EXAMINING CAREER PROFILES AND FACTORS ASSOCIATED WITH LONGEVITY & PERFORMANCE DECLINE IN ELITE TEAM SPORTS ATHLETES

PATRICK HOGBEN

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School of Sport, Exercise and Rehabilitation Science

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Abstract

To increases chances of success, sports teams aim to maximize the number of high-quality players at their disposal. Managing player development and recruitment in a way that increases the odds of players having long and successful careers is therefore an important objective for all sports organizations. Despite the benefits of increasing effective career length, little research has examined the professional phase of elite team sports careers or sought to explore reasons for performance decline in high level players. The aim of this thesis is therefore to present information useful to practitioners aiming to design interventions towards increasing effective career length. In support of this objective, this thesis will examine career profiles within professional team sport, explore interacting factors which impact career duration and present suggestions and practical recommendations in support of enhancing player longevity.

Study 1

This study aimed to examine career profiles and develop statistical models exploring match participation across the career span of players at the highest level in four codes of football. Match participation data from a recently completed season of league competition were obtained for Australian Rules Football (AFL, n= 672), English Premier League Football (EPL, n=524), National Football League (NFL, n=1883) and English Premiership Rugby Union (PRU, n = 567). Polynomial models were created to explore the effect of age and number of seasons since league debut on match participation. Whole league and positional group population distribution for both age and seasons since debut were presented for each code. In all codes, an ascension of match play was observed across initial seasons following debut and initial years captured by each model. Rate of increase in playing time post debut and timing of peak participation differed between codes with earliest peak occurring in EPL players (6 seasons post debut) and latest peak occurring in AFL and NFL players (9 seasons post debut). In all populations, predicted play time remained within 10% of peak season minutes until at least 30 years of age. Median time since debut was between 3 and 5 years across all codes and median age range between 24 and 27. The results of this study suggest that whilst it is possible for players to play high minutes following more than 10 years in a particular league, in the context of the brevity of many careers and observed drop out at all ages, it is comparatively rare for a player to survive long enough to do so.

Study 2

To understand the extent to which age-related physiological decline may influence career duration, the purpose of this investigation was to examine variation in countermovement jump (CMJ)

performance across the career span in EPL players. A cross-sectional retrospective analysis was performed on pre-season CMJ testing data from 245 players across 7 teams collected between 2014 and 2019. To describe specific neuromuscular (NM) differences between older and younger players all jump trails were conducted on vertical axis, dual platform force platforms with JH and CMJ-kinetic (CMJ-Kin) variables derived. Polynomial models were built to describe the relationship between JH, CMJ-Kin measures, body mass and player age. Players were divided into 5 age categories (17-22, 23-25, 26-28, 29-31 and 32-40) based on a k-means cluster analysis with group performance subsequently compared. The results of this investigation show older players (>29) are likely to record a significantly lower JH, higher body mass and reduced performance in a range of concentric phase CMJ-kin measures compared to younger counterparts. Results presented here also evidence considerable individual variation in JH and CMJ-Kin measures across all age groups. Although diminished NM profiles may contribute to the observed reduction in performance and numbers of players in elite leagues after age 30, it seems likely factors beyond NM performance strongly influence the duration of many high-level team sports careers.

Study 3

Longevity in professional sport is thought to be impacted by multiple individual, team, and environmental factors. Despite this, within sport science, many attempts to understand professional careers are based around examining longitudinal change in single system performance. To provide a more complete perspective, the purpose of this study was to use systems thinking techniques to understand the range of factors that interact to influence the duration of professional playing careers. In this investigation, a group of 19 subject matter experts (SMEs) with extensive experience in professional team sports took part in a group model-building process toward creating a causal loop diagram (CLD) exploring the determinants of longevity. Individual semi-structured interviews informed building of an initial draft CLD which was revised and subsequently approved by participants. Exploration of the thematic breakdown of SME interviews also informed the development of an actor map highlighting the relationships between the player and key stakeholders interacting with them to influence longevity. Based on systems thinking tools created within this investigation, it appears career duration is usefully conceptualized as an emergent product of 25 summary variables influenced by more than 20 different groups of actors. The results of this investigation show interventions designed to maximize the odds of players having long and successful careers will likely be most effective where they consider the interaction between the player and their environment, ensure sufficient playing opportunity exists and help players develop autonomy and leadership skills. Future work is required to explore the specific manner in which such interventions should be designed to maximize practical benefit.

Study 4

Increasing the length of time over which elite team sports athletes can compete at the highest level is likely extremely beneficial for sports organizations and athletes. Despite this, very little information exists to inform practical attempts to increase longevity in professional team sports. This research informed, position paper aimed to summarize current evidence regarding career longevity and present suggestions on how sports organizations can maximise effective player career length. This study was be informed by SME testimony provided as part of study 3 and features extended exploration and synthesis of the practical applications and consequences of the findings of studies 1 and 2. To maximize probability of players having long and successful careers, team should (1) examine the availability of playing opportunity to peripheral players who without exposure will likely quickly drop from the elite level, (2) train older players in a manner focused on maintaining their ability to meet the demands of the most intense aspects of match play, (3) help players develop a career long focus on improving on and off pitch skills and developing self-directed, individual performance maintaining habits and routines.

Summary

Having highlighted the lack of research providing contemporary description of the professional stage of team sports careers, this thesis presents up-to-date career profiles for four major professional team sports. The thesis explores factors that interact to determine the nature of the observed professional career profiles, investigating both the relative importance of potential physical decline and attempting to understand interaction between a broad range of other systems factors influencing career duration. Finally, the thesis offers suggestions on how teams may be able to positively impact the career profiles of their own players towards a greater likelihood of them having longer and more successful careers. In addition to offering answers to specific questions related to career longevity and performance decline, this thesis serves as a learning vehicle to enable the author to fulfil the learning objectives of a professional doctorate.

Acknowledgements

The process of working through my professional doctorate and completing this thesis has been fascinating, satisfying and at times immensely frustrating. It has occupied a significant proportion of my thoughts over the last five years and is an experience that has without doubt left my changed. A huge highlight of my program of study has been the people it allowed me to work with. I am extremely grateful for the time, thoughtfulness and generosity of Patrick Ward, Daniel Cohen, Scott McLean, Paul Salmon and Sudarshan Gopaladesikan. Working with such highly intelligent people who have truly developed an ability to think has been a real pleasure and has benefitted me more than they realize. Being forced to consider my own learning journey and deeply held beliefs also makes me realize the good fortune I have had to work with some excellent practitioners in my professional field. This doctorate and thesis would not have happened without colleagues like Scott Murphy, Ben Serpell, Laura Tulloch, Tom Sherriff, Eric Leidersdorf and Luke Storey. Working through real-world athlete management scenarios with these people is what has led me to find a passion and curiosity for my work and I am thankful for the time, energy, and insight of all those that have helped me on my path. More than anyone though, I am extremely grateful for the deep knowledge, patience, and intellectual skill of my primary supervisor Barry Drust. On so many occasions he guided me right to an answer but somehow almost always managed to stop just short of telling me, allowing me the satisfaction of learning, and thinking I had discovered it for myself. It has been a pleasure to get to know Barry over this journey and I am grateful for the perspectives he has helped me see.

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List of abbreviations

AFL	Australian Rules Football
CI	Confidence interval
CLD	Casual loop diagram
CM	Countermovement
CMD	Countermovement depth
CMJ	Countermovement jump
CMJ-kin	Countermovement jump kinetic measures
CON	Concentric
DECEL	Deceleration
ECC	Eccentric
EPL	English Premier League Football
FTCT	Flight time: contraction time
HAC	The Holistic Athletic Career Model
HR_{max}	Maximum heart rate
JH	Jump height
NFL	National Football League
NHL	National Hockey League
NM	Neuromuscular
MLB	Major League Baseball
PR	Premiership Rugby
RFD	Rate of force development
RTP	Return to play
SME	Subject matter experts
SSC	Stretch shortening cycle
UEFA	Union of European Football Associations
$\dot{V}O_{2max}$	Maximal oxygen uptake (L.min-1)
VRDF	Vitae Researcher Development Framework

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CHAPTER ONE

GENERAL INTRODUCTION

General introduction

A professional doctorate requires experienced professionals to produce research that makes a clear contribution to their profession (Fulton et al., 2013) whilst developing awareness, skills, and maturity in themselves (Sanders et al., 2011). The thesis that follows is therefore about both presenting a series of linked scientific studies in service of specific questions, and at the same time, a vehicle for personal development. To establish clear objectives for the research studies and learning aspects of this project, this general introduction is split into two parts. In the first section, the scientific rationale and objectives will be outlined and in the second section specific learning goals will be presented.

1.1. Introduction to the research project

To maximize their chances of success, team sports organizations aim to assemble playing squads of the highest possible quality. Given the finite nature of players' careers and the vast economy around transferring players (Hoey et al., 2021), teams must perpetually manage squad composition and as such devote considerable resources to scouting and developing players. In addition to adding high talent players, teams can attempt to maximize the quality of their playing squads by expanding the time span over which their best players contribute at the highest level. By preparing young players to compete earlier or extending the productive years of high talent, older players, teams can increase the number of quality players at their disposal. To assemble the best squads possible, it is also advantageous if teams can forecast the duration of players' careers and the trajectory of their performance across them. An understanding of change in player performance over time, particularly in relation to decline with age, has the potential to assist teams in optimizing contract lengths and therefore ensuring financial resources are best allocated towards securing and retaining the most impactful players available (Sullivan et al., 2020). As well as benefitting teams, increasing longevity at the highest levels of team sport is extremely beneficial for players, providing them more years of high earnings and increased opportunity to win trophies. Interventions which could help increase career longevity would therefore seemingly be of great interest to sports organizations and players alike. To design such interventions, a thorough knowledge of factors related to career longevity in professional team sports appears essential. Currently, however this information is lacking within sports science literature.

In attempt to better understand high-level athletic careers, aspects of longevity including reasons for player retirement, transitions between career stages and the progression of players towards professional status have been extensively investigated. Longitudinal change in elite player performance has also been well researched (Bradner et al., 2014; Dendir, 2016; McIntosh et al., 2019; Sullivan et al., 2020). Additionally, many studies have sought to explore causes of performance decline by comparing older and younger players based on either in-game output metrics or measures of physiological function. Typically, the findings of longitudinal performance profiling studies suggest, players' within-competition performance improves up to a peak age in the mid to late twenties, before declining until retirement (Faulkner et al., 2008; Brander et al., 2014). Although this work provides useful perspective regarding professional populations, many studies use inclusion criteria that restricts analyses to a sample of very elite players and in doing so ignores significant parts of the professional population (Fair, 2008). In addition, due to the complexity of understanding individual player performance in team sports (Robertson et al., 2015), and the frequent examination of single performance statistics within longitudinal examinations, the practical utility of information stemming from such work is questionable. Furthermore, whilst an understanding of typical change in performance across the career span is interesting, without an understanding of the causes of such change, it appears to have limited application. Although evidence suggests high intensity in-game running outputs are typically lower in older versus younger professional football players (Sal de Rellán-Geurra et al., 2019; Zhou et al., 2020) an underpinning physiological mechanism which can explain either this finding or the observation of reduced in-game performance in older professionals is lacking. Studies examining differences between older and younger players in maximal aerobic capacities have reported equivocal findings (Signorelli et al., 2012; Botek et al., 2016). In addition, despite the likely importance of the anaerobic metabolism and neuromuscular system to high intensity actions in decisive moments of games, very little research has examined changes in related qualities across professional team sport athletes' careers.

To aid practitioners in designing interventions that can help maximise the time over which players can compete, further understanding of a potential physiological basis of age-related performance decline appears warranted. It however also seems important future research efforts recognise practitioners require an increased awareness of the possibility playing careers end for reasons beyond the physical. Given athlete career journeys have been described as multifaceted (Stambulova et al., 2020), approaches to understand potential performance change within them should include efforts to move beyond reductionist models of enquiry focused on single factor decline. Although it seems likely the interaction between important career variables will strongly influence trajectory and duration of playing careers, an understanding of what these variables are and how they interact is currently missing. To design interventions and systems with maximum chance of setting players up for long and successful careers, it is clear practitioners and coachers require enhanced understanding of playing careers and the range of factors influencing longevity within them.

1.2. Research aims and objectives

To support the design of effective interventions, the aim of this thesis is to understand career profiles and identify factors associated with longevity and performance decline in elite team sports athletes.

To achieve this aim, the thesis has the following objectives:

1. Describe career profiles in high-level professional team sport.

2. Examine the physiological basis of performance variation across team sport careers.

3. Apply systems thinking approaches to gain a greater understanding of the factors that may influence career longevity in professional team sports.

4. Highlight potential strategies that may allow sports organizations to influence the duration and trajectory of sports careers.

1.3. Introduction to the doctoral personal development journey

I had thought about doing doctoral study for a long time prior to beginning this research project. I had long been impressed by the thinking and analytical skills of the practitioners I knew who held doctorates and aspired to be a little more like them some day. However, for whatever reason I didn't ever quite get around to taking the next step and enrolling in a PhD or professional doctorate. That changed shortly after a continuing education trip to Australia. I was at a point in my career where I wanted to progress. I wanted to hold positions where I had more decision-making responsibilities. I also wanted to improve as a practitioner. I felt I needed more knowledge. I also needed to become a more reflective and creative coach, able to critically explore and evaluate my work in a research informed manner. In Australia, I witnessed an organization striving to win championships in a slightly different way, and seeing this during a time when I was reflecting on my professional future sparked a strong interest in conducting research.

Geelong football club was an organization I visited on a continuing education trip and subsequently worked at. Geelong football club is an Australian rules football team and as such competes in a sport with a salary cap and a draft system. These measures exist to equalize the quality of players across teams within the sport and can be found in team sport leagues across the world. Following years of success and therefore lower draft selections, Geelong football club had preferentially recruited older players as the club felt they were undervalued by other teams and so represented a means of having a more talented squad than their competitors, despite spending to the same salary cap. The notion that at some point team sports players get too old is familiar to everyone who watches sport. However, the concept of attempting to outperform rival teams by getting more out of older players seemed like a shrewd way a team could gain a winning advantage. Regardless of whether it was a team's major strategy to win or a way to boost the performance of one or two squad members, getting more from older players, seemed like a measure which could potentially help many sporting organizations. As a practitioner who aims to gear performance training towards gaining a competitive edge this was interesting, and something I wanted to focus on more in my professional practice. The trouble is, how you get more out of older players is not clear. When I started work at Geelong I needed to know more. Lots of practitioners have worked with one or two 30 something-year-olds who have defied time, but there is scant literature offering evidence on how to best go about it. There's work on masters' athletes and there's work on ageing humans but I was not sure this stuff related to elite team sports athletes. As far as I looked, I could not find much information explaining why there are lots of 28- or 29-year-old professional football players but far fewer 34-year-olds. Even less how to increases the odds of a particular 28-year-old finding himself still in an elite league at 34. Given this topic aligned with the type of work I wanted to do, appeared to be something my profession needed to know more about, and seemed like a direction via which I could build useful skills, it made sense to see if it was possible to do some of this research myself. I was excited about both the potential to increase understanding of a potentially high value topic in performance sport and the way in which doing so could help me advance my skillset. My first task upon deciding to commit to a professional doctorate was to work out exactly what I wanted and needed to learn from it. As a result, I carried out a personal skills audit. This audit served to inform the specific learning aims I have adopted here and can be found in appendix 9.1.

1.4. Learning aims and objectives

In terms of personal development, this thesis aims to generate new insights for my profession while facilitating my growth as a researching professional who has a high level of knowledge, an applicable research informed skill-set, and is able to handle high degrees of complexity within their work.

To achieve this aim, this thesis has the following objectives:

1. Enable me to develop a comprehensive knowledge of my research topic, greater understanding of theoretical aspects of research methodology and their practical applications, and improved cognitive skills, including critical thinking, problem solving and synthesis of information.

2. Carry out a research project addressing specific, applied questions towards the creation and interpretation of new knowledge useful to my profession.

3. Present reflections and meta reflections on my learning journey to facilitate iterative development of my research project and enhance efficacy of my personal learning journey.

THESIS MAP

A GUIDE TO THE STRUCTURE OF THIS THESIS

Thesis map: a guide to the structure of what is to follow

The purpose of this section is to describe the overall layout of this thesis. It is presented as the thesis is non-traditional in its format and it is therefore important to orientate the reader to the purpose and location of each chapter. In showing the relationships between thesis sections, Figure 1.1 illustrates the route this project takes towards achievement of the research and learning objectives described in the General introduction. As shown in Figure 1.1, following the Approach to the problem section (Chapter 3), each study (Chapters 4-7) is informed by an applied reflective pause and followed by a reflective doctoral learning pause. The applied reflective pauses present real world scenarios based on the authors experience and serve to ensure this thesis addresses questions situated within the practice of those working in elite team sport. The function of the doctoral pauses is to illuminate the authors learning journey over the doctorate, provide evidence regarding the fulfilment of learning objectives and offer reflective insights into the challenges and lessons of doctoral study as they were experienced. Although the sections relating to each study (applied reflective pause, research study and doctoral learning pause) appear sequentially in the thesis it is, as shown in Figure 1.1, perhaps more useful to think of them as occurring simultaneously. In all investigations, aspects of the applied reflective pause informed the methodological design and interpretation of findings. In addition, learnings described in the reflective doctoral generally took place whilst the study was under construction. As well as describing the relationship between different sections, the thesis map shows all research studies are very much linked. These links exist as the findings of each study had a strong bearing on the direction of the next, with results from the first three studies informing a synthesis-based position piece presented as Study 4 (Chapter 7). The thesis map also shows links between the doctoral learning pauses. This describes the way in which learnings over the doctoral process built upon and reinforced each other. A detailed presentation of the underpinning approach adopted towards knowledge creation and learning throughout the thesis will be presented in the Approach to the problem section (Chapter 3).

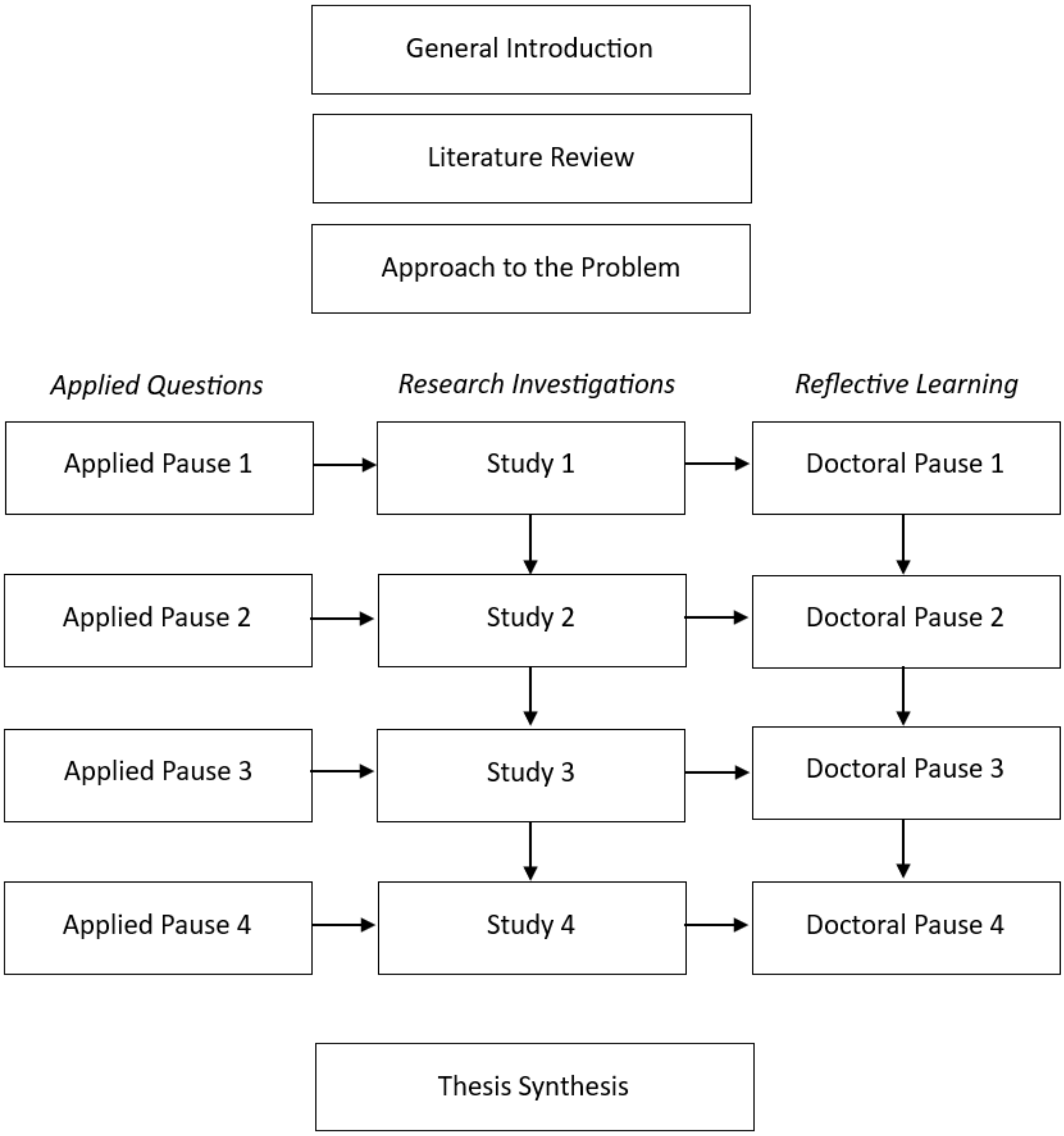


Figure 1.1. Map showing the relationship between the components of this thesis.

The applied pauses, research studies and doctoral pauses should be considered as influencing each other simultaneously. For both the research studies and doctoral pauses, findings and lessons from early work influenced subsequent study direction and allowed for further learning and development.

CHAPTER TWO

LITERATURE REVIEW

Literature review

2.1. Introduction

Understanding the likely length and trajectory of professional team sport careers is important for organizations aiming to optimize squad composition and for those designing interventions with the objective of increasing longevity. To effectively support players across the career span, practitioners need to understand likely changes in performance and the underlying factors driving them. Despite the potential benefits of information which may aid in extending careers, many aspects of team sports player's careers remain under investigated (Roderick, 2017). To design future research studies which can provide potentially impactful information for practitioners, it is important to first review current evidence describing professional team sport career journeys and evaluate the extent to which performance change within them is understood at a practically useful level. The purpose of this narrative review is therefore (1) to examine available evidence describing the nature of the professional phase of team sports careers in terms of duration and end points (2) to present evidence detailing performance changes occurring over professional sports careers and (3) to elucidate factors potentially explaining changes in performance with increasing age.

2.2. Contextualizing professional team sports careers

To effectively explore aspects of professional team sports careers relevant to the aims of this review it is important to first establish the boundaries within which they are to be examined. To provide appropriate context for this review, the scope of the term professional will be defined. The way in which an athlete's professional career is situated within their overall career journey will also be explored, with boundaries for the following review subsequently presented.

2.2.1. Professionalism in team sports

Before the nature of the professional phase of team sports can be explored it is important to understand what is meant by the term professional and the limits of this categorisation. The term professional is used to differentiate an athlete who draws their income playing a particular sport from an amateur, who is said to compete for the love of the sport whilst having a vocational focus elsewhere. Professional status is a general label, providing limited information, applied to athletes competing for some type of payment (e.g., salary, prize money or substantial endorsements). It can refer to multiple levels of sport, even within one nation (e.g., different divisions of the English Football League) and does not denote a specific playing standard, level of income, network of support structures or public profile. The categorization 'professional' is used in this review to allow examination of a sector of the sports world many athletes strive to become or remain part of. In a competitive, free market, achieving or maintaining professional status implies that the athlete offers their employer an increased likelihood of success versus an alternative player. Maintaining professional status also suggests a given athlete can continue to operate above a certain minimum standard. Athletes no longer able to do so, are likely to drop out due to failure to secure further employment even though they can elect to continue to participate in their sport at an amateur level. Due to the high commitment required by professional athletes, achieving or maintaining professional status also suggests the athlete has sufficient motivation to continue to live and train in the required manner. To provide greater resolution than the term professional conveys, details of the specific levels of players mentioned in studies in this review will be provided. Evidence relating to the highest-level leagues within team sports will be prioritised as it has greatest potential to elucidate changes in human performance with advancing age.

2.2.2. Professional sports careers as part of the overall athletic career journey

Although professional sports careers are the focus of this review, it is important the professional stage of careers is considered within context of the overall athletic career. The 'Athletic career' has been defined as a 'multi-year sport activity, voluntarily chosen by the person, aimed at achieving her individual peak in athletic performance in one or several sport events' (Alfermann & Stambulova, 2007). It describes the entire path taken by a sports person as they transition through successive stages of a whole career, from junior to senior and into retirement (Stambulova et al., 2009; Carapinheira et al. 2018). A variety of different models have been proposed to explain the athlete career journey (Stambulova, 1994; Salmela, 1994; Wylleman & Lavailee, 2004; Stambulova et al., 2020), each one dividing the entire career into phases and transitions. The Holistic Athletic Career Model (HAC) (Wylleman et al., 2013; 2019) describes careers as multi-layered processes which can be divided into in four developmental stages: initiation, where young athletes (from around 6-7 years old) are introduced to competitive sports, development, where (from around 12-13 years old) athletes' talent is recognised and the intensity of training and competition subsequently increases, mastery, where athletes (from around 18-19 years old) can begin to compete at the highest levels and finally discontinuation, where elite athletes transition out of competitive sports (Wylleman & Rosier, 2016). Although the HAC is useful in 'guiding researchers to take the holistic developmental perspective' (Stambulova et al., 2020), the integrated career change and transition framework (ICCT, Samuel et al., 2019) offers an alternative perspective in describing a career journey by examination of the transitions taking place across it (Stambulova & Samuel, 2019). The ICCT describes movement through a career as being characterised by transition processes, said to begin with a 'change event that compromises an athlete's status quo' and in doing so leads them into a pre-transition state where the demands of a transition must be considered (Stambulova & Samuel, 2019). A further, alternative view of careers is offered by the multiple-metaphor career framework (Inkson, 2006) (MMCF). Whilst the HAC is thought to be limited by an implied linear presentation of careers (Stambulova & Samuel, 2019), the MMCF uses nine complementary metaphors to describe aspects of the career journey and so provides examination of career journeys through multiple complimentary lenses. Despite its potential limitations, the HAC will be used to situate professional careers within this review as it acknowledged as contemporary (Lopez-Flores et al., 2021) and by aligning the athletic career to life stages, references it to broader life events as well as chronological ages and thus likely age-related physiological change that may impact career longevity. Furthermore, given the focus of this review will be the professional phase of the mastery stage of team sports careers it is not better served by alternative models offering greater focus on career transitions or contrasting non-linear views of the overall career journey. In addition to examining the professional phase of the mastery stage of team sports careers, this review will cover aspects of the discontinuation stage. Whilst the initiation and development stages of athletic careers, as outlined by the HAC are doubtless important in an athlete's path to the mastery stage and professional status, they will not be directly discussed here.

Utilising the HAC and examining team sports careers from a holistic perspective requires the acknowledgement that the nature of an individual's career journey will vary based on contextual factors including sport, culture, gender, nation, and other individual characteristics (Stambulova et al. 2009; Weissensteiner, 2017). To provide a more complete picture of team sports careers, this review will investigate evidence relating to careers across a variety of team sports. Not following a single-sport approach presents challenges in reconciling how differences between games may influence the transfer of study findings. Differences in game characteristics, physical requirements, and environmental constraints such as financial resources, systems of talent intake and global reach will doubtless influence professional careers within sports such as Rugby, Football, Ice Hockey, and Baseball. Examining professional team sports careers through the lens of their differences, however, offers a way to explore how variations in competitive activity and professional environments may influence human longevity at the highest levels of performance.

Within this review, career longevity and trajectory will be examined based on players' chronological age. Although biological age may impact the speed at which an individual moves through career stages, it is not widely used throughout the team sports literature and may not figure as prominently in executive decisions relating to player contract length and salary (Frick, 2007). Throughout this review, careers will be examined from the perspective of sports performance. Whilst change across the professional stage of a sports career will influence many aspects of an athlete's life, it is beyond the scope of this review to examine all aspects of change from all perspectives. Due to the current, disappointing lack of work investigating professional careers in female athletes, all information presented in this review relates to male athletes. The review was conducted based on a search of PUBMED, SPORTDiscus and Google scholar with additional articles sourced from reference lists of relevant papers.

2.3. Professional career population characteristics, durations, and end points

To effectively make decisions relating to succession planning and recruitment, organisations should understand the composition of their sport's professional population and how long athletes are likely to remain part of it. This section will explore research presenting professional population characteristics, career durations, and reasons for career termination.

2.3.1. Population characteristics within professional team sport

Relative to the human lifespan, the age range and average age of players in the highest-level professional competitions of most team sports are similar (Table 1). In elite soccer competitions (Champions' league, Bundesliga, LaLiga) players typically range in age from 16 to the late 30s (Frick, 2007; Dendir, 2016; Kalén et al., 2019; Sal de Rellán-Geurra et al., 2019). The professional stage spans a similar range in Baseball (MLB) (Fair, 2008), Ice Hockey (NHL) (Bradner et al., 2014) and Australian Rules Football (AFL) (McIntosh et al., 2019). The minimum age of players is however slightly older (18-20) in these sports compared to football, due to different eligibility rules. Examination of population distributions shows most professional players in elite leagues are aged between 21 and 29 years old in football (Dendir, 2016; Kalén et al., 2019; Sal de Rellán-Geurra et al., 2019), and between 23 and 29 years old in Ice Hockey (Bradner et al., 2014). The majority of players in the AFL are slightly younger. The AFL population distribution is more positively skewed with the most represented age group being 20-22 years of age, after which age group numbers progressively decline with age (McIntosh et al., 2019). In all professional team sport populations, it seems there is a steep drop off in numbers of athletes in each age group from approximately 30 years of age onwards. In Ice hockey and football, playing position influences the precise age at which this large decrease in numbers of players appears to occur (Bradner et al., 2014; Dendir, 2016; Kalén et al., 2019; Sullivan et al., 2020). In football, although a greater proportion of defenders compared to midfielders were older than 27, a substantial reduction in numbers of players by age 30 was apparent in all positional groups (Dendir, 2016; Kalén et al., 2019). Whilst research examining population characteristics in additional team sports would be of interest, it seems safe to conclude that although population distribution varies, age span and a large drop off in player numbers after age 30 are common to all.

2.3.2. Duration of professional phase of team sports careers

The duration of the professional phase of team sports can be considered as the time between a player signing their first professional contract and the discontinuation of their professional career. A high level of inter-individual variation has been shown to exist in the typical duration of the professional phase, underlining the individual nature of the athlete's overall career journey (Stambulova et al. 2009). In American football (NFL) mean career length was found to be 5.5 years (±4.1) with significant differences in career longevity between positional groups (Baker et al., 2013). Average career length appeared longer amongst NBA (8.2 ± 5.4), NHL (7.8 ± 5.8) and MLB players (7.8 ± 5.8), however in all populations career length was highly variable (Baker et al., 2013). Several studies suggest football careers are likely longer in duration. In a systematic review of career termination, professional football players were reported to retire following an average career duration of 8 to 11 years at between 31 and 35 years old (Drawer & Fuller, 2002; Gouttebarge et al., 2015; Carapinheira et al., 2018,). However, other studies in football suggest players are unlikely to have careers lasting this length of time. In an online questionnaire administered to 307 former professional footballers, age at retirement was 25.3 ± 5.2 years old (Sanders & Stevinson, 2017). Furthermore, in the Bundesliga average career duration was four years, with a minority of careers exceeding nine (Frick, 2007). It is likely differences in reported durations of football careers are partly due to differences in what each of these studies considered as a professional career. Some studies examined only careers in the highest national leagues (Frick, 2007) whereas other looked at a spectrum of levels (Drawer & Fuller, 2002). Reported variation by sport may also be at least partly explained by differences in environmental constraints impacting careers. In football where multiple tiers of professional play exist within many nations and labour migration is frequent, the variation in possible career paths is greatly expanded versus professional spots played primarily in one nation (e.g., Australian Rules Football). In addition to difficulties defining career length, large inter-individual variation in the duration of the professional phase of team sports careers can be explained by the many factors reported to influence career duration (Frick, 2007; 2011). A player's age, experience (number of games played), playing ability, team quality and the availability of additional leagues, are all likely to impact upon career duration (Frick, 2007, Bradner et al., 2014, Dendir, 2016) and may do so in a non-linear manner (Wylleman & Rosier, 2016). Whilst much information describing career durations is available within the literature, differences between studies in methodologies and boundaries applied to what is considered a career make it difficult to understand what real differences exist within and between sports. Without further work exploring the factors impacting upon career longevity it is difficult for practitioners to forecast an individual player's likely longevity within their sport.

2.3.3. Reasons for retirement from professional team sport

Based on the large inter individual variation in career durations reported within the literature, it is clear team sports players can approach the end of their careers at a range of ages. Arriving at the discontinuation stage and retiring from professional sports has been well acknowledged as a potentially difficult transition, with many athletes struggling to adjust (Blinde & Stratta 1992; Webb et al., 1998; Wylleman et al., 2004; Lavallee & Robinson 2007). Much research has therefore focused on the provision of support services to retiring athletes (Drawer & Fuller, 2002; Park et al., 2013; Sanders & Stevinson, 2017) and understanding psychological antecedents of healthy transitions away from professional sport. This body of work provides some useful information with which to understand why an athlete's professional career ends. Commonly cited reasons for retirement from team sports are age, injury (chronic or acute), contract end, declined performance, reduced motivation to remain a professional athlete and prioritisation of a future career path or family (Ogilvie & Taylor, 1993; Drawer & Fuller, 2002; Fernandez et al., 2006; Rintaugau & Mwisukha, 2011; D'Angelo et al., 2017; Sanders & Stevinson, 2017, Carapinheira et al., 2018; Koch et al., 2021). Performance pressure, particularly in the final year of a contract (Roberts et al., 2015) and conflict with coaches, or administrators (Rintaugau & Mwisukha, 2011; D'Angelo et al., 2017) have also been cited as reasons for career termination amongst team sports athletes. Although single reasons are often given for retirement, career termination is acknowledged as being a complex, multifaceted process, caused by multiple sources (Fernandez at al., 2006, Stambulova et al. 2009). Despite its accepted multi-factorial nature, few studies have attempted to describe how reasons given for retirement may interact (Sanders & Stevinson, 2017). As such, it is currently unclear how factors prompting the decision to retire may lead to the end of a player's career. For example, amongst 307 professional footballers, injury was cited as a reason for retirement by 42% of participants (Sanders & Stevinson, 2017). It is, however, unclear whether injury led to retirement via declines in performance due to movement deficits, such as diminished speed and the subsequent result was no offer of a contract extension, or if pain resulting from injury lead to reductions in motivation to continue, and the player subsequently made the decision to retire.

In addition to failing to explore the interaction between factors leading to the decision to retire, the available research provides limited exploration of the 'voluntariness' of retirement decisions. The voluntariness of a retirement decision can be explained as the degree of control athletes have over their decision to retire (Park et al., 2013). To frame attempts to prolong careers it seems important to understanding the extent to which athletes choose to retire versus the extent to which the team controls this process. Despite the potential utility of this concept, considerable variation in the voluntariness of retirement decisions is reported in the literature, even where studies have examined the same sport. According to Rintaugau & Mwisukha (2011), the majority of football players (66%) planned their own retirements and retired voluntarily. In contrast, in the study of D'Angelo et al., 2017, only 2 out of 14 (14%) formerly elite Italian football players described their decision to retire as voluntary. Whilst cultural and methodological differences may explain some of this discrepancy, deeper exploration of decisions relating to retirement and career termination is required to provide information elucidating the specific interacting factors that prompt a decision to step away or continue. A player's decision to retire is often presented as a decision taken in isolation without focus on the specific choices available (e.g., financial, and geographical options available to continue playing vs alternative employment choices). Very little evidence exists relating to contract offers made to older players and discontinuation decisions from the perspective of the sports organisation involved in deciding whether to offer a player the chance to continue playing. The major reasons decision making executives do not renew player contracts have not been described within the literature. Anecdotal evidence suggests the decision-making process relating to contract offers and their subsequent duration is based on current and projected player performance (Dendir, 2016). However, further research investigating factors that are considered and choices offered to players would be insightful to practitioners and those wishing to further understand the voluntariness of player career termination decisions.

2.4. Examining performance change across a professional career

Research examining reasons for career termination does not suggest a decrease in sports performance always underpins a player's drop out from the elite professional level. Although in many circumstances a player will have considerable agency in deciding when they retire, clearly to continue playing professionally an offer of continued employed is required. Whilst it is possible many factors are involved in a sports executive's decision to offer a contract; it seems likely there is some requirement for a player to be able to perform above a minimum level. Understanding likely changes in performance over the course of a player's professional career is therefore important to practitioners charged with assembling playing squads. The following section examines changes in performances over the course of team sports careers. Methodological approaches used to understand performance change will be examined prior to an exploration of findings showing longitudinal change in performance over team sports careers. Research studies examining longitudinal performance change are presented in Table 1.

2.4.1. Methodological approaches to understanding career performance trajectory

Compared to objectively quantifiable individual sports, where the age-performance relationship is well understood, evaluating the performance of an individual athlete in team sports presents a greater challenge to researchers. Various techniques have been used in attempt to understand the trajectory and age of peak performance across team sports careers (Table 1). The most straight forward analytical method examines numbers of players in each age group within a professional team sport population. Using this 'participation' technique, the most common age group signifies the age of peak performance, as it is when the highest relative frequency of players are able to perform at the required standard. Previously described population characteristics therefore provide useful insight into when peak age is likely to occur for each activity. It should however be noted that when using this technique precise peak age is likely to be heavily influenced by peripheral players who have relatively short careers (Bradner et al., 2014). Indeed, purely examining population distribution may provide an indication of peak year of performance but cannot provide a good indication of relative performance levels across a career and fails to account for the potentially later peak ages of top performing players (Bradner et al., 2014). Alternative approaches to profiling career performance trajectory use mathematical models, such as regression-based techniques to investigate the relationship between age and performance metrics or player market value (Kalén et al., 2019). It is however, accepted that selection of an appropriate metric to quantify team performance is challenging (Frick, 2007; Bradner et al., 2014). It is also acknowledged that inclusion criteria generally applied to facilitate meaningful application of modelling techniques often leads to a selection bias which prioritises players with longer careers and may underestimate the true extent of age-related decline (Bradner et al., 2014). Whilst regression and other modelling-based techniques represent a more sophisticated and potentially accurate means of examining career performance trajectory versus distribution-based analyses, specific models must be understood in the context of performance metrics utilized as well as the inclusion criteria and statistical methodology applied.

2.4.2. Estimating age of peak performance

Across a range of analytical methods, it is well established that players' performance improves up until their peak years and subsequently declines as they approach retirement (Table 1). In four elite European football leagues, Dendir (2016) examined player rating statistics using mixed effect models to show (from 2010 to 2015) players performance peaked between 25 and 27 years of age depending on playing position. In a similar investigation, Kalén et al. (2019) used a 1-way analysis of variance and linear regression to show average age of peak performance, based on calculated market value for champion's league football players was 26.5 in 2018, having increased from 24.9 since 1992. The ageing trend highlighted by these authors shows the dynamic nature of age-performance trends in sporting leagues and suggests temporal proximity should be considered when interpreting the extent to which study findings are likely to apply to current league populations. Further evidence that football players peak in their mid to late twenties was provided by Frick (2011); who showed that a player's maximum income is generally reached at age 27 or 28. The author however noted that age-earnings profile, is much flatter for players with the highest incomes, suggesting by certain metrics the relationship between age and performance in a given league may differ based on player status. Within the Bundesliga, leadership skills and the player's geographical origin also influence earnings. This suggests factors without a direct, statistical link to performance can also impact how players are valued by organisations. This further confirms the difficulty of fully evaluating the performance of individual players in team sports that take place in dynamic social environments.

Within AFL it appears age of peak performance occurs at a slightly younger age than that found in football. In an examination of career performance trajectories, Sullivan et al. (2020) found mean age of peak performance (based on an AFL specific performance statistic) is between 24 and 27 depending on position (24 y for forwards, 25 y for defenders, 24 y for midfielders, and 27 y for ruckmen) with a substantial decline in performance evident at 30 in defenders, forwards and midfielders. McIntosh et al. (2019) found AFL players reach their peak performance by 22 years of age but show no substantial drop off in performance in subsequent career years. In interpreting this finding, it is important to note that McIntosh et al. (2019) showed declining numbers of players in each age group from age 22 onwards. This suggests that whilst players remaining in the AFL were able to maintain a flat performance trajectory, it is unclear if this was the case for those dropping out. Differences between the ages of peak performance reported in these two studies examining the AFL population are likely due to differences in selection criteria for players and the nature of the performance statistic examined (Sullivan et al., 2020). Reported differences within the same sport exemplify how findings are influenced by performance metrics selected and statistical methods applied.

In both Ice Hockey (NHL) and Baseball (MLB) peak performance occurred slightly later than in football and AFL, at between 27 and 29 years of age (Fair, 2008; Bradbury, 2009). Playing position influenced age of peak performance in both sports (Brander et al., 2014)). Within baseball, Bradbury (2009) also investigated peak performance in isolated performance aspects of the sport. Performance in more athletic tasks such as hitting and running were found to peak at an earlier age compared to overall sports performance, whilst skills based on experience and knowledge such as drawing walks, peaked later (Bradbury, 2009). Age of peak performance is known to vary between activities due to differences in attributes required for success (Allen & Hopkins, 2015). Peak age is influenced by the extent to which success in a particular sport or skill requires a bias towards explosive power or endurance type qualities (Allen & Hopkins, 2015), as well as the extent to which performance can be improved through enhancements in skill and decision making, resulting from increased exposure to high-level competition (Bradner et al., 2014). Whilst age of peak performance appears approximately similar in all team sports relative to the human lifespan, there is clear evidence of variation within and between sports. This variation is likely, in part, due to between sport and position differences in the contribution of physical, technical, and tactical capabilities to performance. However, environmental differences between sports in areas such as talent development systems and the size of global labour markets are also likely to contribute to the observed variation. Given performance is known to improve up to a certain point in a career before declining and the best players are accepted as having the longest careers, it seems likely the 'height' of a players' peak performance has a strong influence on their longevity. Although findings showing changes in performance across careers are clearly useful to practitioners, comparison of findings is made difficult due to methodological differences. Future work would be improved by providing a thorough description of the full implications of specific inclusion criteria and statistical techniques selected. In addition, whilst understanding longitudinal changes in performance are useful, it is also important practitioners understand longitudinal change in how much players are likely to play. Understanding the extent to which players ability to contribute over long seasons may change with age seems important for those charged with assembling playing squads and carrying out succession planning. Currently however such information is unavailable.

Table 2.1. Studies describing longitudinal performance trends or career duration.

Study	Population	Aim	Methods	Results
Baker et al., 2013.	All players drafted into MLB (n = 3927), NBA (n = 476), NFL (n = 3341), NHL (n = 1776) between 1980 and 1989.	Compare typical career durations in major American team sports. Examination of effect of performance and position on career duration.	Examined average career length for all players drafted into each professional league. Grouped players within each sport based on career duration and compared career performance statistics between groups.	Percentage of drafted players who played in each league: MLB: 27% (full season played), NBA: 85%, NFL: 72%, NHL: 57%. Mean career length (for drafted players who made the big leagues): MLB: 7.8 seasons, NBA: 8.2 seasons, NFL: 5.5 seasons, NHL: 8.2 seasons. High variability in career length in all sports (SD 4.1-5.8).
Bradbury, 2009.	MLB batters and pitchers playing between 1921 and 2006 (86 seasons) (n= 450). Players required to play ≥ 10 seasons with ≥ 5000 plate appearances (batters) or faced ≥ 4000 batters (pitchers).	Understand impact of ageing on various baseball skills within an elite player cohort.	Retrospective longitudinal analysis. Multiple regression analysis examining aspects of hitting and pitching performance versus age. Compared multiple baseball performance statistics.	Batters and pitchers peak around the age of 29. Batters hitting peak is at approximately 28 but peak age for drawing walks is 32. Suggests performance in an area of the game more influenced by experience peaks later than an area of baseball performance which is more influenced by physical ability.
Brander et al., 2014.	NHL players involved from 1997-1998 season through to 2011-12 season (14 years) (n = 2033). Players required to be involved in >20 games per season.	Understand impact of age on performance in Ice Hockey. Compare various methods for determination of peak age of performance.	Multiple regression-based and distribution-based techniques used to determine peak age of performance. Forwards and defencemen evaluated on points scored per game and plus minus	Within NHL population median age is 25 for forwards, 26 for defencemen and 28 for goal tenders. Peak age of scoring is 27-28 for forwards and 28-29 for defencemen. Both forwards and defencemen exhibit near peak performance from 24 to 32 and 24 to 34 respectively.

			rating. Goal tenders evaluated on save percentage.	Goal tenders save percentage displays little variation across career span from early 20s to late 30s.
Dendir, 2013.	Football players in four elite European leagues (Bundesliga, English Premier League, La Liga, Serie A data) (n=3102). Sample restricted to outfield players playing ≥270 minutes from 2010-11 through 2014-15 (5 years).	Establish peak age of performance in elite football. Compare various methods for determination of peak age of performance.	Distribution, bivariate and regression-based techniques used to determine peak age of performance. Player performance evaluated using Whoscored.com player rating scores (composite, proprietary, algorithm calculated rating).	Whole population mean ages Forwards 26.8, Midfielders 26.4, Defenders 27.2 years old. Outfield players peak age of performance is between 25 and 27. Forwards peak age is 25, midfielders 25-27 and defenders 27.
Fair, 2008.	MLB players who played ≥10 seasons between 1921 and 2004 (84 seasons) (n= 441).	Understand effect of ageing on aspects of performance in baseball. Compare various methods for determination of peak age of performance.	Age effect estimated via non-linear, fixed effects regression models. Examined three hitting performance statistics and earned runs average (ERA) for pitchers.	Peak age for batters: 28. Peak age for pitchers: 26. Rates of decline post peak age have decreased in more recent years compared to early years within the sample.
Kalén et al., 2019.	Football players participating in the UEFA champions league between 1992-1993 and 2017-18 (23 seasons) (n = 16062 player seasons).	Understand ageing trend in elite soccer over last 20 years.	Examine peak age of performance by investigating relationship between player age and market value.	Mean ages of players by position group: Goalkeeper: 28.2, Centre back: 26.3, Central midfield: 25.4 Forwards: 25.3, Wing: 24.7 years. Based on relationship between player age and market value, peak age of performance for all positions is between 26 and 30. Goal keepers and centre backs tended to peak later than other players.

