Team Performance Indicators Which Differentiate Between Winning and Losing in Elite Gaelic Football

Declan Gamble, BSc, MSc

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Declan Gamble, BSc, MSc

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Supervisors

Prof. Niall M. Moyna[1] and Dr. Andrew McCarren[2]

1 School of Health and Human Performance

2 School of Computing

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of PhD is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: D. Gamble **ID No.**12210040 **Date** 27/7/20

Declan Gamble (PhD candidate)

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Publications

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AIC	All-Ireland Championship
AICSFF	All-Ireland Championship semi-finals and finals
AFL	Australian Football League
ANOVA	Analysis of variance
AU	Arbitrary units
BBC	British Broadcasting Corporation
CHAID	Chi-squared automatic interaction detection
CPU	Central processing unit
DA	Discriminant analysis
DF	Discriminant function
DVD	Digital versatile disk
ES	Effect size
FB	Full back
FF	Full forward
FG	Full game
GAA	Gaelic Athletic Association
GEE	General estimating equations
GPS	Global positioning system
GLM	Generalised linear model
GLONASS	GLObal NAvigation satellite system (Russian)
GNSS	Global navigation satellite system
H	Half
HB	Half back
HDOP	Horizontal dilution of precision
HF	Half forward
HIR	High-intensity running
HR	Heart rate

ICC	Intraclass correlation coefficient
INC.	Incorporated
KMO	Kaiser-Meyer-Olkin
KPI	Key performance indicator
L	Loser
LIA	Low-intensity activity
LINR	Linear regression
LOOC	Leave-one-out cross-validation
LOGR	Logistic regression
MF	Midfield
MLM	Mixed linear model
NFL	National Football League
OLS	Ordinary least squares
OT	Opposition team
P	Percentile
PA	Performance analysis
PCA	Principal component analysis
PI	Performance indicator (denoting team unless otherwise stated)
Q	Quarter
QIC	Quasi likelihood under independence model criterion
RPE	Ratings of perceived exertion
RT	Reference team
RTÉ	Raidió Teilifís Éireann
SC	Structural coefficient
SE	Standard error
SPSS	Statistical product and service solutions
TG4	Teilifís Gaeilge Ceathair
U	Under
UEFA	Union of European football associations

USA	United States of America
VS	Versus
VHIR	Very high-intensity running
W	Winner
Z	Zone

Abstract

Declan Gamble

Team performance indicators which differentiate between winning and losing in elite Gaelic football

The primary aim of the PhD was to identify the team technical, tactical and physical performance indicators that differentiated winners from losers during full games, halves and quarters in elite Gaelic football. A secondary aim was to examine temporal changes in performance between the first and second half of play and from the first to the fourth quarter. Video analysis was used to examine 83 technical and tactical performance indicators from 13 teams, during 16 National Football League (Division 1) and 10 All-Ireland Championship games, throughout 2014–2015. This sample included 22 games involving a reference team and their opposition. To enable benchmarking, the sample also incorporated an additional 4 games, involving teams competing in the All-Ireland Championship semi-finals and finals from 2014-2015. Player tracking technology was used to examine 11 physical performance indicators in the reference team only. Data was analysed using univariate and multivariate statistics including: principal component analysis, discriminant analysis, logistic regression and general estimating equations. Novel performance indicators were found to differentiate winners from losers in full games (defensive-counterattacking), halves (midfield-counterattacking, possession, low-press efficiency and tackle pressure) and quarters (midfield-counterattacking, possession, offensive dead ball efficiency and high-press efficiency). Temporal analysis revealed that winners were more effective at retaining possession. Conversely, losers experienced greater declines in possession characteristics and passing profiles than winners. In the reference team, temporal changes in performance were more pronounced when examined by quarter periods than by half. Physical performance levels were maintained across halves and quarters in games that were won, compared to declines in performance observed in games lost. This thesis has highlighted the team performance indicators that distinguished between winning and losing and extended knowledge of what it takes to win. Coaches and practitioners can reference the winning profiles presented, to enhance current practice and refine preparation programmes and match day strategies.

