Africa, only five interviews were conducted.
8. Due to the COVID-19 pandemic, interviews could only be conducted over the internet.

6.5 SUMMARY OF CONTRIBUTIONS

There is currently limited research with regards to how technology can be used to reduce the risks of OTS. There is little to no research in this area with regards to South African football. There is limited research with regards to OTS in South African football. This

research study has made new findings with regards to OTS in South African football, technology and OTS in general as well as technology and OTS in South African football. The major discovery by the researcher was that there is a need for the integration of subjective and objective data. This integration is called a holistic view and increases the overall well-being of the footballer. This is discussed below.

6.5.1 Integration of Subjective and Objective data

The main finding from this research study is that the technical staff require a way to integrate the objective data from performance tracking devices and the subjective data from the players' mental well-being questionnaires to understand the holistic well-being of a footballer. Currently, objective and subjective data live on different platforms and are not fully integrated. The technical team analyses these two separate datasets to find any correlations. Many valuable insights are missed because of the data not being integrated. The researcher has developed The Player Monitoring Information System shown in Figure 29: and discussed in section 5.7. This information system integrates subjective, objective, technical and tactical data to gain a holistic view of a football player and reduce the risk of OTS.

6.6 FUTURE RESEARCH

Future research can be undertaken to investigate further into the design of the Player Monitoring Information System mentioned in section 5.7. Given that this proposed solution is a high-level design, the future researcher should delve further into the foundation of the design. The researcher should focus on the following topics:

6.6.1 Algorithm Design

The researcher should investigate what types of algorithms can be designed to satisfy the insight requirements of the coach, technical team, and players. Each club will have tailor-made algorithms to provide insight into their available data. These algorithms will provide insights for each of the three views in the information system.

6.6.2 Data Objects

The researcher should investigate what types of data objects will be required by the coach, technical team, and players. These data objects should be created to take full advantage of the four different data sources that provide data on the four different dimensions of football. Each view on the information system will allow that user to craft their own data reports using the available data objects.

6.6.3 Security

The researcher should also investigate the various security standards and protocols required when designing an information system of this nature.

6.7 CONCLUDING REMARKS

During this research study, the researcher made use of interview questions to gain insight into OTS in South African football. These interview questions were designed to answer the sub-research questions. The answers to these sub-research questions would ultimately answer the main research question. It was discovered that OTS in South African football is indeed an issue that needs a solution. Various forms of technology are being used to reduce the risk of OTS, however, there are still gaps. The researcher uncovered that the biggest gap currently in OTS prevention technology is the integration of subjective and objective data. The researcher then proposed a high-level solution that would integrate all four dimensions of footballer well-being data, namely subjective, objective, tactical and technical.

During this research study, the researcher gained valuable insight into the world of football, OTS and technology. The entire research study has been a very enlightening and enjoyable experience.

I would like to conclude this research study with a quote by football's all-time highest goalscorer:

"Stay Strong. Be Brave. Go Beyond."

Cristiano Ronaldo

7 REFERENCES

Ade, J., Fitzpatrick, J. and Bradley, P. S. (2016) 'High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills', *Journal of Sports Sciences*, 34(24), pp. 2205–2214. doi: 10.1080/02640414.2016.1217343.

altexsoft (2019) *What is API: Definition, Types, Specifications, Documentation*. Available at: https://www.altexsoft.com/blog/engineering/what-is-api-definition-types-specifications-documentation/.

Alves, J. V. M. *et al.* (2010) 'Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities', *Journal of Strength and Conditioning Research*, 24(4), pp. 936–941. doi: 10.1519/JSC.0b013e3181c7c5fd.

B Miller (2015) *What It Means to be "In Form"*. Available at: https://pca-nwa.com/what-it-means-to-be-in-form/#:~:text=Form typically refers to a,their potential level of performance.&text=Let's say that there's a,then 30%2C then 10 again.

Beato, M. and Jamil, M. (2018) 'Intra-system reliability of SicS: Video-tracking system (digital.Stadium®) for performance analysis in soccer', *Journal of Sports Medicine and Physical Fitness*. doi: 10.23736/S0022-4707.17.07267-X.