				Results suggest an ageing trend has occurred over the last 3 decades in the Champions League. Player average age has increased by 1.6 years since start of study sampling period.
McIntosh et al., 2019.	AFL players playing between 2013 and 2017 seasons (5 seasons) (n = 1052).	Develop a model to describe longitudinal performance in AFL. Examine influence of experience (games) and age on AFL performance.	Built linear mixed models to describe longitudinal performance. Player performance was evaluated using Champion data AFL player rank metric. (Composite score measuring the impact of a player's actions on the equity between the two competing teams (Jackson et al., 2009)).	Modal age for all positions within the AFL was 20-22. Player performance improves up to around 22 years of age and then begins to plateau. Players typically improved performance with increased experience. A break point in rate of improvement shown at approximately 60 games (after this point rate of improvement slowed or plateaued). After reaching peak age there was no substantial drop-off in performance with increasing age.
Sullivan et al., 2020.	AFL players drafted between 1999 and 2015 who played ≥4 seasons and completed careers between 2003 to 2017 (15 seasons) (n = 207).	Understand age of peak performance and career performance trajectories for different positional groups.	Regression based analysis of performance-age relationship. Champion data AFL Player Rank metric was used to evaluate players (Algorithm calculated metric based upon the outcomes of player match activity and its associations with winning margin).	Mean age of players within each positional group: Defenders: 24, Forwards: 23, Midfielders: 24, Ruckmen: 24. Peak ages of performance by positional group: Defenders: 24, Forwards: 24, Midfielders: 24, Ruckmen: 27.

Wakim & Jin, 2014.	MLB hitters playing from ages 24 to 36 between 1921 and 2012. Player seasons with less than 200 plate appearances were excluded (n = 217). NBA players playing in eight seasons between 1981-82 through to 2012-13 (n = 645).	Demonstrate utility of functional data analysis (FDA) procedures. Illustrate techniques for FDA based hypothesis testing. Show how FDA techniques can be used to group players with similar age-performance trajectories.	Conducted an analysis of relationship between offensive production and age in MLB players. Offensive production examined using weighted on-base average statistic (Tango et al., 2007). In NBA cohort study examine relationship between players age and win share (single statistic considering wins a player produces for their team accounting for both offensive and defensive performance).	MLB hitters peak between 29-30. Categorisation of hitter (Power hitter vs non-power hitter) is associated with difference in ageing curve. Power hitters are closer to their peak offensive performance in years prior to peak but show a higher rate of decline post peak versus non-power hitter. In the NBA population mean age of peak performance is 26.3 years. Performance appears to decrease most rapidly between ages 29 and 31. A further period of rapid decrease in performance appears to take place between ages 36 and 38.

AFL, Australian Football League. MLB, Major League Baseball. NBA, National Basketball Association. NFL, National Football League. NHL, National Hockey League. UEFA, Union of European Football Associations.

2.5. Explaining decline in performance post peak years

Studies modelling career performance trajectory detailed in the previous section show, that although age of peak performance may vary by sport, position and player status, athletes over the age of 30 are unlikely to perform as well as they did in their mid to late twenties. A decline in performance after age 30 is also evidenced by the sharp decline in player numbers found at and beyond this age group across all professional sports populations (Baker et al., 2013). The potential mechanisms explaining such an age-related decrease in performance after peak years have received considerable research attention. Despite the holistic view of careers encouraged by models such as HAC (Stambulova et al., 2020), the majority of attempts to explain performance decline have been from a physiological perspective. This section of the literature review will examine the various models exploring the physiological basis of performance decline, from both the perspective of changes in measurable game output and the perspective of potentially causative, underlying physiological system change. Alternative models of decline based on psychological and cognitive changes as well as a model based on accumulated damage will also be explored. It should be noted that all evidence relating to a decline in match output and much of that describing change in physiology is drawn from football-based studies.

2.5.1. Change in match running outputs with age

To elucidate the source of performance decline in older team sports athletes, several studies within football have examined changes in match running outputs with increasing age. Cross sectional examinations of the highest level leagues in Germany, Spain, and China (Bundesliga, La Liga, Chinese Soccer Super League) showed players over 30 covered significantly lower total distance (Sal de Rellán-Guerra et al., 2019; Zhou et al., 2020), performed a significantly lower frequency of fast runs and sprints (Sal de Rellán-Guerra et al., 2019) and produced significantly fewer accelerations and decelerations (Lorenzo-Martínez et al., 2021) throughout a match compared to younger players. Older players were also shown to have higher between match variability in high intensity running and sprinting versus younger counterparts (Lorenzo-Martínez et al., 2020). Similar trends were reported in a longitudinal analysis of 154 players who competed in the Spanish first division (LaLiga) between the 2012–13 and 2019–20 seasons. Over consecutive seasons, as players aged, they showed reductions in total distance covered, number of high intensity efforts and distance covered at high intensity (Rey et al., 2022). It should be noted that positional differences were found in changes in running output with age (Zhou et al., 2020; Lorenzo-Martínez et al., 2021). Declines were apparent in nearly every positional group, however in one study, no reduction in running output was found in older wide midfielders (Sal de Rellán-Guerra et al., 2019). Whilst multiple reasons could explain this finding, it is possible players unable to maintain running performance were unable to survive in the league, in this position group and were removed from the population prior to reaching the age of 30. Interestingly, alongside reduction in running performance, all studies examining technical performance, showed improvements in passing ability with increased age (Sal de Rellán-Guerra et al., 2019; Zhou et al., 2020; Rey et al., 2022). Within cross sectional studies, a finding of improved skill in older groups may reflect a higher drop-out rate amongst less technically able players (Rey et al., 2022). However, the finding of longitudinal improvement in passing accuracy suggests players surviving to older ages can develop technical aspects of their performance throughout their careers (Rey et al., 2022). By continuing to make improvements in technical and experiential qualities such as match knowledge, anticipation, and tactical awareness (Dendir, 2016) older players can perhaps offset some of the inevitable age-related decline in physical performance (Allen & Hopkins, 2015).

In demonstrating reduced match running output, the results of these studies appear to offer an explanation as to why performance decline and a substantial drop off in player numbers in soccer appear to occur at approx. 30 years of age (Dendir, 2016; Kalén et al., 2019). It is however important we stop short of considering this association a causal link. In the absence of fitness testing data and match performance information, it is unclear if reduced running numbers in older players are a function of reduced physiological capability, or the result of improved decision making and reading of the game leading to a lower requirement to perform high intensity running. Furthermore, it is possible the finding of higher between-match variability in running output in older players is indicative of an improved ability to attune to different match demands and not physiological decline per se. Without clear evidence showing reduction in physiological function is the cause of changes in running output, it is hard to conclude with certainty that age-related physiological decrement explains observed reduction in performance. Given all evidence presented regarding changes in match running outputs with age relates to football, it is currently unclear if changes in running output are likely to take place in older athletes in different team sports. It is possible team sports with similar running demands to football may find similar trends in older players, however further research is required to understand if and how such changes may manifest.

2.5.2. Physiological changes with age in team sport athletes

The following section presents evidence relating to the potential for age related reductions in aerobic function, anaerobic function, and maximum strength to explain reductions in both physical output and spots performance observed with advancing age in professional team sports. Many studies have investigated age related change in physical output in elite football and team sport populations. However, comparisons are generally between junior/academy age groups (e.g., u15 vs u19) (Vanderford et al., 2004; Al Haddad et al., 2015; Karahan et al., 2016) or between junior age groups and seniors (Chamari et al., 2005, Nikolaidis, 2016; Kelly et al., 2017). When comparing amongst high level juniors and between juniors and adults, it is clear performance improves with increased chronological age (Till et al., 2017). However, despite the potential benefits of a greater understanding of age-related decline in senior professional populations, few studies provide age related comparison within adult age groups.

2.5.3. Decline in aerobic capacity

$\dot{V}O_{2max}$ represents the 'highest work rate at which oxygen can be taken up and utilized by the body during exercise' (Bassett & Howley, 2000). There has been considerable interest in $\dot{V}O_{2max}$ as a potential determinant of running performance in football (Albano et al., 2019; Modric et al., 2020). In the context of ageing players, it has been suggested that reductions in this measure may be responsible for previously reported declines in within-game running output with age, and may also reflect a more general reduction in the overall function of an athlete's aerobic metabolism (Sal de Rellán-Guerra et al., 2019). Despite age related reductions in $\dot{V}O_{2max}$ being a seemingly intuitive explanation for reductions in running outputs in older players, studies examining changes in $\dot{V}O_{2max}$ with age in professional soccer players have reported equivocal findings. In a cross-sectional analysis of 153 high level Czech players who completed a pre-season lab test, Botek et al. (2016) showed players aged >30 years old exhibited a significant decrease in both $\dot{V}O_{2max}$ (5%) and HR_{max} (5.8%) compared to the younger age-groups. In contrast, in a similar cross-sectional examination of 162 high level Brazilian players tested as part of pre-season battery, Signorelli et al. (2012), reported no significant differences in $\dot{V}O_{2max}$ between younger (17–22 years) and older (27–36 years) players. It is possible differences between the results of these studies can be explained by differences in body mass between respective older and younger age groups. In the study of Botek et al. (2016), older players had higher fat free mass (approx. 4 kg heavier) compared to younger counterparts, and although they recorded greater absolute $\dot{V}O_{2max}$ scores, they had lower relative values compared to the younger age groups. In contrast, in the study of Signorelli et al. (2012) there were no differences in body mass between age groups. Based on these results, whilst gain in mass with age and a subsequent reduction in relative parameters seems possible, reductions in the maximal rate at which body consumes oxygen during exercise do not appear to be an inevitable consequence of ageing in older professional athletes.

When evaluating the potential of any decline in $\dot{V}O_{2max}$ with advancing age to explain age related performance decrement, we must consider the extent to which a decrease in $\dot{V}O_{2max}$ has the potential to impact upon performance. To date no longitudinal study has examined the effect of a progressively declining $\dot{V}O_{2max}$ on football performance. However, when looking at the beneficial effects of augmented $\dot{V}O_{2max}$ on performance, it been suggested that beyond a certain level of $\dot{V}O_{2max}$, thought to be around 60 $mL \cdot kg^{-1} \cdot min^{-1}$, further increases are unlikely to enhance team or individual success

(Reilly et al., 1999; Tonnesson et al., 2013). Beyond this threshold, other qualities are thought to be more predictive of performance. It is therefore possible, that even if age related declines in $\dot{V}O_{2max}$ were to take place, such reductions would be unlikely to impact performance whilst the maximal value remained above a threshold. Given equivocal findings and question marks regarding the relevance of $\dot{V}O_{2max}$ to performance, it seems unlikely age-related changes in this variable explain decline in performance in the years following a football player's peak age of performance. Although it is possible age-related reductions in other measures of aerobic metabolism are of consequence, current evidence relating to reductions in such markers also seem to be equivocal. In a study presenting positional comparisons, Modric et al., 2020, found forwards, who were the oldest positional group, had the lowest anaerobic threshold values compared to other outfield players. Whilst this may constitute evidence of age-related reduction, it is also possible positional specific demands influence such cross-sectional observations. Furthermore, Signorelli et al. (2012) showed no significant differences between older and younger players in any measure of anaerobic threshold, a variable thought to be more sensitive to training induced change than $\dot{V}O_{2max}$ (Hoff & Helgerud, 2004). Although reductions in HR_{max} reported in the previously described study of Botek et al., 2016, may also suggest diminishing aerobic function with age, it has been shown that a decline in HR_{max} can be compensated for by an increase in stroke volume which ensures maintenance of optimal cardiac output (Perim et al., 2011). Whilst in general terms, human aerobic function clearly declines over the lifespan (Hawkins & Wiswell, 2003), currently there is no clear evidence suggesting a decline in aerobic capability causes reductions in game running outputs or match performance for professionals able to play into their mid-thirties.

2.5.4. Decline in anaerobic qualities

Although sprinting and high-intensity actions only account for 8-12% of total game distance, situations requiring high intensity running and sprinting often constitute key moments within a match (Bangsbo et al., 1991, Haugen et al., 2013). It is therefore possible reported age-related reductions in overall football performance (Dendir, 2016; Kalén et al., 2019), and within match high intensity work output (Rey et al., 2022), could result from diminished anaerobic or power generating qualities within ageing players. Despite the likely importance of the anaerobic metabolism and neuromuscular system to high intensity actions, very little research has examined changes in related qualities across professional team sports athletes' careers. In a cross-sectional examination of 1723 trials from 939 football players, at a range of performance levels, Haugen et al., 2013, showed peak sprint velocity was highest between 20 and 28 years of age, with subsequent small but significant decreases occurring thereafter. Whilst this finding is potentially significant in attempting to explain age related decline in professional sports, other studies have not reported reductions in speed or neuromuscular output with age. In an examination of 20m sprint performance in 474 male, national league football players, Nikolaidis et al., 2016, showed no major differences in speed from u16 to u35 age groups. Botek et al., 2016, also showed, running based peak power output was equivalent across all professional aged players. However, given in this study PPO was measured as part of an incremental treadmill test, it is unlikely players reached speeds and outputs that could have been achieved during maximal sprinting. In addition to examining sprinting performance, Haugen et al., (2013) also performed a cross-sectional examination of countermovement jump (CMJ) performance vs age and found no differences between age categories. The authors however only present jump height, a measure which may lack resolution as a means of fully understanding neuromuscular capability (Gathercole et al., 2015; Cohen et al., 2020). It is therefore possible age-related deficits in CMJ were present but required further analyses with greater discriminatory capability. Based on methodological limitations and a lack of research, it is currently difficult to evaluate the way in which anaerobic qualities are likely to change with age in professional team sports athletes. Given the potential of changes in anaerobic qualities to impact performance, further investigation of age-related changes in such qualities is required.

2.5.5. Decline in maximum strength

At a general level, maximum strength is defined as the greatest force an athlete can produce under specified conditions (Stone et al., 2002). It can be assessed in variety of ways, specific to different muscular contraction types, capturing force outputs from single joint actions through to global movements. Although not a marker of sporting ability itself, maximum strength is closely related to a series of performance measures that are important in a wide variety of team sports (Allerheiligen et al., 1994; McGuigan et al., 2013). Maximum strength is considered an underpinning physical quality essential for the development and expression of explosive power (Baker & Nance, 1999; Stone et al., 2003; Cormie et al. 2011). It is also of importance as possessing low levels of maximum strength within high level sporting populations has been shown to be related to increased injury risk (Timmins et al., 2015: Opar et al., 2015). Maximum strength is therefore thought to be important towards developing resilience in athletes and for successful return to play following injury (Risberg et al., 2018). Maximum strength capabilities have been shown to differentiate between levels of senior sport e.g., professional and semi-professional (Fry & Kraemer, 1991; Baker & Newton, 2008; Argus et al., 2012) and between elite juniors of different ages (Till et al., 2016). Despite its importance to performance, very little research has examined how maximum strength may vary with age within high level professional team sport populations (Slimani & Nikolaidis, 2017). Scoz et al., 2021, compared isokinetic concentric and eccentric, peak torque profiles of the quadriceps and hamstrings in 570 elite male Brazilian soccer players across different age categories. All players had played for at least 5 years in Brazilian first or second divisions. Results showed a moderate effect of age on strength, with a significant reduction in quadriceps strength of midfielders and goalkeepers in oldest age categories compared to younger players. Although reductions in strength were not clear and significant across all age and position categories, these results suggest a reduction in strength occurs with age in some elite football players. It is however important to note that all strength testing scores were normalised to BW. In both GKs and Midfielders mean BW was more than 10kg heavier in oldest vs younger players. Clearly this would impact the observed comparative relative decline in older players compared to their youngest positional peers. It is unclear how comparison of age groups would have been affected if an allometric scaling process had been adopted.

A reduction in strength with age in professional team sports athletes has also been shown by studies examining injury risk across professional team sport populations. In a cross-sectional regression-based analysis of 284 male, sub-elite, Spanish, soccer players (age 18-38 years, playing at clubs from 4th to the 6th tier of Spanish football), Vicens-Bordas et al. (2020) showed age had a negative association with preseason eccentric hamstring strength. The authors demonstrated a 0.9% reduction per year in peak relative eccentric force produced by the hamstrings. Although this reduction in strength was smaller in magnitude than that shown in peak concentric torque by Scoz et al. (2021), it constitutes further evidence that a decrease in maximal force generation with age is possible within professional sports populations. It is however important to recognise that it is unclear if trends observed in football players in the 4th to 6th tier of Spanish football apply to athletes playing at the highest levels of professional team sport.

When examining the extent to which findings suggesting a decrease in strength with age are likely to transfer to other cohorts it disappointing that no details on training protocols followed were provided in either study. Whilst such cross-sectional data are of interest to practitioners, given the plasticity of muscle physiology in response to imposed demands it would be more useful if observed changes in strength were presented in the context of training carried out. Indeed, understanding players capacity to respond to training with age may be of greater interest to practitioners than cross-sectional strength levels at the start of pre-season. Appleby et al., 2012, looked at changes in maximal strength over a 2-year period in 20 professional rugby union athletes. Whilst starting strength was negatively correlated to improvement, chronological age was not associated with magnitude of change in maximal strength. It is therefore possible age-related declines in strength in both studies previously described, may have been prevented with more thorough physical performance programs. Without details of training programs followed and compliance, it is unclear if observed change in strength with age is due to inevitable physiological decline or some aspect of change in physical stimulus applied. Interestingly, within gerontological literature, there is no evidence for age related atrophy beginning until 50 years of age (Faulkner, 2008). However, given high intensity match play represents an important part of stimulus for physiological adaptation in normal training week (Morgans et al., 2017), it is possible to speculate that, in the event older players were to play less, they would likely receive less adaptive stimulus which may in time lead to a regression in performance levels. Although it is possible maximum strength may decrease with age, results presented here do not allow us to conclude that reduction in strength with age is a universal occurrence in professional team sport populations. Without a more mechanistic understanding of changes in strength with age within professional athletes, it is unclear if such changes are the result of age-related decline in physiology or reduced exposure to adaptation inducing stimulus. Given age related changes in strength may be specific to testing methods, muscles, and movements as well as potentially off set by well-designed training, further work is needed to understand changes in maximum strength in professional athlete populations.

2.5.6. Alternative models of age-related decline

Although physiological models describing decline in a specific system or physical quality dominate attempts to explain age related decline in output and performance, several alternative mechanisms have been suggested. In the absence of an accepted, objectively tested reason for reduced performance in older professional athletes, Faulkner et al. (2008) proposed that changes in fine motor coordination may be responsible for diminished performance. These authors suggest prior to the actual loss of motor units with advancing age, there are subtle changes in fine motor control that are not picked up by the gross motor control tests used to assess age-related changes. Such changes in fine motor control would presumably impact performance across an array of tasks. Whilst there is no evidence of a decline in skill performance (Sal de Rellán-Geurra et al., 2019) or reduction in coordination during a professional career, the authors suggest small decreases in fine coordination could impact the ability of an older athlete to effectively defend or evade ever younger opponents. Whilst a neural or cognitive basis of decline is interesting, further research is needed to substantiate this suggestion. Schultz et al., (1994) proposed that the performance deficits observed in athletes after 30 years of age are in part the result of accumulated wear and tear on the body. The authors do not describe a specific mechanism but suggest that the cumulative effects of injury and sport related wear and tear are likely minor in the 20s but perhaps felt in the 30s and manifest in diminished performance (Shultz et al., 1994). This description of age-related decline has parallels to the description of ageing at a cellular level which describes a complex process of damage accumulation to genetic material (Kirkwood, 2005). Whilst the hypothesis of injury accumulation in athletes is lacking in detail, it does appear that the number of players reporting significant somatic degeneration following a playing career may be high. In an investigation of 185 retired professional football players who had played in England, 32% of respondents reported having been medically diagnosed with osteoarthritis in at least one lower limb joint (Drawer & Fuller, 2002). Even accounting for a selection bias in this study, it seems likely that a high frequency of match play and training over a long career can have a detrimental effect on joint health in many professional and former professional team sports athletes. Furthermore, the finding that amongst professional athletes increasing age is associated with greater risk of a variety of soft tissue injuries (Meeuwise, 1994), suggests athletes do become more susceptible to damage later in their careers. The extent to which this is due to cumulative trauma, age-related change in tissue, or a combination of the two is unclear. In addition to the alternative theories of decline presented above, it also has been suggested that changes in motivation and mental health (Purcell et al., 2019) as well as variety of social and economic factors (Fick, 2007) may impact upon an athlete's performance in the later stages of their careers. Whilst potential alternative models of decline are interesting, it is clear definitive causal supportive for any one of them is lacking. Given the breadth of factors which could impact performance decrement and drop out, and their potentially interactional mode of action, it appears important future research efforts embrace the likely complexity of longevity within professional team sports

2.6. Summary and future research directions

Across professional sports, the reported span of careers and the timing of peak ages of performance appears approximately similar. However, given the various inclusion criteria and statistical methodologies applied by investigations examining longitudinal performance change it is unclear to what extent data presented explain the experience of all professional team sports athletes. To better understand the nature of professional team sports careers, further work is required which provides simple, contemporary information relating to career durations and player age profiles. To provide practitioners with a basis of comparison it would be useful for such work to examine multiple team sports using standardized methodologies and apply minimal inclusion criteria. By comparing different sports with broadly similar physical requirements, this approach has the potential to highlight factors influencing career profiles and longevity. Given longitudinal performance has been extensively studied, future work should also examine change in availability or game time with advancing age as a means of offering information complimentary to existing literature.

Evidence presented within this review shows professional team sports athletes' performance typically declines following their peak years of performance. Regression in game movement profiles with compensatory improvements in skill execution appear likely to occur in athletes surviving in professional sports into their thirties. Although a physiological basis for such changes appears likely, it is currently not well understood. Future work should therefore evaluate the extent to which physiological decline governs longevity in professional team sports. Considering equivocal findings relating to age-related change in aerobic qualities, future work should examine differences between older and younger players in terms of NM performance. A greater understanding of NM decline in team sport athletes could prove insightful for those designing interventions aimed at maximizing the time players are able to compete at the highest level. It is also important future work examines longevity via a more holistic lens. A broader understanding of the interacting factors potentially impacting performance decline and drop out from elite level team sport would be extremely useful for practitioners. To move beyond currently available, reductionist attempts to explain performance decline, researchers may need to consider adopting new investigative paradigms which embrace the likely complexity of longevity in sports careers. Whilst much remains to be elucidated, given the benefits of extending successful team sports careers, it seems important a focus is placed on providing practitioners with useful information which can inform the design of effective interventions.

CHAPTER THREE

APPROACH TO THE PROBLEM

Approach to the problem

3.1. Introduction

The purpose of this chapter is to describe how I attempted to achieve the aims and objectives of this thesis. This chapter therefore details the methodological approach that was applied to both the overall research project and its constituent studies. This chapter also shows how, in addition to being a series of linked studies, this thesis functioned as a learning vehicle, allowing me to achieve the fundamental personal development targets central to my motivation for pursuing doctoral education.

3.2. Format of this chapter

In section 3.3 of this chapter, I will examine the foundational philosophical viewpoint I adopted towards the research questions of this thesis. I will also explore my positionality in relation to my topic and subsequently describe how it, along with my learning aims, influenced my approach to this project. In section 3.4, I will describe how the projects philosophical foundation and my positionality, in the context of practical considerations, shaped the methodologies applied in the individual studies of this thesis, and informed the synthesis and interpretation of findings from them. In section 3.4, I will also describe how I attempted to understand progress towards my specific learning objectives. Figure 3.1, shown below, highlights the factors influencing the methodological approach used in this thesis and the ways in which they interact.

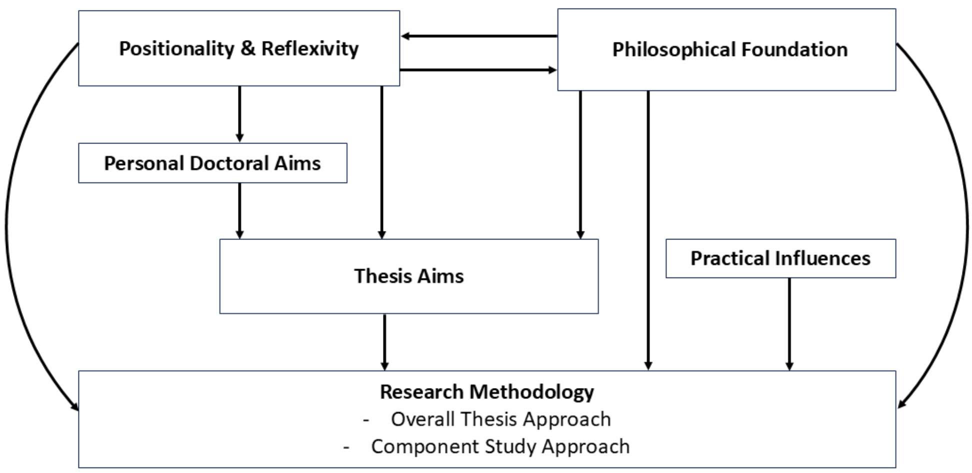


Figure 3.1. Schematic illustrating factors guiding the formation of the research methodology.

3.3. The influence of philosophical position and positionality on my research approach

Answering a linked set of research questions as exists in a thesis requires a consistent and recognisable approach to the conceptualization of reality, truth and what can be known (Gringeri et al., 2013). A coherent, approach to the treatment of reality is necessary for congruence between research questions, methodology, and interpretation of findings (Fryer & Navarette, 2024). Although it is common for qualitative researchers to explain their philosophical orientation and positionality, it has been suggested this is also both appropriate and useful within quantitative and mixed methods studies (Jafar, 2018). To emphasise the utility of contextualizing research findings within a description of the researcher and their goals, it has been stated that *'To understand what is really being measured and why, it is important to know who is doing the measuring' (Jafar, 2018).* What follows, in this section, is therefore an exploration of the philosophical perspective I took towards this research project, and a description of my positionality as it relates to the research problems of this thesis and subsequently described methodologies.

3.3.1. Philosophical foundation of this thesis

This thesis used critical realism as a philosophical foundation for the examination of career profiles and factors associated with longevity and performance decline in elite team sports athletes. Critical realism is a philosophical approach to research that combines a realist ontology with a relativist epistemology. The paradigm emerged in the 1970s in response to limitations of both positivist and interpretivist perspectives (Bhaskar, 1978). As a research philosophy, critical realism presents a nuanced understanding of the social world, arguing that reality exists independently of our knowledge of it, whilst simultaneously acknowledging the need to accept human experience of reality as being socially rendered (Bhaskar, 1998). Critical realism has been recognised as a robust and versatile philosophical perspective that can provide a strong foundation for a doctoral thesis (Fryer, 2022). Furthermore, based on several of the key tenets of critical realism, which are presented in Figure 3.2, and described below, it represents as an extremely suitable paradigm for the study of team sport careers.

Adoption of a stratified ontology is both at the core of critical realism and wholly appropriate for the study of professional team sports careers. The idea of a stratified ontology was presented by Bhaskar (1998) as a layered distinction between, the real, referring to deep objects and their causal powers and liabilities; the actual, which describes the activation of these causal powers (or mechanisms) through events and the empirical, which consists of our experiences of events and observations. Adopting this stratified ontology within this thesis allowed investigation of not only observable phenomena (e.g., statistically observable career profiles) but also their underlying, influencing mechanisms (e.g., physiological decline) and the interaction between them. Moving from surface level observations in this manner, to deeper causal factors and their interaction, enabled this thesis to offer deep theory driven explanations of career profiles and longevity in elite team sport.

As a result of its explanatory capacity, critical realism has been described as '*primarily an account of causality'* (Groff, 2004). In addition to its adoption of a stratified ontology, critical realism is well suited to explaining causality within complex phenomena because of its acknowledgement of the prevalence of open systems (North, 2017). An open system exists where observable outcomes (empirical level) are impacted by a vast array of objects and their causal powers (North, 2017). Given the numerous stakeholders involved in professional team sports and the likelihood the industry operates as a complex system (Salmon & McLean, 2020), a philosophical foundation based around the idea of open systems is appropriate for this research topic. Critical realism is also compatible with systems thinking tools designed to describe the nuance of complex environments (Armstrong, 2019). The focus on identifying causal powers and exploring open systems supported by this philosophical foundation, aided this work in delivering on its practical objective of identifying actionable interventions to address real-world issues relating to understanding and enhancing the effective length of elite team sports players' careers.

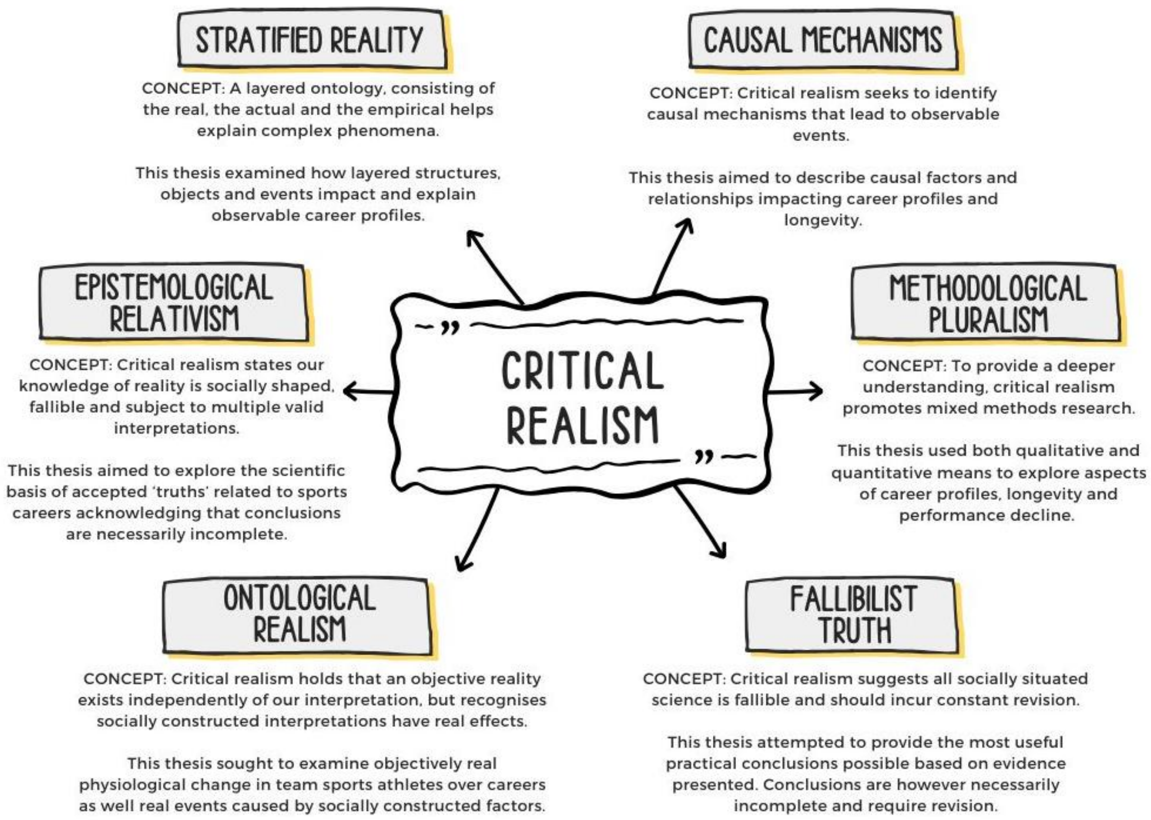


Figure 3.2. Key features of critical realism and a summary of their applications within this thesis. (Constructed based on material presented by North (2017) and Prime (2024)).

A recognition of the fallible nature of all socially situated science is a further key tenet of critical realism that is important within the context of this thesis. Emphasising the fallible nature of truth relates to the idea that knowledge is often socially constructed, contingent on societal variables (e.g., group structures, language, power dynamics) (Smith, 2010), and as such always open to correction (North, 2017). Critical realism maintains that knowledge accumulation takes place as more research is undertaken and that progress is unlikely to be universally smooth (Sayer, 1984). Given the lack of practically situated work describing career profiles and longevity in elite team sport, adopting this stance allowed the conclusions of this thesis to be presented in the context that they will inevitably require revision. This approach offered this thesis a certain degree of freedom to offer conclusions and practical suggestions based on the information presented, without restrictive consideration of the need to provide irrefutable evidence to substantiate them. A critical realist foundation was also deemed useful within this thesis as it allowed the overall work to embrace a mixed methods design and so combine the strengths of quantitative and qualitative approaches to uncover mechanisms and contextual influences. To facilitate a search for causal explanation, critical realism embraces interdisciplinary thinking (North, 2017). A philosophical foundation based on critical realism therefore allowed a combination of tools and thinking models from physiology, psychology, and social science to be used to explain features of careers and allowed for the possibility of recognising emergent outcomes as disciplinary paradigms were combined.

3.3.2. Positionality and Reflexivity in relation to research methodology

In addition to accounting for their philosophical worldview within studies, researchers should understand and articulate their positionality towards their inquiry (Holmes, 2020). Positionality has been defined as the position a researcher takes within a study in relation to their subject, participants, and research context (Savin-Bader & Major, 2013). It recognizes researchers are inseparable from the social world they investigate and that their background, values, and relation to this world will influence how they view their own work and interpret that of others (Holmes, 2020). As shown in Figure 3.1, my positionality influenced my research methodology via its effect on my personal doctoral aims and my research aims for this thesis. To understand and subsequently describe their positionality a researcher must demonstrate reflexivity (Jafar, 2018). Reflexivity is simply 'self-reflection that considers how one's own opinions, values and actions shape how data is generated, analysed and interpreted' (Oxford English Dictionary, 2016). It requires researchers to consciously examine the potential effect of their characteristics and perspectives upon the research process (Wilson et al., 2022).

Informed by my self-reflective practice, I was able to acknowledge that several aspects of myself and background likely influenced how I related to my research topic and participants within this thesis. As a physical performance coach, I realised I often gravitate towards a practitioners' viewpoint and place a high value on practically useful information that may have potential to impact athletic performance.

I was also aware that my professional role also means I likely hold a bias towards physical explanations for change in sports performance and may fail to fully acknowledge the role of other influences. In addition to being a coach, within this thesis I was also an aspiring researcher and although I have been involved in several studies, I did, and still do consider myself a relative novice. With reflection, I felt that this aspect of my positionality my have meant that despite the flexibility offered by philosophical foundation adopted within this thesis, I was at risk of being overly reliant on following the format and conventions of existing research and not sufficiently focused on finding solutions and interpretations that best fit my work. A further aspect of my positionality that I realised was important to acknowledge was that I am an educated, English, white male. Whilst I do not feel these were aspects of me that would greatly influence my work as a researcher, I acknowledged that my consciousness of the full impact of my social standing and life journey on my views and biases is limited, and it is therefore naive to dismiss the potential influence of ethnic background, gender, and nationality. In acknowledgment that my positionality is both inherently part of my research and a dynamic construct subject to change and development, I aimed to maintain some conscious awareness of it by conducting regular reflexivity promoting self-reflection throughout my doctoral journey (Appendix 9.1).

3.3.3. Recognising other influences on my research approach

In addition to my positionality and the philosophical throughline described above, Figure 3.1 shows my research methodology across this thesis was also influenced by my personal doctoral learning aims and practical constraints emanating from my professional role. To effectively build skills towards my development as a researching professional I carried out a self-audit (Appendix 9.1) and spent much time in reflection. To advance my skillset and be more capable of progressing in my career, my self-audit process showed I needed to improve my competency in all areas indicated in table 3.1. These criteria represent a more itemized version of the learning aims and objectives presented in the General introduction of this thesis. A full description of my starting level and goal levels of competency across the Vitae Researcher Development Framework (Careers Research and Advisory Centre, 2010) is presented in appendix 9.1. To enable development in these areas, it was important I chose study designs that would require me to build impactful skills and understanding in service of my learning objectives. As an example, to advance my ability to practically apply knowledge of research methodologies, I wanted at least one study to help me build underpinning skills by requiring a component of statistical analysis and coding.

Whilst I do not feel my professional role imposed many constraints on the potential methodologies I could have used to investigate aspects of professional team sport careers, I did actively seek to avoid certain potentially problematic study designs. My role requires irregular hours, schedule change at short notice and frequent travel. It has also led me to be based a long flight away from the University campus. As a result, although I was initially interested in the idea of a lab-based DNA study into ageing, this quickly seemed unfeasible. In addition, like many coaches working in professional sport, I am generally employed on relatively short-term contracts so felt it was unwise to commit to a study design that required an elongated data collection period with a single playing group.

Table 3.1. Doctoral learning objectives derived from those presented in the General introduction with an outline of the key steps towards their fulfilment. A more complete description of the process through which I identified and worked towards my learning objectives is provided in appendix 9.1.

Doctoral learning objective	Learning vehicle
Develop comprehensive knowledge of research topic.	Literature review, all constituent studies and concurrent reflective process.
Increased understanding of research methodologies (theoretical and practical).	Design and development of thesis and constituent studies. Statistical analysis in each constituent study.
Cognitive skill development (critical thinking, problem solving, synthesis).	Design and development of studies. Overcoming challenges inherent in research process.
Acquire knowledge and skills to conduct a research project (project management, collaboration, personal efficiency).	Design and implementation of studies alongside reflection and feedback on process.
Creation and interpretation of new knowledge useful to my profession.	Process of research and thesis construction. Using applied reflective pauses to base study questions/objectives on real-life applied scenarios.
Enhanced personal learning process (using consistent reflection and meta-reflection to draw lessons and understand personal learning journey).	Use of on-going reflection process. Summarized reflections presented as Doctoral learning pauses throughout thesis.
Improved general academic skills (writing, argument construction, numeracy).	Continual drafting and refining of research studies and thesis chapters with tutor feedback. On going data handling, methodology design and statistical learning.
Developed professional and research networks.	Subject recruitment and interviews within Study 3 (Chapter 6). Dissemination and discussion of thesis findings.

3.4. Methodological approach to the research question

This section will begin by detailing the research methodology I chose to adopt toward the overall thesis. I will then summarise the methodological approaches employed within each of its constituent studies. For each study, I will present the specific thesis objective they were designed to fulfil, offer a rationale for the investigative approach applied and offer some justification of my decision to use it over alternative research strategies. Within this section I will also describe how I attempted to understand my progress towards the learning aims and objectives of this thesis.

3.4.1. Whole thesis methodology

Based on my adoption of a critical realist philosophical foundation (Figure 3.2), I chose to conduct this thesis using a mixed methods research methodology. A mixed methods approach permitted examination of my research topic from a broad range of perspectives, enabled usage of a combination of quantitative and qualitative approaches (Teddlie & Tashakkori, 2009) and as such offered scope to produce an overall thesis presenting a breadth and depth of insight (Johnson et al., 2007).

This mixed methods thesis began with a quantitative examination of career profiles within professional team sports. It then investigated the physiological basis of performance decline via a quantitative analysis of NM variation over the athletic career span, before presenting a qualitatively informed exploration of the determinants of career duration. To fulfil the requirement of the philosophical foundation of this thesis to simultaneously explore the layers of reality pertaining to team sports careers and leverage the strength of the mixed methods approach, the final research chapter of this thesis provided synthesis and development of the findings of prior studies towards practical objectives. In this way, and by virtue of each study informing the development of subsequent investigations, despite their specific research aims, none should be considered as a stand-alone contribution. To avoid possible confusion regarding the specific research approaches employed in this thesis under the banner of mixed methods research (Creswell et al., 2004) the following sections will describe and justify the methodology of each of its constituent studies.

3.4.2. Study methodologies toward fulfilment of thesis objectives

Thesis objective 1: Describe career profiles **in high-level** ***professional team sport.***

To fulfil the initial objective of this thesis I carried out a retrospective analysis of statistical data relating to career profiles and longevity at the highest level in four codes of football. This study was based on a quantitative examination of within and between code differences in age of players, time spent in elite leagues and the relationship between the length of time a player spends in a league and how much they play. This study compared descriptive statistics and numerical models in attempt to describe the range and distribution of career durations in elite codes of professional football. Within the thesis it served to provide an examination of the variability in career longevity within team sport populations and in doing so provided context for subsequent research studies. In the context of the philosophical foundation of this thesis, this study offered a description of careers in football codes at the observable, empirical level, with later chapters providing deeper, causal explanation through description of underpinning real and actual objects and structures.

Selection of an appropriate means of examining careers was an important aspect of the design of this study that requires explanation and justification. Given the pervasive measurement culture in professional sports (Wilson & Kiely, 2023), there is no shortage of statistical measures that could have been employed towards profiling careers. Furthermore, an examination of career profiles based on metrics describing change in performance, skill execution or movement output could have added additional depth to the analysis outlined above. It is however important to state that performance statistics related to individual players in team sport are all somehow limited. Typically, they focus on only offensive or defensive involvement (e.g., goals scored, assists or shots blocked) or are impacted by performance of other players on the field with the player of interest (e.g., plus minus scores, or win shares) (Bradner et al., 2014). Within team games it is very difficult to fully capture all aspects of a player's effect on match outcome, with areas such as a players influence on strategy (Bradbury, 2009), or the performance of team mates seemingly impossible to objectively quantify. Measures of movement output (e.g., distance covered, high-speed running distance) present a useful means of capturing individual activity in team sports and appear to offer great potential towards elucidating age-related change. These measures are however also limited, as both the extent to which they reflect game performance and the degree to which they are impacted by tactical and game style factors is currently unclear. In acknowledgement of the limitations of both performance and output measures and importantly, due to a desire to compare codes of football, I chose to examine variation in game time over the career span. Measuring play time (participation in match play) is informative from a performance standpoint. To be selected and afforded game time in elite leagues, a player must be good enough to be both employed by an elite team and selected from within a competitive squad (Bradner et al., 2014). Play time over a season in elite leagues also samples the extent to which a player is physically able and sufficiently free from injury to compete at the highest domestic level. In addition, an examination of the relationship between play time and age was missing from the literature and had the potential to add useful practical context to the findings of existing performance profiling studies. Selecting a means of investigating longevity that is applicable across four codes of football was vital within this thesis as it supported the exploration of common causative powers impacting career duration in later studies. Comparative exploration of different codes of football allowed a more comprehensive examination of the open system impacting longevity than could be achieved via examining a single sport and helps broaden the population to which findings apply.

Thesis objective 2: Explore the physiological basis of variation in performance across team sport careers.

A popular narrative in team sport suggests players get slower as they age and reach a point where they can no longer compete (Dendir, 2016). In view of this, and the importance placed on physical aspects of performance in relation to ageing; to fulfil the second objective of this thesis I investigated variation in NM performance over the career span of high-level professional team sport athletes. An examination of the potential physiological basis of performance decline offered a means of understanding the extent to which physiological decay may explain the career profiles observed in study 1 of this thesis. In this way, in the context of the critical realist foundation adopted here, this investigation sought to examine how real level phenomena with causal powers may explain the empirical observations made in study 1. By examining the extent to which physiological change occurred across the career span, this investigation also served to contribute causal factors for description and discussion in later thesis chapters (Chapter 6 and 7).

Although age related differences in NM performance qualities of elite athletes could be examined in a variety of ways, this study was based on a retrospective, cross-sectional examination of CMJ testing data from a large sample of professional football players. I Initially considered attempting to fulfil this objective of the thesis via a longitudinal examination of multiple physiological systems. I also explored the feasibility of both invasive sampling of muscle tissue and investigating within-career change in physiology at a genetic or epigenetic level. However, given its accessibility and widespread usage, examination of change in CMJ performance fitted with the practical aim of this thesis around providing accessible suggestions towards improving practice. In the context of the difficulty of obtaining performance testing data from a large sample of elite players, having access to the dataset examined here also contributed to my decision to investigate variation in CMJ performance as opposed to another measure.

Thesis objective 3: Apply systems thinking towards gaining greater understanding of factors influencing career longevity in professional team sports.

The fulfilment of the third objective of this thesis was via an examination of expert practitioners' perceptions regarding factors influencing career duration. This study used semi-structured interviews to inform a group model building process with the aim of creating a systems thinking model of career longevity. I selected this methodological approach as sampling expert opinion offers a means of obtaining a large amount of information in a research area where little exists. By examining expert perceptions and then creating a systems thinking model, this investigation identified a breadth of factors impacting longevity and was able to describe the relationships and causal powers acting between them. Employing a systems thinking approach to examining the many potential factors impacting career longevity allowed this study to situate information related to physiological decline examined in the previous investigation (Chapter 5) within a broader causal system. This investigation also formed part of the qualitative aspect of this thesis, essential towards the aim of leveraging the strength of multiple research paradigms to gain a deeper understanding a professional team sports careers.