FOREWARD

To identify variables that differentiated between winning and losing in elite Gaelic football, this research project was initially designed to investigate the physical, technical and tactical performance indicators in a reference team and their opposition during the National Football League and All-Ireland Championship throughout one competitive season. Following approval to trial the player tracking devices being granted by the Gaelic Athletic Association (Appendix A), the rationale for the study along with a description of the procedures and an invitation to participate, was emailed to the county secretaries of the two Ulster teams due to compete in Division 1 of the league in 2014, Derry and Tyrone (Appendix A). An Ulster-based team was required as the research project was funded and resourced by Sport Northern Ireland. The management team of Tyrone declined the invitation to participate in the study as they were already using a player tracking system, whereas Derry accepted the offer to be involved and hence were established as the reference team. The rationale for the study along with a description of the procedures and an invitation to participate was then emailed to the county secretaries of all of the teams scheduled to compete against Derry during the pre-season McKenna Cup competition (Appendix B) and in the league (Appendix A) in 2014. Although, two opposition teams agreed to participate in the McKenna Cup pilot study, unfortunately, none of the opposition teams competing against Derry in the league agreed to participate, with some citing historical agreements with other player tracking companies as a reason for not engaging. Although, the technical and tactical performance indicators from both Derry and their opposition teams could be examined through video analysis, evaluation of physical performance was subsequently limited to Derry only.

Having been promoted from Division 2 the previous year, the Derry management team targeted a positive start to the league in 2014 and progressed their physical preparation and training programme accordingly. Derry performed well in the league and finished second in the table behind Cork (Appendix C). Derry defeated Mayo in the league semi-final but then lost to Dublin in the final. Although Derry played in 9 league games, they only contested 2 championship games as they were eliminated from the quarter-final of the ensuing Ulster Championship by Donegal and then un-expectantly lost to Longford, a Division 4 team, in the first round of the All-Ireland qualifiers. Therefore, to increase the sample of games, the research project continued with Derry for a second season. The disappointment of the limited championship experience in 2014 provided motivation for the management team to extend their championship campaign in 2015. The league was not prioritised to the same extent as it was the previous year and this contributed to Derry finishing bottom of the table and being relegated back to Division 2 (Appendix C). In the ensuing Ulster Championship quarter-final, Derry defeated Down, but then lost to Donegal in the semi-final. Derry then overcame Wexford in the second round of the qualifiers, but then lost to Galway in the third round. This resulted in a further 7 league and 4 championship games being included in the study, providing a sample of 22 games. To assist with benchmarking and analysis of performance at the highest levels of competition, the sample also included an additional 4 games, involving teams competing in the All-Ireland Championship semi-finals and finals from 2014-2015. In total, 26 games were included in the research analysis.

It was initially anticipated that ball tracking would be incorporated to assist with possession chain analyses, however, although sensors similar to those used in Australian football were fitted to 3 Gaelic footballs, the instruments were not sufficiently durable and unfortunately detached from the balls during trials, eliminating this component of analysis from the study. As the research evolved, the focus of the analysis remained on team performance and therefore examination of positional differences from the significant volume of individual player profiles obtained from the match sample were not incorporated into this thesis.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Gaelic football is a popular team sport in Ireland and among the Irish diaspora around the globe (1). Elite inter-county players adopt a quasi-professional training regime (2), yet in comparison to the established professional football codes of soccer, Australian football and rugby, there is a paucity of scientific literature describing and interpreting the performance components of Gaelic football. Therefore, coaches and practitioners have traditionally relied on research from the other football codes and related areas (1,3,4) to inform their preparation programmes and performance strategies. Unfortunately, from both an academic and applied perspective, this lack of information inevitably limits current understanding and knowledge of performance indicators (PI) associated with successful and unsuccessful performance and what it takes to win in Gaelic football. Thus, to understand the factors contributing to game outcome, key indicators that define aspects of performance need to be examined (5). Accordingly, PIs differentiating winners from losers have been identified by researchers using a variety of methods and analyses in soccer (6–10), rugby (11–15), Australian football (16–19) and recently in Gaelic football (20,21).