Bian, F. (2018) 'Electroencephalogram analysis of athletes with over-training syndrome', *NeuroQuantology*, 16(5), pp. 153–157. doi: 10.14704/nq.2018.16.5.1347.

Bieuzen, F. *et al.* (2012) 'Recovery after high-intensity intermittent exercise in elite soccer players using VEINOPLUS sport technology for blood-flow stimulation', *Journal of Athletic Training*, 47(5), pp. 498–506. doi: 10.4085/1062-6050-47.4.02.

Björnsdóttir, M. M. (2018) 'BSc in Psychology Depression , Anxiety , and Stress Symptoms among Football Players in Iceland : The Effects of Injuries , Overtraining and Insecurity'.

Blumberg, B., Cooper, D. and Schindler, P. (2008) 'The nature of business and management research', in *Business Research Methods*.

Boyas, S. and Guével, A. (2011) 'Neuromuscular fatigue in healthy muscle: Underlying factors and adaptation mechanisms', *Annals of Physical and Rehabilitation Medicine*, pp. 88–108. doi: 10.1016/j.rehab.2011.01.001.

Bryman, A. (2012) *Social research methods Bryman*, *OXFORD University Press*. doi: 10.1017/CBO9781107415324.004.

Bryman, A. and Bell, E. (2008) *Alan Bryman and Emma Bell, Business Research Methods*, *Management Learning*.

Burngardner, W. (2019) *Resting Heart Rate and Fitness*, *Verywell Fit*. Available at: https://www.verywellfit.com/resting-heart-rate-3432632.
Cadegiani, F. A., Kater, C. E. and Gazola, M. (2019) 'Clinical and biochemical characteristics of high-intensity functional training (HIFT) and overtraining syndrome: findings from the EROS study (The EROS-HIFT)', *Journal of Sports Sciences*, 37(11), pp. 1296–1307. doi: 10.1080/02640414.2018.1555912.
Campbell, P. G. *et al.* (2020) 'The effect of overreaching on neuromuscular performance and wellness responses in Australian rules football athletes', *Journal of Strength and Conditioning Research*. doi: 10.1519/JSC.0000000000003603.
Cardinale, M. and Varley, M. C. (2017) 'Wearable training-monitoring technology: Applications, challenges, and opportunities', *International Journal of Sports Physiology and Performance*, pp. 55–62. doi: 10.1123/ijspp.2016-0423.
Carter, J., Potter, A. and Brooks, K. (2014) 'Overtraining Syndrome : Causes, Consequences, and Methods for Prevention', *J Sport Human Perf*, 2(1), pp. 1–14.
Chen, W. and Hirschheim, R. (2004) 'A paradigmatic and methodological examination of information systems research from 1991 to 2001', *Information Systems Journal*, 14(3), pp. 197–235. doi: 10.1111/j.1365-2575.2004.00173.x.
Clemente, F. M. *et al.* (2017) 'Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer', *Physiology and Behavior*. doi: 10.1016/j.physbeh.2017.06.021.
Collins Dictionary (no date) *Definition of 'hyperbaric chamber'*. Available at: https://www.collinsdictionary.com/dictionary/english/hyperbaric-chamber.
Cresswell, J. W. (2003) 'Qualitative, Quantitative. and Mixed Methods Approaches', in *Research Design, Second Edition*. doi: 10.3109/08941939.2012.723954.
Culvin, A. (2019) 'Football as Work: The New Realities of Professional Women Footballers in England', (July).
Dishaw, M. T. and Strong, D. M. (1999) 'Extending the technology acceptance model with task-technology fit constructs', *Information and Management*, 36(1), pp. 9–21. doi: 10.1016/S0378-7206(98)00101-3.
Djordjevic, D., Dragojlovic Ruzicic, R. and Jakovljevic, V. (2016) 'Oxidative stress in training, overtraining and detraining: From experimental to applied research', *Serbian Journal of Experimental and Clinical Research*, pp. 343–348. doi: 10.1515/SJECR-2016-0002.
Dr. Ananya Mandal, M. (2009) *Heart Rate Reserve*. Available at: https://www.news-