In this study I used semi-structured interviews in place of electronic surveys or a Delphi method as I felt the increased depth of interviews offered scope for a greater richness in responses. Given the use of semi-structured interviews in this investigation, it is important to further clarify aspects of my positionality which influenced how I related to the studies' subjects. Within qualitative research, when a phenomenon situated within a specific culture is under investigation, the researcher should consider whether they relate to that culture as an 'insider' or an 'outsider' (Holmes, 2020). In view of my occupation within professional team sport and therefore my 'lived familiarity' with this culture (Mercer, 2007), I considered as an insider relative to my subjects. This positionality is advantageous, as it means I likely understood many of this culture's specific social norms and was more likely to be given full answers encompassing technical detail (Holmes, 2020). The insider position however also meant I likely held preconceived notions about the people I interviewed, I may not have thought to ask fundamental, basic questions and interviewees may have presume I had more knowledge than I did (Holmes, 2020). To counter potential problems with my insider positionality I developed the interview guide used here (appendix 9.3) with an external academic who would be considered an outsider. Despite taking this step to promote neutrality, in keeping with my critical realist position, I acknowledge that how I related to the subjects of this study and the social world they inhabit must have influenced my interpretation of it. In addition to allowing me to investigate professional team sport careers from a different perspective, interviewing SMEs from professional domains closely related to my own, allowed me to use his study to fulfil my learning objective of expanding my professional and research networks.

Thesis objective 4: Highlight potential strategies that may allow sports organizations to influence the duration and trajectory of sports careers.

To fulfil the final objective of the thesis, I presented a research informed position piece summarizing what is known about career longevity and offering suggestions on how sports organizations might maximise the odds of their players having long careers. This study was informed by SME testimony provided as part of study 3, and featured an extended exploration of the practical applications and consequences of the findings of studies 1 and 2. In offering a synthesis of previous findings, this study aimed to provide a practically focused conclusion to the linked studies forming my thesis.

Having planned to explore variability in career longevity, investigated NM variation across the career span, and examined at factors influencing career duration at the highest level, the final study of this thesis could have taken it in a variety of directions. I considered creating a comparative longitudinal case study investigation focusing on various aspects of the career journey of one or a small group of players. I felt such a study design would have allowed exploration of how individual determinants of longevity may impact a specific player's career and would bring forward practically useful suggestions for enhancing longevity. Despite planning to use a case study format, I received such rich insights into possible means of extending longevity from SMEs in pilot work for Study 3, I decided to add some additional themes to my interview guide for that study to allow sampling of potentially useful information. I initially thought this information would serve as a useful background for a case study based final thesis chapter, however once synthesised, I realized I had an amount of material that would be better and more practically used outside of a case study. I felt a research informed position piece was a useful means of encapsulating this information. This approach seemed to fit with the philosophical foundation underpinning the design of this thesis; critical realism advocates the combination of different facets of knowledge and its synthesis towards practically focused objectives. Its acceptance of fallibilist truth also allowed conclusions towards fulfilment of the final objective of this thesis to be presented as 'best currently available' in the context that further research will inevitably prompt their revision. Producing a practically focused position piece also allowed me to address my learning objectives of contributing useful information to my profession and developing cognitive skills related to synthesis.

3.5. Understanding progression toward my personal learning objectives

To capture the ways in which this research project enabled me to achieve my personal learning aims, I have included doctoral learning pauses throughout the thesis. These pauses serve to illustrate how each study and its underpinning, applied questions led to challenges and subsequently a learning process required for my development as a researching professional. By including these reflective pauses, I was better able to understand aspects of my growth as a researching professional in the context of objectives described in the General introduction and have a learning commentary to inform a more complete meta-reflection on the results of my learning journey within later sections of this thesis (Chapter 8). In addition to the doctoral learning pauses, I have also included a series of applied reflective pauses. These provide insight into the practice-based thinking or scenarios that led me to undertake this thesis and its constituent studies. As depicted in Figure 3.3, I think the inclusion of both types of reflective pauses helps to reinforce the link between my studies and professional practice and can elucidate the cyclical learning and development process that occurred in-part, due to challenges inherent in research-based study.

Figure 3.3. Schematic illustrating the learning process central to the research project.

3.6. Chapter Summary

The mixed methods approach I chose to fulfil the objectives of this thesis is the result of a philosophical foundation based on critical realism. I used key tenets of critical realism, my positionality as a researcher-practitioner and my learning objectives to inform the development of whole thesis and specific study research methodologies. Over the course of this thesis, I investigated typical variation in career longevity, examined the extent to which NM changes occur over playing careers, and described the range of factors SMEs feel impact longevity as well as the causal forces operating between them. I then attempted to draw together findings from these studies in combination with further SME testimony to provide practical suggestions as to how sporting organizations can increase the odds of their players having long and successful careers. Whilst I think the view of careers this thesis provides is both of interest to practitioners and practically useful, the foundational critical realist philosophy I have adopted allows me to acknowledge that it will necessarily be incomplete due to the impossibility of understanding reality in its entirety (McEvoy & Richards, 2006). In accordance with the aims of a professional doctorate, whilst addressing my research objectives, I worked towards building skills and competencies in service of the personal development targets at the heart of my reasons for pursuing doctoral study.

APPLIED REFLECTIVE PAUSE 1

The twists and turns of athlete career journeys.

The most satisfying and thrilling moments of my career have come watching athletes achieve goals and exceed their own expectations. I cannot describe how it feels to see someone you knew as a young teenager progress to a level of sporting success that no one, including themselves, ever imagined possible. I was lucky enough to coach one such rugby player who went on to have a fabulous career. I was especially privileged to witness his final competitive game prior to retirement. Knowing it would be his last appearance he led the team onto the pitch, he was brought off the ground before the final whistle to a standing ovation and delivered an incredible speech in the changing rooms after. Also watching that day was another player who had been part of the retiring legend's academy class. Both were the same age; both had played in similar positions and arguably, it was the guy watching from the stands who had shown the higher initial potential. The guy in the stands had been an England age group stand out and had made his first team debut a full 12 months prior to his former team-mate. By now he had retired too. He had transitioned into a city job and shortly after stopped playing semi-professionally in England's third tier. These two players had been part of the same talent development system, had similar physical stature and potential, yet their careers had turned out very differently. Both suffered injuries, both were at times overlooked in selection and like all humans, both had good and bad days at work. The player enjoying his standing ovation had benefited from new coaching staff arriving at a club that wanted to build a culture based on home-grown, hard-working players. He was in tremendous physical condition when these new coaches arrived at the club as he was returning from a medium-term knee injury and had started his preparation for the new season earlier than most. The coaches liked what they saw and continued to select him and work with him until he became one of the team's most important players. In contrast, the player watching from the stands had signed a contract at a different club in the off-season prior to the new coaching staff arriving. He played a lot in his first year but after a disappointing season, that club also changed their coaching staff, and he fell out of favour.

This comparison between two initially similar players whose careers turned out very differently would be possible in most professional team sports. I have seen and heard about countless examples. For every player who gets cheered off in their final game in their mid-thirties, there are others whose careers end in a quiet off-season meeting or via a short call with an agent. It seems clear dynamic and non-linear interactions between many different factors can heavily influence careers. Poorly timed injuries, a change in coaching staff or the loss of a key senior player can provide or remove opportunities for developing players to feature in teams and in doing so have huge bearings on career trajectories. Although it is easy to see evidence of large variation in career paths within professional team sports, there appears to be very little information available which describes the frequency at which different outcomes occur. Furthermore, whilst a large amount of literature has focused on aspects of development pathways by which athletes may achieve professional status, very little work is available which describes professional career norms. To my knowledge, no comparative study examines professional athlete cohorts in terms of mean career length, typical variation in longevity, or the amount which players play for their team(s) over their professional journeys. Understanding more around base rates related to such parameters, therefore, seems an important place to start in a thesis aiming to understand professional sports careers.

CHAPTER FOUR

STUDY 1: HOW DOES PLAYER CONTRIBUTION VARY ACROSS THE CAREER SPAN WITHIN ELITE PROFESSIONAL FOOTBALL CODES?

How does player contribution vary across the career span within elite professional football codes?

4.1. Introduction

To support effective decision-making directed at optimizing squad composition, practitioners require an understanding of players' present and potential future performance contributions. To appraise the likely extent of performance change in specific players it is important practitioners are aware of typical career durations, league age profiles and normal changes in players' ability to contribute to team performance across the career span. Patterns associated with longitudinal performance change across team sport athletes' careers have been extensively examined (Bradner et al., 2014; Dendir, 2016; McIntosh et al., 2019; Sullivan et al., 2020). Such studies illustrate that a player's performance improves up to a peak age which is, on average, between the mid and late twenties in AFL (Sullivan et al. 2020), Football (Dendir, 2016; Kalén et al., 2019), Baseball (Fair, 2008; Bradbury, 2009) and Ice Hockey (Bradner et al., 2014). This peak is then followed by a decline until retirement (Faulkner et al., 2008; Brander et al., 2014). Whilst this evidence is of great interest to practitioners, many of the metrics used by studies quantifying longitudinal change in individual players offer a limited view of performance (Bradbury, 2009; Sullivan et al., 2020). Typically, they capture only offensive or defensive actions (e.g., goals scored, assists or shots blocked) or are impacted by overall team performance (e.g., plus minus scores, or win shares) (Bradner et al., 2014). Investigations examining change in longitudinal performance also often apply inclusion criteria restricting their analysis to a reduced proportion of those playing in any one season. Without complete knowledge of career profiles across entire playing populations, practitioners are limited in terms of their understanding of the extent to which performance trends apply to their whole playing squads. Additionally, while understanding a player's likely future performance level is essential in evaluating their utility as a squad member, such performance is tied directly to the amount of play time a team might expect that player to play as they age across their career. An objective, detailed description of playing involvement across team sport careers has however yet to be presented. Beyond providing information about the quantity of game time a player will play; profiling game time provides an informative view of performance change across the career span. To be afforded playing time in elite leagues, a player must be good enough to be both employed by an elite team and selected from within a competitive squad (Bradner et al., 2014). Examining game time over the career span also captures changes in the extent to which the player is physically able and sufficiently free from injury to compete at the highest domestic level. Crucially, profiling play time enables comparative examination of multiple football codes. Although little work has sought to compare career profiles between team sports (Baker et al., 2013; Wakim & Jin, 2014) this approach has the potential to highlight the effect on career profiles of differences between sports and the commercial and talent management systems that operate around them. A comparative examination of various codes of football supports future research exploring common causative powers impacting career duration. The primary aim of this study is therefore to provide an examination of the pattern associated with career match participation across a number of team sports. We hypothesize that players will exhibit a pattern similar to previous research showing changes in performance across careers, whereby players will progress to a peak of play time and then slowly decline before terminating their careers. To provide necessary contextual information for practitioners, this study also presents a simplified examination of player age profiles and career durations to facilitate comparison between sports and positional groups.

4.2. Methods

4.2.1. Experimental approach to the problem

This investigation used a retrospective, observational design to produce statistical models exploring the effect of age and number of seasons since league debut on match participation in four codes of professional football. Whole league population distributions and box plots for each positional group for both age and seasons since debut were produced for each code. This was done to provide contemporary information regarding career profiles, illustrate how modelled samples relate to overall populations and to highlight potential limitations in models. Owing to the public availability of data used within this investigation institutional ethical approval was not required (Navalta et al., 2019).

4.2.2. Data Processing

Data from a recently completed season of league competition were obtained for AFL, English Premier League Football (EPL), National Football League (NFL) (American football) and English Premiership Rugby Union (PR). In codes where a choice existed between international and domestic competition (i.e., PR but not NFL), a high-level domestic league was selected as the increased length of the competitive season provides greater scope to examine changes in playing time with increasing age and seasons since debut. One recently completed season in each code was analysed to reduce the effects of disruption to schedules caused by the global pandemic and ensure data is as current as possible. Data relating to the 2021 AFL season, and 20-21 seasons of EPL, NFL and PR were obtained via a combination of data request and web scraping. AFL match data was obtained from the official statistical provider for the AFL, Champion Data (Champion Data Pty Ltd, Victoria, Australia). Data pertaining to the EPL was scraped from football reference website https://fbref.com/en with additional positional information from https://transfermarkt.com. NFL game data, roster information and snap counts were obtained from www.lineups.com/nfl/snap-counts with additional biographic details from www.pro-football-reference.com. PR match data was obtained from the Rugby Football

Union (Twickenham, England) with additional biographical details from Premier Rugby's player archive (www. Premiershiprugby.com/67gallagher-premiership-rugby/statistics/player-archive).

For all players, date of birth, age at 31.12.2020, season of competitive debut, position, team(s), and total season minutes or snaps played (NFL) were recorded. Players were assigned to the positional group they had played most frequently played in during the 20-21 season. AFL players were placed into eight positional categories, as assigned by Champion data (Midfielder, Midfielder-Forward, Ruck, Key Defender, General Defender, Key Forward, General Forward, Wing). Six positional categories, similar to those used by Kalen et al., 2019, were applied to EPL players (Goalkeeper, Central Defender, Wide Defender, Central Midfielder, Wide Midfielder, Forward). Ten position groups were applied to the NFL population (Offensive Line, Running Back, Wide Receiver, Quarterback, Defensive End, Defensive Line, Tight Ends, Linebackers, Cornerbacks, Safeties). Positional categories were similar to those used by Mack et al., 2020, however here the position group 'defensive secondary' was split into Corner Backs and Safeties following consultation with practitioners currently working in the NFL. Punters, Kickers, and Long Snappers were removed from analysis. In PR, eight position groups were used (Props, Hooker, Second Row, Back Row, Scrum half, Fly Half, Centres, Outside Backs). Categorizations were similar to those of Lindsay et al., 2015, however scrum halves, fly halves and centres were treated as distinct. Where teams play in multiple competitions within the same season, only league games were included in analysis. In the AFL, NFL and PR finals series games were excluded from analysis so all players within each league had an equal maximum theoretical game time available to them.

4.2.3. Statistical analysis

Data scraping, processing and visualisation were carried out using R statistical software (R foundation for statistical computing, v3.3.4). Descriptive statistics and violin or box plots for age and seasons since debut were produced for each code population and composite positional groups. All players who participated in at least 1 competitive league fixture were included in population distributions. Involvement in a competitive fixture was defined as playing at least 1 minute of time on ground in AFL, 1 minute of match play in EPL or PR or least 1 snap in NFL. Polynomial regression models (examining change in participation with both age and seasons) were constructed to capture the hypothesized parabolic nature of aging curves within professional sports. Within each code, prior to model construction, inclusion criteria were applied so that each population was constrained by a range for age (AFL:18-30, EPL: 18-32, NFL:21-33, PR: 20-32) and participation (>25th percentile for play time). Low participation players and those in youngest or oldest age categories containing few players were excluded from models as they have the potential to add more noise than useful information to findings

(Bradner et al., 2014). The number of players removed from each population prior to model construction is shown in table 1. Model and model coefficients and were interpreted to explain the average population effect of playing additional years in each league. Regression coefficients were deemed statistically significant at the p = .05 level and 90% confidence intervals (Sullivan et al., 2020) were used to estimate uncertainty around each coefficient. For each code, models were constructed using a second order polynomial in the following form:

$$y = ß_0 + ß_1x + ß_2x^2$$

Where y represents minutes or snaps played and $ß_0$ represents the model intercept and $ß_1$ and $ß_2$ represent the coefficients for age and age squared or season and season squared, respectively, for the given football code.

Table 4.1. Reductions in sample size of each code following data cleaning procedures.

Code	Full sample size	Adjusted sample size	Percentage of full sample retained
AFL	672	448	67%
EPL	524	347	66%
NFL	1883	1324	70%
PR	567	363	64%

4.3. Results

4.3.1. Age distribution of players

Violin plots showing age distribution of all players in each code are presented in Figure 4.1. Across all populations, age range and interquartile range (IQR) were from 17 to 43 years and 21 to 30 years respectively. The AFL population had the lowest median age (24) compared to EPL (27), NFL (26) and PR (27). The AFL (28) and NFL (28) had a lower 75th quartile for age compared to EPL (30) and PR (30). The IQR was lower in the NFL (4) compared to AFL (6), EPL (6) and PR (7).

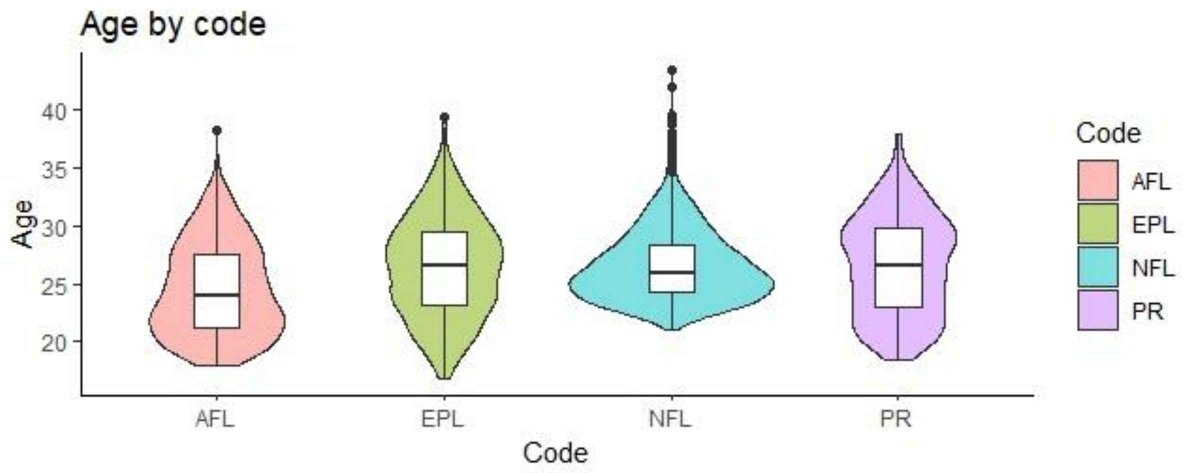


Figure 4.1. Violin plots showing age range of full playing populations in AFL, EPL, NFL and PR. Abbreviation: AFL, Australian Football League. EPL, English Premier League. NFL, National Football League. PR, Premiership Rugby.

Violin plots showing number of seasons since league debut for whole populations in all codes are presented in Figure 4.2. Across all codes, overall range and IQR were from 1 to 21 seasons and from 2 to 9 seasons respectively. The highest median number of seasons since debut was found in AFL (5) compared to EPL (3), NFL (4) and PR (3) populations. The AFL population also had a higher 75% percentile (9) for seasons since debut compared to EPL (7), NFL (6) and PR (7) and the highest proportion of players in their 10th season or more post debut (22.8%) compared to EPL (11.3%), NFL (6.9%) and PR (14.1%).

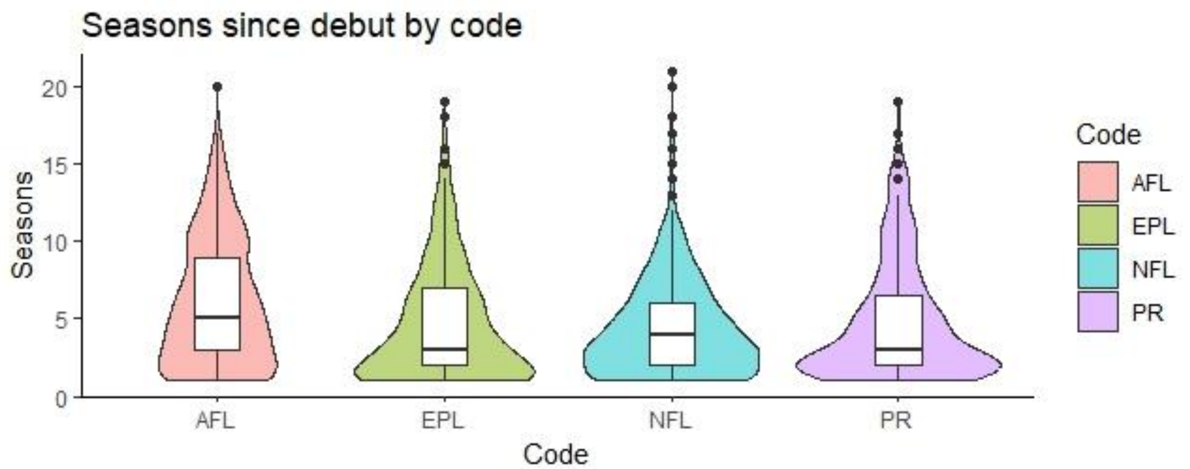


Figure 4.2. Violin plots showing range of seasons spent in each league for full playing populations in AFL, EPL, NFL and PR. Abbreviation: AFL, Australian Football League. EPL, English Premier League. NFL, National Football League. PR, Premiership Rugby.

4.3.2. Change in participation across careers

Estimates of the effect of age and seasons since debut on play time are shown in Tables 4.2 and 4.3. Associated modelled relationships are shown in figures 4.3-4.6. Timing of peak participation differed between codes. In AFL players, peak play time occurred at 27 years old, or in the 9th season post league debut. EPL players' play time peaked at age 26 years, or in their 6th season post league debut. In the NFL, snaps per season increased up to age 33 with peak snap count occurring in player's 9th season post debut. In PR, a player's peak participation occurred at age 27, or in their 7th season post league debut.

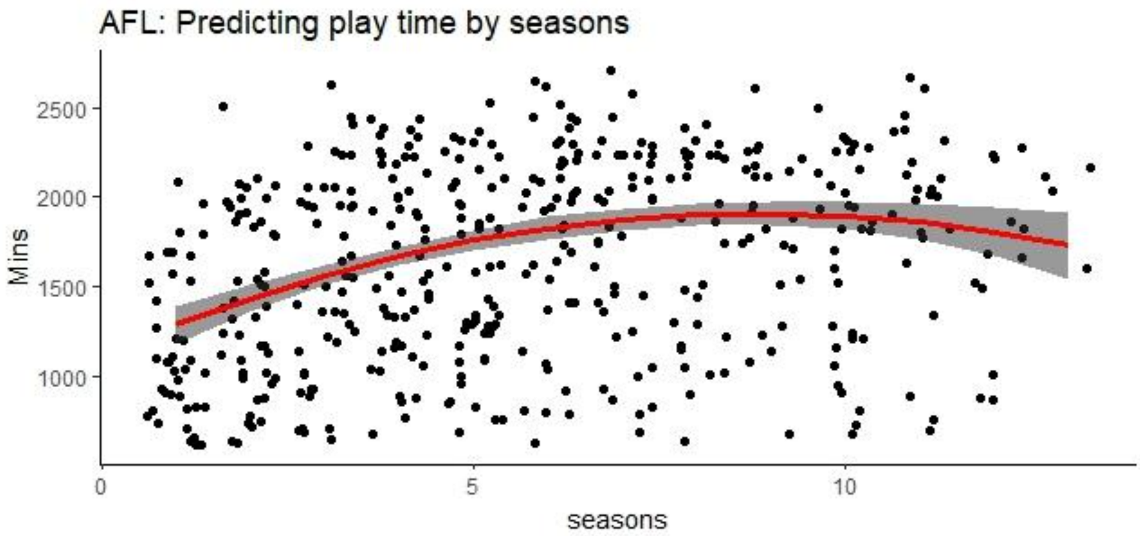
Table 4.2. Relationship between seasons since debut and minutes/snaps.

	AFL	EPL	NFL	PR
n	448	347	1324	363
Intercept	1115(966 to 1264)	1748(1560 to 1936)	314(269 to 359)	503(415 to 591)
Seasons	180(126 to 234)	88(12 to 164)	63(43 to 82)	82(48 to 117)
Seasons^2	-10(-14 to -6)	-8(-14 to -2)	-4(-6 to -2)	-6(-9 to -4)

Table 4.3. Relationship between age and minutes/snaps.

	AFL	EPL	NFL	PR
n	448	347	1324	363
Intercept	-3826(-6474 to -1178)	-5582(-10795 to -369)	-1001(-2321 to 316)	-2376(-4504 to -248)
Age	413 (193 to 633)	567(167 to 967)	94(11 to 177)	230(164 to 395)
Age^2	-7.5 (-12 to -3)	-10.6(-18 to -3)	-1(-3 to 0)	-4(-7 to -1)

In all codes, an increase in play time was observed over initial seasons following league debut and over initial ages captured by each model. The EPL had the smallest early career ascension in minutes and highest quantity of match participation in initial season relative to season/year of peak participation. Players within the AFL and NFL showed less decrease in participation in later career stages, with both advancing age and increased seasons since debut compared to EPL and PR populations. When comparing models showing the effect of age to those examining seasons since debut, within the EPL, PR and NFL, there was a greater decrease in participation in later career years for players who had played an increased number of seasons versus equivalent age peers.



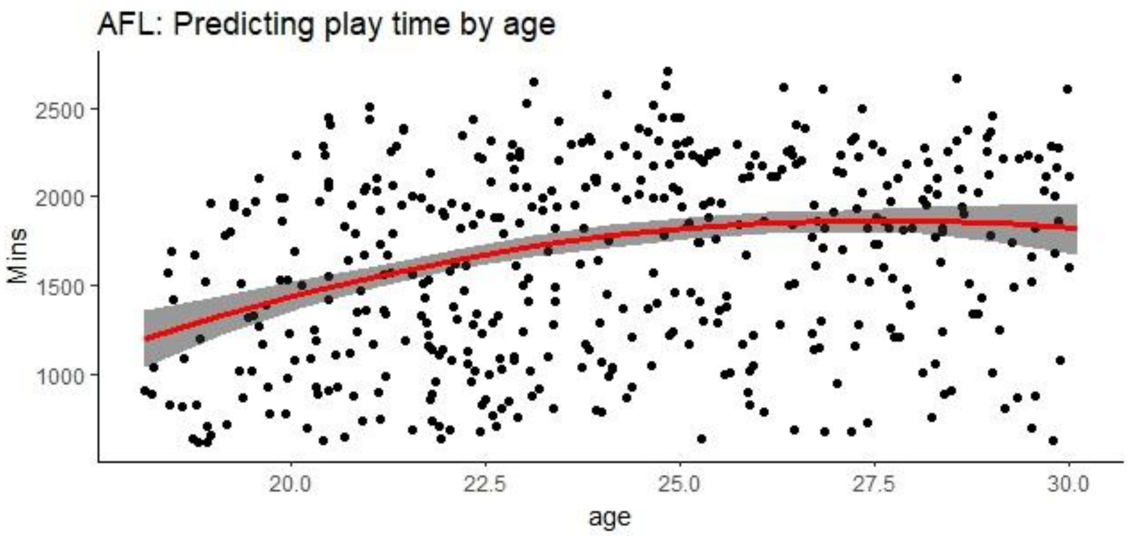
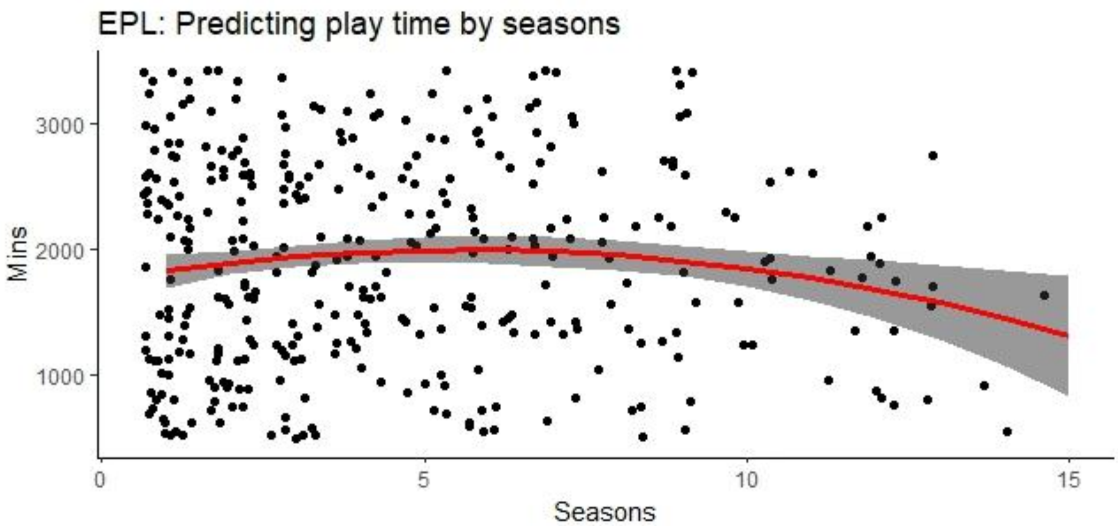


Figure 4.3. The relationship between minutes played and seasons since debut (top) and age (bottom) for AFL players.



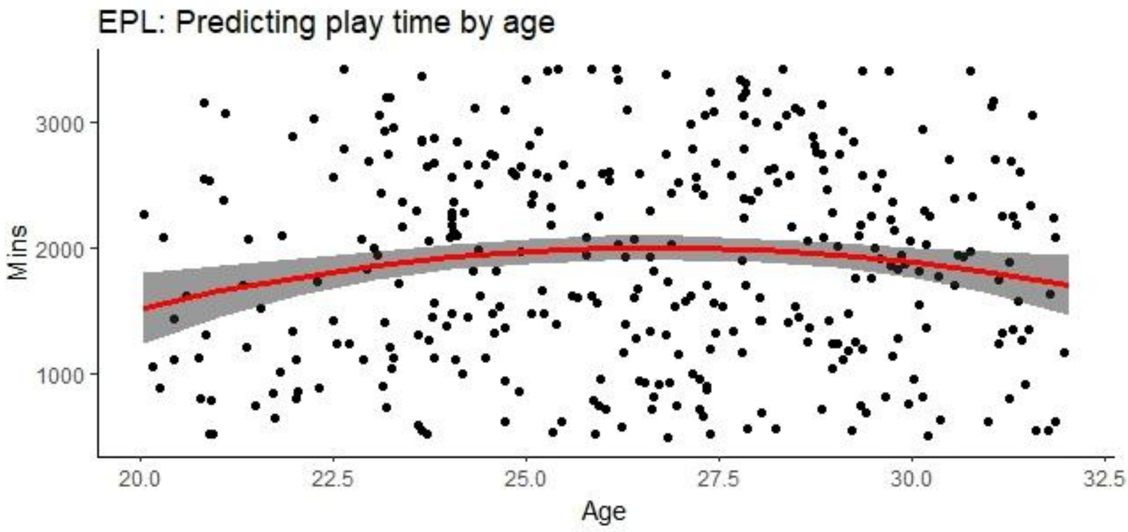


Figure 4.4. The relationship between minutes played and seasons since debut (top) and age (bottom) for EPL players.

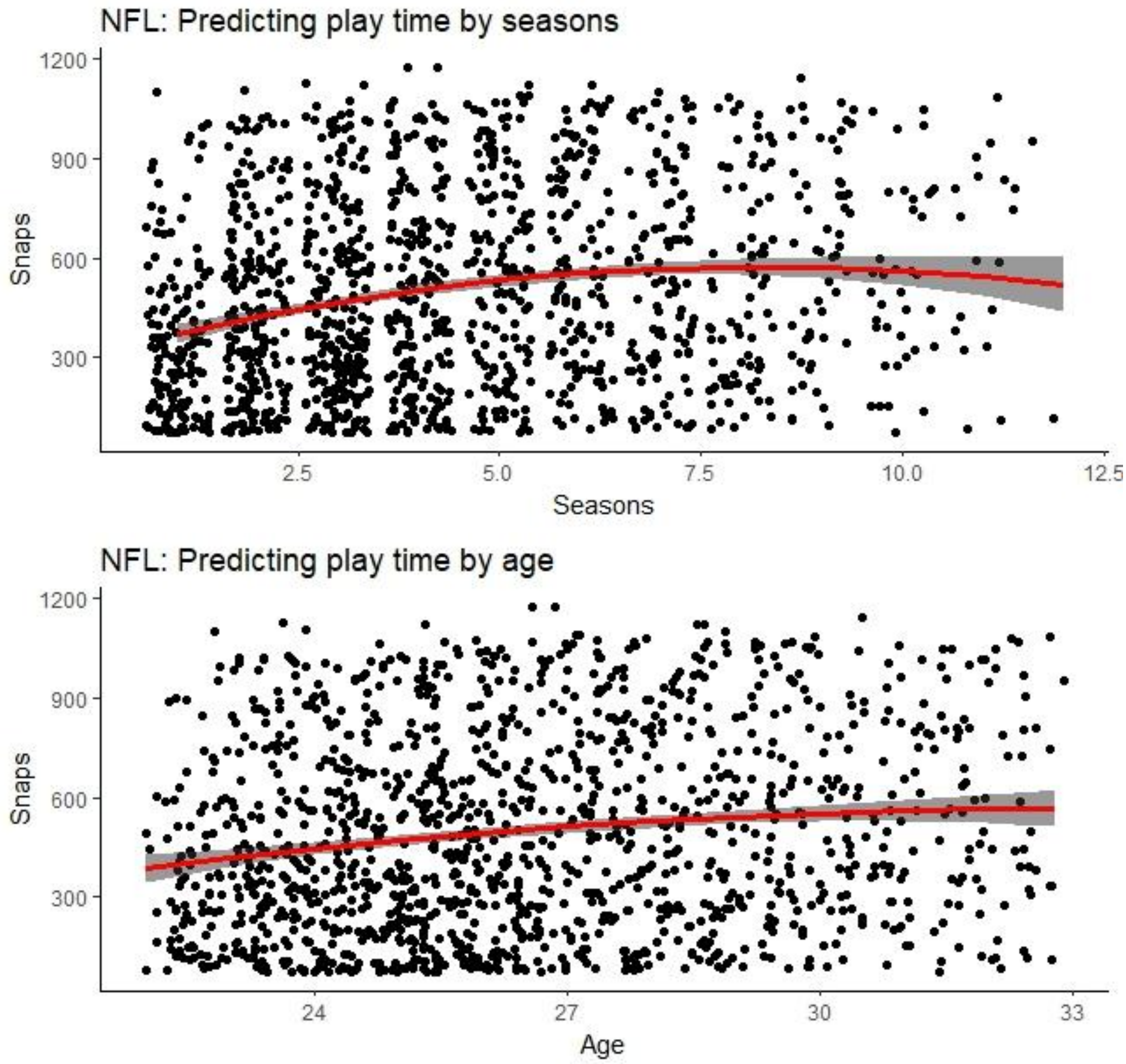


Figure 4.5. The relationship between snaps played and seasons since debut (top) and age (bottom) for NFL players.

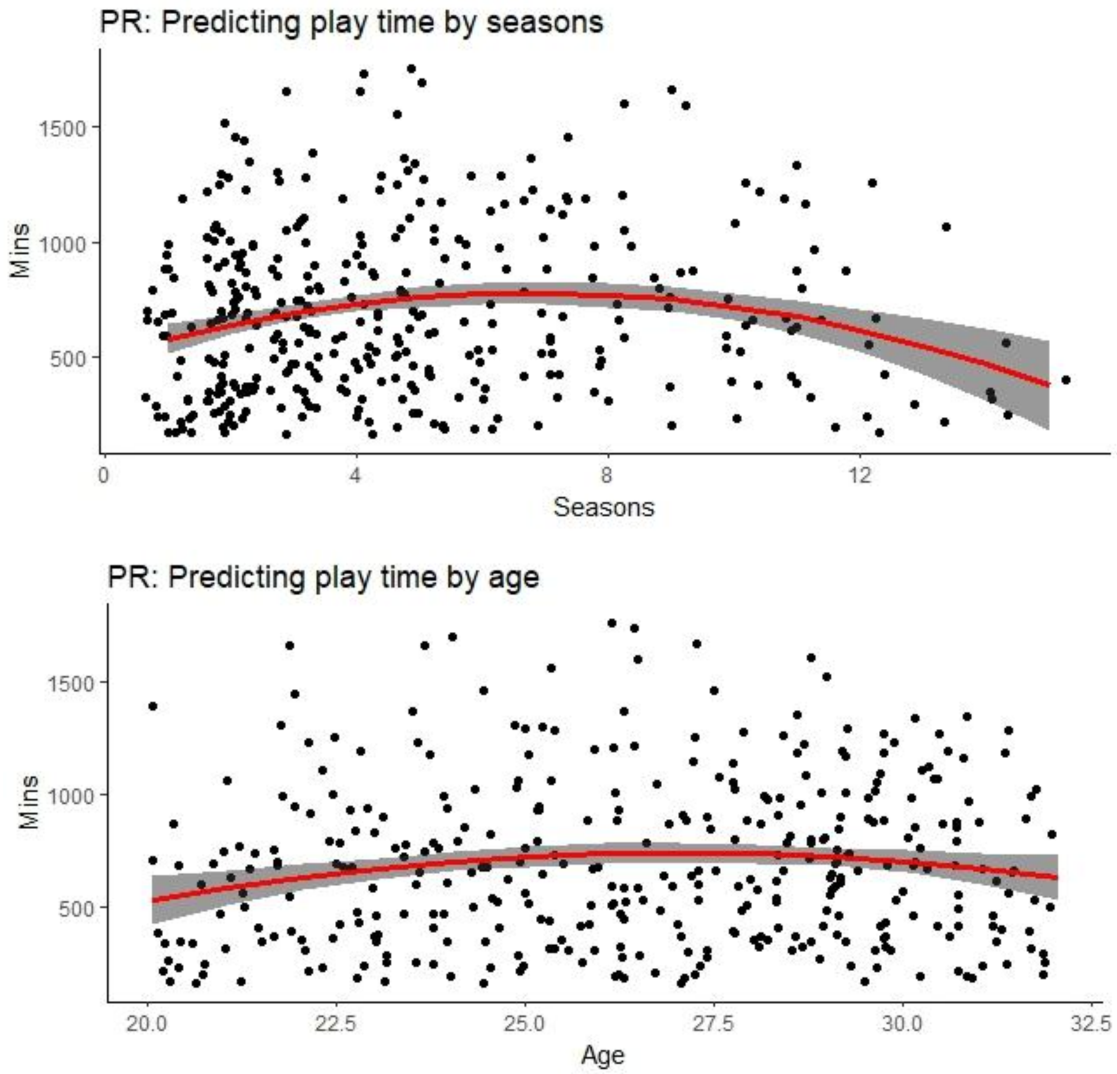


Figure 4.6. The relationship between minutes played and seasons since debut (top) and age (bottom) for PR players.

4.3.3. Positional distributions of players

Box plots showing distributions of age and seasons since league debut for position groups within each code are presented in Figures 4.7-4.10. All codes contained positional variation in age and seasons since debut. Within each code, positional differences in median and IQR for age and seasons since debut suggest position group influences career longevity.

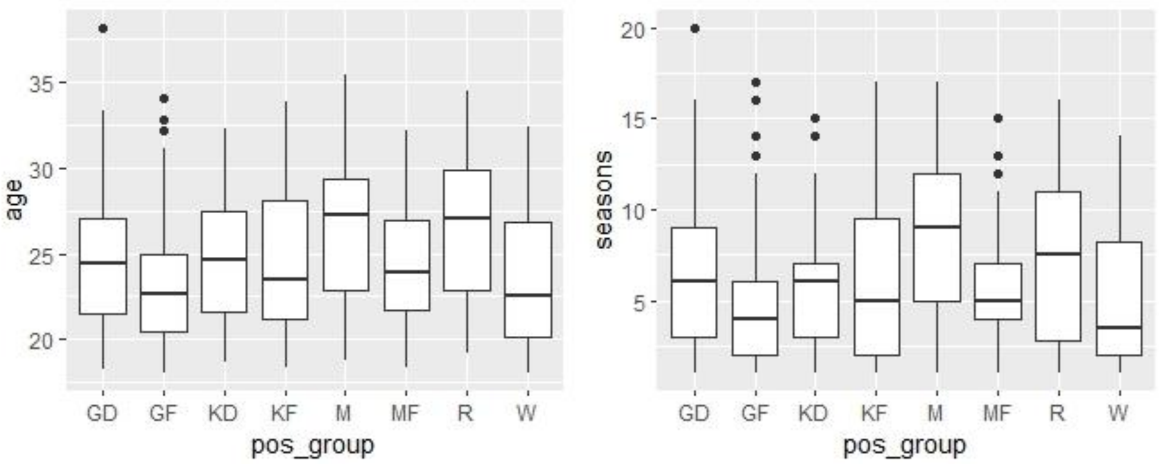


Figure 4.7. Age profile and seasons since debut in AFL by positional group.

Abbreviations: GD, General Defender, GF, General Forwards, KD, Key Defender, KF, Key Forward, M, Midfielder, MF, Mid-Forward, R, Ruckman, W, Wing.

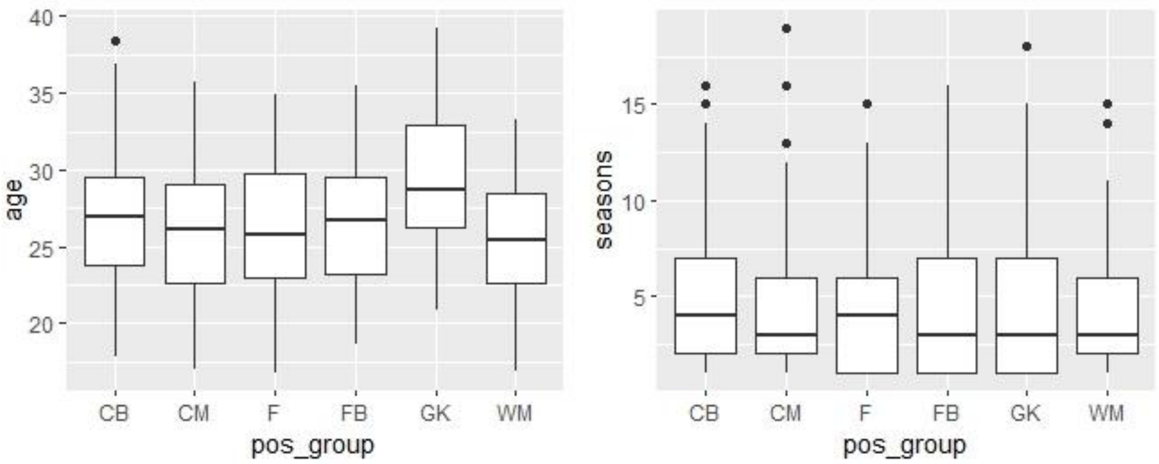


Figure 4.8. Age profile and seasons since debut in EPL by positional group.

Abbreviations: CB, Centre Back, CM, Centre Midfield, F, Forward, GK, Goalkeeper, WM, Wide Midfield.

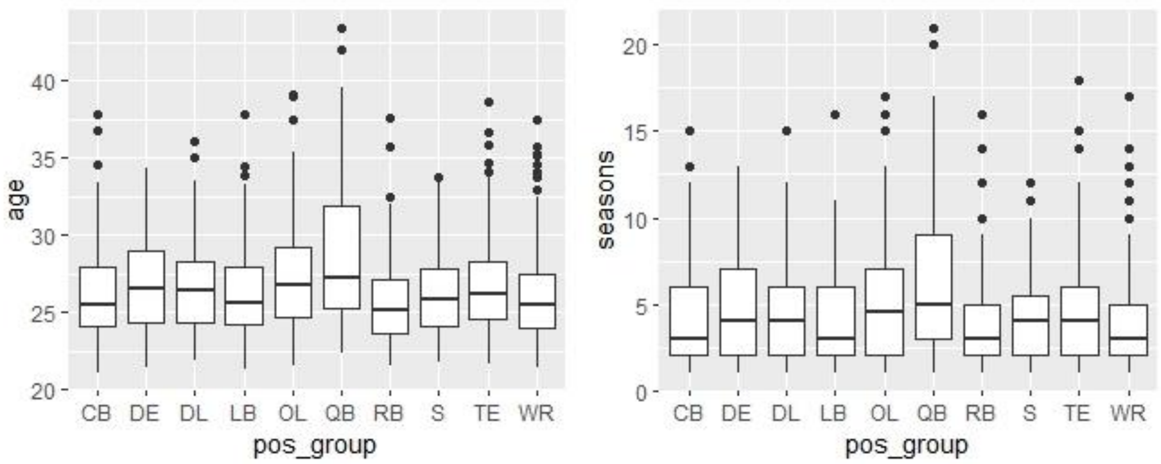


Figure 4.9. Age profile and seasons since debut in NFL by positional group.

Abbreviations: CB, Corner Back, DE, Defensive End, DL, Defensive Line, OL, Offensive Line, QB, Quarter Back, RB, Running Back, S, Safety, TE, Tight End, WR, Wide Receiver.

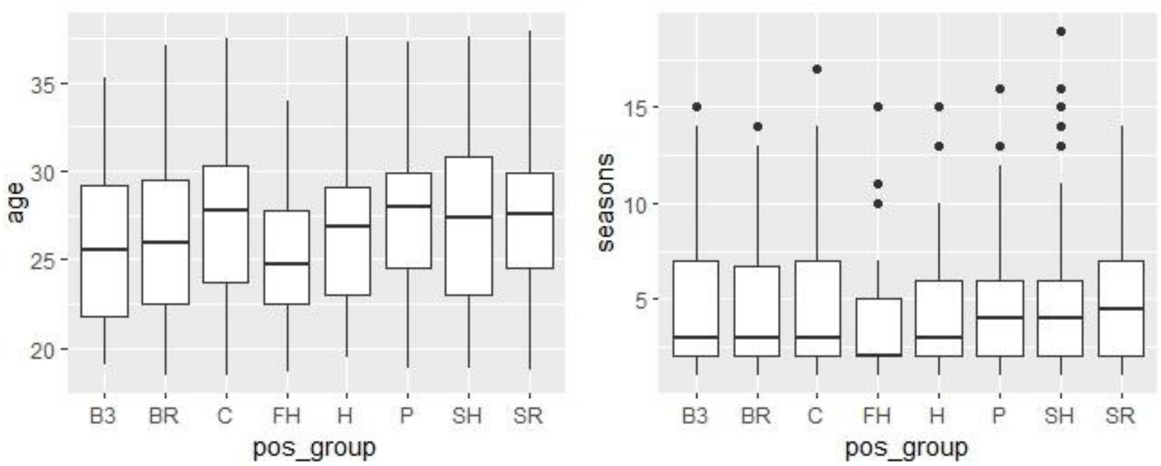


Figure 4.10. Age profile and seasons since debut in PR by positional group.

Abbreviations: B3, Back Three, BR, Back Row, C, Centre, FH, Fly Half, H, Hooker, P, Prop, SH, Scrum Half, SR, Second Row.