Innovations in science and technology, along with the adoption of sport science support programmes (22) has greatly facilitated examination of different aspects of match play including characterisation of components that predicted successful performance.

Originally, practitioners used notational analysis to examine the technical, physical and tactical components of games. Pioneering time motion analysis in soccer (23–26), Australian football (27–29), rugby (30) and in Gaelic football (31,32) was facilitated by the introduction of video based technology (5). Knowledge from these early studies were progressed with the development of computer and video aided analysis systems (33), which dramatically enhances the objective analysis of team-based sports (34). More recent advances in technology, including the multiple camera method and global positioning systems (GPS) with higher time resolutions, have facilitated a more thorough study of performance (35). Player tracking devices incorporating GPS are now used extensively in team sports to provide a comprehensive evaluation of physical performance (36) and can be used along with tactical analysis and physiological data to characterise match play (37). The evolution of this technology within professional sport and its widespread accessibility has contributed to it being embraced and incorporated into Gaelic football.

Both video analysis and player tracking technology are now embedded within the preparation programmes and performance evaluation of most elite inter-county teams. Video analysis has been used to document the characteristics of successful counterattacks (38) and kick outs (39) in Gaelic football. Studies comparing differences in the technical skills of teams competing at different levels (40) and in different era's (41) have also been undertaken. Further insights have emerged through investigation of PIs specifically associated with winning (20,21) and examination of contextual factors such as the influence of home advantage on match outcome (42). Investigations using GPS devices with a sampling frequency of 4 Hz have documented the influence of team rating (43), match outcome (44), seasonal changes (45) and technical indicators (46) on running performance in Gaelic football. The same technology has been used to examine differences between the technical and physical profiles of players in higher and lower divisions (47). The additional contextual information provided in recent studies has extended previous findings related to the positional (48), duration specific (49) and temporal (50) running profiles of players.

Although studies evaluating physical performance in Gaelic football have contributed greatly to the emerging evidence base, interpretations of data (relating to distance) from investigations using player tracking systems measuring between 1 and 5 Hz, may be limited, particularly with respect to; high-intensity running, velocity measures and short linear running (36,51). GPS devices with a measurement frequency of 10 Hz are considered to be more accurate compared to lower frequency units (51). Another limitation of previous Gaelic football studies utilising the GPS technology is that the thresholds employed by the researchers to classify both high-speed and maximum-speed running (or sprinting), were lower than the zones previously established and widely used in soccer (52–55) and Australian football (56–58), which precludes direct comparisons with these sports.

1.2 Statement of the problem

Despite the expanding scientific literature base on Gaelic football, information relating to the technical, tactical and physical PIs associated with winning and losing at elite inter-county level remains limited. Consequently, there is a need to determine the PIs that distinguish between winning and losing in relation to the outcome of full games. In addition, knowledge of PIs contributing to the outcome of halves and quarters could also provide valuable insights. Further, there is currently no published research that has evaluated temporal changes in technical and tactical PIs across match periods. Is it therefore unclear whether declines in technical performance occur and whether or not temporal differences can differentiate between winners and losers? Although, declines in physical performance have previously been documented (48,50), the influence of physical performance on technical and tactical execution across halves and quarters has yet to be examined. Indeed, there is a paucity of research on overall team physical performance and activity profiles. Interpretations of findings from previous studies are often limited because specific aspects of performance have been isolated, analysed and discussed in the absence of other performance data or contextual information. Adopting a holistic view that combines analyses of different aspects of performance can potentially enhance our understanding and knowledge of the factors that contribute to successful performance and match (or period) outcome, i.e., winning.