medical.net/health/Heart-Rate-Reserve.aspx.
Ehrmann, F. E. *et al.* (2016) 'GPS and injury prevention in professional soccer', *Journal of Strength and Conditioning Research*, 30(2), pp. 360–367. doi: 10.1519/JSC.0000000000001093.
Ekstrand, J., Waldén, M. and Hägglund, M. (2004) 'A congested football calendar and the wellbeing of players: Correlation between match exposure of European footballers before the World Cup 2002 and their injuries and performers during that World Cup', *British Journal of Sports Medicine*, 38(4), pp. 493–497. doi: 10.1136/bjsm.2003.009134.
Fagundes, L. H. S. *et al.* (2019) 'Can motivation and overtraining predict burnout in professional soccer athletes in different periods of the season?', *International Journal of Sport and Exercise Psychology*. doi: 10.1080/1612197X.2019.1655778.
Flatt, A. A., Esco, M. R. and Nakamura, F. Y. (2017) 'Individual heart rate variability responses to preseason training in high level female soccer players', *Journal of Strength and Conditioning Research*. doi: 10.1519/JSC.0000000000001482.
Flick Uwe (2012) 'Introducing Research Methodology: A Beginner's Guide to Doing a Research Project', *The Modern Language Journal*. doi: 10.1111/j.1540-4781.2012.01382.x.
Galib, M. H., Hammou, K. A. and Steiger, J. (2018) 'Predicting Consumer Behavior: An Extension of Technology Acceptance Model', *International Journal of Marketing Studies*, 10(3), p. 73. doi: 10.5539/ijms.v10n3p73.
Giacobbi, P. R., Poczwardowski, A. and Hager, P. (2005) 'A Pragmatic Research Philosophy for Sport and Exercise Psychology', *The Sport Psychologist*, 19(1), pp. 18–31. doi: 10.1123/tsp.19.1.18.
Gill, P. *et al.* (2008) 'Methods of data collection in qualitative research: interviews and focus groups.', *British dental journal*. doi: 10.1038/bdj.2008.192.
Goldkuhl, G. (2004) 'Meanings of Pragmatism: Ways to Conduct Information Systems Research', in *2nd International Conference on Action in Language, Organisations and Information Systems (ALOIS-2004)*, pp. 17–18. Available at: http://www.vits.org/publikationer/dokument/457.pdf.
Goodhue, D. L. and Thompson, R. L. (1995) 'Task-Technology Fit and Individual Performance', *MIS Quarterly*, 19(2), p. 213. doi: 10.2307/249689.
Gulati, P. (2009) *Research Management: Fundamental & Applied Research*, *Global India Publications Pvt Ltd*.
Hägglund, M., Waldén, M. and Ekstrand, J. (2006) 'Previous injury as a risk factor for