4.4. Discussion

The aim of this study was to provide objective description of playing involvement across football careers. The study also sought to offer context by presenting a comparative exploration of elite professional team sport populations in terms of both age and seasons since debut. Results show aspects of change in participation across careers are common to AFL, EPL, NFL and PR populations. In all codes, an ascension of match play was observed across initial seasons following debut and initial years captured by each model. In addition, for all populations, predicted play time remained within 10% of peak season minutes until at least 30 years of age. This study is the first to show that examining ageing across careers based on advancing age and seasons since debut may yield different, yet complementary information, useful in guiding recruitment and player development decisions. This study also adds to work describing longitudinal change in performance within team sports by providing an objective description of how play time is likely to change with increasing age and seasons since debut. Whilst the relationship between age and play time appears to follow a similar trajectory to that shown between age and performance, evidence presented in this investigation shows many professional careers are short-lived with drop out possible at all ages. It is therefore apparent that trends in performance and play time with age show a strong survivorship bias. Within this investigation variation between codes was found in typical profiles of participation across the career span and in median number of seasons since debut. Within all codes, positional variation was found in median age and seasons since debut.

4.4.1. General trends in game time change

In all codes, match participation increased from 1 to 3 seasons post debut, peaked between 6 and 9 (5.5-8.7) seasons post debut and by the final seasons modelled, had declined (5.4-23.6%) compared to peak years. In showing a somewhat U-shaped participation trajectory over the potential duration of players' careers, results of this study confirm the initial hypothesis and resemble findings of studies examining longitudinal performance change (Faulkner et al., 2008; Brander et al., 2014). It is generally accepted performance improves in early career years (McInstosh et al., 2019), peaks in the mid to late twenties (Fair, 2008; Bradbury, 2009; Bradner et al., 2014; Dendir, 2016; Kalen et al., 2019,) and declines as athletes move through their 30s (San Rellan-Guera et al., 2019). The finding of this investigation, showing that predicted participation is maintained within 10% of peak levels for at least 6 seasons in all codes, also aligns with results from longitudinal performance studies showing many elite players are able to maintain near peak performance for much of their professional careers (Bradner et al., 2014; McIntosh et al., 2019). It is likely similarities between trajectories of performance and participation are driven by players who are near peak performance ages being selected ahead of those that are not. It is also possible that the ability to play a large amount of game time/snaps allows players to perform at career high levels. In following a trajectory of initial increase, a period of time around peak levels and a subsequent phase of decline between the late teens and mid-thirties, changes in both performance and participation appear to follow a fundamental human tendency of development followed by decline in physical competencies (Berthelot et al., 2011).

When interpreting models describing participation across the career span it is important to consider population distributions presented for each code. Population distributions of each code by number of seasons since debut show a progressive decline in player numbers from initial seasons onwards. The likely brevity of many careers and possibility of drop out at any number of seasons post debut is further evidenced by median time since debut being between 3 and 5 seasons across all codes. The possibility players are unable to maintain close to peak participation across a large part of the career span is therefore likely underestimated by models presented here, as they do not account for players dropping out of each population. Although most pronounced in the NFL population, all models presented are affected by selection bias (Bradner et al., 2014). It is important to recognise that the impact of selection bias on results reported here is increased by inclusion criteria applied prior to the construction of models. As with studies investigating ages of peak performance, applying inclusion criteria requiring a minimum number of minutes each season and collapsing smaller age groups means ignoring significant proportions of a whole playing population. It should be noted that by providing context via presentation of whole population distributions alongside participation models and demonstrating the number of players cut from each population, this study goes beyond previous work in describing how the population used within models relates to the league population from which it was drawn.

4.4.2. Between code differences

Although no formal, between code statistical comparison was carried out, between code variation was observed in rate of increase in participation across initial ages and number of seasons post debut, exact timing of peak involvement and magnitude of decline in involvement in later stages of careers. The EPL population had the smallest relative increase in minutes played over initial seasons. Models predicted EPL players to have 92% of peak involvement in their first season post debut compared to 75% in PR, 67% in AFL and 65% in NFL. Between code variation in the difference between minutes/snaps played in first season and at peak participation is likely due to the systems of talent intake within each code. EPL and PR organisations can acquire more developed and experienced, mature age players from a world-wide market of same code professionals. These leagues also have promotion of teams from lower divisions (although not in PR in the season investigated) meaning mature age players arrive into these leagues in much larger numbers compared to the NFL and AFL which rely on a draft intake of relatively younger players. Within the EPL and PR, it appears more frequently older debutantes with previous high-level experience are given larger initial roles than players new to the AFL and NFL who have had less exposure to high-level, senior competition.

Variation by code was also found in the timing of peak participation and change in minutes thereafter. Models presented here show game time participation in the AFL, EPL and PR increased up until a participation peak at between 26 and 28 years of age (26.7-27.6) or between 6 and 9 (5.5-8.7) seasons post debut. In contrast, in the NFL population, whilst number of snaps played peaked following a player's 9th seasons (8.2), they increased with age up until the end of models range at 33. Given the

NFL had the lowest relative proportion of players playing 10 years post debut and the smallest IQR for career length (2-6 years), the increasing snap count with age is likely a consequence of players not playing high snap counts being progressively removed from the population. The contrast between the NFL, where snap count increased within the modelled age range, and the AFL, EPL and PR where game time declined post peak age of participation, may be related to a greater availability of alternative talent in the NFL. In leagues with less availability of high talent players it may be necessary for teams to continue playing diminishing players due to lack of high calibre alternatives.

Between code variation in both the proportion of players who had been in each league for 10 seasons or more and the slope of decay within population distributions following the late twenties offers an interesting perspective related to longevity in elite team sport. Although differences in specific sports examined doubtless impacts the precise traits required for success, all are running based, invasion games requiring approximately similar physiological capabilities. Between code differences in proportions of players surviving into the later years of their careers (22.8% of AFL players at 10 or more seasons post debut vs 6.9% in NFL), appear to suggest player drop out is unlikely to be a function of physiological decline alone. Although there is a popular narrative in sports suggesting players reach an age where they can no longer physically compete (Dendir, 2016), the drop out of players at all numbers of seasons post debut appears to suggest careers end for many reasons beyond simply age-related changes in physiology. It is important future work examines the extent to which physiological decline occurs across the age span of professional athletes and investigates other factors that may be responsible for player drop out from elite level team sport leagues.

4.4.3. Positional differences

Positional variation in population distribution for player ages and seasons since debut was found in all codes. This suggests position will influence the likelihood of players being in a league long enough to reach peak ages of participation and experience subsequent declines in participation. Given the most common ages in a league population offer an indication of age of peak performance (Bradner et al., 2014), it is possible differences in positional population distributions within a code reflect slightly different positional physical and skill demands, corresponding to a subtly different peak age of performance. Whilst positional trends presented here are likely an enduring feature of each population, given the single season nature of the analysis applied, it is possible findings are influenced by the specific cohorts examined. Future work should therefore seek to examine population profiles and participation trends over career spans across a multi-year timeframe. In view of the failure of models produced here to take into account playing position, it is also important future work seeks to objectively examine the influence of position group on play time trajectory as athletes age across their careers.

4.4.4. Seasons v age differences

Results presented here show differences between age and season models in participation change in the later part of careers in EPL, NFL and PR populations. In these codes, a greater decline in participation occurred with advanced numbers of seasons since debut compared to age. Differences between models for age and seasons since debut exist as whilst models apply a set age range for each population (based on inclusion criteria), all codes contain variation in ages of players at debut. This means players over 30 years of age in EPL, NFL and PR can have substantially different numbers of seasons since debut. The finding of a greater decline in participation by an advanced number of seasons, as compared to age, could be the result of increased wear and tear in players having experienced more seasons within the same elite level league. Although speculative, it is possible increased accumulated damage reduces the frequency with which those who have played a high number of seasons are available to play. Within the AFL, season and age models show similar changes in participation over the career span. This is likely due to a more homogenous range for age at debut within the AFL, meaning these models cover a more similar time span for all players versus other codes.

4.5. Practical applications

Increased understanding of player participation across professional careers is useful to professionals aiming to optimise squad composition. Understanding the likely timing of peak participation and that it can be close to maintained until players are at least 30 years of age is important when evaluating if squad depth is sufficient to compete over a season and beyond. The median length of time players in EPL, PR and NFL had been in each league (<5 years) suggests the extent to which most players should be considered as remaining part of a squad in the long term is likely limited and must be considered in forecasting and planning. Given that, for equivalent age players in later career stages in EPL, NFL and PR, game time participation was lower amongst those who had played a higher number of seasons since their league debut, both seasons since debut and age should be considered when evaluating an older player's likely future contribution.

4.6. Conclusions

This study presented an objective description of playing involvement across football careers in the context of population profiles relating to player age and seasons since debut. Results show an increase in minutes played occurs in all leagues examined over both initial seasons since debut and ages shown by models. Players who remain within each league are able to maintain close to peak participation from 5 to 10 seasons post debut with a decline in minutes played occurring post peak age of participation in AFL, EPL and PR but not NFL. It is however essential these trends are understood in the context of player drop out. It is important practitioners are aware of the likely brevity of many careers, drop out from populations at all numbers of seasons post debut and therefore the comparative rarity of a player being able to occupy a high minute playing role beyond their earlier thirties. Given within and between code differences in participation profiles across the career span and apparent large variation in longevity, it seems important future work examines factors influencing career duration and drop out from elite professional team sport.

DOCTORAL LEARNING PAUSE 1

Doctoral learning pause: some of what I wrestled with and learnt from in study 1

My first study was difficult from start to finish. Throughout it all, it seemed nothing went smoothly, and I spent a lot of time confused about where it was all going. Carrying out statistical examinations of professional sports populations took a lot of work. On a practical level I had to learn about statistics, modelling, data handling and coding. And inevitably, I had to repeatedly go through the process of getting stuck in R and loosing hours trying to understand what eventually became totally obvious. I also spent a lot of time wrestling with understanding what I was actually studying. Although prior to starting this investigation, I had felt confident I knew what my thesis was about, once underway I realized I needed to clarify my direction. I was initially interested in longevity as it related to older team sports players, but the early data I examined showed not many players reached what would be considered old age and that many careers ended before they had really begun. The task of clarifying my research direction and deciding on my first study was made more difficult as it coincided with me becoming much more familiar with the concepts of epistemology and ontology. A better knowledge of paradigms from which to view the creation of knowledge and how research is conducted, coupled with a focus on self-reflection lead me down many different paths. It forced me to consider why I wanted to study this area, the lenses I have frequently applied in my learning, and how I have come to some of the views I hold. It also made me consider the gaps in my knowledge and subsequently see my professional world and my views on it in a different light. It even made me reconsider the quality of my previous work and challenge what I thought of as good practice.

My work towards Study 1 was confronting, inefficient and frustrating. During this time, I however learnt that a large part of adult learning is about ‘reframing oneself’ (Shum et al., 2022). I also appreciated that learning is about negotiating meaning by exploring the views we hold (Wenger, 1998). Understanding that work-related learning via a research degree was supposed to force me to struggle and question my assumptions helped me see Study 1 with greater clarity. Study 1 was extremely hard, but when examined in the context of my personal learning objectives it was also extremely useful. Work within Study 1 helped me understand my research area in greater detail, it forced me to read and apply a lot of information related to research methods, and helped me develop skills in analysis and problem solving. It also provided me with a great introduction to how the overall task of producing my thesis would unfold. Even the frustration of making a lot of data handling mistakes helped me work out how to do that more efficiently. In short, study 1 was hard going but it had allowed me to make significant progress against my learning objectives and it helped me reframe the purpose of challenge and problems within doctoral study. It helped me realize that the non-linear path I had found so frustrating was likely a necessary feature towards the learning and development I sought.

APPLIED REFLECTIVE PAUSE 2

Even the very best get old

There are certain conversations we remember perfectly. For me, one of those conversations happened with a player I coached over the final 3 years of his storied career. Throughout that time, I felt lucky to work with him, but I also felt a strong responsibility to help him finish up as best as he possibly could. Prior to his final year we were having a coffee together and he explained how he wanted his final season to go:

'Last year, I wasn't myself in too many games. I couldn't trust my body. I couldn't move like I wanted to. Players who aren't good enough got the better of me. They felt like they had beaten me, but they didn't see the real version. I can't have people watching me thinking they are seeing a guy who used to be good. I need help this year. I need to be myself. I don't care if I play less or do something different. I just want to have some legacy games and go out as the full me, doing what I do.'

This was a guy who had the ability to change games. He was a leader and a key member of our team. He had managed to play into his mid-thirties, but as his final season approached, he was clear he could no longer rely on his body as he once had done. Although he didn't describe a precise physiological basis of this decline what he said is familiar to all sports fans. The way he described his decline was also similar to the description given by a former professional player I interviewed as part of Study 3:

'In my last couple of years, my acceleration just wasn't what it had been… I couldn't separate myself from defenders as well (as before), I couldn't create that same gap, so I had a little bit less time to think and a bit less time to get the ball away cleanly or set myself to shoot. That hurt my confidence and I rushed things'.

There seems to be a general acceptance speed and power diminish with age. There is however little evidence exploring this phenomenon in professional players. During my coffee with the player I wanted to do my best for, I was aware top end qualities probably fade with age, but as a practitioner I felt there really wasn't much beyond this generally accepted observation to work with. Before practitioners can devise interventions to reduce the rate of such a decline, further work is needed. Work is needed to establish, if speed and power decline, the extent to which such a reduction may occur and how it may vary within a professional playing population. The second study of my doctorate would therefore examine longitudinal NM change in professional players over the course of their careers.

CHAPTER FIVE

STUDY 2: HOW DOES NEUROMUSCULAR PERFORMANCE VARY WITH AGE? A DESCRIPTIVE ANALYSIS IN PREMIER LEAGUE FOOTBALL PLAYERS

How does neuromuscular performance vary with age? A descriptive analysis in Premier League football players

5.1. Introduction

To both reach and remain at elite levels of professional team sport, players must be capable of high levels of physical performance. An understanding of the extent to which a players' physical performance potential varies across the career span is therefore important towards understanding longevity and to inform interventions aimed at maximizing effective career length. It is well accepted that both typical performance of elite footballers and as shown in Chapter 4, the amount they play declines after age 30. It is also acknowledged that the number of players in elite leagues progressively decreases from such an age (Dendir, 2016; Chapter 4). Currently, however no consensus exists to explain these observations (Faulkner et al., 2008). Compared to their younger teammates, older professional players have been shown to perform fewer fast runs and sprints (Sal de Rellán-Geurra et al., 2019) and significantly less accelerations and decelerations (Lorenzo-Martínez et al., 2021) during match play. Whilst no underpinning physiological explanation for these findings is available, given such actions require an ability to express large, relative forces in short periods of time, it is possible diminished performance in older players is the result of reduced NM capability compared to their younger counterparts.

Although many studies have investigated age related change in NM performance by assessing CMJ performance in elite, junior football (Nikolaidis et al., 2014; Karahan, 2016; Till et al., 2017), the effect of advancing age within senior populations remains unclear. Haugen et al., 2013, offer the only large-scale comparison of CMJ performance across senior professional age groups. In an examination of 633 players aged 16-37, divided into age categories from <18 to >28, no age-related differences in CMJ performance were reported (Haugen et al., 2013). It is, however, important to note that the authors only examined jump height (JH), a measure which may lack resolution as a means of understanding NM capability (Gathercole et al., 2015; Howarth et al., 2023). It is, therefore, possible age-related deficits in CMJ performance were present but remained undetected. Compared to JH, CMJ kinetic (CMJ-kin) variables have been shown to respond differently to competition (Cormack et al., 2008), training interventions (Cormie et al., 2010; Gathercole et al., 2015b; Kijowski et al., 2015) and deconditioning (Cohen et al., 2020). CMJ-kin variables also provide additional information relating to acceleration (Maulder et al., 2006), maximum velocity and deceleration abilities (Harper et al., 2020). Considering the observed reductions in high intensity movements within matches in older players (Sal de Rellán-Geurra et al., 2019) and the potential of CMJ-kin variables to elucidate changes in NM qualities fundamental to performance, a more comprehensive analysis of change in CMJ performance across professional careers appears warranted.

Given the likely complexity of both human ageing and professional sport careers, it is unrealistic for a single study to attempt to provide practitioners with a complete understanding of NM change in professional football players. A cross-sectional approach to the problem however represents a logical first step. It offers a means of obtaining a population overview, signposting best next steps in understanding this phenomenon (Wang & Cheng, 2020) and providing useful information to practitioners attempting to positively impact sports careers. The purpose of this investigation is therefore to present a cross-sectional examination of variation in CMJ performance across the career span of high-level professional football players. The investigation will evaluate the extent to which such physiological change is likely to impact career duration. It will also examine the potential for CMJ-kin variables to provide a more nuanced view of age-related change compared to that offered via examination of JH alone.

5.2. Methods

This investigation used a cross-sectional retrospective design to analyse preseason CMJ assessments of professional football players. Polynomial models were built to describe the relationship between JH, CMJ-Kin measures, body mass and player age. Players were then divided into 5 age categories (17-22, 23-25, 26-28, 29-31 and 32-40) based on a k-means cluster analysis. JH, CMJ-kin measures, and body mass for each age group were subsequently compared. This investigation was based on secondary analyses of data compiled from multiple sources, all given with the expressed consent of the original owners. Ethical approval for this study was not required as all analyses featured data from the routine monitoring of professional athletes as a condition of their employment (Winter & Maughan, 2009).

5.2.1. Participants

The cohort comprised 245 players from 7 English Premier League (EPL) teams. Descriptive statistics describing players (mean ± SD) are presented in table 1 and the composition of each age group by playing position is shown in table 2. To be included in analyses players had to be free from acute injury and must have played in at least five EPL matches during the subsequent season.

5.2.2. Procedures

All players featured in this investigation performed CMJ testing between 2014 and 2020 as part of their club's routine pre-season monitoring procedures. All players were previously familiar with CMJ testing. In all trials, following warm up, players completed three CMJs with hands on hips, resting for 10s between jumps. Players were required to remain stationary for 3 to 4s prior to their first trial to obtain a stable body mass (Hart et al., 2019) and were instructed to rapidly dip to a self-selected depth and to jump as high as possible. No lifting of the knees or partial use of arms was permitted, and trials were discarded where these instructions were violated, or where players failed to reach an EPV of >1.0ms. The mean values of the 3 jumps were used for subsequent analysis. All tests were performed on a vertical axis, dual force platform system sampling at 1000 Hz (FD4000, Vald Performance, Brisbane, Australia). Calculation of JH and CMJ-kin was performed using proprietary software (ForceDecks v1.2.6109, Vald Performance). A description of CMJ-Kin variables is provided in appendix 9.2.

5.2.3. Statistical analysis

The relationship between age and JH, CMJ-Kin measures and body mass was assessed through the creation of a second order polynomial in the following form:

$$y = ß_0 + ß_1x + ß_2x^2$$

Where y represents JH, a specific CMJ-kin variable, or body mass, $ß_0$ represents the model intercept and $ß_1$ and $ß_2$ represent the coefficients for age and age squared respectively. Regression coefficients were deemed statistically significant at the p = 0.05 level and 90% confidence intervals (Sullivan et al., 2020) were used to estimate uncertainty around each coefficient. Loess, GAM, and simple linear regression models were also created as a comparative means of exploring relationships between age and JH, CMJ-Kin measures, and body mass. Mean absolute error was calculated to determine the appropriateness of fit of each model. Given there was no case where an alternative modelling form provided a practically significant advantage in terms of appropriateness of fit, only second order polynomials are presented here. Model building was carried out using the nlme package in R statistical software (version 4.3.2). Following model building, differences between age groups were determined using one-way analysis of variance (ANOVA) or Kruskal-Wallis tests in the event the assumptions of ANOVA were not met. Where significant differences were identified, post-hoc comparisons were performed using Bonferroni's post-hoc test. Cohen's d effect sizes were calculated to evaluate pairwise differences in JH, selected CMJ-kin measures, and body mass between age categories. Magnitudes of effect sizes were interpreted using the following thresholds: small effect d = 0.2, medium effect d = 0.5

and large effect d = 0.8 (Cohen, 1969). Age group comparisons were carried out using JASP statistical analysis software (JASP, version 16.4, Amsterdam, Netherlands) with alpha level set at 0.05.

Table 5.1. Age group position breakdowns.

	17-22	23-25	26-28	29-31	32-40
GK	1	5	7	4	6
EXTDEF	10	11	9	6	1
CB	10	8	9	8	7
CM	15	16	15	11	7
EXTMID	14	4	8	5	4
FWD	11	8	13	9	3

Table 5.2. Participant characteristics.

Variable	**Mean (SD)**
Body mass (kg)	81.7 (8.3)
Jump height (cm)	39.1 (5.0)
FTCT	0.73 (0.14)
CM depth (cm)	35.3 (6.9)
Contraction time (s)	0.80 (0.14)
Eccentric duration (s)	0.52 (0.10)
Concentric duration (s)	276 (45)
Net ecc yielding Impulse ($N{\cdot}s^{-1}$)	54.7 (14.5)
Net ecc decel Impulse ($N{\cdot}s^{-1}$)	107 (23.7)
Net con impulse ($N{\cdot}s^{-1}$)	221.6 (26.9)
Net con impulse 100 ($N{\cdot}s^{-1}$)	107 (26.8)
Ecc mean force ($N{\cdot}kg^{-1}$)	17.8 (2.9)
Con mean force ($N{\cdot}kg^{-1}$)	19.9 (1.9)
Ecc peak force ($N{\cdot}kg^{-1}$)	23.9 (3.7)
Con peak force ($N{\cdot}kg^{-1}$)	25.1 (2.9)
Ecc peak velocity ($m{\cdot}s^{-1}$)	1.36 (0.25)
Con peak velocity ($m{\cdot}s^{-1}$)	2.81 (0.17)
Con peak power ($W{\cdot}kg^{-1}$)	53.2 (6.1)
Ecc peak power ($W{\cdot}kg^{-1}$)	19.9 (6.5)
Ecc RFD ($N{\cdot}s^{-1}{\cdot}kg^{-1}$)	70.1 (30.6)
Con power slope ($W{\cdot}s^{-1}{\cdot}kg^{-1}$)	264.1 (72.8)

FTCT – flight time: contraction time, CM – countermovement, Ecc – eccentric, Decel – deceleration, Con – concentric.

5.3. Results

The results of this investigation show statistically significant relationships exist between the age of professional soccer players and JH, body mass and performance in a range of CMJ-Kin measures. Both polynomial models and age group comparisons produced here show, at a population level, aspects of NM performance are lower in older professional players compared to their younger counterparts. The results of this investigation, however, also show there is considerable individual variation in all CMJ-kin measures across all ages of players within this cohort.

Modelled relationships between player age and CMJ-kin variables are presented in Table 5.3. Polynomial models show variation across the age-span of professional football careers in JH, FTCT, concentric mean force, concentric peak force, concentric peak velocity, concentric peak power, and concentric power slope is significantly related to age. Polynomial models also show players aged 33 and over were outside a 90% CI for peak performance in JH, FTCT, concentric mean force, concentric peak power, and concentric power slope. No significant relationship was found between player age and any measure of eccentric performance. Differences in JH, CMJ-Kin variables, and body mass by age group are shown in table 5.4. Compared to 17–22-year-olds, JH was significantly lower in both 29-31- (ES: 0.58, p = <0.05) and 32–40-year-old players (ES: 0.68, p = <0.05). Concentric peak power was also significantly lower in the 29-31 (ES:0.58, p = <0.05) and 32-40 (ES: 0.65, p = <0.05) age groups compared to players aged 17-22. In comparison to 23–25-year-old players, 29-31- and 32–40-year-olds recorded significantly lower FTCT (29-31 ES:0.64, p = <0.05, 32-40 ES: 0.77 p = 0.01), concentric mean force (29-31 ES:0.77, p = <0.01, 32-40 ES: 0.75, p = <0.05), concentric peak force (29-31 ES: 0.75, p = <0.01, 32-40 ES: 0.8, p =<0.01) and concentric power slope (29-31 ES: 0.8, p = <0.01, 32-40 ES: 0.84, p = <0.01). Although not significantly related to age across the whole population, CM depth was significantly higher in players aged 17-22 versus those aged 23–25 (ES: 0.7, p = <0.01). Players aged 32-40 were found to be significantly heavier than those aged 17-22 (ES: -0.78, p = <0.01) and 23-25 (-0.67, p = <0.05).

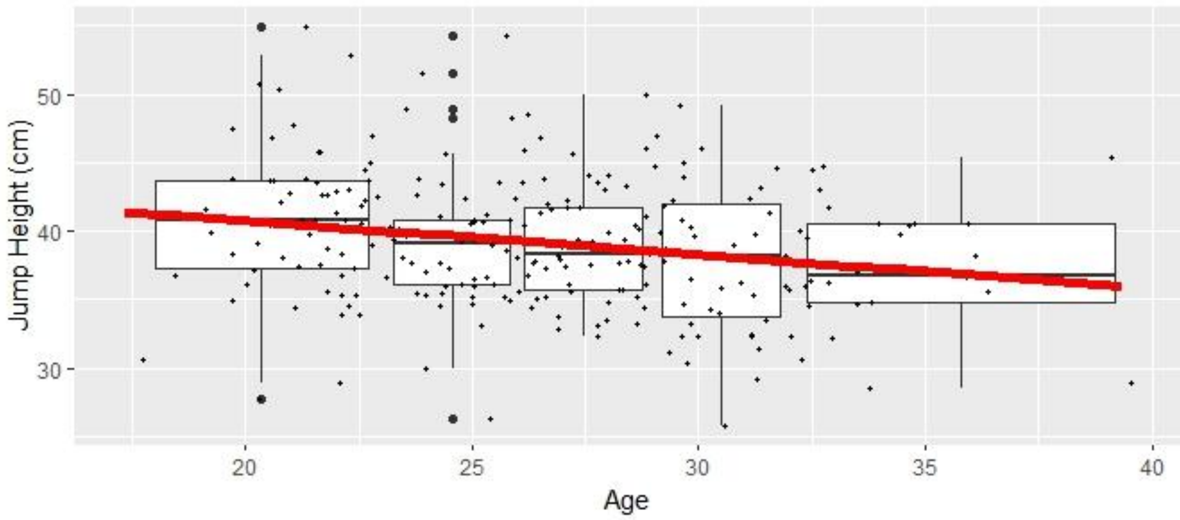


Figure 5.1. Polynomial model and box plots showing variation in jump height with increasing age in professional football players.

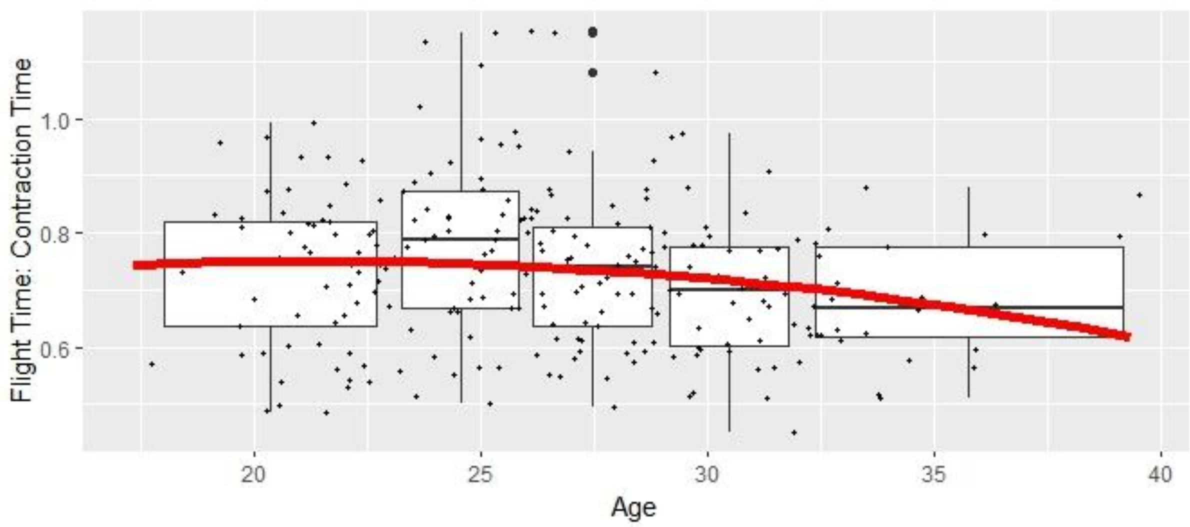


Figure 5.2. Polynomial model and box plots showing variation in flight time: contraction time with increasing age in professional football players.

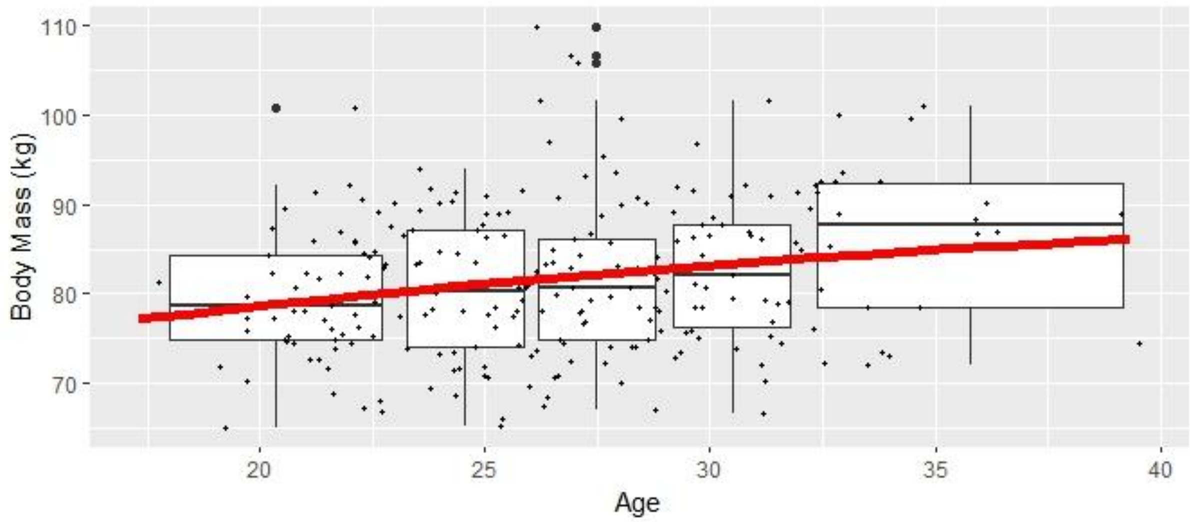


Figure 5.3. Polynomial model and box plots showing variation in body mass with increasing age in professional football players.

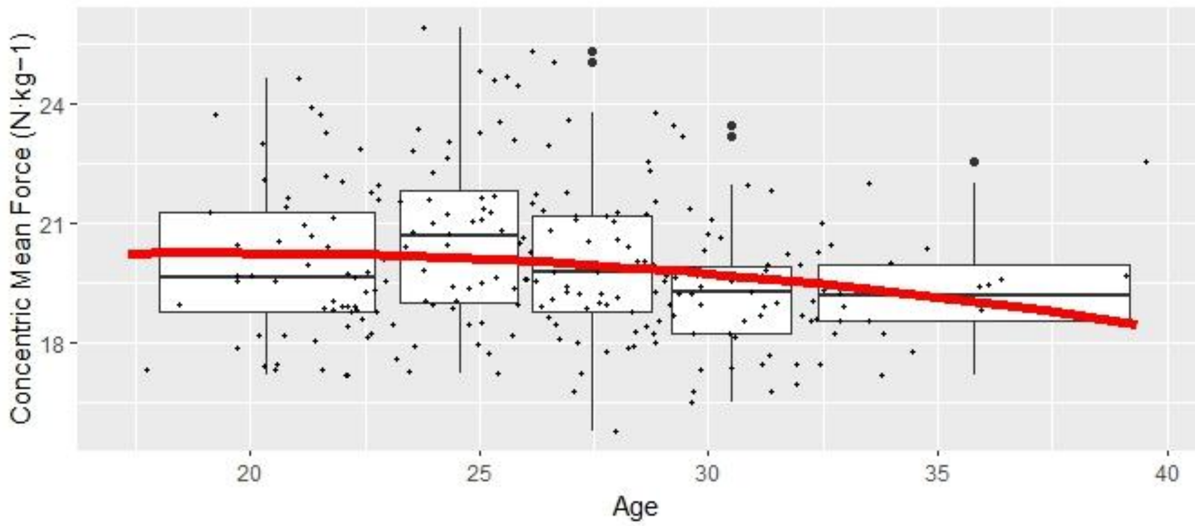


Figure 5.4. Polynomial model and box plots showing variation in concentric mean force with increasing age in professional football players.

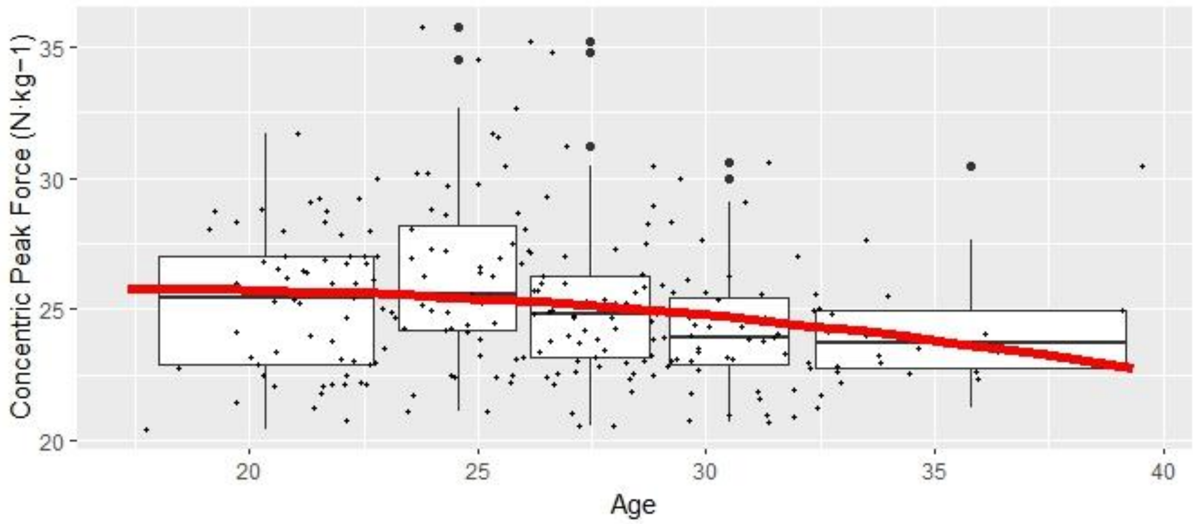


Figure 5.5. Polynomial model and box plots showing variation in concentric peak force with increasing age in professional football players.

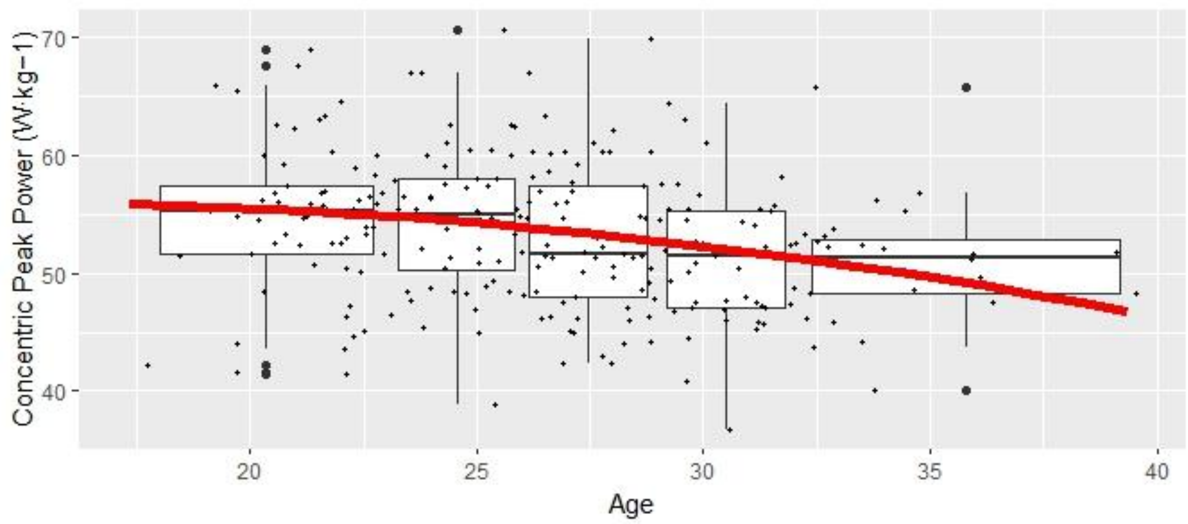


Figure 5.6. Polynomial model and box plots showing variation in concentric peak power with increasing age in professional football players.

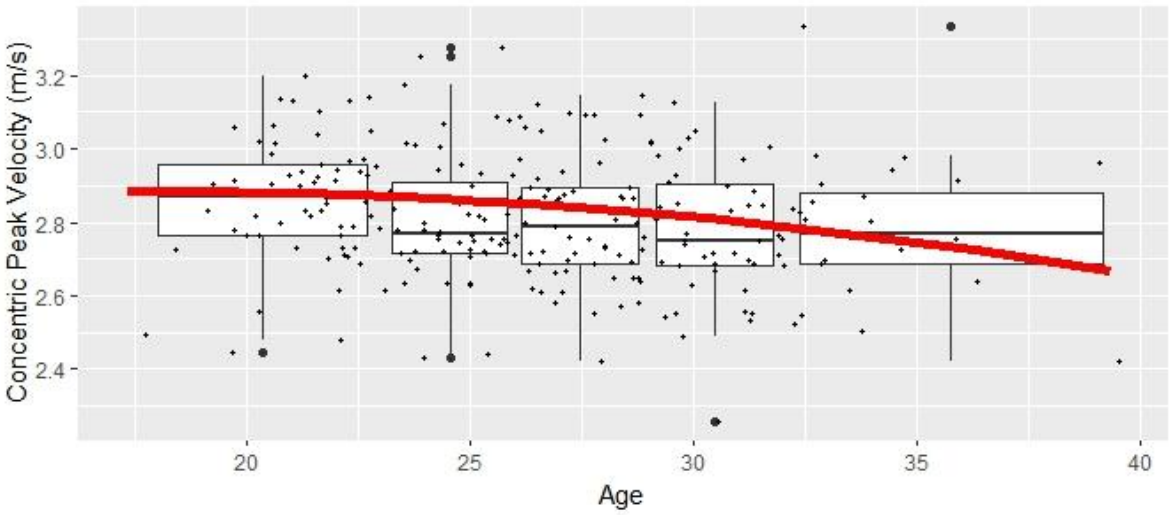


Figure 5.7. Polynomial model and box plots showing variation in concentric peak velocity with increasing age in professional football players.

Table 5.3. Results of polynomial models showing relationship between player countermovement jump performance and advancing age.

	Peak age (90% CI)	**Model intercept**	**Model Age Term**	**Age2**	**F Statistic (P value)**
Body mass (kg)	39 (17-39)	65.061	0.830	-0.007	5.84 (0.003)*
Jump height (cm)	17 (17-29)	45.384	-0.222	-0.001	5.61 (0.004)*
FTCT	23(17-31)	0.568	0.017	-0.001	3.34 (0.037)*
CM depth (cm)	N/A	37.054	-0.096	0.001	0.04 (0.96)
		Temporal			
Contraction time (s)	N/A	1.055	-0.021	0.0004	0.97 (0.38)
Eccentric duration (s)	N/A	0.732	-0.017	0.0003	0.85 (0.43)
Concentric duration (s)	N/A	0.321	-0.004	0.0001	1.04 (0.36)
		Impulse			
Net ecc yielding Impulse ($N{\cdot}s^{-1}$)	N/A	17.440	2.588	-0.044	1.01 (0.37)
Net ecc decel Impulse ($N{\cdot}s^{-1}$)	N/A	51.367	3.899	-0.066	0.85 (0.43)
Net con impulse ($N{\cdot}s^{-1}$)	N/A	186.470	2.128	-0.030	0.85 (0.43)
Net con impulse 100 ($N{\cdot}s^{-1}$)	N/A	41.846	5.138	-0.098	0.92 (0.4)
		Force			
Ecc mean force ($N{\cdot}kg^{-1}$)	N/A	11.562	0.532	-0.011	1.90 (0.15)
Con mean force ($N{\cdot}kg^{-1}$)	20 (17-32)	18.682	0.165	-0.004	3.45 (0.03)*
Ecc peak force ($N{\cdot}kg^{-1}$)	N/A	17.740	0.558	-0.012	2.01 (0.14)
Con peak force ($N{\cdot}kg^{-1}$)	17 (17-39)	23.971	0.211	-0.006	4.53 (0.01)*
		Velocity			
Ecc peak velocity ($m{\cdot}s^{-1}$)	N/A	0.925	0.036	-0.001	1.04 (0.36)
Con peak velocity ($m{\cdot}s^{-1}$)	17 (17-39)	2.924	-0.001	-0.0001	4.004 (0.02)*
Con peak power ($W{\cdot}kg^{-1}$)	17 (17-28)	57.604	0.027	-0.007	7.91, (0.001)*
Ecc peak power ($W{\cdot}kg^{-1}$)	N/A	-3.690	-1.369	0.028	2.24 (0.11)
		Rates			
Ecc RFD ($N{\cdot}s^{-1}{\cdot}kg^{-1}$)	N/A	7.87	5.713	-0.117	1.50 (0.23)
Con Power Slope ($W{\cdot}s^{-1}{\cdot}kg^{-1}$)	20 (17-32)	201.906	8.411	-0.213	3.53 (0.03)*

FTCT – flight time: contraction time, CM – countermovement, Ecc – eccentric, Decel – deceleration, Con – concentric. * P = <0.05.

Table 5.4. Age group comparison of player countermovement jump performance.

	17-22		23-25		26-28		29-31		32-40	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
n	61		52		61		43		28	
Body mass (kg)	79.58	7.05	80.47	7.67	82.3	9.71	82.61	7.61	85.99*^	8.62
Jump height (cm)	40.75	5.34	39.18	4.87	39.13	4.13	37.94*	5.33	37.45*	4.54
FTCT	0.73	0.13	0.78	0.15	0.74	0.14	0.7^	0.12	0.68^	0.1
CM depth (cm)	37.1^	6.74	32.37*	7.67	35.86	6.53	36.3	6.45	34.81	5.59
Temporal										
Contraction time (s)	0.82	0.15	0.76	0.15	0.79	0.13	0.82	0.13	0.83	0.12
Eccentric duration (s)	0.54	0.11	0.49	0.11	0.52	0.1	0.53	0.1	0.55	0.09
Concentric duration (s)	0.28	0.05	0.26	0.05	0.27	0.04	0.29^	0.04	0.29	0.04
Impulse										
Net Ecc Yielding Impulse ($N{\cdot}s^{-1}$)	53.84	13.66	53.57	16.67	54.89	13.85	56.08	14.41	56.37	14.48
Net Ecc Decel Impulse ($N{\cdot}s^{-1}$)	106.91	22.43	102.15	22.98	109.45	24.37	108.48	24.07	108.62	4.88
Net con impulse ($N{\cdot}s^{-1}$)	219.7	22.92	219.39	28.03	222.15	30.3	220.41	23.97	230.22	29.52
Net con impulse 100 ($N{\cdot}s^{-1}$)	104.02	26.04	115.15	32.93	110.33	26.79	110.39	21.75	104.69	18.75
Force										
Ecc mean force ($N{\cdot}kg^{-1}$)	17.84	2.78	18.3	3.09	17.97	3.11	17.34	2.75	17.06	2.24
Con mean force ($N{\cdot}kg^{-1}$)	19.95	1.89	20.71	2.17	19.98	1.87	19.29^	1.61	19.33^	1.23
Ecc peak force ($N{\cdot}kg^{-1}$)	23.98	3.7	24.73	4.09	24.32	3.88	22.94	3.37	22.91	2.74
Con peak force ($N{\cdot}kg^{-1}$)	25.29	2.69	26.25	3.36	25.16	2.91	24.16^	2.38	24.04^	1.96
Velocity										
Ecc peak velocity ($m{\cdot}s^{-1}$)	1.39	0.26	1.33	0.25	1.37	0.22	1.36	0.28	1.3	0.26
Con peak velocity ($m{\cdot}s^{-1}$)	2.87	0.16	2.81	0.17	2.81	0.17	2.77	0.18	2.78	0.18
Con peak power ($W{\cdot}kg^{-1}$)	54.76	6.28	54.65	6.16	52.81	6.27	51.29*	5.67	50.83*	4.83
Ecc peak power ($W{\cdot}kg^{-1}$)	-20.44	6.28	-20.1	6.41	-20.47	6.87	-19.58	6.84	-18.04	5.52
Rates										
Ecc RFD ($N{\cdot}s^{-1}{\cdot}kg^{-1}$)	72.2	29	86.5	42.77	76.01	38.72	68.02	27.8	66.71	26.9
Con Power Slope ($W{\cdot}s^{-1}{\cdot}kg^{-1}$)	269.56	77.73	309.45	104.82	274.11	86.89	243.6^	62.58	240.94^	53.5

FTCT – flight time: contraction time, CM – countermovement, Ecc – eccentric, Decel – deceleration, Con – concentric. * Denotes statistically significant difference vs 17-22, ^ denotes statistically significant difference vs 23-25.