injury in elite football: A prospective study over two consecutive seasons', *British Journal of Sports Medicine*, 40(9), pp. 767–772. doi: 10.1136/bjsm.2006.026609.
Hilton, D. J. (2020) 'Sports Monitoring with Moving Aerial Cameras Maybe Cost Efficient For Injury Prevention', *SciMedicine Journal*. doi: 10.28991/scimedj-2020-0203-3.
Holmes, T. (2007) *Macrocycles, Mesocycles and Microcycles: Understanding the 3 Cycles of Periodization*, *Trainingpeaks*. Available at: https://www.trainingpeaks.com/blog/macrocycles-mesocycles-and-microcycles-understanding-the-3-cycles-of-periodization/.
Hu, P. J. *et al.* (1999) 'Examining the Technology Acceptance Model Using Physician Acceptance of Telemedicine Technology', *Journal of Management Information Systems*. doi: 10.1080/07421222.1999.11518247.
Hughes, M. D. and Bartlett, R. M. (2002) 'The use of performance indicators in performance analysis', *Journal of Sports Sciences*, pp. 739–754. doi: 10.1080/026404102320675602.
Iaia, M. F., Rampinini, E. and Bangsbo, J. (2009) 'High-intensity training in football', *International Journal of Sports Physiology and Performance*, pp. 291–306. doi: 10.1123/ijspp.4.3.291.
Islam, M. S. (2020) 'Introducing Drone Technology to Soccer Coaching', 5(1), pp. 1–4. doi: 10.11648/j.ijsspe.20200501.11.
Kajaia, T. *et al.* (2017) 'THE EFFECTS OF NON-FUNCTIONAL OVERREACHING AND OVERTRAINING ON AUTONOMIC NERVOUS SYSTEM FUNCTION IN HIGHLY TRAINED ATHLETES', *Georgian medical news*.
Kenttä, G. and Hassmén, P. (2006) 'Overtraining and Recovery', *Sports Medicine*, pp. 1–16. doi: 10.2165/00007256-199826010-00001.
Khan, A. *et al.* (2018) 'Soccer Event Detection', in. doi: 10.5121/csit.2018.80509.
Klenke, K. (2017) 'Philosophical Foundations: Qualitative Research as Paradigm', in *Qualitative Research in the Study of Leadership*. doi: 10.1108/978-1-78560-651-920152002.
Kreher, J. (2016) 'Diagnosis and prevention of overtraining syndrome: an opinion on education strategies', *Open Access Journal of Sports Medicine*. doi: 10.2147/oajsm.s91657.
Kreher, J. B. and Schwartz, J. B. (2012) 'Overtraining Syndrome: A Practical Guide', *Sports Health*, pp. 128–138. doi: 10.1177/1941738111434406.
Kuipers, H. and Keizer, H. A. (2009) 'Overtraining in Elite Athletes', *Sports Medicine*, pp.

79–92. doi: 10.2165/00007256-198806020-00003.
Kvale, S. and Brinkmann, S. (2009) ‘Learning the craft of qualitative research interviewing’, in *InterViews: Learning the craft of qualitative research interviewing*.
Lacome, M. *et al.* (2018) ‘Small-sided games in elite soccer: Does one size fit all?’, *International Journal of Sports Physiology and Performance*, 13(5), pp. 568–576. doi: 10.1123/ijspp.2017-0214.
Lastella, M. *et al.* (2018) ‘Can sleep be used as an indicator of overreaching and overtraining in athletes?’, *Frontiers in Physiology*, 9(APR). doi: 10.3389/fphys.2018.00436.
Lexico (no date) *in form*. Available at: https://www.lexico.com/definition/in_form.
Liebermann, D. G. *et al.* (2002) ‘Advances in the application of information technology to sport performance’, *Journal of Sports Sciences*. doi: 10.1080/026404102320675611.
Loturco, I. *et al.* (2017) ‘Mixed training methods: Effects of combining resisted sprints or plyometrics with optimum power loads on sprint and agility performance in professional soccer players’, *Frontiers in Physiology*, 8(DEC). doi: 10.3389/fphys.2017.01034.
Lovell, G. P., Townrow, J. and Thatcher, R. (2010) ‘Mood states of soccer players in the english leagues: Reflections of an increasing workload’, *Biology of Sport*, 27(2), pp. 83–88. doi: 10.5604/20831862.913072.
Lu, J. *et al.* (2003) ‘Technology acceptance model for wireless Internet’, *Internet Research*. doi: 10.1108/10662240310478222.
Malone, J. J. *et al.* (2020) ‘To infinity and beyond: the use of GPS devices within the football codes’, *Science and Medicine in Football*. doi: 10.1080/24733938.2019.1679871.
Marcelo Pires and Vítor Santos (2018) ‘Assessing the Impact of Internet of Everything Technologies in Football’, *Journal of Sports Science*. doi: 10.17265/2332-7839/2018.01.005.
Mathers, N., Fox, N. and Hunn, A. (1998) ‘Trent focus for research and development in primary health care: Using interviews in a research project’, *Trent Focus Group*.
Mathieson, K. (1991) ‘Predicting user intentions: Comparing the technology acceptance model with the theory of planned behavior’, *Information Systems Research*, 2(3), pp. 173–191. doi: 10.1287/isre.2.3.173.
May, T. (2011) *Social Research: Issues, Methods and Research*, *Mc Graw Hill*.
Meeusen, R. *et al.* (2013) ‘Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the european college of sport science and the American College of Sports Medicine’, *Medicine and Science in Sports and Exercise*, 45(1), pp. 186–205. doi: 10.1249/MSS.0b013e318279a10a.

Merriam-Webster.com Dictionary (no date) *baseline*. Available at: https://www.merriam-webster.com/dictionary/baseline.
Michael L. Irick (2008) 'Task-Technology Fit and Information Systems Effectiveness', *Journal of Knowledge Management Practice*, 9(3).
Morgan, D. L. (2014) 'Pragmatism as a Paradigm for Social Research', *Qualitative Inquiry*, 20(8), pp. 1045–1053. doi: 10.1177/1077800413513733.
Morgans, R. *et al.* (2014) 'Principles and practices of training for soccer', *Journal of Sport and Health Science*, pp. 251–257. doi: 10.1016/j.jshs.2014.07.002.
Onwuegbuzie, A. and Leech, N. (2005) 'On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies', *International Journal of Social Research Methodology: Theory and Practice*, pp. 375–387. doi: 10.1080/13645570500402447.
Owen, A. L. *et al.* (2014) 'Physical and technical comparisons between various-sided games within professional soccer', *International Journal of Sports Medicine*, 35(4), pp. 286–292. doi: 10.1055/s-0033-1351333.
Pankanin, E. (2018) 'Overreaching and overtraining syndrome - causes , symptoms , diagnostics and prevention', 8(7), pp. 424–429.
Patton, M. Q. (2015) *Qualitative research & evaluation methods : integrating theory and practice*, *TA - TT -*.
Pedersen, H. *et al.* (2021) 'Electromyographic comparison of flywheel inertial leg curl and nordic hamstring exercise among soccer players', *International Journal of Sports Physiology and Performance*. doi: 10.1123/IJSPP.2019-0921.
Physiopedia (no date) *Tendinopathy*. Available at: https://www.physio-pedia.com/Tendinopathy.
Piesik, A. *et al.* (2017) 'Importance of fatiguing , overtraining and chronic fatigue in athletes', *Journal of Education, Health and Sport*, 7(9), pp. 203–216.
Popovych, I. *et al.* (2021) 'Psychological factors of competitiveness of the women's youth handball team', *Journal of Physical Education and Sport*. doi: 10.7752/jpes.2021.01030.
Principe, V. A. *et al.* (2020) 'GPS technology to control of external demands of elite Brazilian female football players during competitions', *Retos*. doi: 10.47197/RETOS.V1I40.81943.
Proietti, R. *et al.* (2017) 'Heart rate variability discriminates competitive levels in professional soccer players', *Journal of Strength and Conditioning Research*. doi: 10.1519/JSC.0000000000001795.

Ranjbarzadeh Yamchi, F., Letafatkar, A. and Esmaeilpour, S. (2021) ‘The Effect of 8 Weeks Virtual Reality Training on Static and Dynamic Balance and Performance in Male Athletes With Functional Ankle Instabilit’, *Physical Treatments: Specific Physical Therapy Journal*, 11(1), pp. 45–54. doi: 10.32598/ptj.11.1.453.1.
Riccardo, I. and Ciro Hosseini, I. (2017) ‘Differences By Field Positions Between Young and Senior Amateur Soccer Players Using Gps Technologies’, *Romania The journal is indexed in: Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST*, XVII(2), pp. 344–352. Available at: http://www.analefefs.ro/anale-fefs/2017/i2s/pe-autori/IZZO Riccardo.pdf.
Ryan, S., Kempton, T. and Coutts, A. J. (2021) ‘Data reduction approaches to athlete monitoring in professional Australian football’, *International Journal of Sports Physiology and Performance*. doi: 10.1123/IJSPP.2020-0083.
Saldanha, G. and Zanettin, F. (2016) ‘Gabriela Saldanha and Sharon O’Brien: Research Methodologies in Translation Studies’, *Across Languages and Cultures*. doi: 10.1556/084.2016.17.1.8.
Sandbrink, F. and Culcea, E. (2010) *Motor Unit Recruitment in EMG*, *Electromyography and Nerve Conduction Studies*. Available at: http://emedicine.medscape.com/article/1141359-overview.
Saunders, M. and Lewis, P. (2012) ‘Doing Research in Business and Management CourseSmart eTextbook’, *ingentaconnect.com*, p. 106.
Saunders, M., Lewis, P. and Thornhill, A. (2009) ‘Research Methods for Business Students Fifth edition’, in *Research Methods for Business Students Fifth edition*. doi: 10.1017/CBO9781107415324.004.
Savioli, F. P. *et al.* (2018) ‘Diagnosis of overtraining syndrome’, *Revista Brasileira de Medicina do Esporte*, pp. 391–394. doi: 10.1590/1517-869220182405185927.
Silvestre, R. *et al.* (2006) ‘Body composition and physical performance during a National Collegiate Athletic Association Division I men’s soccer season’, *Journal of Strength and Conditioning Research*, 20(4), pp. 962–970. doi: 10.1519/R-18165.1.
sports-training-adviser (no date) *The Overload Principle for Sports Fitness and Skills*. Available at: https://www.sports-training-adviser.com/overloadprinciple.html.
Stein, M. *et al.* (2018) ‘Bring It to the Pitch: Combining Video and Movement Data to Enhance Team Sport Analysis’, *IEEE Transactions on Visualization and Computer Graphics*. doi: 10.1109/TVCG.2017.2745181.
Techterms (no date a) *Android Definition*. Available at:

https://techterms.com/definition/android.
Techterms (no date b) *Frontend Definition*. Available at: https://techterms.com/definition/frontend#:~:text=The frontend of a software,that makes the interface function.
Techterms (no date c) *iOS Definition*. Available at: https://techterms.com/definition/ios.
Techterms (no date d) *Mac OS Definition*. Available at: https://techterms.com/definition/macos.
Techterms (no date e) *Windows Definition*. Available at: https://techterms.com/definition/windows.
Tee, J. (2020) *Injury niggles: manage small problems for a big difference*, *sportsinjurybulletin*. Available at: https://www.sportsinjurybulletin.com/injury-niggles-manage-small-problems-for-a-big-difference/#:~:text=Niggle is a cute word,they will return the field.&text=When an athlete reports a,execute a previously honed skill.
Tools, M. (no date) *Cognitive Load Theory*. Available at: https://www.mindtools.com/pages/article/cognitive-load-theory.htm#:~:text=%22Cognitive load%22 relates to the,t directly contribute to learning.
Valle, C. (2018) *Decoding the Isometric Mid-Thigh Pull Strength Test - SimpliFaster*. Available at: https://simplifaster.com/articles/isometric-mid-thigh-pull-strength-test/.
Vanderplaetse, B. and Dupont, S. (2020) 'Improved soccer action spotting using both audio and video streams', in *IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*. doi: 10.1109/CVPRW50498.2020.00456.
Verardi, C. E. L. *et al.* (2014) 'Burnout and playing position: A study of Brazilian soccer players', *Journal of Physical Education and Sport*, 14(3), pp. 324–330. doi: 10.7752/jpes.2014.03049.
Vignais, N. *et al.* (2015) 'Which technology to investigate visual perception in sport: Video vs. virtual reality', *Human Movement Science*, 39, pp. 12–26. doi: 10.1016/j.humov.2014.10.006.
Wang, Y. C. and Zhang, N. (2016) 'Effects of plyometric training on soccer players', *Experimental and Therapeutic Medicine*, pp. 550–554. doi: 10.3892/etm.2016.3419.
Weber (2017) 'Editor's Comments: The Rhetoric of Positivism versus Interpretivism: A Personal View', *MIS Quarterly*, 28(1), p. iii. doi: 10.2307/25148621.
Wilson, J. G. (2021) 'A N INVESTIGATION INTO GPS BRAND REPORTING DIFFERENCES AND VALIDATION OF A BETWEEN - BRAND CALIBRATION TOOL FOR FOOTBALL'.