5.4. Discussion

This investigation aimed to examine age related differences in NM performance capability in elite football players, by firstly modelling variation in JH, body mass and CMJ-kin measures across professional career spans, and subsequently examining differences between specific age-groups of players. To the best of the author's knowledge, this is the first investigation to examine CMJ-Kin variables as well as JH across the age span of EPL careers in a large sample of players. The main findings of this study are firstly, that the oldest players showed reduced JH and performance in aspects of concentric output compared to players aged between their late teens and mid-twenties. Secondly, the study shows CMJ-kin variables provide greater resolution in describing variation across the career span compared to the examination of JH alone. Thirdly, the results of this investigation show there is considerable individual variation in CMJ-kin measures across all ages of players within this cohort, suggesting that despite population trends showing older players typically have lower NM capabilities, many are still able to achieve JH and CMJ-kin outputs equivalent to younger players. From an applied perspective, results presented here suggest that whilst decline in NM performance may contribute to observed decrements in performance in some older players, it alone is unlikely to govern the duration of elite level professional careers.

Analyses conducted in this investigation revealed a significant relationship between JH and player age. Polynomial models (Figure 5.1) suggest JH decreases with age, with comparisons between age categories revealing players aged over 29 (29-31 and 32-40) achieved significantly lower displacement, compared to those aged 17-22. In showing reduced JH in players aged 29 and over, compared to those aged 17-22, the findings of this investigation contrast those of Haugen et al. (2013), who found JH remained stable across all age groups of senior players. It is possible, that in defining their oldest age group as players aged >28, these authors age categorization did not provide sufficient resolution to detect an effect of increasing age. It is also possible that by examining performance in players from a wider variety of playing levels (i.e., domestic semi-professional to international compared to only EPL players in the present investigation) Haugen et al. (2013) were examining a cohort with greater variation in NM profiles compared to the present study. Greater variation in NM profiles may have reduced the sensitivity of the investigation of Haugen et al. (2013) to detect small age-related differences. By presenting CMJ-kin variables in addition to JH, the results of this investigation extend the work of Haugen et al. (2013) and offer greater detail regarding NM trends across a professional football population. Alongside reduced JH in players over 29 versus those aged 17-22, this study found significantly lower levels of concentric peak power. This finding is unsurprising given concentric peak power has been shown to be highly correlated to JH (R = >0.76, Gonzalez-Badillo et al., 2010; Jimenez-Reyes et al., 2014). To further explain the differences in JH between players aged 29 and over, and those aged 22 and below, this investigation found that whilst not statistically significant, the youngest players (≤22) appeared to produce higher peak and mean concentric and eccentric force and velocity compared to older players (<29). Additionally, although polynomial models showed body mass was positively related to age, only 32–40-year-olds were found to be significantly heavier than those aged 17-22.

Age group comparisons in this investigation also showed reduced CMJ-kin performance in players over 29 compared to those aged between 23 and 25. Compared to 23–25-year-old players, players aged 29-31 and 32–40-produced significantly inferior mean and peak relative force in the concentric portion of the CMJ. Whilst differences between 23–25-year-olds and those aged over 29 in JH and concentric peak velocity did not reach statistical significance, the observation that FTCT, and concentric peak slope were significantly lower in the older athletes suggests a diminished ability to produce high forces quickly. It is interesting to note that the observed deficits in CMJ-kin performance in players aged >29 and those aged 23-25 are concentric in nature. Compared to isometric and eccentric contractions, concentric muscle actions reach higher velocities during the CMJ (Harper et al., 2018). The ability to produce high concentric peak forces at high angular velocity is associated with greater thickness and pennation angle of leg extensor muscles (Secomb et al., 2015). It is therefore possible that deficits in concentric performance observed here are representative of one or both of a reduced ability to produce force at high contraction velocity and morphological change.

In addition to providing useful information about age related NM variation in professional football players, the findings of this investigation showing differences between older and younger professionals are likely reflective of a reduction in NM capability detrimental to football performance. JH has been shown to be positively related to sprinting speed (Locturco et al., 2015), peak in-match running velocity (Pedersen et al., 2021) and change of direction performance (Koklu et al., 2015). Reactive Strength Index modified, a construct shown to be almost perfectly correlated to FTCT (McMahon et al., 2018), is accepted as a valid general measure of lower body explosiveness (Kipp et al., 2016) and has been shown discriminate between levels of performance in team sports (McMahon et al., 2022). In addition, CMJ peak force and peak power have been shown to be strongly correlated with maximal force output across a variety of strength assessments (Nuzzo et al., 2008; Thomas et al., 2015). Reduced JH, FTCT and concentric peak force shown here, amongst older professional players may therefore reflect an overall diminished NM profile likely to impact high intensity in-game actions, and potentially the ability of older players to perform at the level of their younger counterparts. Given the importance of high intensity actions to in-game performance (Bangsbo et al., 1991), it is possible such NM deficits may contribute to observed reductions in performance in older players and may explain part of the significant decrease in numbers of players aged over 29, who able to remain as professionals at the highest levels of football (Dendir, 2016; Kalén., 2019).

Whilst this study is the first to examine age related change in NM performance via examination of CMJ-kin variables, other work presents evidence in support of NM decline occurring in older professional players in or after their late twenties. Scoz et al. (2021) reported a significant reduction in quadriceps strength of midfielders aged 29 and over. Given that the quadriceps are likely to play a significant role in propulsion across range of jumping strategies (Sahrom et al., 2020) this finding appears in keeping with results reported here. The finding of reduced NM output in older players is also in keeping with findings showing a significantly lower frequency of fast runs and sprints (Sal de Rellán-Geurra et al., 2019) and significantly fewer accelerations and decelerations (Lorenzo-Martínez et al., 2021) throughout match play in players over 30 compared to their younger professional peers.

The results of this investigation show players aged 17–22 utilized a jump strategy based on a significantly greater CMD compared to players aged 23-25. Although there were no further statistically significant differences in performance between 17-22 and 23-25 age-groups, it appears that the younger players rely on a strategy of moving through a greater CM range and therefore utilizing a greater time epoch to develop an equivalent impulse versus their 23–25-year-old counterparts. Adoption of a greater CMD has been previously associated with a more velocity as opposed to force orientated CMJ strategy (Ripley et al., 2016) and may reflect a higher training status towards high force output in the 23–25-year-old players. Although speculative, the finding that younger players required increased time to produce equivalent propulsive forces may mean that specific NM qualities represented by variables differing between these two groups but not expressed by measuring JH alone, are developed during the early phase of the playing career. Given intense activity in match-play is an important stimulus for NM adaptations in elite players (Morgans et al., 2018), it is possible the way in which 23–25-year-old players were able to produce equivalent JH and force with a significantly lower CMD compared to 17–22-year-olds, is a result of specific adaptations resulting from the accumulated demands of high-level competition and training (Arabatzi et al., 2010) promoting the development of specific NM qualities.

Whilst it is tempting to conclude results presented here show players NM capabilities change across their careers with increases up to approximately age 25 and subsequent decreases beyond age 30, we must stop short of such a conclusion. Due to the cross-sectional nature of the evidence presented, it is impossible to definitively state that NM output of the identified variables changes with age. Whilst an early career increase followed by a decrease in the later stage of the career span seems likely and additional evidence supports this assertion; it is also possible that lower NM output in the youngest and oldest players reflects a selection and survival bias for players with lower levels of NM performance who possess another useful attribute such as a very high level of skill. It is therefore possible, lower mean scores in JH and CMJ-kin variables amongst older (29-31 and 32-40) players or altered jump strategy in 17-22 vs 23–25-year-old players reflect a change in composition of the population and not a change in individuals.

The results of this investigation show there is considerable variation in both JH (28-63cm) and other CMJ-kin measures across this cohort of EPL players. In the context of inclusion criteria requiring all participants to have played in multiple games (5 or more) in the season following assessment, this within population variation suggests it is possible for players to play in the EPL with a wide range of NM profiles. This variation in profiles likely reflects the observation that individual players can contribute to success in team sport in many ways (Bradbury, 2009). Given the complexity of defining successful individual performance in football, it is possible there is a broad range of playing styles, each biasing a different blend of underpinning physical qualities that allow players to reach and remain at an elite level of football. The considerable variation in NM performance observed across all ages of players suggests some retain highly developed NM qualities for long periods of their careers, and that others can continue to perform at very high levels without them. The variation present in this cohort suggests factors beyond the purely physical must be considered if we are to develop a deeper understanding of the determinants of career longevity. The ability of certain older players to remain in the EPL with apparently lower NM profiles compared to teammates may mean a blend of individual skills and perhaps environmental circumstances (e.g., team playing style, squad composition, additional player qualities) influences the extent to which players are retained to a far greater extent than physical performance metrics alone. In addition to a broader examination of factors determining career duration, it seems important future work investigates change in individual players in a longitudinal manner to elucidate specific factors contributing to performance changes.

When considering differences between age-groups presented here, it is important to acknowledge differences in their positional composition. Clearly, the relatively higher proportion of goalkeepers within the 32-40 age group will influence group mean characteristics. The greater age range covered by the oldest age-group must also be acknowledged. It is, however, important to accept having relatively fewer older players is an inevitable consequence of the accepted large drop out of players from elite leagues following 29 years of age (Dendir, 2016). The rarity of surviving into the mid-thirties in high level, professional team sport (Bradner et al., 2014) therefore means older players are inherently scarce and as such difficult to group in narrow descriptive bands. The use of pre-season testing data represents a further limitation of this investigation. Prior to pre-season, clubs have little control over players in terms of the type or volume of preparatory training they complete. It is therefore likely observed performance differences between players are influenced by differences in training completion as well as age.

5.5. Practical applications

Results presented here suggest that clubs must account for a likely general decrement in NM performance when recruiting older players or forecasting the timescales over which individuals are likely to contribute to team performance. This seems especially important for players in positions or roles where a high level of NM output is essential towards successful game outcomes. Although beyond the scope of this investigation, it may be possible for sports teams to assist older players in maintaining game performance via prescription of training designed to maintain high levels of NM performance. Given deficits in older players' concentric performance presented here likely reflect a reduced ability to produce high relative force at high contraction velocity versus their younger counterparts, it seems prudent to train players to produce high concentric forces at high contraction velocities throughout the career span. Although the inclusion of concentric-only movements may appear a logical choice towards this objective, it is important to acknowledge that eccentric outputs have been shown to directly contribute to performance in the following concentric phase (Cormie et al., 2011; Baker et al., 2018). Considering this and the associational level of evidence presented here, it is important that practitioners do not dismiss the potential importance of eccentric strength qualities and whole stretch-shortening cycle movements when prescribing training aiming to maintain NM performance in older players.

5.6. Conclusions

The results of this investigation show older players are likely to record a significantly lower JH, higher body mass and reduced performance in a range of concentric phase CMJ-kin measures compared to younger counterparts. The results of this investigation also show considerable variation in NM performance across all ages of players within this EPL cohort and suggest high level football performance can be achieved and perhaps maintained in many ways involving traits beyond the purely physical. Although it is possible diminished NM profiles may contribute to the observed reduction in performance and numbers of players in elite leagues after age 30, it seems likely factors beyond the purely NM strongly influence these observations. Within this study examining CMJ-kin as opposed to JH alone provided greater resolution in attempting to understand age related variation in NM performance. The cross-sectional nature of this analysis however limits the extent to which variation in CMJ-kin across the career span can be said to describe ageing per se.

DOCTORAL LEARNING PAUSE 2

Doctoral learning pause: some of what I wrestled with and learnt from in Study 2

Going into my second study I was much better prepared. Thanks to learnings from Study 1 I had more research skill and greater clarity around what I needed to do to effectively manage my tasks within the project. Working on Study 2 helped me progress further towards my learning objectives. I increased my knowledge of research methodology, learnt more about my research topic and I believe identified some trends that will be useful to fellow practitioners. However, the biggest area of learning for me in Study 2 was around how best to work with collaborating researchers. Clearly collaboration is an essential part of research and actively managing such interactions is a key aspect of project management. I had seen and considered criteria related to this in my self-audit (appendix 9.1, VRDF sections C2 and D1) but I certainly didn't realize the problems a lack of competence in these areas could cause. To action Study 2 I needed a lot of help modelling variation in jump performance over time. I wanted to build several different statistical models and was very dependent on input from a collaborator in relation to coding and the statistical methodology underpinning my approach to the research question. The problem was, the process of frequently asking the collaborator for their opinion on my next steps led me to conduct a lot of work that was peripheral to my study and to answer questions that didn't contribute to my research at all. The exercise was very inefficient and took up too much of mine and my collaborators time. Reflecting on the situation, I made the mistake of asking for help and suggestions on how to deal with my data without managing the study direction appropriately. In handing my collaborator licence to direct me, I wrongly presumed he had my study question front of mind, which of course he did not, nor should he have had. I should have changed my approach sooner and should have been far clearer on my expectations of the collaborator's role.

In my initial reflections on this episode, I regarded the whole thing as a waste of time that I needed to move on from. Thinking on the process later I realized the challenge it presented, and my response were hugely beneficial. The situation forced me to acknowledge my role in inadvertently handing control of the study to the collaborator. It made me see my desire for assistance led me to be far too passive and not help the collaborator efficiently offer guidance. This helped with subsequent interactions with collaborating researchers and allowed me to reflect on my management style at work in relation to what level of guidance is most useful. Understanding the way in which this problem had helped me develop skills that benefitted me as both a researcher and a practitioner, reinforced the reframing of my conception of challenge I had experienced working on Study 1. Again, encountering a specific problem, in this case around collaboration, had helped me develop towards my learning objectives specifically as they related to project management. Arguably, by improving my ability to collaborate, I had also improved my ability to learn more from the excellent minds I was working with.

APPLIED REFLECTIVE PAUSE 3

Understanding Father Time's undefeated status

Performance team meeting room, any professional team:

"Just so everyone is clear we are currently talking to Matty and his agent about next season. Obviously, he's playing well, and we like him. The issue is they want two years as a minimum and we cannot get away from the fact he's already 32. The agent is talking about how much we've got out of Tommy this year even though he's 34, and he's right, Tommy has been excellent. However, our other defender Jon is a year younger at 33 and he really hasn't gone as well… The general manager will make the final decision, but there's a bit at stake here, to keep Matty we probably have to let one of the younger forwards go, and he isn't cheap, but that being said, I don't need to tell you what will happen if he goes somewhere else and scores 2 against us… From you guys, I just need to know if Matty has got two more good seasons in him."

Performance teams are regularly asked these types of questions. Clearly, it is impossible to be 100% sure how a specific ageing player will fair in a complex environment such as team sport in the future. Despite this, due to the high stakes of large contracts, sporting executives want expert input into the likely extent, rate, and implications of any age-related decline. Such discussions are not limited to ageing players. Very often, projecting how a young player may progress over coming seasons is a key part of the decision-making process in awarding long-term contracts. Although performance statistics will play a key role in informing these decisions, coach and management opinion is weighed heavily when projecting the likely value of a particular player to an organisation in coming seasons. Despite the financial implications of these decisions, there appears to be very little research evidence elucidating some of the underpinning concepts fundamental to projecting future performance. Whilst statistical analyses of longitudinal trends in elite player scoring trends are widely available, very little attention has been paid to other factors that may impact longevity in the complex world of professional team sport. For this reason, I wanted to explore the things that influenced how long players were able to survive in top level professional sport. Given the lack of academic research available, I felt speaking to those closest to the action was likely the best means of understanding what governs who survives and who does not.

CHAPTER SIX

STUDY 3: CAREER LONGEVITY IN PROFESSIONAL FOOTBALL CODES: A SYSTEMS THINKING, SUBJECT MATTER EXPERTS' PERSPECTIVE STUDY

Career longevity in professional football codes: A systems thinking, subject matter experts' perspective study

6.1. Introduction

Professional playing careers in all football codes are situated in extremely competitive environments where every season teams recruit new high talent, high potential players, and release those deemed surplus to requirements. In the context of this selection pressure, Chapter 4 (Study 1) showed the career duration of individual players is highly variable. Efforts to understand variation in career longevity have typically focused on examination of longitudinal change in performance (Fair, 2008; Dendir, 2016), differences in potentially underpinning physiology across the career span (Signorelli et al., 2012; Botek et al., 2016; Chapter 5) or reasons for retirement provided by ex-players (Rintaugau & Mwisukha, 2011; Carapinheira et al., 2018,). However, given the brevity of many professional careers (Frick, 2007; Keim, 2016), the wide variation in physiological profiles within elite leagues evidenced by Chapter 5 (Study 2) and the likely complex and multifaceted nature of career termination (Fernandez at al., 2006; Stambulova et al. 2009), attempting to understand career profiles through various single system analyses appears limited. Research in sports economics has suggested career duration is impacted by multiple individual, team, and environmental factors (Frick 2007; 2011). However little practically focused work in sport science has investigated what these factors are or how they interact (Sanders & Stevinson, 2017). In view of the vast sums of money spent on player development, the potential competitive advantage to be obtained by increasing the duration over which elite players can compete and the lucrative rewards available to players who remain as high-level professionals, it is clear extending playing careers offers huge benefits. An alternative investigative paradigm may therefore be required to provide practitioners with a more useful perspective from which to understand professional team sport careers and develop interventions with scope to increase effective career duration.

Considering aspects of professional team sports have been shown to operate as a complex system (Salmon & Mclean, 2020), a systems thinking perspective may be useful in understanding longevity in professional team sport careers. Systems thinking is based on a foundational principle that system behaviour cannot be understood by examining its isolated components and instead considers the whole system as the focus of analysis (Ottino, 2003). It is an approach to understanding complexity which considers the influence of multiple dynamic, often non-linear interactions occurring between system parts and the presence of feedback loops (Cilliers, 1998; Allender et al., 2015). As a result of its acknowledgment of open systems and acceptance of the potential for emergence (Cilliers, 1998), systems thinking is entirely compatible with the philosophical foundation of critical realism that underpins this thesis (Armstong, 2020). Indeed, in highlighting the link between the two paradigms, Mingers (2014) described critical realism as *'fundamentally systemic in character'* and suggested that whilst little reference to systems thinking exists within the key texts of critical realism, a large amount of the dialogue utilises systems terms. It is therefore wholly appropriate, to engage systems thinking as a means of exploring the causal forces and deeper, real level generative mechanisms that impact career longevity as is required by critical realism (Buch-Hansen & Nielsen, 2020). Systems thinking has been widely used as a means of understanding complexity in diverse areas including counter terrorism, economics, engineering, safety science, and sustainability (Senge, 1990; Bosch et al., 2007; Cabrera et al., 2008; Nguyen & Bosch, 2013). It is becoming more frequently used within sports science (Bittencourt et al., 2016; Mooney et al., 2017; Hulme et al., 2019; Mclean et al., 2019) with increased interest likely due to the failure of existing reductionist methodologies to comprehensively account for the breadth of factors and interactions which influence athlete, team, club, and sport system performance (Cilliers*,* 1998*;* Salmon & Mclean, 2020).

One systems thinking tool that has been widely used to examine complex systems is the Causal loop diagram (CLD) (Senge, 1990). A CLD is a diagrammatic method of system description, used to uncover the underlying feedback structures and leverage points in a system (Sahin et al., 2020). CLDs present a means of exploring the relationships between system factors and therefore allow examination of the causal powers impacting career longevity in professional team sports. CLDs are frequently constructed via a group model building process involving subject matter experts (SMEs) (Allender et al., 2015; Sahin et al., 2020). In an area that has received little research attention at a holistic level, such a methodology follows the suggestion that a highly effective means of acquiring knowledge is to seek the input of experienced individuals in their field of interest (Fifer et al., 2008). To provide practically relevant information to those wishing to develop interventions with the goal of enhancing career longevity, the aim of this study is therefore to develop a CLD and Actor map in conjunction with SMEs to examine the determinants of longevity and influencing stakeholders impacting longevity within professional team sport careers.

6.2. Methods

6.2.1. Study design

A CLD describing the dynamic behaviour of professional team sport careers by visualizing system variables and the reinforcing and balancing relationships between them (Nguyen & Bosch, 2013) was developed with SMEs via the 5-step model building process (Sterman, 2000; Bérard, 2010) shown in Figure 6.1. Following development of the CLD, an actor map was created to show the relationships and individuals involved in interactions described within the CLD. Causal tree diagrams were also constructed to illustrate the systemic influence of and causal powers related to key variables within the CLD (Mclean et al., 2021). In this investigation, the boundary for system analysis was considered as areas that could be influenced by sporting organisations and professional players were considered as those playing in elite leagues within their sport. This study received ethical approval from the University of Birmingham (ERN_2022-0462).

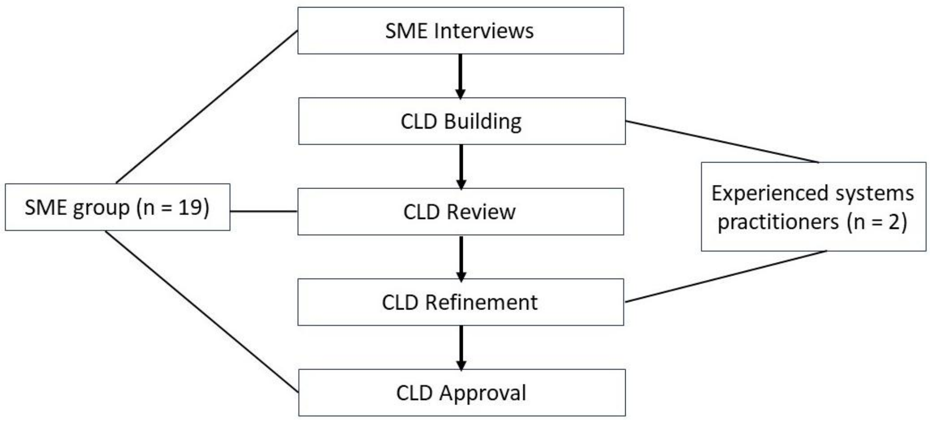


Figure 6.1. Causal Loop Diagram development process.

6.2.2. Participants

A group of 19 SMEs (mean age: 41 ± 6, 1 female, 18 male) with extensive experience (mean years: 15 ±7) in professional team sport were recruited to inform and refine CLD development. To be eligible to take part in the study, participants had to have worked in AFL, English professional football, NFL, or PR for a minimum of 5 years. SMEs were either ex-professional players, coaches, or employed in decision making roles within player recruitment, medical support, or physical performance support (Table 6.1). One performance psychologist and one player agent were also interviewed. At the time of interview all participants were employed within professional sports related occupations. In several cases, across long careers, SMEs had held more than one high-level role which qualified for involvement in the study (e.g. they were currently employed as coaches but were also former professional players or had been heads of medical in both AFL and PR). Where practitioners had held each of these roles for 5 years or more, they were asked to provide reflections from both perspectives.

Table 6.1. Participant roles by sports.

Sport	Participant role	Participant gender	Participant experience in related role
Australian Rules Football	Former professional player	Male	14 years
	Former professional player	Male	13 years
	Senior coach	Male	15 years

	Recruitment analyst	Male	8 years
	Head of physical performance	Male	15 years
	Head of medical	Male	11 years
English Premiership or Championship football	Former professional player	Male	14 years
	Former professional player	Male	8 years
	Head of medical	Male	22 years
	Head of medical	Male	14 years
	Strength & conditioning coach	Male	27 years
	Head of recruitment	Male	9 years
National Football League	Former professional player	Male	9 years
	Position coach	Male	6 years
	Head of physical performance	Male	8 years
	Member of medical staff	Male	14 years
Premiership Rugby Union	Former professional player	Male	13 years
	Former professional player	Male	14 years
	Senior Coach	Male	9 years
	Senior Coach	Male	11 years
	Head of medical	Female	16 years
	Head of physical performance	Male	22 years
	National Talent Manager	Male	8 years
Other	Performance psychologist (experience in several sports).	Male	11 years
	Player agent (experience in two codes of football).	Male	7 years

6.2.3. Procedures

In the first phase of CLD development, semi-structured interviews exploring the determinants of career longevity in professional team sports were carried out with SMEs. Prior to interviews, participants were informed of study aims and the basic conventions of systems thinking. A semi-structured interview format was deemed appropriate based on the technique's scope to elicit interviewee's ideas and opinions and encourage discussion of the links they saw between pertinent factors impacting career longevity without leading them toward preconceived choices (Zorn, 2008). An interview guide (appendix 9.3) was used to direct questioning and ensure dialogue remained related to study aims. The Interview guide was developed in accordance with the framework presented by Kallio et al. (2016). The areas for questioning within the guide were determined by an extensive literature search related to career longevity and reasons for career termination as well as the findings of study 1 (Chapter 3) and 2 (Chapter 4) of this thesis. Questions for a preliminary draft of the guide were prepared by the author before being reviewed and revised over 4 meetings with collaborating researchers with significant experience of conducting qualitative research. The effectiveness of the interview guide was evaluated through a pilot study carried out with a small convenience sample (n = 3) of participants matching inclusion criteria applied here (Stoszkowski & Collins, 2018). Following pilot testing, the wording of several questions was adjusted and options for 'wrap up' questions were revised. In all interviews, SMEs were asked to reflect on the specific careers of athletes they had worked with and their own experiences. The Interviews were conducted online, by phone or face to face and lasted between 38 and 91 minutes (67 ± 12 minutes). They were transcribed live, with transcripts edited post interview. Following the interviews, transcripts were analysed thematically (Braun & Clarke, 2006) and then coded with flexible categorizations describing determinants of longevity expressed by SMEs (Rynne & Mallett, 2012). Key themes extracted from each interview were compared and combined to create summary variables impacting career longevity (appendix 9.3) and were incorporated into an initial draft CLD. This was sent to SMEs who were asked to provide feedback on the determinants of longevity included in the CLD, interactions, link polarity, feedback loops and any areas they felt were missing or overlooked (Mclean et al., 2020). Feedback from SMEs was then used to refine the CLD which was subsequently retuned to them for approval. The CLD was developed with input from two members of the research team with extensive experience in CLD development and systems thinking analyses using Vensim software (Ventana Systems Inc, Harvard, MA).

Exploration of the thematic breakdown of SME interviews also informed the development of the actor map shown in Figure 6.3. The actor map shows the relationships between the player and key stakeholders interacting with them to influence factors identified by SMES as important in determining professional career longevity. The actor map was produced based on social organisation and cooperation analysis techniques (Vicente, 1999; Mclean et al., 2021). The points at which different actors interact with a player's career journey were orientated around the Holistic Athlete Career Model (HAC). The HAC (Wylleman et al., 2013; 2019) describes careers as multi-layered processes which can be divided into developmental stages and was used to provide context to the player career journey and influencing relationships taking place around it. To explore their systemic and generative influences, causal tree diagrams were produced for key variables describing their primary and secondary effects across the system.

6.3. Results

A CLD showing the determinants of career longevity in professional team sports is presented below (Figure 6.2). The CLD shows 25 summary variables interact as part of a complex system to determine career longevity in professional team sport. All variables shown represent a summary of a thematically similar group of related terms described by SMEs. A description of each summary term presenting alternative language and scope of each variable as given by SMEs is presented in Appendix 9.4. The variables included in the CLD were related to the individual players themselves, the team and organization they played within, as well as the broader sport systems they were part of. The CLD contains both reinforcing and balancing loops. The higher number of reinforcing loops versus balancing loops show careers are subject to many potential sources of growth, erosion and failure that must be managed by sports organizations if longevity is to be maximized (Sahin et al., 2020). An actor map showing people and relationships influencing career longevity is shown in Figure 6.3. The actor map details 29 different groups of individuals who make decisions and/or interact with players in a manner that can influence their career trajectory and longevity. The actor map shows interactions potentially significant for longevity can take place in all career stages from initiation to discontinuation. Causal tree diagrams exploring variables influencing and be influenced by player contentment and squad quality are shown in Figures 6.4 and 6.5 respectively.

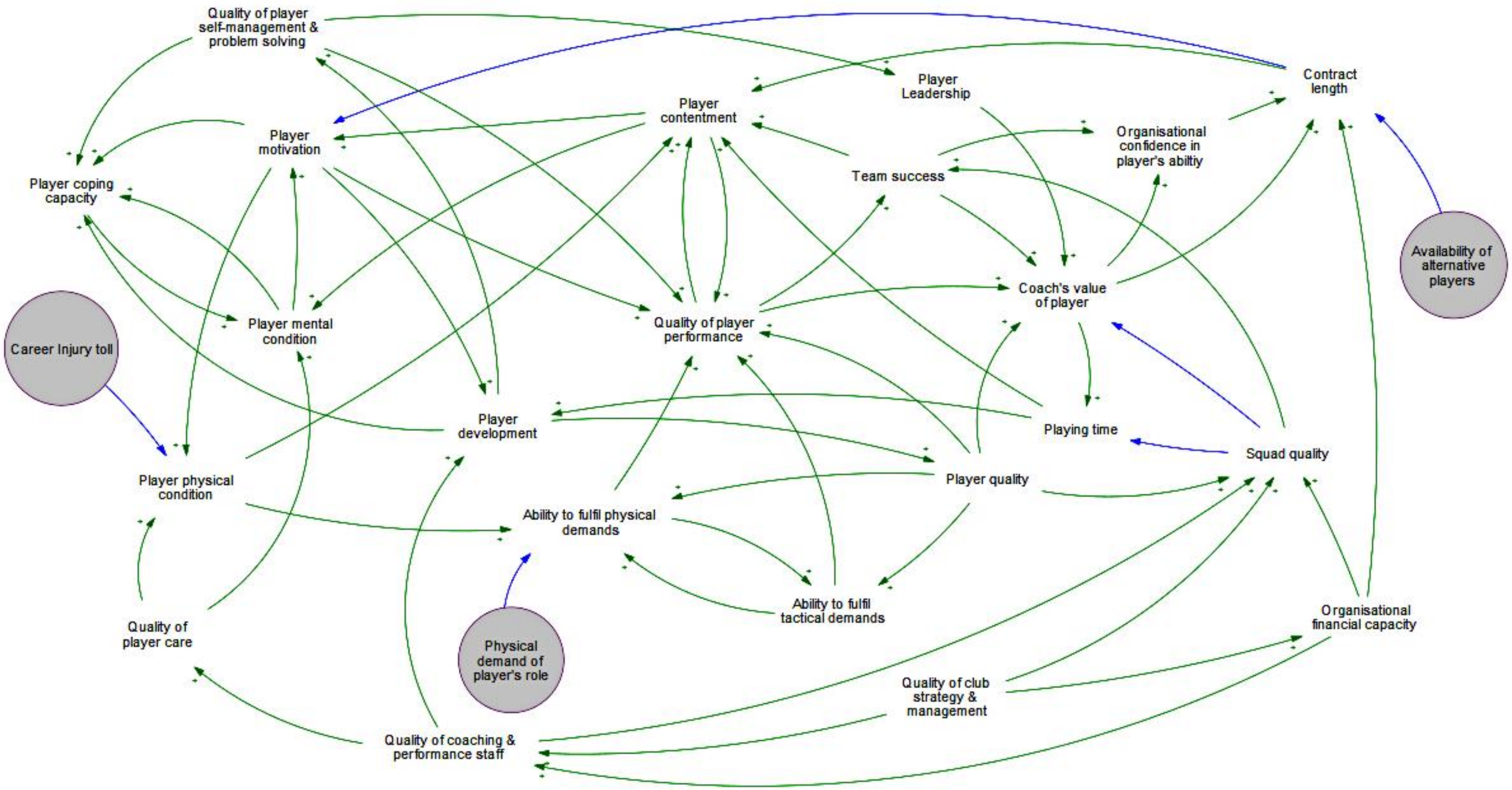


Figure 6.2. CLD depicting the determinants of professional team sport career longevity. Variables shown in grey shaded circles represent factors outside of the system boundary of analysis.

		Actor group	Non sport life	Development Staff	Performance Support	Playing Population	Coaching Staff	Selection Decision Makers	Recruitment decision	Club Governance	Sport Governance
		Specific actors	Partner/Children Family Friends Mentors	Academy coaches Academy management Teachers	Performance director Medical staff S&C/Nutrition/Psych Sport Science	Playing squad Team acad players Alternative players	Head coach Assistant coaches Analysts	Head coach General managers Trusted assistants Ownership/board	Sporting directors Recruitment staff Head Coach Ownership Agent Scouting	Board of directors Ownership Manager Head Coach	League rule makers Financial rule makers International gov bodies
HAC career stage		**Specific factors**									
Discontinuation	*Retirement*	Retirement decision	•					•	•	•	•
Mastery	*Staying in contention*	Contract (renewal) decision				•		•	•	•	
		Length of contract				•		•	•	•	•
		Player coping capacity	•	•	•	•					
		Player support network	•		•	•	•			•	•
		Player contentement	•		•	•	•	•	•		•
		Player motivation	•	•	•	•	•	•	•		•
		Availability of alternative players		•	•	•			•	•	•
		Organisational resources (finanical capacity)							•		•
		Organisational governance						•			•
		Player's busness value to organisation		•		•	•	•	•	•	
		Team success		•	•	•	•	•	•	•	
		Player game load			•	•	•	•	•	•	•
		Team game style			•	•	•	•	•	•	•
		Team training demands			•	•	•	•			
		Team objectives					•		•		
		Quality of culture		•	•	•	•	•	•	•	•
		Quality of player care		•	•	•	•	•		•	•
	Getting picked	Organisational confidence in player's ability		•	•	•	•	•	•	•	
		Opportunity to play: selection		•		•	•	•	•		
		Squad quality		•		•			•	•	
		Ability to carry out playing role		•	•	•	•	•	•		
		Player quality		•							
		Physical status		•	•						
Development	*Foundation*	Quality of player development (experience)	•	•	•	•	•	•			•
		Early career education	•	•							
Initiation		Childhood experience	•								

Figure 6.3. Actor Map showing key individuals and relationships impacting individual player longevity.

6.4. Discussion

The aim of this study was to show the interaction of key variables and feedback loops, and describe causal powers influencing career longevity in professional team sport. To achieve this, a CLD was developed with SMEs as a pictorial representation of their views regarding the determinants of career longevity. An actor map was also built to show the human relationships within which the system governing longevity is situated. The main finding of this study is that players' career longevity is an emergent property of the overall system within which they work and is governed by multiple feedback loops influenced by many different human actors. The study also found that SMEs universally agreed sports career longevity is accurately described as a complex phenomenon and usefully depicted via a systems lens using a CLD. This study adds to the body of work utilizing systems thinking principles to enhance understanding of complex phenomena within professional sport. Based on the results of this investigation, individuals and organisations wishing to maximise the effective duration of sports careers will have most success using whole system interventions that involve multiple stakeholders.

6.4.1. Quality of player performance

The CLD produced here shows player quality and quality of player performance are of fundamental, causal importance for career longevity. The identification of these requisites by all participants confirms findings of previous work highlighting exceptional performance as necessary for a long career (Bradner et al., 2014). The positive feedback loops within the CLD that are driven by high player quality and a high quality of player performance constitute an example of a well-known systems archetype called success to the successful, widespread throughout achievement domains (McLean et al., 2019b). In this archetype, as one entity achieves success, they are granted more resources, enhancing their chances of future success (Senge, 1990). In contrast, those who do not achieve initial success are given less and find it more difficult to be successful. One participant simply described the existence of this archetype in relation to the reinforcing loops acting between playing time, player contentment, player development, quality of player performance and coach's value of a player:

'*Playing good minutes every week, it keeps you happy and helps you play well. From there you get the coach's trust and you stay in the team'*.

The reinforcing nature of this loop highlights the importance of regular match play and the difficulty of obtaining meaningful minutes for players who are not given initial exposure to competitive first team games. If the goal of actors involved in club governance is to broaden selection options by having the largest pool of players available, they must recognize and attempt to counter this archetype by creating additional means of development for players not afforded significant playing time.

An understanding of the causal impact of player quality on career longevity is intuitive to those working in professional sport. Given the influence of player quality and quality of player performance on many reinforcing loops within the CLD, it is important organizations consider the deeper level causal force of underpinning, potentially subjective judgements regarding the quality of individual players and their performance. Although many stakeholders influence career longevity, the opinion of a relatively small group of individuals (head coach, sporting director, ownership), potentially impacted by a variety of power dynamics and incentivization, can determine the way an organization perceives a particular player and as a result, the opportunity they are afforded. This small group of stakeholders have a direct influence on playing time, contract length and squad quality, all of which influence quality of player performance and player quality and are likely to impact longevity. It is important sports organisations are aware of how they judge player quality and ensure they are mindful of the impact of both influencing variables and key stakeholder opinions.

The CLD shows player quality positively relates to the player's ability to fulfil both tactical and physical demands of their profession. The reciprocal relationship between the ability to fulfil tactical demands and the ability to fulfil physical demands suggests deficits in one can be at least partially overcome by increases in the other. It follows that an ageing player experiencing a decrease in physical qualities (Zhou et al., 2020*)* may be able to off-set the potential performance impact of such a decline by improving their tactical and technical abilities. Career long development programs pursued by motivated players working with high-quality coaches therefore appear to be an important means of increasing the odds of longevity. Participants interviewed here described how many players who have enjoyed longevity continually developed their skills and game styles to take advantage of their accumulating situational experience and in doing so, at least partially off-set ageing or injury related changes to their physical tools. One coach nicely summarised this process:

'He's played in the middle of the ground against the best (players in the league) his whole career. By now, he can see what's going to happen before anyone else. He also worked hard on passing off his left, and now he's better, he can unlock any of the options that open up. He couldn't always do it but adding that to his game has taken him to another level'.

The CLD suggests an ageing player experiencing physical decline may also be able to continue to meet the physical demands of their role by transitioning to a less demanding position or tactical system. It is however likely that this opportunity may only be afforded to players based on strengths of other systems variables. As an example, given the link between player leadership and coach's value of player it is possible a player with high levels of leadership may demonstrate sufficient value to be afforded playing time in a less demanding playing role.

6.4.2. Player contentment

The CLD and supporting causal tree diagram (Figure 6.4), describe a positive relationship between player contentment and player mental condition, player motivation, and quality of player performance. Both figures highlight the causal force of player contentment, and the resulting potential of increased contentment to drive greater application towards player development, higher levels of player coping capacity and improved quality of player performance. This relationship between player contentment and such potentially career sustaining behaviours also offers some explanation as to why periods of unhappiness in a player's life can bring about downward spirals. The CLD and causal tree diagram show poor performance, injury and looming contract end points have the potential to negatively affect feelings of contentment. In doing so, the CLD suggests they are likely to impact player coping capacity, player motivation, player physical condition, and quality of player performance. Given its underpinning, real level effect on increasing chances of longevity, sports organizations should attempt to ensure levels of player contentment remain high.

The CLD shows player physical condition and therefore quality of player care and quality of coaching and performance staff have the potential to impact player contentment. Sports organisations can however go further than delivering a high quality of service in these areas. On participant provided the following account regarding the importance of developing an ability to cope with adversity in professional team sport:

'Towards the end of that season I was out of the team again. The boss would barely speak to me and his assistants didn't want to know. The difference was I able to keep things in perspective, I still enjoyed being around the boys and I was happy to work on my body and my game for a bit. Earlier on (in my career), there was no chance of that. That situation would have put me in dark place.'

Based on this testimony and other similar accounts, it appears player coping capacity, player mental condition and quality of player self-management and problem solving, all exert a causal effect on player contentment (Figure 6.4) and can help players remain focused on their own development. Considering this and the suggestion that intervening at deeper level system levels has the greatest potential to enact system change (Meadows, 1999; Naughton et al., 2024), it seems logical that sports organizations help players build healthy mindsets, coping strategies, and goals towards managing their own levels of contentment. It is likely development in these areas will have greater long-term efficacy in maintaining player contentment versus short term incentivization. However, given six out of nine stakeholder groups shown in Figure 4 impact quality of player development, the difficult task of helping grow players in these areas cannot be the sole responsibility of coaches and instead requires a multi-agent strategy.

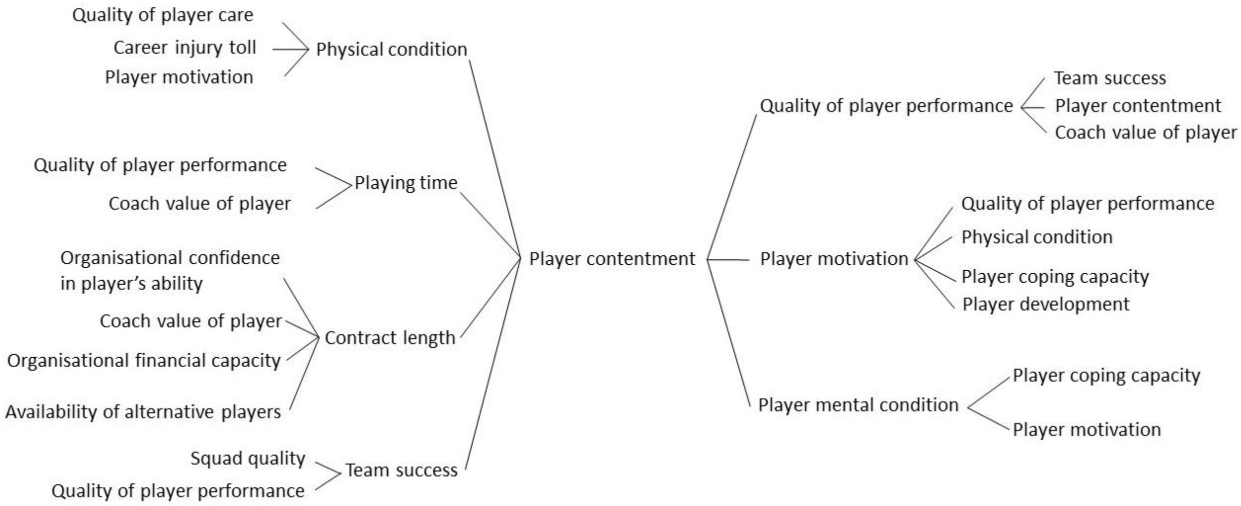


Figure 6.4. Causal tree diagram showing the influencing and consequential variables related to player contentment.

Findings from the present study suggest that it may be worthwhile to explore the concept of psychosocial hazards in sport. Psychosocial hazards have been found to have adverse impacts on worker health and wellbeing in other areas and refer to aspects of work design, organisation, and management that have the potential to cause psychological or physical harm to individuals and have adverse impacts on organisational outcomes (Derdowski et al., 2023; Leka & Jain, 2010). Commonly reported psychosocial hazards in other areas include work pressures, job insecurity, low job control, high physical and psychological demands, overload, and lack of co-worker, supervisor, and/or management support (Derdowski et al., 2023). Though most studied as a workplace safety issue, it is notable that a number of related factors were identified in the CLD. For example, factors such as player contentment, player physical and mental condition, player development, ability to fulfil physical demands, and contract length are all characteristic of the psychosocial hazards found in other domains. Further exploration into psychosocial hazards in sport and their influence on both career longevity and other issues such as injury and athlete health and wellbeing is therefore recommended.

6.4.3. Squad quality

The CLD shows the quality of the squad a player is a part of can have either a beneficial or negative impact upon longevity. Squad quality is positively related to team success which is in turn positively related to coach's value of a player and organisational confidence in a player's ability, both of which are positively related to contract length. Being part of a squad which is successful therefore has potential to boast a player's value and engender feelings of importance towards playing and retaining them. The CLD however also shows that squad quality has a negative relationship with playing time and coach's value of a player. These negative relationships exist as if the quality of a given squad increases it would likely mean game time would be distributed towards newly acquired players and potentially away from the original player in consideration. Having more high-quality players also means a coach is less likely to value a specific individual as highly as prior to the increase in squad quality. One participant described how this situation could manifest:

'That next season new owners came in, and the club brought in some top players. I went from playing every minute to barely getting on the pitch. By the end of the season, I knew I was gone. Clubs knew why I hadn't been playing, but I still felt I got less offers than I should have'.

This quote suggests that although being part of a good squad is a likely to have a positive impact on a player's longevity, this is diminished if the player plays far less and is not equivalently valued within the higher standard group. Given the relationship between playing time and both player development and player contentment, it may be more beneficial for some players to be part of a less high-quality squad where they play more. When evaluating contract offers, players and agents should therefore carefully consider the quality of a prospective playing squad in the context of a player's needs. It is also important to consider the deeper level influence of team success in mitigating how squad quality impacts coach's value of a player and organizational confidence in a player's ability. The way in which success is defined by a particular organization will shape how the performance of a given team is perceived and will subsequently impact value judgements related to contributing players. Within elite football codes, success as defined by winning trophies can only be achieved by a small number of clubs. Clubs with less potential to win championships will often define success by other means such as avoidance of relegation or improvement in league position. Regardless of the definition employed, due to the benefits of being perceived as part of a successful team, it is likely advantageous for players to join teams with high chances of achieving their objective. The high turnover of stakeholders within sporting organizations who have the potential to determine the definition of success applied to individual players however represents a further issue with the potential to impact career longevity in professional football codes.

The dynamic nature of squad quality and its subsequent effects on an individual player's playing situation, and potentially future career, is an example of system property described as sensitive dependence on initial conditions. This is where actions at the onset of the system such as when a player joins a new team or graduates from the academy to first team level influence future behaviour (Dekker, 2011). One SME provided an example of how the conditions in a specific playing squad can influence a career.

'Because our club was so unstable at that point, us coaches didn't want to take a risk on Franky. He had all the potential in the world, but he was green and would occasionally make a mistake that really hurt us. As a result, we played the older guy. He wasn't better, he was just safer and that meant Franky never got the chance to grow into the role'.

To maximise the number of high-quality players within an organization, it is important the effect of squad quality on individual players development is considered in the context of long- and short-term objectives.

Figure 6.5. Causal tree diagram showing the influencing and consequential variables related to squad quality.

6.4.4. Leadership skills

The CLD produced here suggests improved player leadership and enhanced quality of player self-management and problem-solving can increase coach's value of a player, leading to greater playing time and in doing so advance a player's odds of playing in top level leagues for longer. When acknowledging the benefits of development in these areas, several SMEs spoke of the difficulty of building such skills in elite sports environments due to their low tolerance for mistakes. The actor map (Figure 6.3) shows players' careers are impacted by many coaches and support staff who are likely under some degree of professional pressure to deliver the best outcomes with each player they work with. Unfortunately, their frequently short-term associations with players, and incentivization towards close future targets means coaches are often focused more on things like optimal preparation for the next game or compliance with monitoring, as opposed to more long-term goals such as building players' understanding of how to best pursue their own improvement. As one SME described;
'*It's easy for players not to take much responsibility for their own development. Someone else will always tell them what to do, or help them out of a mess, and that means they avoid the lessons and reflections they need to grow as people'*.

To develop players with maximum chance of achieving longevity, sports systems should consider how to balance the need to create sport science driven, disciplined training cultures with allowing players to develop autonomy and learn from their mistakes. It is important organizations acknowledge the potential power of stakeholder incentivization to impact the extent to which players are likely to develop skills related to leadership as well as self-management and problem solving.

6.4.5. Limitations

Although this study provides useful description of system factors with potential to impact career longevity, it is limited by the general nature of summary variables described. Despite further explanation of variables provided in appendix 9.3, some of the richness, depth and practical implications of original SME meaning has been sacrificed to group terms in a way that can be incorporated into a CLD. Future work should investigate factors impacting longevity in greater detail and provide specific suggestions for practitioners towards maximizing effective career durations. This study is also limited by the analysis boundary applied. Although models have to offer a bounded version of reality, by only examining factors controllable by sports organisations, the CLD fails to account for variables such as government policy or economic change that may have a large bearing on career longevity. In addition, the CLD describes some relationships between determinants of longevity that do not always work in the direction indicated. For example, the CLD describes a positive relationship between coach and performance staff quality and player care. Whilst often better coaches will understand how to balance training volume and intensity to maximise player health, SMEs provided examples of highly successful coaches who imposed training regimes they felt were detrimental to the longevity of certain players. To better capture the detail of how system influences impact career longevity and provide, specific nuanced examples, future studies should consider adopting a case study format, investigating individual career journeys within a system thinking framework. Follow up investigations should also consider examining the effectiveness of whole system attempts to manipulate career longevity.

6.5. Conclusions

This investigation developed a CLD and actor map, showing the complexity and causal forces governing longevity in professional team sports careers. In this study, 19 SMEs identified 25 summary variables and more than 25 different groups of actors able to influence the duration of playing careers, beginning long before the player reached the senior, professional level. The results of this investigation show a high level of player quality and quality of performance is essential for longevity, however in the context of the complex system within which longevity is an emergent product, these traits do not guarantee a long career at the elite level. To maximise the odds of players having long and successful careers sporting organizations should design interventions in the context of the overall system and actors surrounding each player. The results of this investigation show such interventions will likely be most effective where they consider the interaction between the player and their environment, ensure sufficient playing opportunity exists and help players develop autonomy and leadership skills. Future work is however required to explore the specific manner in which such interventions should be designed to maximize their practical benefit.

DOCTORAL LEARNING PAUSE 3

Doctoral learning pause: some of what I wrestled with and learnt from in Study 3

*S*tudy 3 served an interesting pivot in the scientific direction of my thesis. It was also a stage of my doctoral work where I developed some important cognitive skills and experienced a further reframing of myself. At the start of my work on study 3, because of the findings of study 1, I was strongly aware of the brevity of many sports careers. I had also found, via work on study 2, that there was no evidence of universal physical decline across team sports careers. As such, to further elucidate the causes of performance decay in professional team sports, I felt a study exploring the multitude of factors that influence career durations could provide great insight. I just wasn't sure how to appropriately investigate this notion.

Throughout my undergraduate and Masters' degrees I mainly used reductionist and positivist models of thinking, and was most comfortable with a scientific method based on examining single changes between matched groups. However, the valuable lessons I had learnt completing studies 1 and 2 meant I was confident that any mistakes or wrong turns I may make would ultimately be, in some way, beneficial to my project. As such, to explore the world of performance sport in a different manner I was very happy to learn and embrace a new thinking framework. Systems thinking appeared to offer some highly applicable mental models. Whilst systems thinking is becoming a more common paradigm in sport science research, to understand it more fully I had to read in some totally different contexts. Once Barry introduced me to systems thinking experts Scott Mclean and Paul Salmon, I was exposed to studies relating to road safety, obesity prevention, hospital violence and various aspects of manufacturing output. Reading widely around these themes helped me to understand some new thinking techniques. Although I had aimed to develop new skills in analysis and problems solving as part of my learning aims, I was surprised how interesting and useful I found these new perspectives. Understanding more about complexity, emergence and sensitive dependence on initial conditions was enlightening to me. It quickly benefitted how I viewed my area of study by helping me see the interconnected nature of factors impacting playing careers such as a specific player's environment, their skillset, and subsequently the amount of playing opportunity available to them. It had a significant effect on my understanding and appreciation of reductionism versus holism within sport science and helped me understand the likely need for multi-factorial, multi-agent interventions as a basis for aiming to increase career longevity. A greater understanding of systems thinking also positively impacted me in my professional role as a performance coach. An increased appreciation for complexity has improved my problem-solving skills and provided insight into multi-dimensional, dynamic aspects of performance systems such as injury prevention and culture building.

In addition to providing opportunity to build useful cognitive skills, my work towards study 3 was also extremely beneficial towards my learning objective of developing a comprehensive knowledge of my study area. Through the interviews I conducted and the breadth of lived experiences described by SMEs within them, I came to a greatly expanded view of the determinants of longevity. Conducting the SME interviews also lead to a clear shift in my conception of what constitutes an expert practitioner. Reflections on my conversations with many high-level operators challenged my perhaps positivist, epistemological framing of an expert as someone who possess a high quantity of knowledge and has lots of answers. In conversations with long standing, highly successful practitioners, it was clear most were very humble about their understanding of complex problems. Many also seemed to demonstrate some territorialization of their knowledge. They were bounded by the domains they operated in but in most cases quickly acknowledged this. Interviewing these practitioners and reflecting on their stories helped me reconceptualize expertise as being about reasoning, and understanding one's own limitations and blind spots. Following my changed viewpoint, I felt my personal reflections became kinder and I had let go of the notion that there was some type of expert category of professional that I just could not be part of. As reported by Caldwell (2019) in her own reflections on professional doctoral study, this challenged my tendency to experience imposter syndrome and helped me develop more confidence in my ability to do good research by growing my skill set. I also began to see that as a practitioner I could improve my decision-making processes by understanding my limitations and developing my ability to reason and consider different aspects of specific problems. Whilst I had never set out to change my conception of expertise (I didn't know it needed changing!), this shift in my viewpoint and the understanding that it had taken place was a useful reminder of the value of reflection. As on many occasions, my doctorate was about athlete careers but much of my learning went far beyond that!

APPLIED REFLECTIVE PAUSE 4

How to manage ageing Magicians

'If we can just get into the finals, we know these guys are capable of magic…'

I've heard almost the same exact words on two occasions. Both times from respected, former champion Head coaches in charge of faltering, older teams. Both coaches had seen glimpses of the very highest level of play from their teams, built around stars at ages where their best is likely behind them. Both squads failed to find consistency and seemed to be carrying large numbers of small injuries. In both cases, almost complete reliance on older players saw athletes well into their thirties with diminishing powers being asked to find magic and cover the lion's share of work in every match. Unsurprisingly, on both occasions the teams' seasons ended well before the championship games.

Having seen evidence of reductions in NM power in ageing athletes in Study 2, it is understandable that older players maybe less equipped to play the roles they once thrived in. Considering this, I wondered what these organisations could have done differently to get more from them their teams or squads in the final stages of the year. Once they had entered a cycle where older players were limping from one big, consequential game to the next, it seemed that their chances of success rested on being lucky. I wondered what these organisations could have done to have avoided this fate. Could the older players have been carrying less of the small issues that do not stop competitive play, but do severely impact the ability of a team to train? Could the older players have been used or trained in a different way? And where were the 'magicians' assistants' who were needed to shoulder the work that the older players needed help with?

One of my main drivers for doing this professional doctorate was to find answers regarding how best to maximize the contribution older players. I quickly realized it would be impossible to cover all the ground required to do this in the thorough manner I had initially imagined. I also quickly realized that maximizing careers rather than specifically older careers was a more relevant mission. Although I am a long way from being able to provide complete guidelines, I think the studies in this thesis makes some points that are useful to practitioners. Gaining a better understanding of elite team sport populations in Study 1, investigating performance decay in Study 2 and talking to many SMEs in Study 3 have helped me explore a lot of aspects of performance related to older players. It is important to examine these findings with the lens of professional practice that led me to wanting to uncover them, and consider what professional teams could do better to maximize player longevity. In the knowledge that what I write will be incomplete, I wanted to produce some practical information that drew from all aspects of this study. For that reason, study 4 is presented as research-informed, position piece offering synthesized guidelines for maximizing career longevity in professional team sport athletes.

CHAPTER SEVEN

STUDY 4: MAXIMISING LONGEVITY IN PROFESSIONAL TEAM SPORTS CAREERS: A RESEARCH INFORMED POSITION PAPER

This study aims to synthesise and build upon findings of previously presented experimental chapters towards practical strategy. This chapter is in service of thesis objectives relating to the presentation of findings useful to those working in professional team sports.

Maximising longevity in professional team sports careers: A research informed position paper

7.1. Introduction

Sports teams that sustain success over long periods are often based around an enduring core of players, able to play at high levels for multiple seasons. As well as a track record of performance, these highly experienced, older individuals provide leadership, understanding of big game situations and an ability to drive team culture and educate younger players. Given their value, increasing the timescale over which key players contribute at near peak levels can offer clubs significant competitive advantage over rivals. In addition to benefitting teams, increasing longevity is extremely advantageous for players, elongating the time frame over which they can compete for trophies and earn lucrative contracts. The physical and mental stresses of elite team sports, however mean keeping important players available and performing well over long periods represents a challenge for sports organizations. Professional sports careers can end or change tact abruptly and are known to be highly variable in duration with players dropping out of elite leagues at all ages across the potential career span (Baker et al., 2013; Chapter 4). This means whilst the goal of increasing longevity is often used in connection with keeping players over 30 going for additional seasons, extending carer duration is a valid consideration for players of all ages. For clubs to maximize the probability of unearthing their next core group of elite players, it is important they extract maximum potential from all squad members. Despite the potential utility of information related to longevity, little is known about the end stage of sports careers and reasons players drop out of elite level professional leagues. Clearly, designing systems and interventions with the potential to maximise career length is of great interest to sports organisations and players alike. The purpose of this chapter is, therefore, to provide research informed recommendations to practitioners aiming to design systems and interventions with the aim of increasing the effective length of playing careers within professional team sports. To achieve the objective of providing practically useful information related to increasing career duration, this chapter first offers a brief description of career profiles in professional team sports before presenting a simplified model of longevity. The chapter then draws upon research within this thesis and the broader literature to present threats to remaining at the highest levels of professional team sport and describes strategies teams can apply to counter them.

7.2. Background: a description of professional team sports careers

In a systematic review of career spans in professional football, players were found to typically retire between ages 31 and 35, following careers lasting 8 to 11 years (Carapinhera et al., 2018). Although this may apply to a worldwide sample encompassing multiple tiers of professionals, it appears careers at the highest levels of team sport are often far shorter. Results presented in Chapter 4 of this thesis show median duration of time players spend in elite codes of football ranges from 5 years in the AFL to 3 years in the NFL. In addition, it has been reported that more than 30% of careers in the Bundesliga last for just one season (Frick, 2007) and that less than 60% and 30% of players drafted by NHL and MLB teams respectively, play a single season or more at the major league level (Baker et al., 2013). For those able to survive multiple seasons, it seems there is a substantial decrease in the number of players of each age from the late twenties onwards (Brander et al., 2014; Dendir, 2016; Chapter 4). Even amongst players able to become established, it is thus comparatively rare to still be playing at the highest levels into the mid-thirties (McIntosh et al., 2019). It is thought that only the best players in any elite team sport are likely to achieve this feat of survival (Bradner et al., 2014).

Explaining the brevity of many playing careers and difficulty of surviving to old age as a front-line contributor is far from simple. At a basic level, the challenge of remaining in professional teams stems from a fundamentally limited number of places and a stream of new, high talent players joining leagues annually. The period over which a player can remain employed in an elite league will be an emergent property of the interaction of a variety of factors including the player's ability and behaviours, the specific sporting environments they are exposed to and the views and goals of a variety of actors (coaches, agents, player peers, family) who make decisions concerning them (Chapter 6). The multi-factorial nature of career duration means that although age related physical decline may influence the career duration of those able to reach comparatively older ages (Chapter 5), given drop out of players at all possible ages (Chapter 4), it certainly does not determine the duration of all careers. The array of factors impacting longevity can be exemplified by considering the role even commercial factors within the sports environment, such as the short-term nature of contracts and the instability of management, could play in influencing longevity and contributing to the disparate nature of career outcomes.

7.3. Towards a simplified model of career longevity

Given numerous factors influence career duration (Chapter 6), a simplified model of professional longevity is useful in framing efforts towards maximizing the probability of players having long and successful careers. At the most fundamental level, the quality of a player's performance is accepted as the key determinant of their ability to find or continue in a professional role (Chapter 6). To play in an elite level league players must first reach a certain standard of performance and to remain employed they must retain an ability to contribute at a level which is above a given minimum threshold. Figure 7.1 shows a simplified model of career performance, illustrating longitudinal performance change in the context of the level required to play as a professional. For players able to become established, given playing performance is known to improve up to a peak age in the mid to late twenties before beginning to decline (Dendir, 2016; Kalén et al., 2019), it is reasonable to assume that the speed of performance decline will influence how long they remain employed. To appropriately conceptualize careers, we must consider that the standard of performance a player must achieve to be either offered a playing opportunity or remain employed is somewhat subjective in nature. Selecting coaches' opinions and a variety of contextual factors (e.g., quality of alternative players, organizational value of player) will contribute to decisions regarding who should play. It also appears likely the standard of performance a player must reach to remain employed may vary based on other qualities they can bring to a group. Players with leadership skills who can get the best from others and provide decisive input in highly consequential moments may be able to remain in teams even when their own performance level is not superior to alternative players. The playing standard a player needs to achieve is therefore best considered to have some bandwidth. The extent to which a player can maximize this bandwidth may determine how long they are able to stay employed in the context of declining levels of performance. As shown in Figure 7.2, to maximize career longevity, sports organizations should focus on helping players reach their full potential, elongating the time frame over which players are able to maintain performance levels and maximizing the contribution they can make to their wider organization.

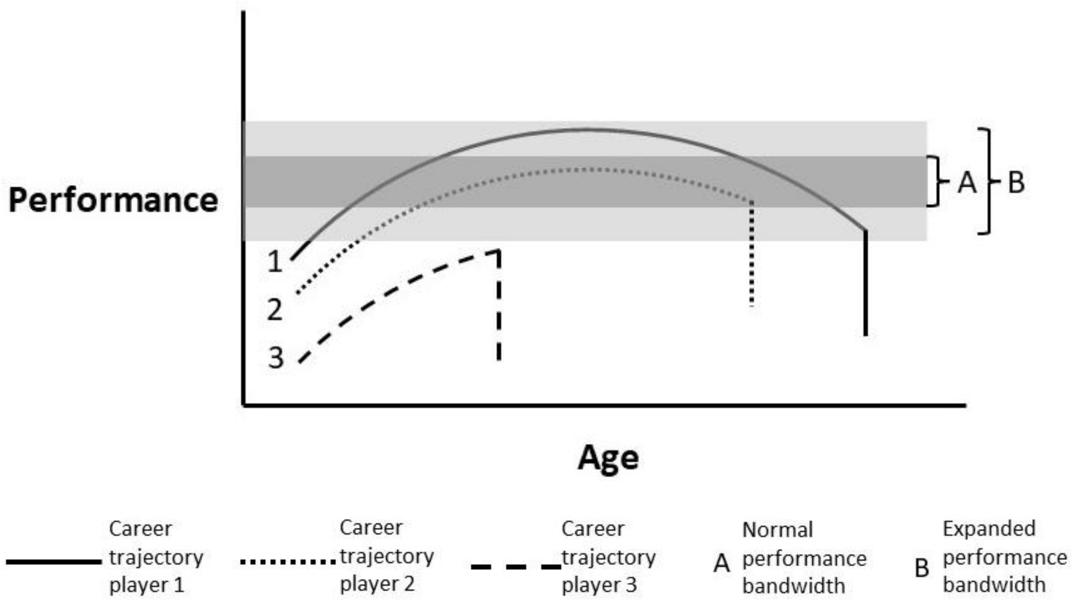


Figure 7.1. Hypothetical career performance trajectories in relation to performance standard required to reach and remain in an elite professional team sport league (Based on Dendir, 2016). To reach and remain professional, performance must be maintained within a bandwidth. It is potentially possible offering additional, off-pitch skills can allow players a wider performance bandwidth and therefore the opportunity to play for additional season(s) beyond peak years (player 1 vs player 2).

Figure 7.2. A simplified model of career longevity.

The model shows that quality of player performance is a key determinant of career duration. The extent to which a player can first reach and then maintain a sufficient level of performance will govern their ability to remain within professional sport. The required performance level may be modified by the extent to which a player can contribute to the wider organization.

7.4. Threats to longevity and potential counter measures

Based on the model presented above, the following sections introduce specific threats to longevity and provide suggestions as to how they could be addressed by sporting organisations. By recognizing the inherent complexity of professional team sports careers (Chapter 6), this paper adopts the position that to increase the probability of players having long and successful careers, teams must consider interactions between various aspects of player performance. For maximum efficacy, strategies aiming to positively influence career trajectory should be applied in combination to address the whole system influencing longevity.

7.4.1. Threat 1: failing to reach the required performance standard

To have any kind of longevity in elite leagues, players must first become established. Whilst clearly players need to be able to operate at high level to achieve this, sufficient playing opportunity is essential for players to reach their potential. Evidence from AFL shows playing performance significantly improves over a player's first 40 games (McIntosh et al., 2019). Playing opportunity has also previously been identified as a key factor in successful academy to senior transitions and a lack there of, as a major source of stress and motivation loss in young professional players (Swainston et al., 2021). Exposure to first team competition is important for players to become valued by coaches, teammates, and their wider organization and influences the extent to which they can showcase their ability to other teams (Chapter 6). Even for already established players, a lack of playing opportunity is likely to harm their overall value and negatively impact development and motivation (Chapter 6). However, in the context of a finite number of games and pressure to pick strongest possible teams, sporting organisations struggle to provide all players with sufficient opportunity to reach their potential and prove their worth. The amount of playing opportunity afforded to a particular player will be shaped by their perceived quality, quality of their initial performances, quality of alternative players available to coaches and the tactical system employed by the team (Chapter 6). The availability of playing opportunities to players will also be governed by the goals of the systems their careers take place within, and those of key actors involved in their career journeys. For example, in a struggling football team, a manager may be strongly incentivized to avoid relegation (fear of dismissal, offer of large financial bonuses). In this climate, it is unlikely the manager would experiment with a young, unproven midfielder if an older, more dependable player was available. This may lead to a lack of exposure and development for the young player and less interest from alternative clubs at the end of her current contract.

7.4.2. Strategies to mitigate lack of playing opportunity

Understanding the crucial importance of playing opportunity at all stages of careers is essential for teams wanting to increase the probability of player longevity. Despite the fundamentally limited nature of opportunities, to make sure high talent prospects are not lost, teams must ensure routes to first team involvement exist. Sports organizations can use loans and second team fixtures but should be aware these will not have all the benefits of first team game involvement. To maximize the potential of younger players, teams must take great care when signing players who can potentially block the path of younger development prospects requiring exposure. Ownership groups and general managers must also be aware of the effect of how they incentivise those involved in selection, if they wish to see young players given chances. In turn, players and agents should carefully consider squad composition and selection policy when signing with a team.

Given the finite nature of playing opportunity, many players will experience periods where they are afforded little playing time. At these times, clear individual plans and communication can help provide purpose (Swainston et al., 2021). Team must also carefully consider training content to limit potentially negative consequences. Unfortunately, limited training involvement can co-exist with a lack of playing opportunity. Anecdotally, it seems not being a starter often leads to diminished training participation due to coaches' preferential focus on the team for the next competitive game. In this situation, clubs must ensure sure players receive sufficient work to be appropriately prepared for any opportunity that presents. Although comparatively straightforward to find physiological top ups for players receiving insufficient involvement, pressurized, game-realistic decision-making tasks are often lacking.

In the inevitable stages of players' careers where sufficient playing opportunity is missing, it is important they remain focused on their development. Clearly easier said than done, self-determination theory (SDT) (Deci & Ryan, 1985; 2000), a meta theory describing the extent to which human goal related behaviours are self-driven, offers a motivational framework teams can use to support efforts to maximize the chance of players positively coping with periods of low match play. As part of its basic needs theory (Deci & Ryan, 2000), SDT describes the human need to experience competence, in this context, a player's perception of proficiency and effectiveness in their playing role, autonomy, which describes a player's experience of having agency and free choice over their actions, and relatedness, which is about their feeling of connection to others (Lonsdale et al., 2009). Research examining the nature of motivational environments has found that where these needs are supported, it is more likely players sustain intensity and duration of effort towards goals, even in contexts they perceive as challenging (Mahoney et al., 2014). Elite team sports environments that are supportive of autonomy, competence and relatedness are also likely to foster effective coping strategies (Ntoumanis, Edwards & Duda, 2009), promote mental well-being (Purcell et al., 2022) and facilitate the development of traits related to mental toughness (Mahoney et al., 2014). To promote longevity, teams must therefore carefully consider the extent to which the environments they create are supportive of these human needs.

As well as being scarce, playing opportunity is often situational and presents due to change in some other part of the broader sports team system. An injury to a starting player, a need for tactical change, a suspension or an international call up may provide a role for a previously unrequired player. For best results sports performance staffs need awareness of when opportunities may present and allow players to focus on performance during these times. The importance of player load restriction, non-urgent medical procedures, and highly fatiguing extra training at such critical points in careers must be weighed against the scarcity of playing opportunity and its potential value for player career trajectories.

7.4.3. Threat 2: declining ability to meet physical demands

For those fortunate to play in elite team sports beyond 30 years of age, a reduction in performance seems inevitable (Bradner et al., 2014). It appears such decline may be due to diminished physical ability of players over 30 to meet the demands of match play. Players over 30 have been shown to cover reduced total distance and perform a lower frequency of accelerations and decelerations versus younger counterparts (Sal de Rellán-Guerra et al., 2019; Zhou et al., 2020). Although results of studies comparing VO_2max in older versus younger professionals are equivocal (Signorelli et al., 2012; Botek et al., 2016), older professionals have been shown to perform worse in tests of NM performance (Chapter 5).

It is tempting to conclude reduced performance and potential physical decline in older players can be explained by findings from gerontological research showing ageing is associated with sarcopenia, reduced strength (Pijnappels et al., 2008), rate of power development (Van Driessche et al., 2019) and neural excitation rate (Clark et al., 2013) as well as increased muscle slack due to greater compliance of tendons and ligaments (Reeves et al., 2003). It must however be noted that available research examining physiological decline with age shows minimal decreases up to 40 years of age. Indeed, number of motor units (Lexell et al., 1988) and fat free mass (Kyle et al., 2001) are thought to remain stable until 50 and 60 years of age respectively. Therefore, whilst a reduction in performance beyond the age of 30 is apparent and a physical basis for this appears likely, there is no consensus regarding a specific biological mechanism explaining performance differences between players in their mid-twenties and those in their early thirties (Faulkner et al., 2008).

Research supports the notion that sub-optimal training management of older players rather than exclusively biological ageing may be responsible for reductions in NM performance (Chapter 5). Within professional team sports it is comparatively easy for older players to inadvertently enter a cycle of detraining likely detrimental to power related qualities (Figure 7.3). Anecdotally, in response to older players not coping well with games or high intensity training, presenting as poor performance, or increased post-activity soreness, clubs will often modify older players training. Very often modifications involve older players being managed out of high intensity activities. In hope of restoring ‘freshness’ or mitigating soreness, they may be removed from high-speed aspects of team training, modified away from speed training, plyometrics and power exercises or taken off traditional strength training movements. Often sound reasons for modifications exist such as long injury lists and evidence of joint degradation. However, regardless of reasoning, a removal of high intensity training stimuli combined with reductions in match high-speed running (Zhou et al. 2020) and accelerations and decelerations (Sal de Rellán-Guerra et al., 2019) in older players can lead to insufficient stimulus being applied to the NM system. Research suggests explosive NM qualities have short residuals and compared to other physical qualities such as maximum strength or aerobic endurance, detrain relatively quickly (Majika & Padilla, 2000). Although not substantiated by longitudinal studies, it is logical that training modifications in older players over time leads them towards a detrained state. Unfortunately, as shown in Figure 7.3, a reduction in exposure to high intensity training and the resulting decline in physical preparedness can lead to a reduced ability to cope with game involvement and may prompt further training modification.

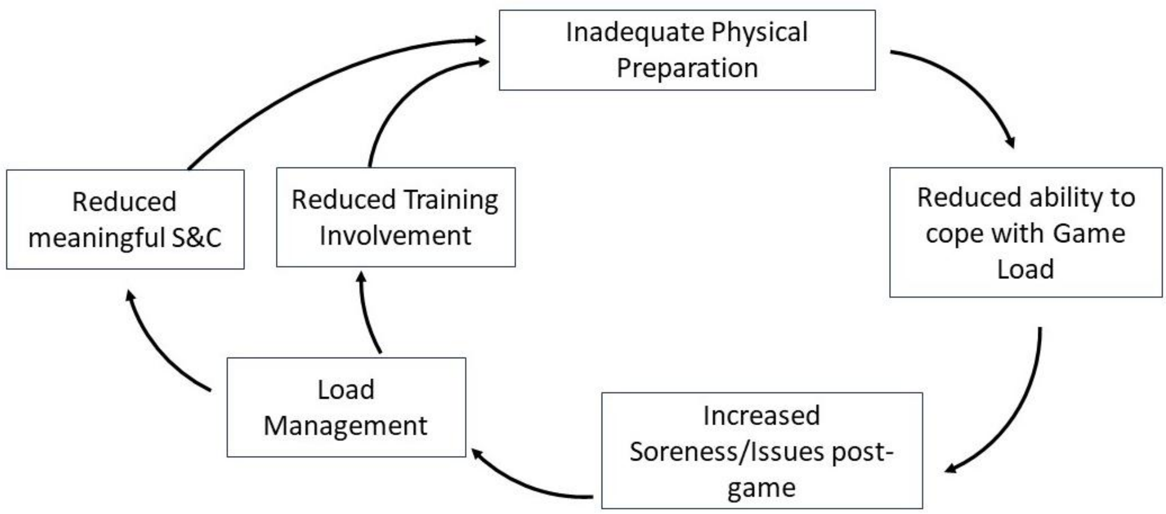


Figure 7.3. Illustration of a cycle of performance decline mediated by suboptimal or unadjusted training load modification.

Available evidence suggests a decline in physical abilities with age can also occur due to the increased susceptibility of older players to injury (Shultz et al., 1994; Stevensson et al., 2016). On an acute basis, it is easy to see how injury enforced absence could temporarily lower a player's performance level upon their return. It is also clear that serial absences or long-term training modification following injury would be detrimental to training, diminishing a player's opportunity to work towards maintaining their standard of performance. Despite these obvious problems, optimal strategies to reduce injury risk in older professionals have yet to be described. This is likely, in part, because no consensus exists regarding a single, specific biological explanation for the observed increased incidence. It is possible previously described reductions in NM performance (Vincens-Bordas et al., 2020; Scoz et al., 2021; Chapter 5) in older versus younger players reflect a decrease in tissue capacity to produce and transmit forces. Older players are also potentially at heightened risk due to greater accumulation of injuries and damage sustained throughout longer careers (Shultz et al., 1994). Past injuries have the potential to set up a positive feedback cycle where injury-initiated compensation strategies lead to altered biomechanics or avoidance of certain body positions or tasks and subsequently increase wear or damage to other structures. Coaches have also described how players may be at increased risk of both reoccurrence and new injury during RTP phases following injury. This situation plays out where injury induced absence from training and games leads to deconditioning and a subsequent need to ramp back to previous work levels. Based on anecdotal experience, the ensuing fatigue from the rebuild of work, particularly if conducted under high time pressure to return to play can leave players vulnerable to further injury or overuse conditions (Gabbett, 2016).

Additionally, within RTP phases, social factors, and system incentivization can play a role in increasing injury risk in older professionals. Players who feel their place in a team is at risk can be highly motivated to make their absence from injury as short of possible, in part to reduce risk of the team finding a credible, younger alternative. Whilst a desire to make a rapid return is welcome, when paired with a deep understanding of the social workings of sports organizations it can mean older players know how to move through rehab stages whilst concealing lingering problems that would benefit from further recovery or reconditioning. Teams and practitioners are often particularly vulnerable to these occurrences, as they too want to see the player return rapidly. Cutting corners in a rehab process can be extremely problematic as it can lead to repeat injuries and chronic issues which compromise training quality or create cycles of injury where one seemingly small injury leads to another, setting up prolonged periods where players are unavailable for selection and cannot perform training at optimal intensity. Such cycles are likely especially problematic for older players as they potentially fuel an organisational narrative suggesting they can ‘no longer cope at this level’.

A similar, socially situated issue can contribute to the detraining of older players previously described. Due to perhaps increasing anxiety about preserving freshness for games, comfort or boredom in their environment, or a desire not to risk injury, older players may self-select a reduced level of training intensity or negotiate less taxing roles within drills. Regardless of whether such a decision is made sub-consciously, this can lead to players missing important training stimulus and over time may compromise their level of preparation to meet and tolerate match demands.

7.4.4. Strategies to mitigate a failure to meet physical demands

To maximize chances of maintaining physical qualities essential for performance, teams must avoid modifying training to the extent players become detrained. It is however unrealistic to think older players can or should perpetually train as they did in their early twenties. When planning appropriate modifications, practitioners must ensure sufficient adaptive stimulus to maintain physical qualities is retained. They should also be mindful that, in the context of known reductions in the game outputs of older players (Zhou et al., 2020), and anecdotal accounts regarding their ability to self-manage, match play alone is unlikely to provide sufficient training stimulus. Figure 7.4 illustrates how the goal of player management should be to reach a positive in-season cycle, which allows purposeful training of qualities likely to decline alongside match play. To reach a state of 'thriving availability' players training should be designed so effort is directed towards training activities that provide stimulus to maintain key physical qualities. It is likely volume of other activities and resulting fatigue will need to be managed to ensure sufficient focused, quality work can be completed. For example, it may be overall training volume is reduced, but the player still participates in a high-speed sports drill before completing additional acceleration training. When designing training for older players who require modification, practitioners should consider if a more basic activity which can be objectively quantified is superior as a means of delivering training stimulus compared to modalities such as small-sided games, despite reduction in specificity. In certain management situations achieving a given dose of high-speed running with a low overall volume of work may be advantageous.

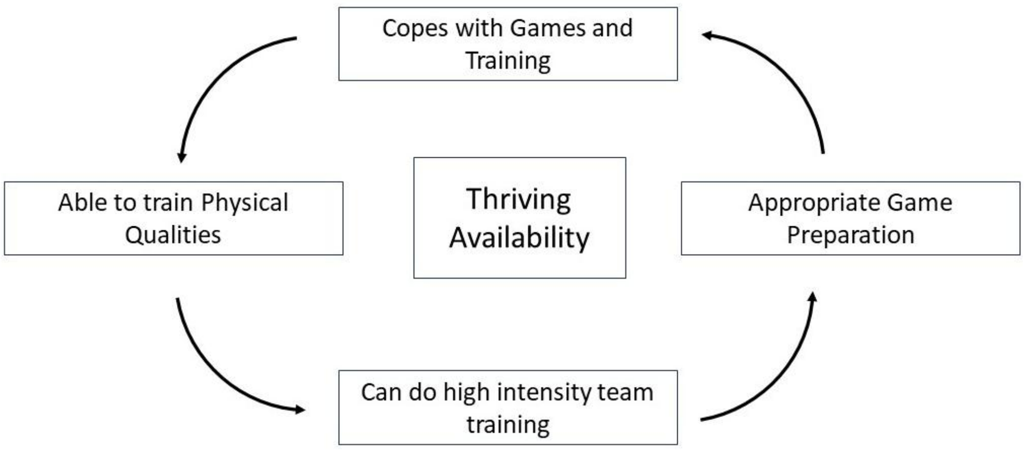


Figure 7.4. A basic model of thriving availability.

The model highlights the importance of older players reaching an in-season status quo that allows training of qualities key to performance, towards maintaining their ability to meet peak demands of match play without undue soreness that may prompt training modification.

Given longevity is an emergent property resulting from the specific factors governing an individual player's performance, it is important to acknowledge that any type of physical decline is likely to have individual effects on performance. Players and positions most reliant on highly developed NM qualities for success are likely to see the largest declines in performance in the event their NM qualities are eroded and are therefore the players who most need to be carefully managed to ensure game critical physical qualities are prevented from decay. For players surviving long enough to experience physical decline, improving performance in areas such as skill and decision making which are less likely affected by age, allows them to take advantage of their evolving experience and may mean they can continue to perform at a high level in the context of declining power. It is likely players will need to evolve their game style with increasing age and may consider a change in position to a role where a decline in NM output is potentially less problematic.

Keeping older players free from cycles of reoccurring injury and in a physical state where only minimal, well-planned training modification is required is key to preserving important physical qualities and slowing age-related performance decline. As a first step in the design of effective individualized training, practitioners must be confident players are ready to return following RTP phases. Much has been written on the efficacy of specific tests to guide RTP processes and will not be repeated here. When planning load progression and return criteria, practitioners should understand that the goal of RTP programs in team sport is generally to return the player to playing multiple games and training at a meaningful level (Figure 7.4). It therefore goes beyond simply preparing them to get through their first match. Whilst basing RTP targets on single game metrics offers some insight, consideration must be made to the escalating density of specific aspects of training or match play following return. As such, returning players must be carefully monitored over early games and training. In addition, risk factors and key themes from rehab should stay as integral considerations within players' training plans.

Based on the socially situated nature of RTP programs explored above, practitioners should understand the importance of how they frame the overall RTP process. Player self-reporting of symptoms and statements of confidence around progression form an important source of information within the rehab process. Practitioners must however understand what specific professional sports systems incentivize and how that may influence behaviour and acceptance of personal risk. Many sports systems do not incentivize player transparency regarding medical history and symptoms, and even where they might, players may not perceive this to be so. In this light, it is possible a seemingly bounded question such as 'how is your shoulder?' is answered in context of upcoming objectives and understanding of team environments. The player may, therefore, answer an altered question: 'how is my shoulder feeling, given I know I must practice today if I want to be considered for selection on Saturday?' An understanding of the incentives acting in a particular system is not required so practitioners can attempt to 'solve' this problem, however situational awareness is essential for the proper evaluation of player feedback. As social pressures and incentivization within specific environments cannot be easily changed, it is likely most effective for practitioners to operate as transparently as possible.

Encouraging players to report their injury status and body condition as fully and openly as their environment allows is important towards facilitating effective management. The extent to which players believe they will not be penalized or humiliated for voicing their questions, concerns, ideas, or mistakes has been termed psychological safety (Edmonson, 1999). It has been rightly emphasised that aspects of elite sports systems, such as commercial pressures and short-term contracts impose boundaries on the degree to which full psychological safety could exist within it (Taylor et al., 2022). However, within high performance environments enhanced psychological safety is associated with increased freedom of communication and improved coach-athlete relationships (Jowett et al., 2023) as well as superior team performance (Smittick et al., 2019) and reduced burnout (Fransen et al., 2020). To make medical decisions with the best possible information and support team performance it is important performance staff and coaches do their upmost to create environments where players feel as psychologically safe as possible. To do this, it has been suggested practitioners should embrace respectful challenge and discussion, respect confidentiality around medical communication, and role model authenticity and vulnerability (Walton et al. 2022). In RTP settings, a flexible approach to progressions and return timetables, which provides scope for individualization is likely to prevent players from feeling the need to fit their reporting of symptoms to a checklist and may promote open dialogue. Developing strong feelings of trust and healthy working relationships between players and performance staff are also important towards promoting feelings of psychological safety (Jozefowicz, 2020) and facilitate enhanced player care. Indeed, trust was described as the central factor determining the strength of the 'therapeutic alliance' between sports physiotherapists and the players in their care, a factor considered as an essential determinant of treatment outcomes (Charmant et al., 2021). As such, given the time it can take to build trust and effective working relationships, organizations should understand the value of stability in medical and performance teams.

Clubs must also be aware certain periods of players' careers may carry higher risk of injury or detraining. Moving clubs can place players in an unfamiliar culture with altered training regimes, changed game roles and new relationships with staff. Practitioners must work hard at these times to ensure reduced familiarity does not lead to players missing required maintenance work and ignoring known long-standing issues. This is especially important for players with specific physical needs or extensive injury histories who have arrived at a new club and do not want to be seen going straight to the medical room. Whilst an appreciation of social dynamics surrounding players doubtless assists clubs in best directing care and managing individuals, helping players understand their bodies and build career-long performance habits is likely more effective towards maximizing longevity. Players who drive their own maintenance routines for key performance qualities and individual, injury risk factors will be more insulated against problems stemming from disrupted continuity of care due to changes in support staff or movement between clubs. Empowering players with autonomy and understanding, to be the 'CEO of themselves' is however likely a long process and requires sustained, well thought out input from multiple practitioners.

7.4.5. Threat 3: failure to offer a wider contribution to the club

As previously stated, long careers in professional team sport are likely only afforded to the highest performing players (Bradner et al., 2014). Whilst this is not in question, the findings of Chapter 6 suggest there is a range of additional skills and competencies an older player could bring to a team, that can help them remain employed at the highest levels of their sport for as long as their ability allows (Chapter 6). As shown in the model above (Figure 7.2), it seems that players who offer a significant contribution to a team's culture may be afforded a greater rate of performance decline versus those that do not. In this way, the wider contribution a player can make to their organization can be thought of as a factor capable of modifying the required bandwidth of performance needed for a player to maintain professional status. Leadership, positive cultural influence, helping the development of younger players, and communicating coach messages are all potentially valuable assets an older player may be, in part, recruited for, or retained because of. Although some consider these types of skills to be natural assets, in the case of athlete leadership it appears clear that behaviours and actions are more associated with efficacy than innate character traits (Fransen et al., 2019). As such, players who have diligently worked on their ability to understand and influence groups throughout their careers are likely to be better equipped to benefit from the need for role models and leadership in professional team sport. In contrast, players with poor self-management, questionable leadership behaviours or those considered detrimental to culture, may see their careers end earlier than could have been the case.

7.4.6. Strategies to mitigate a failure to make a wider contribution

Helping players enhance leadership skills, understand their ability to influence culture, take ownership of their own journey and learn from their mistakes seem like areas sporting organizations could act upon to set players up with maximum chance of longevity. Whilst developing individuals in these areas is possible, it is far from straight forward in elite professional sports environments. In an analysis of the traits of athlete leaders, effective on-field leaders differentiated themselves by virtue of superior problem-solving, enhanced motivational skills, a strong pro-group identity, and more clearly conveying a sense of doing things for their team (Fransen et al., 2019). Although more research into effective means of developing athlete leaders is required (Cotterill & Cheetham, 2017), it seems clear leadership development is an experience driven process (Van Velor et al., 2010). The findings of Machida-Kosuga & Kohno (2022) show exposure to challenge and overcoming difficulty, experience of independent decision making, and an environment that focuses on growth and learning, are key to the development of leadership skills. Unfortunately, a major barrier to the development of such skills in elite sport is that player development systems often paradoxically, have low tolerance for player error, employ staff incentivized to make players journeys as smooth as possible, and in doing so inadvertently take away learning opportunities.

To maximize players' ability to contribute to their teams, it is important organizations create environments that promote career long development of skills and traits that allow players to lead and positively impact team environments. It is likely occasional leadership courses or talks will be insufficient in this area. Sporting organizations should instead focus on maximizing the development of skills underpinning effective formal and informal leadership such as interpersonal skills, team management, the ability to convey vision and both deliver and accept feedback (Machida-Kosuga & Kohno, 2022). To aid this process teams should consider providing leadership learning opportunities through team leadership groups, skilled mentorship (Cotterill et al., 2022) and environments that support the development of player autonomy (Matahela & van Rensburg, 2023). Clearly such a process requires a long-term commitment and shared understanding across staff and departments.

7.5. Conclusions

The highly competitive nature of elite team sport means only the best players are likely to have careers lasting into their 30s. For many others, careers are brief and afford players little opportunity to prove their worth. At the highest level, career longevity is best considered as an emergent property of a complex system, with many factors interacting to determine how long a player can survive. Interventions aimed at increasing the probability of improving longevity are therefore likely most effective if designed at a whole system level. In all team sports, a first step is to examine the availability of playing opportunity to peripheral players who, without exposure will likely quickly drop from the elite level. For players able to reach more advanced ages as professionals, decreased physical performance and a propensity toward an increased injury rate can threaten longevity. To get the most from such players, sporting organisations must ensure they are managed in a way that prepares them for the most intense aspects of match play. Sports organisations should provide excellent care around injury and must be mindful players actions and input into RTP processes are highly shaped by system incentives. Whilst system churn means longevity cannot be guaranteed, players who develop an evolving, career long focus on improving on- and off-pitch skills, and developing individual performance maintaining habits and routines are likely best prepared for long careers.

DOCTORAL LEARNING PAUSE 4

Doctoral learning pause: some of what I wrestled with and learnt from in study 4

From the very start of my doctoral studies, I felt it was important to address practical questions relevant to those working in team sports. I wanted to create and interpret new information useful to my profession. Clearly, study 4 of my thesis was in service of this objective and was about synthesising the findings of my previous work into actionable suggestions. Although much of the evidence informing this study had been reported earlier in my thesis, the process of synthesising it into a practically relevant form was more difficult than I had anticipated.

Over the course of the doctorate, I had investigated lots of different aspects of career longevity. I had read on the principles behind the statistical presentation of variation, examined underpinning concepts within forecasting, and performed a lot of different analyses on real-life examples of change, encountering high variability, methodological issues, and outlying individuals. I had also continued to work in elite team sport and was, therefore, frequently exposed to questions related in some way to maximizing career length. The trouble was, as I had gone deeper and deeper into problems, it had become more difficult for me to provide simple and concise answers to them in a way that was useful for others. In study 4 I wrestled with how best to synthesize what I had found into practically useful answers. Part of the reason for my struggles was obvious; it is inherently difficult to simplify the essentially complex and doing so probably doesn't help. In addition, as has often been the case with my doctoral study, part of the problem was me. To work as a 'researching professional' it is important to think about how best to translate research lessons back into an applied world. Whilst I felt the level of knowledge I had developed was useful, communicating it to others is an often-overlooked skill and not always helped by increased depth and breadth of information.

Study 4 helped me understand that any brief presentation of results cannot contain all levels of my findings. It also helped me realize that context is very important when answering applied questions, and that themes and ideas are likely more important than specific results. By making me think about how to synthesise my findings and translate them for applied usage, study 4 helped me work towards my learning objective of developing cognitive skills around synthesising information. Although I feel I understand the process of synthesis better because of this exercise, I am by no means satisfied with my current level. Conducting study 4 and thinking about how to apply my findings to my professional world also made me reflect on the changes I have experienced as a practitioner. As a result of doctoral study, I am certain I have developed, and I am much closer to being a Researching Professional. However, although I feel I have made significant progress towards all the learning objectives outlined at the start of my thesis, attempting to synthesize my findings made me realize I have got a long way to go, to be at the standard I would like in all areas. That said, if I have learnt anything over the course of my doctoral journey, it's that challenging myself to do more of this and reflecting on it, is probably the best way to improve.

CHAPTER EIGHT

THESIS SYNTHESIS

Thesis synthesis

8.1. Introduction

The purpose of this chapter is to consider the outcomes of this thesis in the context of the multi-level objectives it was designed to fulfil. The chapter will begin by describing how findings presented in chapters 4-7 meet the scientific aims and objectives outlined in the General introduction. It will then explore key themes relating to professional team sport career longevity, which are developed across the four studies comprising this research project, whilst highlighting the theoretical, methodological, and practical contributions this thesis makes to literature. Within this chapter, I will also attempt to describe how working towards fulfilling the research objectives of this thesis allowed me to achieve the personal learning objectives, which were at the heart of my reasons for pursuing a professional doctorate. Finally, this chapter will provide suggestions for future work and offer summary level conclusions. To provide context to the discussion that follows, Figure 8.1, shown below, provides a summary of thesis content and a visualization of the links between research studies and applied and learning components.