Woods, C. *et al.* (2002) ‘The Football Association Medical Research Programme: An audit of injuries in professional football - Analysis of preseason injuries’, *British Journal of Sports Medicine*. doi: 10.1136/bjsm.36.6.436.
Worsey, M. T. O. *et al.* (2020) ‘Assessment of head impacts and muscle activity in soccer using a T3 inertial sensor and a portable electromyography (EMG) system: A preliminary study’, *Electronics (Switzerland)*. doi: 10.3390/electronics9050834.
Wylie, G. R. *et al.* (2017) ‘Cognitive fatigue in individuals with traumatic brain injury is associated with caudate activation’, *Scientific Reports*, 7(1). doi: 10.1038/s41598-017-08846-6.
Zachman, J. (2003) ‘The Zachman Framework For Enterprise Architecture’, *CA Magazine*, p. 15. Available at: http://proquest.umi.com/pqdweb?did=9075313&Fmt=7&clientId=65345&RQT=309&VName=PQD.

APPENDIX A – INTERVIEW GUIDE

UTILISING TECHNOLOGY IN FOOTBALL TO REDUCE THE RISK OF OVERTRAINING

Interview Guide

Background:

Addressing the issue of Overtraining Syndrome (OTS) using technology is still a very open area of research as technology and sport science continues to evolve and adapt at a fast rate. All professional sports teams have various forms of technology that assist staff to extract the best possible results from their group of players. Technology has become an integral part of managing and improving player performance (Liebermann *et al.*, 2002). There is currently insufficient research around how OTS can be reduced in football by using technology, especially in the South African football arena.

OTS is an amalgamation of both psychological and physical factors. A player can become demotivated due to the pressures of training and thus their performance is hindered. Increased training can also negatively affect a player's physical state, thus impeding their performance. Research needs to be conducted around how technology can be implemented to improve the physical and psychological factors surrounding a football player.

Research objectives and questions:

Main research objective:

The main objective of this research study is to investigate the adoption of technology for the measurement and management of factors related to the risk of overtraining syndrome in football.

Main research question:

How can technology be utilised in football to reduce the risk of overtraining syndrome?

Research Objective 1:

To investigate previous cases of overtraining syndrome and their underlying reasons. This sub research objective aims to identify any similarities amongst previous cases in the attempt to find common root causes of overtraining syndrome in football.

Research Question 1:

What are the underlying causes of previous cases of overtraining syndrome and can any similarities/themes be uncovered?

Interview Questions:

- Explain similarities between previous cases of OTS such as causes, symptoms or recovery times? Please elaborate.
- Explain what types of players were affected and with what types of injuries?

Research Objective 2:

To determine all non-physical related contributing factors to overtraining syndrome. This sub research objective plans to gain a holistic view of all elements involving a football player and overtraining syndrome.

Research Question 2:

What are all the non-physical related factors contributing to overtraining syndrome in football players?

Interview Questions:

- Describe how playing styles(team/player), player physical and mental attributes are related to overtraining syndrome?
- Explain how player form [20] plays a part in overtraining syndrome?
- How does a player's personal lifestyle play a part in OTS? Please motivate

Research Objective 3:

To understand the current training methods and recovery processes utilised in modern-day professional football teams. Training and recovery are critical to the physical development and management of a football player. This sub research objective aims to determine the relationship between training, recovery, and overtraining syndrome.

Research Question 3:

What are the current training methods and recovery processes of footballers and how do they influence the player's risk of overtraining syndrome?

Interview Questions:

- Explain what training methods are currently used and for what purpose?
- What technology-driven training methods are currently used? Please elaborate.
- How does technology play a part in player management, such as during training, during matches, during injury periods, during recovery? Please explain.
- Explain how injured players are managed and re-introduced to full training?
- How is overtraining spotted? Please motivate.

Research Objective 4:

To identify and analyse the current training technology encompassing a football player. This sub research objective aims to look for existing gaps and possible improvements with regards to the technology used to assist football players during training.

[20] Form typically refers to a player's level of performance relative to their potential level of performance. Source: (B Miller, 2015)

Research Question 4:

What current training technologies are used by football players and how are these technologies used to address overtraining syndrome?

Interview Questions:

- Explain what training technology is used and the pros and cons?
- How does the current technology help with overtraining? Please motivate
- How can the current technology be improved to assist with overtraining? Please motivate
- Please describe how training data is used and how it can play a role in preventing overtraining syndrome?
- What could be developed to monitor and control overtraining syndrome? Please motivate