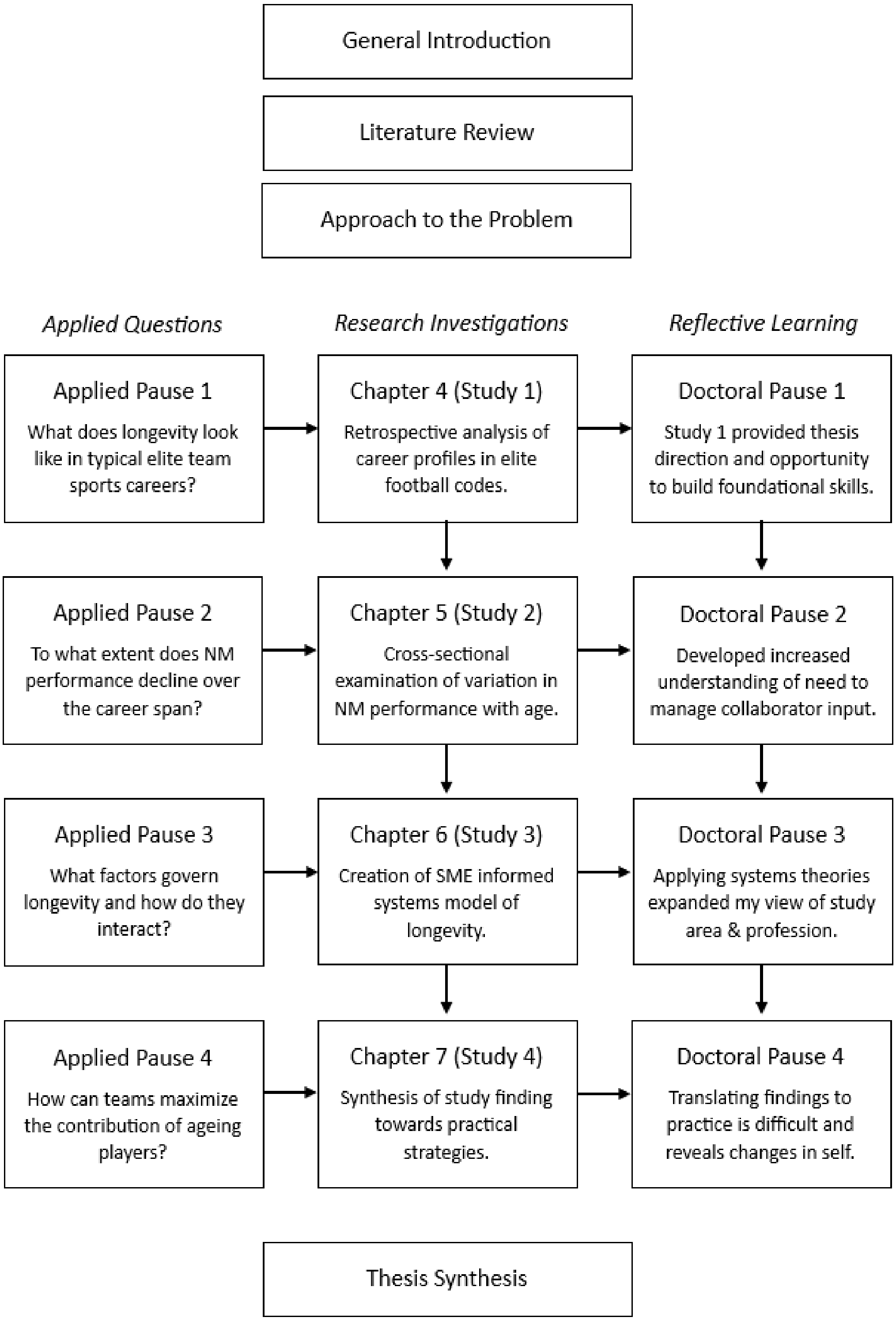


Figure 8.1. Summary of thesis content illustrating the links between applied, research, and learning components.

This schematic describes how key findings from each study informed subsequent investigations. This figure shows that learning over the thesis is an iterative process with lessons from early work providing a foundation for further learning from subsequent investigations.

8.2. Fulfilling the aims and objectives of this thesis

To support the design of effective longevity promoting interventions, the primary aim of this thesis was to understand career profiles and identify factors associated with career longevity and performance decline in elite team sports athletes. To achieve this over-arching aim the thesis is based around four objectives. The following section will describe each objective and explain how and where it is fulfilled within this thesis. It will also outline the structural purpose of each chapter in the context of the overall thesis, and present a high-level summary of both the methodology and results.

Thesis Objective 1: To describe career profiles in high-level professional team sport.

To fulfil the initial objective of this thesis, Chapter 4 investigated career longevity and match participation across the career span at the highest level in four codes of football. This study used a retrospective, observational design to produce statistical models exploring the effect of age and number of seasons since league debut on match participation. For each code of football examined, whole league population distributions for each positional group for both age and seasons since debut were presented. The purpose of this study within the thesis was to capture an empirical level view of professional careers. It was designed to provide context to subsequent work by highlighting the variability of elite team sports careers in terms of their duration and the amount players play. At a very high level, results of this study showed playing careers at the elite level are often of short duration. The amount players play varies by code of football, age and how long they have been in a particular league. The study suggests that whilst it is possible for players to play high minutes following more than 10 years in a particular league, it is comparatively rare for a player to survive long enough to do so.

Thesis Objective 2: To explore the physiological basis of performance variation across team sport careers.

To fulfil the second objective of this thesis, Chapter 5 investigated variation in NM performance across the career span of high-level football players. This study was based on a retrospective, cross-sectional examination of CMJ testing data from a large sample of EPL players. To explore this dataset, polynomial models were constructed to describe the relationship between JH, CMJ-Kin measures, body mass and player age. The cohort was then divided into 5 age categories (17-22, 23-25, 26-28, 29-31 and 32-40) based on a k-means cluster analysis and JH, CMJ-kin measures, and body mass were compared. Within this thesis, this investigation was designed to provide insight into the extent to which physical change across a playing career may impact longevity. This study also served the secondary purpose of highlighting the validity of including physiological factors within the causal model of longevity proposed in chapter 6. At a summary level, results showed reduced JH and performance in aspects of concentric output among the oldest players in the cohort, compared to those aged between their late teens and mid-twenties. The findings of this study suggest an age-related reduction in NM performance does have the potential to impact the performance and therefore career duration amongst the oldest players in this cohort. The results of this investigation however also showed considerable variation in NM performance across all ages of EPL players. This within population variation suggests it is possible for players to play and survive within the EPL with a wide range of NM profiles. It also appears to imply factors beyond the purely physical must be considered, if we are to develop a deeper understanding of the determinants of career longevity.

Thesis Objective 3: To apply systems thinking towards gaining greater understanding of factors influencing career longevity in professional team sports.

To move beyond an examination of the purely physical, Chapter 6 examined SME perceptions of the determinants of career longevity. This study was conducted within a systems thinking framework. It used semi-structured interviews and subsequent thematic synthesis to identify a myriad of variables impacting career longevity. The resulting information was then used in conjunction with findings from Chapter 5 to inform a group model building process for the purpose of constructing a CLD highlighting the relationships and causal powers acting between longevity influencing factors. The CLD identified 25 summary variables able to impact the duration of playing careers. In doing so, it showed career longevity to be an emergent property of a complex system. As well as producing the CLD, SME testimony allowed construction of an actor map showing more than 25 different groups of human actors capable of impacting player carer duration. In the context of this thesis, the purpose of this study was to provide a more complete model from which to understand career longevity.

Thesis Objective 4: To highlight focus areas and develop potential strategies that may allow sports organizations to influence the duration and trajectory of sports careers.

To fulfil the final objective of this thesis, Chapter 7 presents a practically focused, research-informed, position paper summarizing what is known about career longevity and providing suggestions for sports organizations on how they might maximise the odds of players having long and successful careers. This chapter frames career longevity using systems thinking concepts and was informed by additional SME testimony collected as part of Study 3, my personal, professional experience and extended exploration of practical applications from Chapters 4 and 5. Based on recommendations provided in this chapter, organizations aiming to increase longevity should firstly ensure appropriate playing opportunity exists to facilitate the development of peripheral players who will likely drop out of elite leagues without it. Secondly, sports organisations should aim to maximize the time scale over which older professional players can compete at near peak levels by designing physical preparation in a manner which preserves their ability to meet the demands of the most intense aspects of match play. Thirdly, teams should provide opportunity for players to develop autonomy and skills that add value to their on-pitch contributions.

8.3. General discussion

The purpose of the following section is to explore how themes resulting from the combination and synthesis of findings from each of this thesis' constituent studies contribute to the wider literature related to career longevity from both a theoretical and methodological perspective, whilst also presenting useful practical insight. Alongside a description of the practical contribution findings of this thesis offer professional team sports organizations, I will also explore how working to produce it contributed to my personal development as a researching professional.

8.3.1. Theoretical and methodological contributions

Collectively, the findings of the studies comprising this thesis add to the literature describing elite team sports careers by showing longevity is highly variable and determined by interactions between an individual player and their environment. Evidence for high variability in the duration of professional team sport career profiles appears across the thesis. Comprehensive population distributions presented within Chapter 4 suggest drop out from elite leagues is possible at all ages. This is further corroborated in Chapter 5, with the smaller numbers of players across a larger age range in the oldest versus youngest age group, apparently confirming the difficulty of survival. The large number of factors suggested by SMEs as influencing career duration in Chapter 6 show the multi-faceted nature of career duration, and affirm the vast array of career profiles possible within professional team sport. The way in which the interaction between a player and their environment determines career duration is predominantly described in Chapter 6. The SMEs interviewed in this study universally cited the importance of player performance in determining career longevity. The findings of Chapter 6 show a player's ability has a deep causal impact on the duration of their career. Interestingly, however, the relationship between a player's ability and longevity at the highest level is contingent on developmental opportunities (e.g., playing opportunity), the opinion of key stakeholders regarding their performance and the quality of other players within the squad they are part of. Study 6 also shows career duration is causally impacted by a player's ability to sustain a level of contentment, their ability to contribute to team culture and, based on the findings of Chapter 5, the extent to which they can maintain levels of NM performance. Within Chapter 6, SMEs described 25 variables influencing longevity through a variety of feedback loops and interacting with up to 25 different groups of human actors. This implies many factors in addition to playing ability will influence career duration and that a player who did or did not achieve success in one team setting may have experienced a different outcome in another. Chapter 7 builds upon this by concept by suggesting changes to the training environment which may allow high ability, older players to continue to perform at the elite level. Given the complexity and individual nature of interactions between variables influencing longevity, it is perhaps unsurprising little work exists within the literature to guide practitioners' efforts to extend playing careers. Although the first to sample SME perspectives relating to team sport career longevity, this thesis is by no means the first to suggest career duration is influenced by a variety of individual and contextual factors (Frick, 2007; Stambulova et al., 2009; Weissensteiner, 2010). Chapters 6 and 7 however extend existing work and advance current knowledge by specifically describing what these factors are, and showing how these variables and their causal powers interact to influence career longevity in professional team sports. Nonetheless, it must be acknowledged that in presenting summary variables which impact career longevity at an outline level and using a format some have described as messy and hard to read, Chapter 6 fails to fully elucidate the range of ways the factors described in the CLD may impact careers in real world scenarios. Despite the limitations of its outline descriptions, Chapter 6 adds to literature from a methodological perspective. It is the first investigation to apply systems thinking principes to the study of athlete career longevity and in doing so adds to the body of work utilizing systems thinking principles to enhance understanding of complex phenomena within professional sport. It is also the first work within sport science to make the functional link between systems thinking and critical realism. In finding universal agreement amongst SMEs regarding the appropriateness and utility of a systems thinking technique for describing longevity, the study offers future work a theoretical basis from which to understand and examine additional aspects of professional athlete careers. Although Chapter 7 provides greater depth and offers some practical examples, to better capture the detail of how system influences impact career longevity, future studies should consider investigating individual career journeys via a case study approach, within a systems thinking framework.

This thesis both investigates the influence of advancing age on physiology, and examines the determinants of career length through a systems lens. A synthesis of evidence from this work is therefore of interest towards an evaluation of the extent to which age-related physiological decline influences longevity. In Chapter 4, differences in population age profiles between codes of football with broadly similar physical requirements (e.g. AFL, NFL, PR) and the drop out of players at all ages, in all codes, suggest age-related physiological decline does not universally determine career length. By imposing less stringent inclusion criteria compared to many performance profiling studies (Chapter

4), this thesis extends current knowledge by highlighting the large number of elite professional careers which end after a short period of time, at ages where age-related physiological decline is unlikely to have impacted performance. The findings of this thesis therefore appear to prove that physiology is not the primary determinant of career length for those who play in elite leagues but drop out prior to reaching a comparatively old age. When considering this evidence, it is important to note that this thesis offers little exploration of the role of injury in determining career length. Future work should explore the extent to which injury influences career duration amongst those dropping out of elite sport at ages where physiological declines is unlikely to have occurred.

Although the duration of many careers appears unimpacted by age-related change, it is possible performance decay observed in older team sport players (Bradner et al., 2014; Dendir, 2016) is, in part, due to an ageing-related reduction in underpinning physical performance qualities. Chapter 4 highlights that despite differences in career profiles between codes of football, the progressive diminishing frequency of players over 30 years of age is common to all. Chapter 5 built on this finding by exploring the extent to which variation in NM factors explains why it is comparatively rare for players to play at the highest levels into their mid-thirties. To the best of this authors knowledge, Chapter 5 of this thesis is the first investigation to examine CMJ-Kin variables as well as JH across the age span of careers in a large sample of elite team sport athletes. By expanding analysis of NM performance beyond exclusively JH, this study was able to apply enhanced resolution to potential age-related variation in stretch shortening cycle actions. In addition to methodological progression, the findings of Chapter 5 add to the literature by showing differences in NM output between older elite professional players and their younger counterparts. Reported differences in concentric output between players aged 29 or older, and those between their late teens and mid-twenties do not constitute a mechanistic explanation of age-related decline. These findings do however advance understanding by highlighting a specific phase of stretch shortening cycle actions that appears degraded in older professional athletes. By detailing specific NM deficits, the findings of this study offer a potential explanation for the results of previous work comparing match running outputs in older versus younger players. It is possible deficits in concentric output found here explain previously reported findings showing older players cover less high-speed running distance (Zhou et al., 2019) and perform a lower frequency of hard accelerations and decelerations (Sal de Rellán-Geurra et al., 2019) during match play versus younger professionals. Within Chapter 6, SMEs described how a failure to meet the physical demands of a playing role will negatively impact career longevity. It is possible deficits in concentric aspects of CMJ performance observed in Chapter 5 reflect a reduction in functional capacity which impacts game running output and can therefore be considered as representative of a causal force behind observed reductions in older players' ability to fulfil role demands. Although such age-related differences in NM performance appear to present a compelling explanation for performance decline in players following their peak years, the limitations of Chapter 5 mean this explanation for performance decline remains unsubstantiated. Without longitudinal data, it is impossible to definitively state that observed age-related differences in NM output represent an ageing induced change. In addition, identifying a trend towards reduced concentric performance in older players does not constitute a true causal mechanism capable of accounting for diminished on-pitch performance. However, in the absence of more definitive evidence and in keeping with this thesis' philosophical acceptance of fallibilist truth, it is prudent for teams to organize the training of older players in a manner that allows them to effectively maintain NM qualities essential to success in decisive game actions. To provide more actionable information, future work should examine age related change in a longitudinal, and individualized manner. Such work is an important next step, as it has the potential to inform interventions guiding optimal preparation and maintenance of NM qualities with the aim of maximizing an athlete's performance and longevity.

8.3.2. Practical contributions

In addition to providing theoretical and methodological insight, this thesis also offers a significant practical contribution. By presenting SME perspectives on factors determining career duration (Chapter 6) and exploring how the interaction between such factors can be managed toward increasing longevity (Chapter 7), this thesis responds to calls for work providing real world context to increase understanding of ways sport science may benefit applied practice (Fullagar et al., 2019). In view of the importance of contributing practical knowledge to the sports performance profession, and the novel information presented, a bullet-point summary of the practical applications of this thesis is offered following this section (8.3.4).

Despite the potential utility of work designed to promote career longevity, to the best of the author's knowledge, this thesis contains the first attempt at a practically focused piece designed to inform interventions towards this objective. As such, the findings of this thesis provide information which is potentially impactful for a range of different practitioners operating within professional team sports. Comparative career profiles and the exploration of the relationship between longevity and playing time presented in Chapter 4 represents information useful to those in charge of optimizing the composition of playing squads. The broad range of factors impacting longevity, and the numerous surrounding actors highlighted by Chapter 6 provide useful perspective for leaders of sporting organizations. It is important these individuals are aware of the effect of whole system influences and actor incentivization on the probability of their organizations maximizing the potential of their players. In describing the brevity of many careers, findings presented here also provide useful contextual information for performance coaches and those in charge of managing player development as they highlight the limited time frames likely afforded to players at the professional level. An appreciation of the probable short duration of many high-level careers, appears essential to designing interventions with scope to effectively develop qualities and skills coaching staffs have identified as important for specific players. For example, targeting the improvement of maximum strength and movement quality over a two-year period is potentially a worthy goal, but may not be consistent with time periods likely available to players at the highest level of professional sports. Findings from this thesis are also useful to performance coaches as they serve to contextualize the importance of NM decline in determining high level career duration. In showing specific aspects of stretch shortening cycle performance are likely lower in older players, findings from Chapter 5 provide insight into aspects of NM physiology that S&C practitioners should consider monitoring and training in such athletes. Chapter 7 extends this practical insight by offering suggestions as to how a player's overall schedule and training may need to be managed to best preserve such physical capacities. Exploration of the range of factors influencing career profiles provided in Chapter 6 provides further useful information to practitioners. Based on the broad range of factors and stakeholders impacting longevity, multi-factorial, multi-practitioner interventions will be most effective at influencing the whole systems governing career duration. By highlighting the importance of qualities such as leadership and coping skills (Chapter 7), and showing how advanced competencies in these areas can extend players' tenure in elite leagues, evidence presented here suggests developing these skills should be a key component of programs designed to prepare players for long and successful careers.

8.3.3. Summarised practical applications

The summarised practical applications of the work forming this thesis are presented below. In keeping with the philosophical foundation of this thesis they are presented as fallibilist truths. That is, they are research informed suggestions based on the rigorous research completed within preceding chapters of this thesis, but they are presented with the acknowledgement they are based on incomplete evidence and should be revised and updated as new, more complete information becomes available. For ease of reading, practical applications are presented as key headings with bullet point explanations.

Playing opportunity is essential for longevity at all stages of playing careers

- Playing opportunity causally impacts players development, player feelings of contentment, and the extent to which a player can enhance their perceived value.
- Teams wanting to increase the probability of player longevity must find ways to provide adequate playing opportunity.

Periods of low game time are inevitable but require effective management

- Given first team playing opportunities are fundamentally limited, teams should carefully consider how best to manage players in periods of low opportunity.
- This requires well-designed supplementary training which includes game-realistic decision-making activities and a sufficient volume and intensity of work to prepare the player to deal with rapid progression to a starting role, should an opportunity arise.
- In recognition of the scarcity of game time and the unpredictable nature of team sports, annual plans should be flexible allowing development players to take advantage of playing opportunities that present.

Create environments that encourage the development of resilient players

- Levels of player contentment causally impact motivation and therefore quality of performance. To maximise longevity, handle setbacks players, and remain task focused in periods of low game time, players require coping skills.
- Elite team sports environments that are supportive of autonomy, competence, and relatedness are likely to foster effective coping strategies (Ntoumanis et al., 2009), promote mental well-being (Purcell et al., 2022) and facilitate the development of traits related to mental toughness (Mahoney et al., 2014).
- To promote longevity, teams must therefore carefully consider the extent to which the environments they create are supportive of these human needs.

Recognise the potential impact of key stakeholder opinions

- High levels of ability and high quality of performance are necessary for longevity.
- Sporting organisations must however recognise that rather than a full objective analysis of a player's ability, key stakeholders' opinions of players are often the real level driver of how they are viewed and the resulting opportunities they receive.
- Teams must be aware of the causal forces emanating from stakeholder perceptions and should clearly understand the process by which they evaluate players.

Players that offer a wider contribution can extend their careers

- By offering effective leadership and the ability to positively influence culture, players' can maximize their time at the elite level.
- Such skills are thought to be optimally developed in environments that provide exposure to challenge, opportunity for independent decision making and an actioned, philosophical desire to support growth and learning (Machida-Kosuga & Kohno, 2022).
- Teams should understand that environments which remove the possibility for player mistakes run the risk of removing opportunities for personal development and growth.

Train players to maintain peak neuromuscular output as they age

- For players able to survive in elite leagues beyond their late twenties, career duration is causally impacted by the extent to which levels of NM performance can be maintained.
- Whilst the exact causes of reduced performance in older players are unclear, it is comparatively easy for them to enter a cycle of detraining where a reduction in high intensity training can lead to insufficient stimulus being applied to the NM system.
- Training for older players should include regular exposure to stimulus appropriate for maintaining near peak levels of NM power. To facilitate this amidst highly fatiguing schedules, teams must carefully consider how training is organized.
- It is likely easiest to maintain NM output above levels detrimental to performance in players who have worked hard at maximizing power related qualities in the peak physical years of their careers and become proficient at exercises and activities which provide a potent adaptive stimulus (e.g. sprinting, plyometrics, Olympic lift derivatives).

Minimise the risk of injury cycles

- Older players are increasingly susceptible to injury and cycles where one injury repeatedly leads to others.
- To minimise the risk of these occurrences, well-managed RTP training is essential. In addition to adequately preparing returning players to cope with multiple weeks of dense work periods, practitioners must be mindful of the socially situated nature of RTP. A desire to return to play and advanced situational understanding can lead older players to bypass key work steps whilst concealing lingering problems that would benefit from further reconditioning.
- Organisations should aim to facilitate open communication and trust between players and practitioners. Building environments that promote feelings of psychological safety reduce the risk of issues stemming from a lack of communication or concealing information.

Players can keep improving technically and tactically over their whole careers

- Players who play in elite leagues into their late twenties and beyond have far more situational experience than their younger colleagues.
- It is important such players continue to develop skills that allow them to take advantage of likely improvements in decision making and situational anticipation associated with having seen far more game pictures.
- A focus on continual coaching and development of technical and tactical qualities over a whole playing career may also help a player to off-set physiological decline that occurs as they age.

To maximize their players' longevity, teams must appreciate whole system influences

- The whole system around a player influences their longevity in elite leagues.
- The quality of a squad a player is part of, and the presence of other good players in their position determines how much playing opportunity a player receives and therefore significantly impacts their development and contentment.
- Whether a team is successful in the context of the organisation's goals will significantly impact how a player is perceived.
- To maximise the potential of individual players, teams, players, and agents must carefully consider the fit of whole playing squads and the objective by which a club judges success.
- It is important key stakeholders are aware of the real causal force of actor incentivization on the probability of their organizations maximizing the potential of their players. Growth and development are unlikely to be optimal where the gate keepers of playing opportunity and deliverers of education are in must-win situations with little tolerance of error.

8.3.4. Practical contribution towards my development as a Researching Professional

As well as providing insight for practitioners working within professional sports, this thesis has had significant practical benefit through its impact on my own personal development. To describe how this project impacted my learning, I will first examine my progress in the context of the learning objectives presented at the start of this thesis (Chapter 1), before offering a general discussion of my development across my doctoral journey. As previously stated, my learning aims and objectives were developed based on a self-audit (Appendix 9.1), which drew heavily from comparing my starting competency as a researcher to levels outlined by the VRDF (Careers Research and Advisory Centre, 2010).

Fulfilling the learning aims and objectives of this thesis

Learning Objective 1: Enable me to develop a comprehensive knowledge of my research topic, greater understanding of theoretical aspects of research methodology and their practical applications, and improved cognitive skills, including critical thinking, problem solving and synthesis of information.

Performing an extensive literature review and conducting research towards answering specific questions relating to longevity in professional team sport, have allowed me to vastly expand my knowledge of my research topic. Sequentially exploring the population characteristics of elite football codes in Chapter 4, NM variation with age in elite football players in Chapter 5, and sampling SME opinion regarding the factors that influence career duration in Chapter 6 have helped me progress from a core knowledge of my subject area to a detailed understanding. (Criteria for this and other competency descriptors can be found in Appendix 9.6). Work towards the design of all investigations within this thesis and the inevitable difficulties associated with their implementation have helped me greatly expand my knowledge of research methods and how they may be applied. The process of study design also helped towards the development of my problem-solving skills. Conducting Study 3 (Chapter 6) allowed me to further develop my cognitive skills through exposing me to tools related to systems thinking. I found adopting a systems view extremely useful in expanding my ability to critically consider problems in all contexts. Given its specific focus on the synthesis of findings from prior studies to provide practical insight, work towards Chapter 7 was extremely useful in developing my understanding of, and ability to perform synthesis of information.

Learning Objective 2: Carry out a research project addressing specific, applied questions towards the creation and interpretation of new knowledge useful to my profession.

The process of creating this research project (all be it with a lot of help from my tutor) has been incredibly useful in helping me understand the nature of project management within research. Over the course of the sequential studies forming this project, I felt I became more proficient at building realistic plans to action the work required of each one. I also learnt some specific lessons related to conducting a research project that were extremely valuable. For example, in Study 1 (Chapter 4), I came to understand the inevitability of problems within the research process and in Study 2 (Chapter 5), I learnt a huge amount about the importance of effectively managing working relationships with collaborators. To ensure this research project was focused on important applied questions and therefore able to contribute useful information to my profession, I presented applied reflective pauses prior to each research study. The extent to which the information presented in this thesis is novel has been previously described. Whilst I feel findings relating to population characteristics of elite football, NM variation across the career span and the systems-based description of the determinants of longevity are useful to practitioners, it is likely the extent to which this is the case will become clear following further dissemination of findings.

Learning Objective 3: Present reflections and meta reflections on my learning journey to facilitate iterative development of my research project and enhance efficacy of my personal learning journey.

This objective of presenting reflections on my learning was met by inclusion of Doctoral learning pauses describing specific lessons I gained from each study. Whilst there is some evidence of meta reflection in these accounts, reflecting on my reflective process is mostly covered within this section of the thesis (Chapter 8, see below). When viewed sequentially, the reflective accounts presented as Doctoral learning pauses evidence iterative development towards my learning objectives over the course of the four studies comprising this thesis. It is clear from these accounts that changes in my views of myself and my profession, and understanding of constructs such as expertise and challenge, acted as catalysts unlocking additional learning and development throughout this project.

8.4. General discussion describing progress towards learning aims and objectives

In my learning aims presented in Chapter 1, I described my focus on developing as a researching professional. The term 'researching professional' seems to appropriately capture the product of my learning objectives. It intentionally describes an experienced professional who has chosen to undertake research into their professional context with the goal of improving personal practice and adding knowledge to their profession (Bourner et al., 2001; Fulton et al., 2011). According to Lindsay et al. (2017), developing as a researching practitioner requires enhancement of research skills, thinking tools and focus on moving one's own work forward. It also necessitates building cognitive, interpersonal, and intrapersonal skills (Lindsay, 2014). Having now gone through the process of studying for a professional doctorate, I feel confident work towards this thesis has allowed me to progress in all such areas. As described above, I am also confident work towards this thesis has allowed me to fulfil all the specific learning objectives I outlined in the General introduction. Judging my development based on these early targets, however, now seems insufficient. Having nearly completed my professional doctorate, reading my original learning aims and associated reflections makes me appreciate the growth I have experienced and recognize that it has often occurred in areas I was previously unable to see as having scope for development. Reflecting on the accounts of my learnings from each study, it is clear I have developed a far greater understanding and perhaps reframing of my identity through my overall doctoral program. Although I did not mention knowledge of myself or understanding of my own views specifically in my learning aims, an increased understanding of these has been essential in my growth. When considering my reflections on my own development, I am clear that shifts in my conception of learning and the value of challenge have shaped how I view my doctoral experience. These shifts have allowed me to explore new thinking paradigms with greater freedom and they have enabled me to use mistakes as a means of guiding change in process rather than simply a source of stress. Such changes have allowed me to challenge a lot of the views I held at the start of doctoral process and as a result develop far more clarity in my thinking.

When reflecting on my learning journey throughout my doctorate I feel changed as a practitioner. As my program of study has drawn to an end, I have frequently found that I am able to investigate problems within my work with far greater clarity than prior to beginning my course. Whilst I have described some of the changes that I feel have taken place, I struggle to fully articulate all the development I have experienced. It is possible the interconnected nature of developing as a researcher, practitioner, and understanding self makes identification of single learning steps problematic. It also seems likely that the phasic and complex nature of transformative learning as highlighted by Mezirow (2000), means the process I have undergone is based on the aggregation of many changes which are difficult to individually discern. Despite difficulties related to fully articulating the basis of my transformative experience, I am certain improvements in my reflective practice and ability to investigate my views have allowed me to develop a fresh lens from which to view my work, opinions, and life journey (Cunningham, 2018). Overall, completing this research project has greatly improved my ability as a practitioner by allowing me to work in a manner that could be termed 'Research informed practice'. This shift in my working processes means I am better able to find answers to my own practice-based problems and can more critically evaluate my own work. It also means I have a more developed ability to objectively examine research and evaluate the potential utility of initiatives aiming to benefit the aims of my professional program and organization.

8.5. Recommendations for future work

Despite the significant contribution findings of this thesis make to literature relating to career longevity, much further work is required. To advance the single season analysis presented in Chapter 4, a future study should conduct a multi-season examination of population distributions, match participation trends across the career span and variation in league career lengths. A multi-season analysis of career profiles is important to elucidate variation in playing populations between seasons and provide further understanding of the nature of professional team sports careers. To enhance knowledge of the effect of advancing age on NM performance, future work should profile NM change in a longitudinal, and individualized manner. Such work would overcome limitations imposed by the cross-sectional nature of Chapter 5 and has potential to inform interventions guiding maintenance of NM qualities toward maximizing athlete performance and longevity. To provide context to findings of Chapter 6 and move beyond the somewhat general and hypothetical stance of Chapter 7, future studies should consider adopting a case study format to investigate individual career journeys within a systems thinking framework. Longitudinal case studies showing age-related change in players across multiple measures of game performance, health status and physiological output would provide specific examples and capture nuance of how system influences impact career longevity. Such work would also help evaluate the veracity of threats to longevity presented here.

As a result of insight provided into professional team sport career longevity by work within this thesis, several additional avenues for research now appear to be of great interest. Some evaluation of the impact of injury on longevity warrants investigation. Greater understanding of the way in which injury induced absence impacts the system influencing career duration would provide useful insight for teams aiming to minimise talent loss. When comparing NM performance in older versus younger EPL players it appears age-related deficits are predominantly found in metrics sampling the fastest parts of SSC performance. To further understand the discriminatory potential of fast SSC actions it would be of interest to extend the study performed here by contrasting older and younger players' performance in tasks requiring faster SSC performance than is sampled by CMJ assessment. Investigating age-related variation in NM output in drop jump performance and in aspects of sprinting and change of direction has the potential to provide great insight for those aiming to better understand age-related decline. Having demonstrated the variable nature of professional team sports careers it now seems useful to examine specific scenarios in which sports teams may be able to influence player career journeys. Based on the efficacy of working with SMEs to gain insight into under researched areas, it would be interesting to gain further applied understanding of situations where teams have maximized the contribution of players seemingly on course to drop out of elite leagues. An SME informed analysis of career journeys where players leave one club having had little exposure to first team competition before establishing themselves at another club would likely be of great interest. In addition, a systems-based exploration of clubs or training approaches where a statistically high numbers of players have long careers could also prove highly insightful. Identifying and examining 'Longevity blue zones' has the potential to provide useful ideas and examples of practice that could advance understanding in an area where very little practical research exists.

8.6. Thesis conclusions

- Professional team sports careers are variable in duration. Player participation trajectory over the career span is broadly similar across all elite codes of football with many players in all codes dropping out prior to ages where age-related decline is likely to impact performance. Although it is possible for players to maintain close to peak playing minutes until age 30, very few are afforded the chance to do so.

- Older players (>29) are likely to record a significantly lower JH, higher body mass and reduced performance in a range of concentric phase CMJ-kin measures compared to younger counterparts. Although diminished NM performance may impact the on-field performance of older players, large variation in performance across EPL players of all ages suggests it is possible to compete at the elite level with a variety of NM profiles, and that factors beyond physiological decline likely determine the duration of many professional careers.

- Professional team sport careers are usefully conceptualized as a complex phenomenon. Longevity is therefore best viewed as an emergent product of a variety of different factors impacted by numerous human agents. As such, multi-factorial, multi-practitioner interventions are required to most effectively increase players' chances of having long and successful careers.

- Carrying out the studies that make up this thesis, and attempting to counter the problems that inevitably occurred, has enabled me to achieve the learning objectives I initially set and altered my thinking and working processes as a 'researching professional' (Bourner et al., 2001). It has also provided a fresh perspective that allows me to acknowledge personal development beyond the boundaries of my initial goals.

CHAPTER NINE

APPENDICES

Appendix 9.1: Self-audit

Introduction

The creation of new and useful knowledge is amongst the main objectives of a professional doctorate. To achieve this, given their generally applied backgrounds, students will likely need to develop their competency as researchers. The process of systematically improving research competency should begin with an assessment of current skill level, followed by the subsequent generation of a training plan (Vitae Career Research and Advisory Centre Limited, 2020). The purpose of the following document is to outline and report on such a process of skill assessment as it relates to the requirements of the research I plan to carry out within my professional doctorate.

Self-Audit: Background and Overview

The assessment of my current research competency will take place through a technique termed self-audit. This involves systematic and critical evaluation of one's own performance and skills against accepted consensus guidelines (Mahlneckt *et al.,* 2016). This type of introspective analysis can be considered a means of self-reflection and is done with the aim of providing better understanding of the self, improving the effectiveness of one's work and generating new knowledge (Cropley *et al.,* 2010). The following self-audit is designed to provide a holistic view of my current level of competency in the context of the skill requirements and needs of the series investigations that will comprise my professional doctorate. The process of self-audit used here is summarized in Fig. 1. This self-audit draws information from two areas, firstly from a tool providing information relating to my research skills, behaviours, and knowledge and secondly from several tools informing on aspects of my professional self. Information from both source areas is then combined to produce a list of development needs which subsequently informs the generation of my research training plan.

Self-Audit: Methodology

Research competency evaluation

To understand my current competency as a researcher I used the Vitae Researcher Development Framework (VRDF) (Fig. 2). This validated tool is designed to help aspiring researchers develop the knowledge, behaviours and attributes required for a successful career (Reeves et al., 2012). The VRDF has 4 domains composed of a total of 63 descriptors. Each descriptor has 3 to 5 phases representative of development levels across a career and each phase is described by evidencable statements the researcher can evaluate their competency against. To establish my level of research competency, I initially created a sheet for each domain of the VRDF in which each descriptor was written and given scoring options corresponding to the number of phases for each descriptor. I then compared my own competency to the precise terminology provided for each phase of every descriptor (See Vitae, 2011 for exact phase descriptions). An example is provided following this review in *Supporting Material 9.6*. I only considered myself able to operate at a given phase of a descriptor if I was able to cite evidence demonstrating I have fulfilled the exact descriptions of the competency described. The results of my self-audit for each domain of the VRDF as shown within *Supporting Material 9.1-4*.

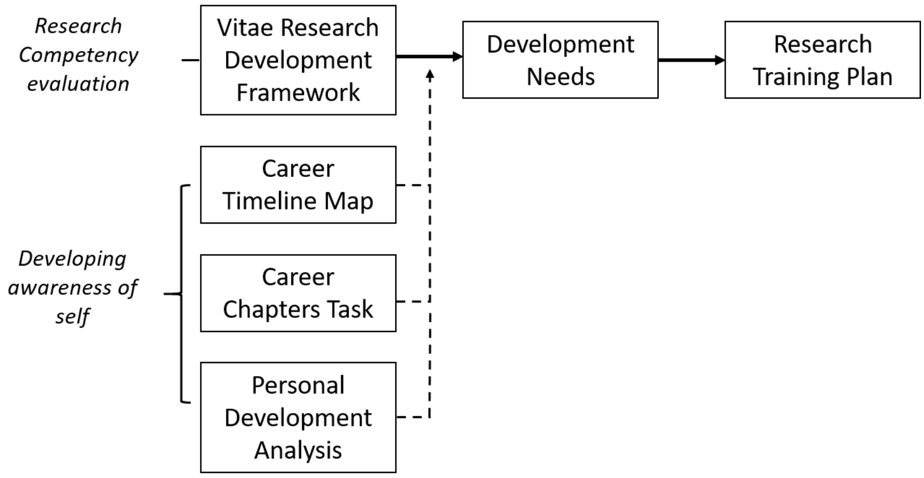


Figure 9.1. Outline of the self-audit process employed here showing how different inputs are combined to produce development needs which will subsequently be addressed by research training plan.

I also used the VRDF to provide insight into the areas of skill development that are most important for my planned research studies. Given the VRDF is designed to provide a framework for development across a whole research career it seems logical to take a more focused approach to development within a three-year project. Considering the methodology of each planned study, my objectives for the overall body of work and my research related career objectives, I rated the importance of each descriptor for successful completion of the project against two 5-point Likert scales (see appendix 5 for more detail). I only considered descriptors for inclusion as development needs where the combined score of the two Likert scales was 7 or greater. Target levels of competency were selected by analysing the phases provided for each descriptor and selecting a phase that fulfilled two criteria; firstly, it would improve my ability to carry out the proposed research studies through directly applicable knowledge or skills and secondly, it appeared to be a level of development I could realistically obtain within the next 12 months whilst working on completion of research, modules and full-time employment. Although subjective, this method was employed to identify areas where my current level of competency was below an obtainable level of competency which would improve my ability to carry out the proposed studies. The VRDF descriptors that I rated as important and subsequently identified target levels for were considered as developmental needs. These are shown in table form in *Supporting Material 9.10*.

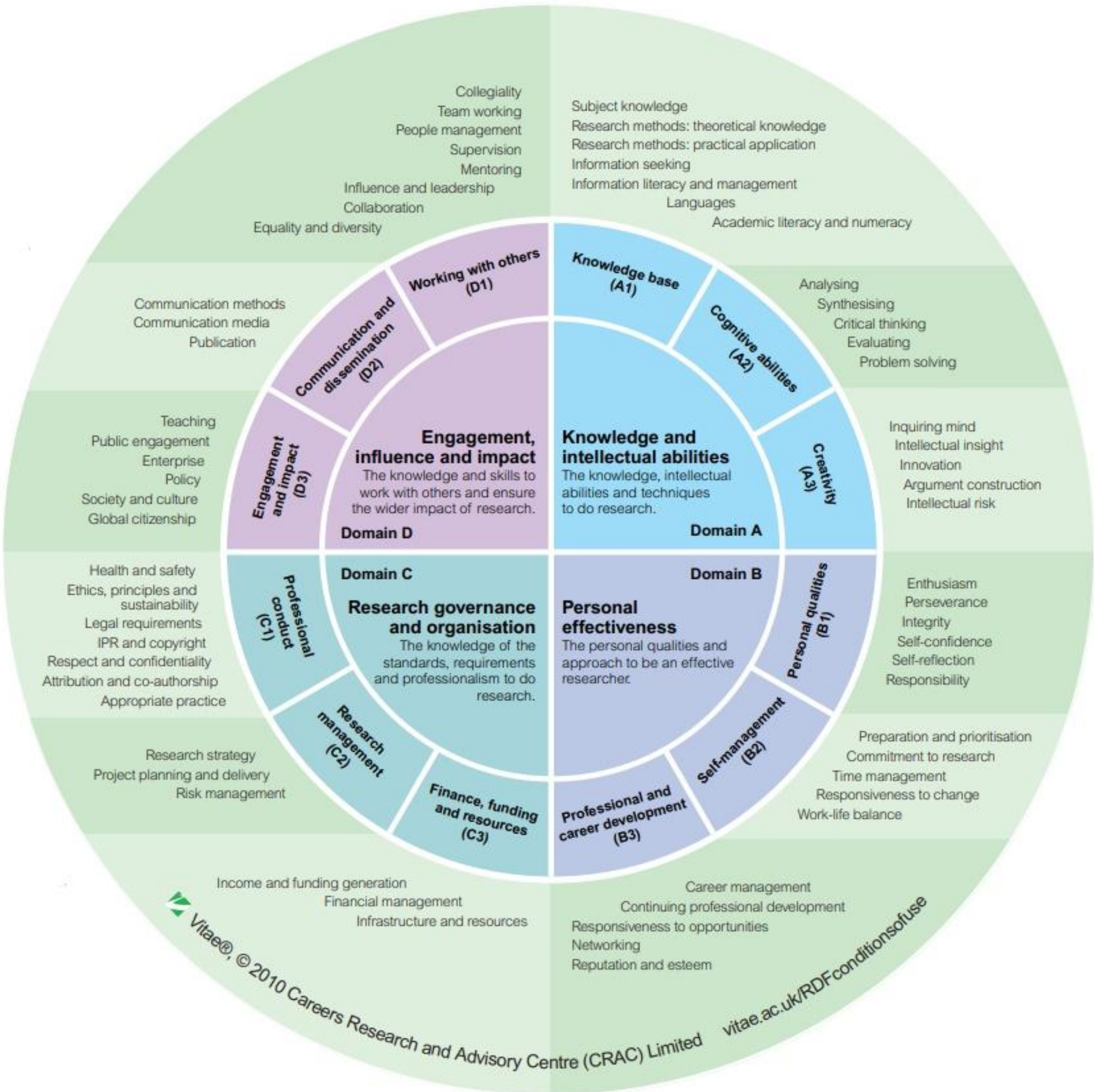


Figure 9.2. The Vitae Researcher Development Framework (VRDF).

Facilitating a greater understanding of self

To enhance understanding of how my values, beliefs, and interactions have been shaped by my experiences and professional journey (Fulton *et al.,* 2013) I used a career timeline mapping exercise (*Supporting Material 9.7*), a career chapters reflective task (CCT) (*Supporting Material 9.8*) and completed a personal development analysis (PDA) (*Supporting Material 9.9*).

The career timeline and CTT were conducted to help me reflect on my career journey and to understand more clearly what my specific professional community of practice is. A more precise understanding of our profession allows us to evaluate how we will contribute new knowledge to it and provides a sense of how membership may have led to the territorialisation of knowledge and ideas. Territorialisation refers to the way our approach can be bound by the context within which we operate and thus how the context can be a barrier to the creation of new knowledge (Baumard, 1999).

My PDA assessment was conducted through a commercial organisation (Cognite, UK). This assessment tool measures surface personality traits across 5 dimensions of behaviour and has been shown to demonstrate good validity (PDA International, 2018). The measurement of surface as opposed to source traits means the tool provides information describing behavioural preferences but is not a means of explaining the causes of behaviour. My PDA assessment explains some of the ways I prefer to respond in certain situations and provides insight into problems I may encounter over the professional doctorate.

Combining VRDF and self-sources of information

In this self-audit process the VRDF should be thought as the principal tool of investigation. Understanding my current competency in terms of my knowledge and ability to carry out my proposed methodology is obviously essential to being able to produce a sound developmental plan. However, knowledge and skills alone do not fully equip a researcher to carry out professional doctoral research. Increased knowledge of self is an important consideration within Professional doctoral research as it is generally conducted in a real world, applied setting by active practitioners, meaning the researcher is frequently an integral part of their own research. This can present a challenge to a purely positivist epistemology and requires the practitioner to recognise the importance of their own subjectivity in the process of investigation and interpretation and understand the potential for their values and beliefs to influence their interactions (Taylor and Medina, 2011). As well as being important within the actual research, increased knowledge of self is required to produce an effective development plan. The tools designed to provide more awareness of self in this self-audit are used to identify areas for development and add insight and detail to the findings of the VRDF. They should not be considered as separate entities to the VRDF but as complimentary and interrelated.

Results of the Self-Audit

Comparison of my current levels of research competency to the levels I believe are required for successful completion of my doctoral research has resulted in the identification of many development needs. These are presented in *Supporting Material 9.9*. For reasons of brevity, in the following paragraphs I will only discuss and provide evidence for results of the VRDF that were deemed important to the aim of better preparing me for the needs of my professional doctoral studies. Given the breadth and diverse nature of the developmental needs identified I have divided the findings into 3 categories. This is purely to facilitate their logical discussion. The 3 categories are as follows:

- Study specific knowledge and skills
- Communication, networking and dissemination
- Foundational skills and practices

Study Specific Knowledge

The self-audit highlighted a discrepancy between my current and targeted level of subject knowledge. Based on the requirements of my studies I think my subject knowledge needs to be at the level described by the third phase of the VRDF subject knowledge descriptor. Here the researcher can 'stimulate new knowledge' and has a 'deep and holistic understanding of the research area' (Vitae, 2011). Currently when comparing my competency to the 3 phases of the VRDF subject knowledge descriptor, I think my competency level only satisfies phase 1. I am at this level as I have a core understanding of my research area and awareness of recent advances evidenced by 16 years in related professional practice and consistent reading in both my research area and related topics. However, I was unable to provide evidence showing I operate beyond this level as I do not possess 'detailed and thorough knowledge' of both my own and related subject areas as required by phase 2 of this descriptor. In support of my conclusions around a lack of detailed knowledge of related areas I cite the examples of my knowledge in the areas of gerontology and muscle physiology. These are certainly related to my area of research interest, and whilst I am aware of central themes within the literature, I do not have a clear understanding of current areas of debate or cutting age measurement techniques. Given the obvious importance of understanding what is known in a subject area to which I wish to contribute (Fulton et al., 2013), increasing subject knowledge will be an important aspect of the research training plan that follows.

The self-aspects of this audit provided additional depth regarding my need to improve my subject knowledge. The career timeline and CCT task have made me aware there is a strong chance a territorialisation of my knowledge has occurred. Based on my career path to date (*Supporting Material 9.7*) I have mainly confronted the phenomenon of athlete ageing through an applied lens supported by self-selected data. It is therefore likely that I do not have a complete view of the problem and would benefit from gaining additional applied perspectives. I therefore plan to increase depth and breadth of subject knowledge from both an academic and professional perspective.

The self-audit also highlighted my need to improve my study specific knowledge of theoretical and applied aspects of research methodology. Currently, my level of competency relating to theoretical aspects of research methodology satisfies phase 1 of this descriptor as following completion of my MSc I understand some relevant methodologies and can justify the use of certain experimental techniques. I however do not have knowledge of a wide range of research methods and techniques so cannot produce evidence to consider myself at phase 2. In terms of required theoretical knowledge, I think I need to operate at the level of a researcher at phase 3 of the descriptor. This requires the researcher to 'combine and justify methods/techniques designed specifically for an investigation in a flexible and vigorous manner' (Vitae, 2011). In terms of the practical application of research methods (domain A1.3), my level of competency also satisfies the first phase of the descriptor. This is evidenced by my previous study having given me some experience using a range of research methods and my recent reading having exposed me to some potentially relevant techniques (particularly related to individual subject analysis). I feel I will be better placed to complete my research if my competency relating to applied aspects of research methodology can be developed to reach phase 2 of this descriptor. To do this I plan to increase my depth of knowledge to a level that allows me to robustly evaluate my use of research methodologies and data collection techniques.

Communication, Networking, and Dissemination

To achieve the objectives of my professional doctorate regarding contributing new knowledge to my profession it is important I can effectively communicate my findings. The self-audit showed I would be better placed to do this if I improve my competency relating to both communications methods (descriptor D2.1) and media (descriptor D2.2). I currently operate at phase 1 of the communications methods descriptor as I have experience presenting arguments, ideas, and data in work-based meetings and am comfortable with rigorous debate within my professional sphere. However, when comparing my current competency to the criteria for phase 2, I have no experience presenting research to varied audiences and have little experience of genuine inter-disciplinary knowledge exchange outside a narrow area of professional practice. I think it would be beneficial for my study if I can reach the level of competency described by phase 2 and develop my ability to use a range of communications media. At this level I would be better placed to effectively disseminate results, obtain critical feedback, and maximise career development opportunities presented by the professional doctorate.

Alongside the contribution of new knowledge to my profession, career progression was amongst my reasons for beginning doctoral study. As such, I rated the career management descriptor (B3.1) of the VRDF as important. The self-audit results show I currently only fulfil the first phase of this descriptor as although I have managed my career, as evidenced by my move to work outside of the UK to increase my breadth of experience and improve my employability, I have not carried out critical reflection and planned cycles of improvement as required by phase 2. Although I thought I had done this, my recently enhanced knowledge of reflection now means I am aware there was insufficient depth and clarity to my prior analysis. I would like to operate at phase 4 in this descriptor where I am able to work as a practitioner who is established as a researcher and someone who develops the careers of others and will detail steps towards this objective in the research training plan.

In addition to being potentially useful for career management, a more research specific professional network is also likely to enhance my ability to carry out my planned studies. Given that previously highlighted findings from the self-audit show my subject knowledge is insufficient and the self-aspects of the audit show I have biases which may prevent me from seeing all aspects of my research area it is clear I will benefit from critical external feedback. As such a well-developed research network is likely of great value. However, to develop this type of network, the results of the self-audit suggest I need to improve my competency in networking (descriptor B3.4). I think I only satisfy part of the first phase of this descriptor and would like to reach the level of competency described by phase 3. I have built a useful network, evidenced by the group of former colleagues I regularly speak to. However, whilst adept in providing professional feedback, my network is not optimal for assistance with creative and critical input as it relates to research.

Foundational Skills and Practices

The numerous development needs highlighted by my self-audit and the work likely required to elevate my levels of competency clearly represents a significant undertaking. Given I will carry out this training around my research whilst working full-time, it seems important I develop my ability to work efficiently. Improvements in skill areas related to overall efficiency such as time management and project planning are likely to facilitate improved doctoral work and the preservation of work-life balance. When comparing myself against the time management descriptor (B2.3) of the VRDF I am confident my professional background means I can manage my time as set out by phase 1. However, in looking at the higher phases, I am aware that I have not established my own process to manage multiple complex projects (phase 3, 4 and 5) which will likely be needed to effectively complete doctoral studies. In terms of project planning and delivery (C2.2), I am clear that whilst I have some general skills around independent work, I do not have the knowledge to independently define a manageable research project or any experience of research project management cycles. To develop my skills in such areas that relate to general work efficiency I plan to complete a series of library courses, discuss development approaches with mentors and regularly reflect on my own performance.

Up to now, I have presented deficiencies in competence and signposted areas for improvement. However, for balance it is important I recognize this audit's positive findings by highlighting current competencies which appear suited to professional doctorate study. As such, I think my career to date has helped me develop perseverance and resilience as well competencies relating to collegiality, team working and collaboration. Whilst these qualities are not currently manifested in a research specific way, I feel I am well placed to quickly develop research specific skills in these areas. I also think some of these competencies such as perseverance represent useful foundational assets for continuing to develop in other areas such as subject specific knowledge which will require significant work over a sustained period.

Conclusions

To best prepare myself for professional doctoral study I carried out a self-audit to assess my research competency. It showed I will be better placed to carry out my proposed research by developing my subject knowledge and gaining greater understanding of the application and theory of research methods related to it. To facilitate these improvements, I require enhanced information seeking and management skills and should develop a network that can provide critical input into my research. The self-audit also showed I should develop my ability to communicate and use different media effectively in preparation for the dissemination of findings. In addition, I need to enhance my competency relating to work practice efficiency and improve my foundational research knowledge of areas including ethics and health and safety. I should also address fundamental academic competencies such as argument construction, critical thinking and analysing as well as academic literacy and numeracy. In the research training plan that follows I will outline a systematic approach and timeline for the improvement of these identified developmental needs.

9.1.2. Research training plan

Introduction

This document describes how I plan to improve the competencies identified for development by my self-audit. Along with the doctorate planning Gantt chart it forms my Research Training Plan (RTP). The RTP aims to outline a systematic path of competency development to best prepare me to carry out my proposed research and to provide a timetable for the both the research components and learning modules of my professional doctorate. It aims to map out a means of equipping me with skills and process that allow my research to be a vehicle through which I develop skills, behaviours and understanding whilst adding knowledge to my area of professional practice.

Scope of the Research Training Plan

My RTP is designed to run over 3 years of full-time study. I present it here as an estimated outline of the overall process for completing my professional doctorate, however I do so in the knowledge that 'no plan survives first contact' and change is inevitable. Following this principle, as the more distant phases of the plan are most likely to change, I have mostly signposted direction and outlined focus areas for these, whereas detailed information is provided for the early phases of the RTP.

The RTP outlines specific dates for each element of the doctorate and provides the sequencing of the various tasks and learning opportunities afforded by the process. I have attempted to order the learning elements of the RTP in a way that is complimentary to the overall research process and gives the plan the best chance of helping me establish effective developmental processes. In providing a sequence of learning opportunities, the RTP should be of value in orientating my efforts even if the precise schedule is subject to change. For example, if the first study takes longer than expected to complete, the order of the elements of the second study will still proceed as outlined in the Gantt chart even if they no longer take place on the dates indicated.

Planning Competency Development

At the start of my RTP I will work on my ability to work efficiently and practice effective self-reflection. Whilst unrealistic to think I can quickly develop mastery in these areas; by investing time in them early, I can start to develop an efficient, iterative process from the early stages of my project. Striving for early improvement in these qualities seems prudent as it maximises my chance to improve efficiency and perhaps therefore quality in all subsequent work within this project. To increase general work efficiency in the first 2 months of my RTP I will address project planning, time management and information seeking through library courses, general reading and discussion with my supervisor and mentors. Researching and trialling different methods of self-reflection, with the long-term goal of developing an effective personal process will also begin in the first 2 months of the RTP. The self-audit showed I have a behavioural preference towards achieving high standards which can lead to an outcome focus. Given many of my developmental target areas highlighted by the self-audit are more related to process than outcome, I think it is important I develop practices around self-reflection that allow me to continue to work on areas my behavioural preferences may see me ignore. From my recent work on self-reflection, I am enthusiastic about its value for overall self-development and positive influence on mental health over the professional doctorate, therefore I plan to revisit it every 6 months with the aim of improving process.

Increasing my subject knowledge is also a major focus early in my RTP. My self-audit highlighted a discrepancy between my current and targeted competency in terms of subject knowledge, with scope to improve on both an academic and professional level. It also highlighted my competency within information seeking and management needs to develop if I am to be properly equipped to develop my subject knowledge through an effectively implemented search strategy. Therefore, following learning more from library sources and mentors around systematic information seeking and management I will begin a thorough yet streamed literature search. Reading, analysing and recording relevant literature will be an ongoing task until I write up my thesis, scheduled for the second half of the third year of the professional doctorate. I plan to improve my subject knowledge from a professional perspective by speaking to applied professionals with different sporting backgrounds for alternative views on ageing in team sports athletes. I will do this to combat territorialization of my knowledge in months 2,3 and 4 of my RTP.

Improving my theoretical and applied knowledge of research methods is another important developmental target. I will address this between months 2 and 7 of my RTP. I will begin general reading in this area before focusing on methodologies and statistical tools suitable for understanding individual athlete response. In addition to being an important part of my study designs, the self-audit has made me aware that caring for athletes on an individual basis is an important professional value for me that I wish to reflect in my research. Whilst working to enhance such competencies relating to research methods, I will concurrently work on improving my use of the programming language R. Addressing these developmental objectives simultaneously allows me to practice applying theoretical knowledge to practical situations and so offers opportunity to develop deeper understanding.

To improve my competency in communication, networking, and dissemination, I plan to initially work on improving my general communication skills. I believe improvements in this area will provide a foundation for developing increased competency in networking and dissemination. My self-audit identified both my ability to effectively communicate to various audiences and the use of communications media as development needs. I think researching effective communication techniques and deliberately applying related principles in my research and work environments with reflection presents a good opportunity to improve general communications competency in different environments and is planned to take place in month 3 of my RTP. I think improving my use of various communications media is however more suited to being a target area later in the RTP when I am closer to disseminating findings and is therefore planned for year 3 of the doctorate. When planning a means of further improving my competency in networking, I think my research gives me the opportunity to build an authentic voice and expertise in an area of athlete preparation I find very interesting. Given the self-audit showed I have a behavioural preference which is more towards introverted than extroverted and I dislike the idea of self-promotion, this maybe a position from which I feel more confident to present my views and grow my profile. It is possible that improved competency in networking and an enhanced professional profile may help with targets discussed in the self-audit around carer progression and improving competency in career management. At present however these remain themes to be addressed later in the RTP schedule.

The self-audit also highlighted weaknesses in my research related problem solving, argument construction, critical thinking, and academic writing. Despite their importance, I do not plan to directly address these areas as I feel supervised academic process with effective self-reflection will organically lead to development. As stated in the self-audit, it is however important I revisit an assessment of such general skills to ensure sufficient progress is being made with this approach.

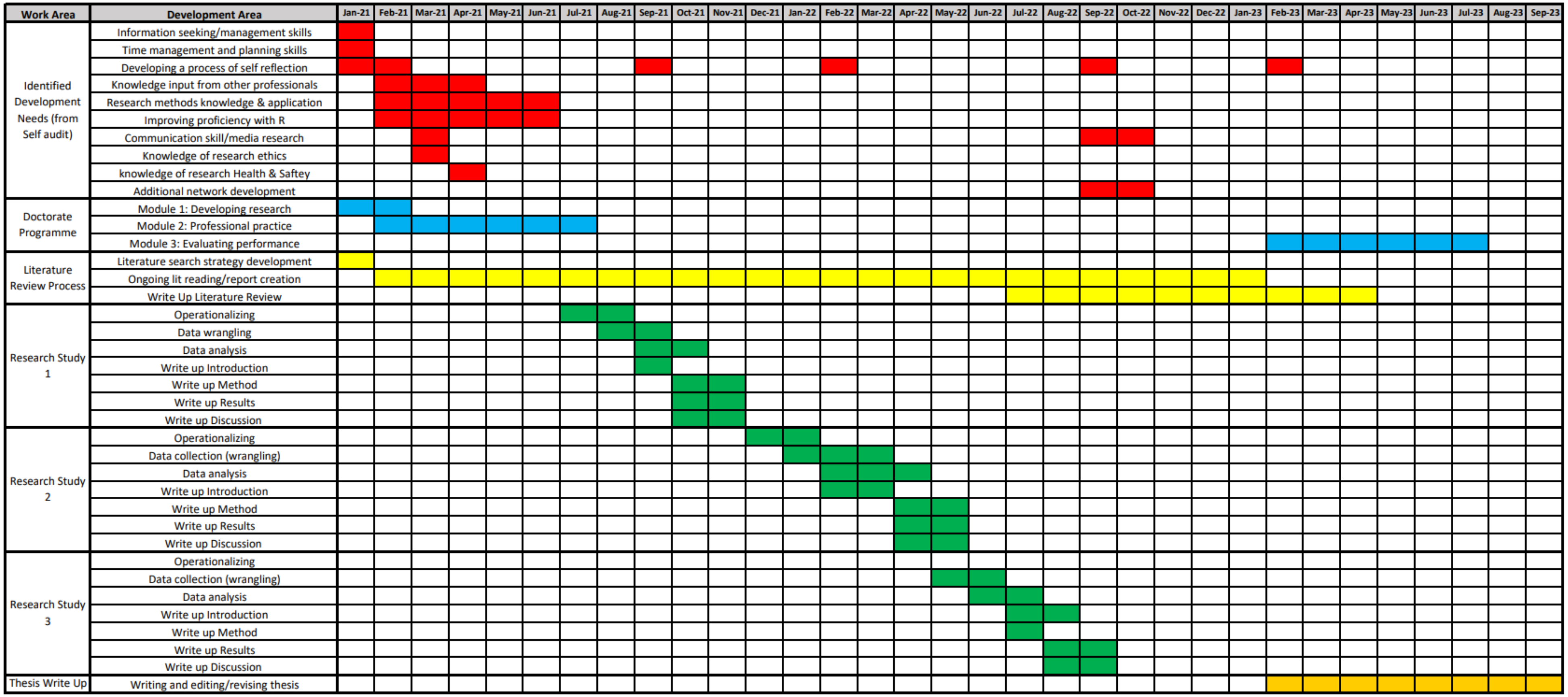
Additional Timetabling Considerations

I plan to begin my first study in month 7 of my RTP. This allows time for completion of first year modules and skill development tasks. The 3 studies that make up my professional doctorate will then run sequentially over 21 months, allowing the results of each to inform the design or implementation of the next. I have allowed extra time to complete study 2 as it is scheduled during the AFL pre-season which is my busiest time of year professionally. I plan to be writing up sections of the studies throughout the 21-month research period. I think consistently writing and revising drafts with my supervisor will help me develop deeper competencies around academic writing, critical thinking and problem solving.

Conclusions

This document provides background and commentary to my RTP. It highlights my developmental needs and how the process of their improvement fits around my professional doctorate. Whilst this plan will certainly change, it sets the foundations for developing knowledge, behaviours, and insight to enable me to carry out a series of research studies to add knowledge to my area of professional practice. Crucially the research is itself a vehicle to further develop knowledge, behaviours, and insight. However, the extent to which this can happen and therefore the potential for the research to be a transformative experience likely depends on my ability to apply the competencies and processes I work on in preparation to complete it.

9.1.3. Gantt Chart



SELF-AUDIT SUPPORTING MATERIALS

Supporting materials 9.1. Vitae reporting sheet domain A

The table below shows my assessment of my current and target level of competency based on the phases described for each descriptor of domain B of the Vitae Researcher Development Framework.

Domain A: Knowledge and Intellectual abilities.		*Current Level*				
		Target Level				
		1	**2**	**3**	**4**	**5**
A1. Knowledge Base	Subject knowledge					
	Research methods: theoretical knowledge					
	Research methods: practical application					
	Information seeking					
	Information literacy and management					
	Languages					
	Academic literacy and numeracy					
A2. Cognitive Abilities	Analysing					
	Synthesising					
	Critical thinking					
	Evaluating					
	Problem solving					
A3. Creativity	Inquiring mind					
	Intellectual insight					
	Innovation					
	Argument construction					
	Intellectual risk					

Supporting materials 9.2. Vitae reporting sheet domain B

The table below shows my assessment of my current and target level of competency based on the phases described for each descriptor of domain B of the Vitae Researcher Development Framework.

Domain B: Personal Effectivness		*Current Level*				
		Target Level				
		1	2	3	4	5
B1. Personal Qualities	Enthusiasm					
	Perseverance					
	Integrity					
	Self-confidence					
	Self-reflection					
	Responsibility					
B2. Self Management	Preparation and prioritisation					
	Commitment to research					
	Time management					
	Responsiveness to change					
	Work life balance					
B3. Professional and Career Development	Career management					
	Continuing professional development					
	Responsiveness to opportunities					
	Networking					
	Reputation and esteem					

Supporting materials 9.3. Vitae reporting sheet domain C

The table below shows my assessment of my current and target level of competency based on the phases described for each descriptor of domain B of the Vitae Researcher Development Framework.

Domain C: Research Governance and Organisation.		*Current Level*				
		Target Level				
		1	2	3	4	5
C1. Professional Conduct	Health and safety					
	Ethics, principles and sustainability					
	Legal requirements					
	I P R and copyright					
	Respect and confidentiality					
	Attribution and co-authorship					
	Appropriate practice					
C2. Research Management	Research strategy					
	Project planning and delivery					
	Risk management					
C3. Finance Funding and Resources	Income and funding generation					
	Financial management					
	Infrastructure and resources					

Supporting materials 9.4. Vitae reporting sheet domain D

The table below shows my assessment of my current and target level of competency based on the phases described for each descriptor of domain B of the Vitae Researcher Development Framework.

Domain D: Engagement, Influence and Impact.		*Current Level*				
		Target Level				
		1	**2**	**3**	**4**	**5**
D1. Working with others	Collegiality					
	Team working					
	People management					
	Supervision					
	Mentoring					
	Influence and leadership					
	Collaboration					
	Equality and diversity					
D2. Communication and Dissemination	Communication methods					
	Communication media					
	Publication					
D3. Engagement and Impact	Teaching					
	Public engagement					
	Enterprise					
	Policy					
	Society and culture					
	Global citizenship					

Supporting materials 9.5. Identifying target areas for skill development

The Vitae Researcher Development Framework (2011) contains 63 descriptors, all of which could offer potential development targets for a neophyte researcher. To ensure best use of my time in improving my levels of research competency I evaluated the importance of improving in each descriptor of the VRDF. I considering the importance of each descriptor in the context of the methodology of each planned study, my objectives for the overall body of work that will form my professional doctorate and my research related career objectives. I did this by rating the importance of each descriptor against the modified 5-point Likert scales shown below. I scored the responses from 5 for a 'strongly agree to a 1 for a 'strongly disagree'. I considered all descriptors with a combined score of >7 to be of importance to improving my current research competency.

Question 1

To what extent do you believe an improvement in this descriptor (based on the phases set out by the VRDF) will improve your ability to carry out your proposed methodologies?

- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

Question 2

To what extent do you believe an improvement in this descriptor (based on the phases set out by the VRDF) will improve your ability to fulfil the objectives of your study and/or help you achieve your objectives for your professional doctorate?

- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

Results

Domain	Descriptor	Question 1	Question 2	Total
A	Subject knowledge	5	5	10
	Research methods: theoretical knowledge	5	4	9
	Research methods: practical application	5	5	10
	Information seeking	4	4	8
	Information literacy and management	4	4	8
	Languages	4	4	8
	Academic literacy and numeracy	4	4	8
	Analysing	4	4	8
	Synthesising	4	4	8
	Critical thinking	4	4	8
	Evaluating	4	4	8
	Problem solving	4	4	8
	Inquiring mind	3	3	6
	Intellectual insight	3	4	7
	Innovation	3	3	6
	Argument construction	3	4	7
	Intellectual risk	3	4	7
B	Enthusiasm	3	3	6
	Perseverance	3	3	6
	Integrity	3	3	6
	Self-confidence	3	3	6
	Self-reflection	5	5	10
	Responsibility	3	3	6
	Preparation and prioritisation	4	4	8
	Commitment to research	4	4	8
	Time management	5	4	9
	Responsiveness to change	4	4	8
	Work life balance	4	4	8
	Career management	2	5	7
	Continuing professional development	3	5	8
	Responsiveness to opportunities	3	5	8
	Networking	3	5	8
	Reputation and esteem	3	5	8
C	Health and safety	4	3	7
	Ethics, principles and sustainability	4	3	7
	Legal requirements	4	3	7
	I P R and copyright	3	4	7
	Respect and confidentiality	3	3	6
	Attribution and co-authorship	3	4	7
	Appropriate practice	3	4	7
	Research strategy	4	3	7
	Project planning and delivery	4	4	8
	Risk management	3	3	6
	Income and funding generation	1	1	2
	Financial management	1	1	2
	Infrastructure and resources	1	1	2
D	Collegiality	2	3	5
	Team working	3	3	6
	People management	2	3	5
	Supervision	2	3	5
	Mentoring	2	3	5
	Influence and leadership	3	3	6
	Collaboration	3	3	6
	Equality and diversity	2	2	4
	Communication methods	3	4	7
	Communication media	3	4	7
	Publication	3	4	7
	Teaching	1	2	3
	Public engagement	3	4	7
	Enterprise	1	3	4
	Policy	1	1	2
	Society and culture	2	3	5
	Global citizenship	2	3	5

Supporting materials 9.6. Examples of the process used to assess current research competency using the Vitae research Development Framework (VRDF).

The text below shows examples of the process I went through to score my current level of competency against the precise wording of each phase of every descriptor from the VRDF. I have picked 3 examples showing the evidence I presented to justify the classification I assigned to my competency. All of the phase examples given below are from descriptors from within domain A classified as having high project importance (>4 on Likert Scale- see appendix ?).

Descriptions of the requirements of each phase are written in black and are exactly as given in the VRDF (2011). Evidence supporting my assessment of my current competency level is written in red. I have only provided evidence up to the first phase of the descriptor that I was unable to satisfy.

A1.1. Subject knowledge.

Phase 1. Four stages:

1. Has, at least, core knowledge and basic understanding of key concepts, issues and history of thought.
   I achieve this based on 16-year professional career having provided good experience with a specific athlete population. Consistent reading and multi-disciplinary meetings during this time have provided some knowledge base.
2. Knows of recent advances within own research area and in related areas.
   Recent reading around areas including up to date conceptualizations of ageing. Example of knowledge of recent advances in related area: An awareness of the scope of epigenetic investigation to understand individual trajectories of ageing.
3. Is working towards making an original contribution to knowledge.
   I have done the preliminary design of a series of investigations designed to add to the applied knowledge base.
4. Is developing a broader awareness of international and non-academic aspects of knowledge creation.
   My early reading has exposed me to some international research groups who have investigated changes in performance with age in some of the major American sports. The introductory aspects of my professional doctorate have raised my awareness of knowledge creating and the way in which non-academic streams can add information to that provided by more traditional academic mechanisms.

Phase 2 and Phase 3.
Three stages:

1. Develops detailed and thorough knowledge/understanding of own and related subject areas, and becomes familiar with associated areas in other disciplines/research areas.
   Based on the scope of the VRDF my knowledge is not at sufficiently detailed level to satisfy this descriptor. I do not have a deep knowledge of muscle physiology which has to be considered a related subject area.
2. Demonstrates link between own research and real-world affairs.
   I cannot do this beyond a very basic level.
3. Situates knowledge in international context.
   My knowledge of the subject area and international generation of related information is not sufficient to put my research in to an international context.

Phase classification: This means I achieve phase 1 of the subject knowledge descriptor but cannot be said to be working at phase 2.

A1.2. Research methods: theoretical knowledge.
Phase 1.
Two stages:

1. Understands relevant research methodologies and techniques and their appropriate application within own research area.
   Having completed BSc (Hons) and Msc by research I have an understanding of some relevant methodologies and techniques and their application to my investigation design.
2. Justifies the principles and experimental techniques used in own research.
   I think the above experience along with data handling projects done at work and research to understand the scope of such technique means I can explain the principles behind techniques I use and justify their usage. For example smallest worthwhile change justified as a measure to assess a group of players jump changes where the study population was too small for null hypothesis testing to have sufficient statistical power.

Phase 2.
One stage:

1. Appreciates the value of a range of standards and methods/techniques for information/data collection and analysis; assesses and demonstrates usefulness and validity of information/data in the context of a specific problem/question.
   I do not have a sufficient depth of knowledge to appreciate the value of range of methods. I also do not think I am at a level where I can robustly examine the usefulness/validity of the data I have in the context of the investigation I wish to carry out and the requirements of professional doctoral study.

Phase classification: This means I achieve phase 1 of the subject knowledge descriptor but cannot be said to be working at phase

A1.3. Research methods: practical application.

Phase 1.

Two stages:

1. Uses a range of research methods linked to study area; documents own activity.
   From previous academic work and work-based investigations, I am able to use a range of research methods and have documented the process I went through.
2. Shows growing competence in own subject area and is developing awareness of alternative methods and analysis techniques.
   Through reading around the subject area and through the supervisory process I have gained greater understanding of techniques used in the study area and have become aware of alternative analysis techniques particularly as they relate to single subject study designs.

Phase 2.

Two stages:

1. Develops research approach and applies a range of appropriate methods and techniques with confidence.
   My current levels of knowledge mean I am not especially confident in the application of research methods. I feel my underpinning knowledge is improving but is not at a level where I have high confidence.
2. Documents and evaluates research processes, using statistics where appropriate.
   I do not think I have enough knowledge to robustly justify the techniques I used and use statistics to confirm my choice of methodologies.

Phase classification: This means I achieve phase 1 of the subject knowledge descriptor but cannot be said to be working at phase 2.

Supporting materials 9.7. Career and Education Timeline (Produced 2020).

Bath Rugby. 2004-2009
Intern (year 1)
Head of Academy S&C
Assistant First Team S&C Coach

British Canoeing. 2009-2012
Canoe Athlete
S&C contractor with Derby Cricket, EIS and Canoe England.

Bedford Blues. 2012-2014
First Team S&C Coach

Saracens. 2014-2018
Head of Academy S&C

P3 Sport Science. 2018-2020
Lead Performance Coach
Atlanta Facility

Geelong Cats. 2020-
Rehab & Conditioning Coach

University of Bath. 2002-2007
BSc (Hons) Sport & Exercise Science

University of Bedfordshire. 2012-2015
MSc (By research)

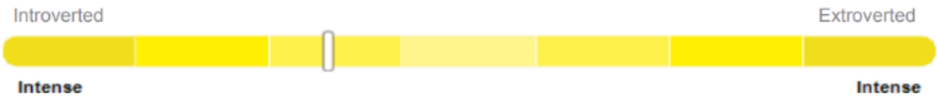
University of Bedfordshire. 2020-
Professional Doctorate

Supporting materials 9.8. Personal Development Analysis: Behavioural Report Findings Summary

Risk Axis

Is an individual who is generally polite and kind. Prefers not to accept risks and will only be situationally competitive. Is motivated by environments and situations free of tension and confrontation as they will confront only when they feel it is essential.

Extroversion Axis



Is a somewhat reserved, discreet individual, with few words. Has no great difficulty interacting and relating with others. Can work individually or in small groups.

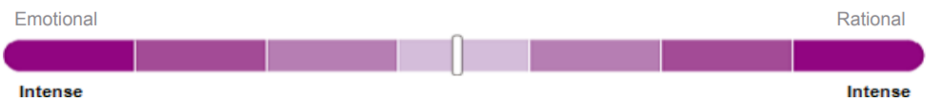
Patience Axis

Is an individual who is generally alert. Can respond positively to changes and can also tolerate a certain level of routine. Although they do enjoy variety and change, these should be planned.

Conformity to Norms Axis

Is a dependent individual with a strong adherence to standards. Is open and accepting of the ideas of others. Generally relies on others to provide direction and set the standards. Is detail-oriented, perfectionistic and precise. Needs guidance from others and is easy to lead. Is obedient, courteous and cooperative. The individual may occasionally be perceived by others as submissive, defensive or extremely adaptable. Seeks others to provide direction and set standards.

Self-Control Axis



Is a situational individual as far as the axis of Self-Control goes. Does not display a clearly emotional or clearly rational inclination. This implies that, depending on each situation, they could eventually be somewhat rational, cold and calculating as well as more sensitive and involved from the emotional aspect.

Supporting materials 9.9. Self-Audit Findings

Self-Audit Finding	Resulting Training Actions
My subject knowledge is not at the required level. • My aim is to work towards having a deep and holistic understanding of what is known around my study area. • Reduce territorialization of knowledge.	• A systematic literature search and dedicated block of reading. • Getting in touch with other practitioners who may have good insight into the area to sample additional thoughts.
I currently lack sufficient theoretical and applied knowledge of research methods. • Need to understand, be able to justify usage and apply a broader range of relevant research methods/analysis techniques.	• Planned block of reading and investigating potentially relevant research methods. • Continued R learning and practice (including tutored sessions).
I wish to develop improved information seeking and management skills that can help overall efficiency and quality of my work.	• I am going to do one of the library courses relating to information seeking and management. • I will use End Note to help with referencing. I will plan extra time around my literature search as I become more competent with it.
I need to develop my academic literacy and numeracy to a higher level.	• I think supervised academic process will organically lead to development in these areas. • I will not formally plan the development of these qualities but will re-evaluate my performance in these areas to ensure improvement is taking place.
Improvement in a range of cognitive abilities is required (as described by domain A2 of VRDF). • These are analysing, synthesising, critical thinking, problem solving and evaluating.	• I think supervised academic process will organically lead to development in these areas. • I will not formally plan the development of these qualities but will re-evaluate my performance in these areas to ensure improvement is taking place.
Improvement in a range of abilities related to creativity is required (as described by domain A3 of VRDF). • These are Inquiring mind, intellectual insight, innovation, argument construction, intellectual risk.	• I think supervised academic process will organically lead to development in these areas. • I will not formally plan the development of these qualities but will re-evaluate my performance in these areas to ensure improvement is taking place.
Improving my ability to use self-reflection will help me to make continual improvements in a variety of areas over the course of the professional doctorate.	• I will read around the area of effective self-reflection and speak to supervisors and mentors about techniques that work well for them.

	• I am going to try some different approaches over year 1 to find best fit for me.
I wish to develop Improved time management and project planning skills to help with overall efficiency and sustainability of research work alongside my job.	• I will read around some areas of project management, talk to mentors and investigate library courses. • I am going to regularly reflect on my performance in this area.
My ability to manage my career is not at the level required to achieve what I would like to do following my professional doctorate studies. • I would like to be able to develop a professional role that includes involvement in research. • I aim to be at a level where I can develop the careers of others.	• I think aspects of developing a research strand to my career (or at least the potential to do so) will progress over the course of my studies with dissemination of results. • Improvements in self-reflection and seeking feedback as well as expanding my network (as covered in other areas) will help to develop my competency in terms of career management.
I currently do not have a useful network to help develop the quality of my research.	• Over the course of my studies, I need to be responsive to the need to develop a network with research utility.
I currently have no reputation or esteem as a researcher.	• I will not plan to develop this per se. I think by ensuring commitment to other aspects of the training plan I will arrive at a point where I can consider the active development of this in future.
My current knowledge of health and safety, ethical, and legal aspects of research as well as my understanding of co-authorship and confidentiality considerations is not up to date.	• I will use the library to find out what is needed in these areas. • Some of these are also dealt with by upcoming work in the taught elements of the professional doctorate.
My ability to communicate findings is not sufficiently developed.	• In preparation for the dissemination of my work I will plan to develop my ability to articulate complex aspects of my project in an accessible manner. • Read a book and watch some videos on public speaking and begin practicing and reflecting.
I am not confident with a broad range of communications media.	• In preparation for the dissemination of my work I will plan to learn to use additional communications tools.

Appendix 9.2

Table 9.2. Countermovement jump variable definitions.

Variable	Description
Jump height (cm)	Maximum jump height calculated using flight-time method.
FTCT	Flight time divided by contraction time.
CM depth (cm)	Maximum displacement of centre of mass in the eccentric phase.
Contraction time (s)	Time between the initiation of movement[a] and take-off.
Eccentric duration (s)	Time between initiation of movement [a] and zero velocity.
Concentric duration (s)	Time interval between zero velocity (end of eccentric phase) and take-off.
Net ecc yielding Impulse ($N \cdot s^{-1}$)	Force multiplied by time above bodyweight between time points of minimum force and greatest negative velocity.
Net ecc decel Impulse ($N \cdot s^{-1}$)	Force multiplied by time above bodyweight between the time points of greatest negative velocity and zero velocity.
Net con impulse ($N \cdot s^{-1}$)	Force produced during the concentric phase multiplied by the time over which it was produced, given relative to body mass.
Net con impulse 100 ($N \cdot s^{1}$)	Average force produced during first 100ms of the concentric phase multiplied by 100ms
Ecc mean force ($N \cdot kg^{-1}$)	Average force produced between initiation of downward movement [a] and zero velocity.
Con mean force ($N \cdot kg^{-1}$)	Average force produced between the time point of zero velocity and take-off.
Ecc peak force ($N \cdot kg^{-1}$)	Largest negative force recorded in the eccentric phase relative to body mass.
Con peak force ($N \cdot kg^{-1}$)	Largest force recorded during the concentric phase relative to body mass.
Force at con peak power ($N \cdot kg^{-1}$)	Force recorded at the instance of peak power during the concentric phase.

Ecc peak velocity ($m \cdot s^{-1}$)	Maximum negative velocity of the centre of mass during eccentric phase.
Con peak velocity ($m \cdot s^{-1}$)	Maximum velocity of centre of mass during the upward, concentric phase.
Con peak power ($W \cdot kg^{-1}$)	Maximum power achieved during the upward, concentric phase.
Ecc peak power ($W \cdot kg^{-1}$)	Maximum value for negative power recorded during the eccentric phase.
Ecc RFD ($N \cdot s^{-1} \cdot kg^{-1}$)	Average rate of force development during the eccentric phase.
Con Power Slope ($W \cdot s^{-1} \cdot kg^{-1}$)	Average rate of increase in power during the concentric phase.

FTCT: flight time: contraction time, CM: countermovement, Ecc: eccentric, Decel: deceleration, Con: concentric.

[a] Initiation of movement is calculated from initial detection of force 20N below body mass.

Definitions based on Cohen et al., 2020 and Harper et al., 2021.

Appendix 9.3

Table 9.3: CLD longevity determinants: summary descriptions

Summary/grouped variable	Specific variables/SME descriptors
Player quality	Importance of player within system. Perception of player quality based on previous teams or development system. Player's perceived level of talent or potential. Resources given up acquiring player (based on perceptions of player's potential impact).
Quality of player performance	Previous career performance record. Quality of recent performances. Career achievements/reputation. Player's statistical record.
Physical demand of playing role	Physical requirements of playing position. Extent success in position requires specific physical qualities to be at an elite level. Team game style demand of playing position. Player workload. Player contact load. Potential for role to be adjusted.
Ability to fulfil physical demands	Physical/physiological qualities required to play specific role. Ability to maintain physical ability to meet requirements of team tactical approach. Reliance of game style on physical traits/abilities. Game trends (coaching/tactical). Capacity to complete (impactful) training. Capacity to perform in frequent fixtures. Club willingness to manage player. Organisational/club training style. Organisational/club training culture. Commitment to national team
Ability to fulfil tactical demands	Skillset and game understanding required to play a specific position. Extent to which a player has skills to move to a different less physically demanding role within a team system. Player's ability to use tactical aspects of play to overcome weaknesses and out perform a variety of opponents. Reflects the extent to which a player can find solutions to diminishing physical qualities.
Playing time	Availability of first team playing opportunity. Extent to which player can establish key role. Opportunity to prove ability. Exposure to first team game play. Exposure to shop window of first team match play.

	Building trust/relationships with teammates/coaches in games. Length of time player/mins player is required to contribute. Requirement for player to play dense fixture blocks/short turnarounds. Playing time allows avoidance of non-match day training extras.
Coach's value of player	Coach/selectors level of trust in player. Coach perception of player's importance. Coach's belief in players ability to influence group. Extent to which coach wants player to remain at club. Extent to which systems are built around individual skillset. Extent to which the coach believes player can contribute to an organisational/team objective (winning trophies, developing others/culture, appreciating in value, increasing chances of beating relegation). Coach perception of player's potential to improve. Whilst separate from organisational confidence in player ability, this can be heavily influenced by it. In cases where coaches are brought in to develop a specific group of players or to run a specific game style by a powerful executive group it is likely the coach will heavily value players the organisation has high confidence in.
Contract length	Length of time club is financially committed to a player. Extent to which club sees player as part of their long-term plans. Extent to which player represents value to the club. Extent to which the player/player's contract helps the club achieve their objectives. Perceived benefit of player towards team/organisational targets. Potential for player value to appreciate. Timing of injury relative to contract end date. Includes contextual factors: Club's desire to sell players, Club financial strategy.
Organisational financial capacity	Wealth of ownership. Financial status of club. Financial health of sport. Extent which club can/will spend in service of their objectives. Contextual factors influencing spending: Sport financial regulations/contract law/CBA rules.
Squad quality	Quality of players available to selectors. Depth of players available to selectors.

	Competition for playing places. Extent to which team must accommodate deficiencies/baggage of perceived high ability players. Team performance record. Ability of squad personnel to cover for player weakness.
Injury toll	Accumulated damage and/or compromises in movement quality resulting from injury history. Extent to which athleticism/physical confidence has eroded/decreased/changed over career. Risk of future injuries. Player genetic/innate robustness. Quality of rehab.
Player coping capacity	Player coping skills. Player ability to handle change. Player emotional intelligence/social skill. Player social support. Player self-awareness.
Quality of player self-management and problem solving	Player psychological/emotional self-management. Player ability to control negative feelings. Player ability to control behaviour. Player ability to accept feedback. Player ability to remain a good teammate in face of difficulty. Player ability to continue to enjoy positive aspects of professional sport and not be adversely impacted by the negative. Player ability to evolve/adapt playing style or be open to doing so. Ability to adapt playing style/communication to get the most from less experienced or highly gifted players. Player understanding of individual preparation needs. Player understanding of individual lifestyle needs. Player capacity to function in a suboptimal state. Player emotional intelligence/social skill.
Player leadership	Player ability to influence a group. Player ability to keep group on task during games. Player ability to manage in-game situations for less experienced teammates. Player presence in locker room. Player ability to help coaching staff deliver message.
Player mental condition	Player mental health. Player enthusiasm for club mission. Desire/ability to live athlete lifestyle. Understanding of team systems, expectations. Ability to handle setbacks (injury, media scrutiny, non-selection).

	Ability to retain love/enjoyment of some aspect of game.
Player physical condition	Physical and physiological profile of player. Ability to cope with hardest physical aspects of match play. Capacity to complete large volumes of match play over a season. Capacity to complete impactful training. Player genetic/innate robustness (resistance to injury). Toll of injuries. Risk of future injuries. Speed of recovery post-game.
Quality of player care	Quality of S&C/medical support. Quality of rehab. Player care required/mandated by league. Organisational willingness/ability to accommodate individual needs.
Quality of coaching & performance staff	Quality of practitioners. Technical coaching competence of staff. Ability of staff to connect to players. Ability of staff to collaborate.
Organisational confidence in player's ability	Perceived potential of player to contribute to organisation's future aims. Extent to which the player can help club realise aims. Importance of player within system. Scarcity of alternative similar players. Player injury history. Note: Although distinct from Coach value of player, organisational confidence in player could be strongly linked to/influenced by coach value of player. This is likely where a coach has highly influential position within fabric of whole organisational decision-making structure.
Availability of alternative players	Cost/scarcity of similar players. Number of players who can likely perform player's role. Quality of club player development. Quality of club scouting/recruitment.
Player contentment	Extent to which environment supports player objectives. Player social support. Player enjoyment of environment. Player feeling of support/reciprocal loyalty to organisation.
Player motivation	Player's drive for continued success. Extent to which player has achieved their career goals. Financial status of player.

	Player social support. Player interest in non-playing opportunities. Willingness to drop to a lower league. Willingness to accept team friendly contracts. Willingness to move clubs.
Quality of club strategy and management	Quality of club culture. Extent to which club's direction is likely to bring about success. Quality of organisational culture and governance. Continuity of systems and philosophy. Ability to retain and develop staff and players. Quality of club development pathways.
Player development	Extent to which developmental experiences equipped player with skills for longevity. Extent to which player developed foundational skills and game knowledge. Extent to which player developed habits and routines beneficial to their journey. Extent to which player was able to develop skills related to problem solving/handling adversity. Player understanding of game/industry/self. A player's development will be related to the quality of the development system the player was involved with, investment into player's development pathway and the quality of practitioners involved.
Team success	Success in current team group. Influences rate of turnover/continuity/desire to preserve cultural influence. Influences extent to which key stakeholders wish to retain players. Likely related to stability of club management.

Appendix 9.4

Interview guide: determinants of career longevity in professional team sports

Pre-Interview Considerations

- *Check their current team/season point*
- *Have I received consent form and subject information form?*

Section A: Initial business: formalities/set up interview

- Thanks (for your time/agreeing for interview- very excited to get your views).
- Before we start, I'll explain what this study is about and the types of things I'm going to ask you.

Section B: Background information (Presentation of systems dynamics slides and outlining of study boundaries).

- What the study is about.
- Show some study 1 data (or pilot decay graph).
- Introduction to systems thinking (3 slides).
- Aims of the study.
- Frame what I mean by professional (covers multiple levels, important to be specific).

Section C: How I want them to approach to answering questions

- Confidentiality/anonymised presentation of results.
- Answers should be about specific players/examples (don't have to give names, if they do remains confidential).
- Think about how different influencing factors interact to determine career longevity and trajectory.
- Study concept/what will happen: Idea is you discuss specific examples and how you see it. Myself and some of the researchers I work with will later pull themes out and try to find commonalities.

Section C: Start of recording

- Is it ok to record this interview? (Begin recording).
- Thanks for letting me record. Confidentiality reminder. Talk/no wrong answers.

Ice breaker question:

- Something descriptive about their overall career/aspect of their role that relates to the study (get them talking).

Section D: Launch question:

'I want you to think about your career/a player who had a really long, playing career in your sport: Why do you think you/they were able to play as long as they did?'

- *Talk to me about some of the factors that may have allowed them to play (professionally at highest level) for as long as they did.*
- *If this person had a short career: Why do you think your career came to an end when it did? Talk to me about some of the factors that may explain that.*
- *From here the aim is to move into the domain specific questions.*

Section E: Relaunch questions (For use if/when conversation dries up or to pivot to a new area)
'I'd like you to think of player who had a different type of career. If we think of a player who was only able to be at the top level for a short period of time, why do you think their career didn't last longer?'

- If further relaunches are needed: Ask them to think about different factors leading to players having either medium length vs long careers or medium vs short: what was different?
- (These maybe useful at the end of the interview to generate further information).

Section F: Questions related to specific domains with potential influence on career longevity
This may come in any order that feels natural/it may be naturally segued to.

Physiology related
Main questions:

- *Do you think the player(s) declined physically towards end vs best years of their career?*
- *To what extent do you think that player changed or evolved their game style as they got older?*

Potential follow up questions

- *How did that manifest?*
- *Why do you think that happened? What factors do you think caused that decline?*
- *What did the player do to try to minimise the decline?*
- *Did the player work hard to minimise the extent of age-related changes? What did they do?*
- *Do you think other players do that as well?*
- *Did they decline less than those that had shorter careers?*
- *What did they do? Why? Conscious decision?*
- *Did how the player trained influence their career length?*
- *Did the player change the way they trained as they got older?*

Game style related
Main question:

- *Do you think the way that player played affected how long his/her career lasted?*

Potential follow up questions

- *To what extent do you think that player changed or evolved their game style as they got older? What did they do? Why? Conscious decision?*
- *Did their role in the team change as they got older?*
- *How did their role fit within the way the team/manager/coach wanted to play?*

Organisation related
Main questions:

- *Is it fair to say this guy was highly valued by organisation? And if so, why do think that was? How did that effect career length?*
- *Why did coaches like this player?*
- *How did this player fit into how the organisation was going after it's objectives?*
- *(For shorter career guys) Why do you think the organisation didn't give this player more opportunities?*

Potential follow up questions

- *What did the player bring to the organisation? On the field? Off the field?*
- *What was the club's aim? How did the player help them towards that?*
- *What influences how much a club values a player?*

- *How important is being valued highly by an organisation for having a long career?*
- *What factors affect how much opportunity a player gets?*
- *Who (what roles) in a sporting organisation influence the extent to which a player is valued/given opportunities?*
- *What do you think effects how these people see a player?*
- *What roles do agents play in this?*
- *Do you think the club's ambitions/finances influenced that player's career?*
- *Do you think being highly valued by a sporting organisation effects how a player is managed/played/dealt with?*

Injury related

Main questions:

- *Did injuries or wear and tear from playing influence this players career in anyway?*
- *(If it hasn't come up: Link to it with: Injuries get a lot of press when it comes to career longevity).*

Potential follow up questions

- *Do you think injuries impacted how this player played? How they trained? Their enjoyment of their sports?*
- *Why do you think some players who have big injuries do manage to have long successful careers and some don't?*
- *For players who have shorter careers how do you think injuries can influence things?*
- *How much do you think the wear and tear on this player's body affected them?*

Player training management

Main questions:

- *Did the way this player trained change across their career? And if so how?*
- *(In terms of quantity, intensity, and frequency) What did this players training week look like at the end of their career vs the middle years?*

Potential follow up questions

- *Did the team change/manage the player's training towards the end of their career?*
- *(Study 4 question) What mistakes do you think organisations can make when dealing with older players?*
- *Could this player have been managed differently to get more from them?*
- *Was that player able to train with consistency throughout their career?*
- *How was the player managed by the team in later part of career?*
- *Do you think the club's management of the player helped extend the player's career or not?*

Behaviours/motivation related

Main questions:

- *What was behind the player eventually taking the decision to stop?*
- *Do you think any lifestyle factors were behind this guy wanting to finish*
- *How did the way this player lived allow him/her to have a long career?*

Potential follow up questions

- *What lifestyle factors do you think impacted this player's longevity?*
- *Did the player enjoy living the lifestyle of a professional athlete?*
- *How do you think the player's financial situation impacted upon the end stages of his career?*
- *When approaching retirement were they excited to pursue something outside of the sport?*
- *Is motivation important in determining career length?*

- *Did the player have high levels of motivation for their work over the course of their career?*
- *Is this unusual? Why do you think some guys don't do this?*
- *Would you say that the player enjoyed training? Is that an important determinant of career length?*

Alternative/multi-area questions

- Do you think this situation is common amongst other players? (check relatability of answer to wider population).
- Is that the case for other players in a similar situation?
- Are most of the players with this sport/type of career similar?
- Do you think the important thing is how good the player is or how good the club think the player is?
- How important is perceived potential?
- Did the players off pitch skills help keep them around a bit longer?
- Do you think the club's ambitions/finances influenced this player's career?
- What could have been done differently to help extend this players career?

Final question: Is there anything else you think has a determining influence on player's career length/longevity at the elite level in X sport?

CHAPTER TEN

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