The use of advanced microtechnology devices (i.e., 10 Hz) incorporating player tracking can potentially increase the accuracy of the data presented and lead to more valid interpretations and conclusions. Furthermore, adoption of speed zones established in the team sport literature can also enable direct comparisons between elite Gaelic football teams and players with their professional colleagues in soccer, Australian football and rugby, and provide additional evidence to support or challenge trends already established in previous Gaelic football investigations.

1.3 Study purpose

The primary purpose of this PhD research was to evaluate team technical, tactical and physical performance to identify traditional or novel component PIs that differentiated between winning and losing games and specific match periods in elite Gaelic football. A secondary objective was to determine whether temporal changes in PIs occurred between the first and second halves and from the first to the fourth quarter.

1.4 Specific aims

1) To compare differences in the technical and tactical PIs that distinguish between winning and losing in a sample of games from the National Football League (NFL; Division 1) and All-Ireland Championship (AIC) (Study 1 / Chapter 3).

2) To identify novel PIs by using data reduction techniques to combine existing PIs (Study 1 / Chapter 3 and Study 2 / Chapter 4).

3) To examine temporal changes in technical and tactical performance between the first and second half of play and from the first to the fourth quarter in winning and losing teams (Study 1 / Chapter 3).

4) To evaluate the contribution of established and novel technical and tactical PIs to winning match halves and quarters (Study 2 / Chapter 4).

5) To examine physical, technical and tactical performance in a reference team (RT) in relation to winning and losing, and evaluate temporal changes across match halves and quarters (Study 3 / Chapter 5).

1.5 Hypotheses

1) Winning teams demonstrate superior technical and tactical performance across different aspects of play including possession, offence, defence, passing and dead ball distribution profiles, in comparison to losing teams.

2) The complexity of large data sets cane be reduced, enabling novel PIs capable of distinguishing between winning and losing in relation to the outcome of full games, halves and quarters, to be identified and characterised.

3) Winning teams maintain technical and tactical performance levels across halves and quarters, whereas losing teams demonstrate declines in technical and tactical performance across these match periods.

4) In winning, the RT maintains physical, technical and tactical performance levels across full games, halves and quarters, whereas a decline in performance across these match periods is demonstrated in losing.

1.6 Thesis structure

A synopsis of the structure and content of this thesis is illustrated in Figure 1.1. The overall rationale for the PhD is outlined in Chapter 1. In Chapter 2, an overview of the

GAA and characteristics of Gaelic football is presented along with a review of the existing research (part 1). In part 2, the evolution of performance and match analysis and development of PIs within team sports is outlined. This section culminates with a critical review of relevant literature pertaining to Australian football, Gaelic football, rugby and soccer. In Chapters 3 and 4, technical and tactical PIs are examined in the RT, the opposition teams (OTs) and from teams competing in the All-Ireland Championship semi-finals and finals (AICSFF). Chapter 3 focuses on the PIs that distinguished between winners and losers across full games, whereas Chapter 4 differentiates between the winners and losers of halves and quarters. In Chapter 5, physical performance is examined, in addition to technical and tactical PIs in the RT only. For each of the Chapters 3 to 5, the rationale, aims, hypotheses, methods and results are presented. A general discussion is included in Chapter 6, incorporating interpretations of the main findings from the three studies. Chapter 7 contains the research summary and conclusions. In this chapter, the practical applications for coaches and practitioners and impact of the research is highlighted. Finally, limitations of the studies and suggestions for future research are also presented.

1.7 Summary outcome

It is envisaged that the information presented in this research project regarding the team PIs that distinguish between winners and losers, will enhance the existing scientific knowledge base of what it takes to win in elite Gaelic football and stimulate further applied investigations. The main findings also provide a reference for coaches and practitioners to enhance current practice by improving the preparation programmes and match performances of inter-county players and teams.

CHAPTER 1

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CHAPTER 2

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- **STUDY 1**
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CHAPTER 4

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  - EVALUATION OF DIFFERENCES IN TECHNICAL AND TACTICAL TEAM PERFORMANCE INDICATORS BETWEEN WINNERS AND LOSERS IN RELATION TO THE OUTCOME OF HALVES AND QUARTERS

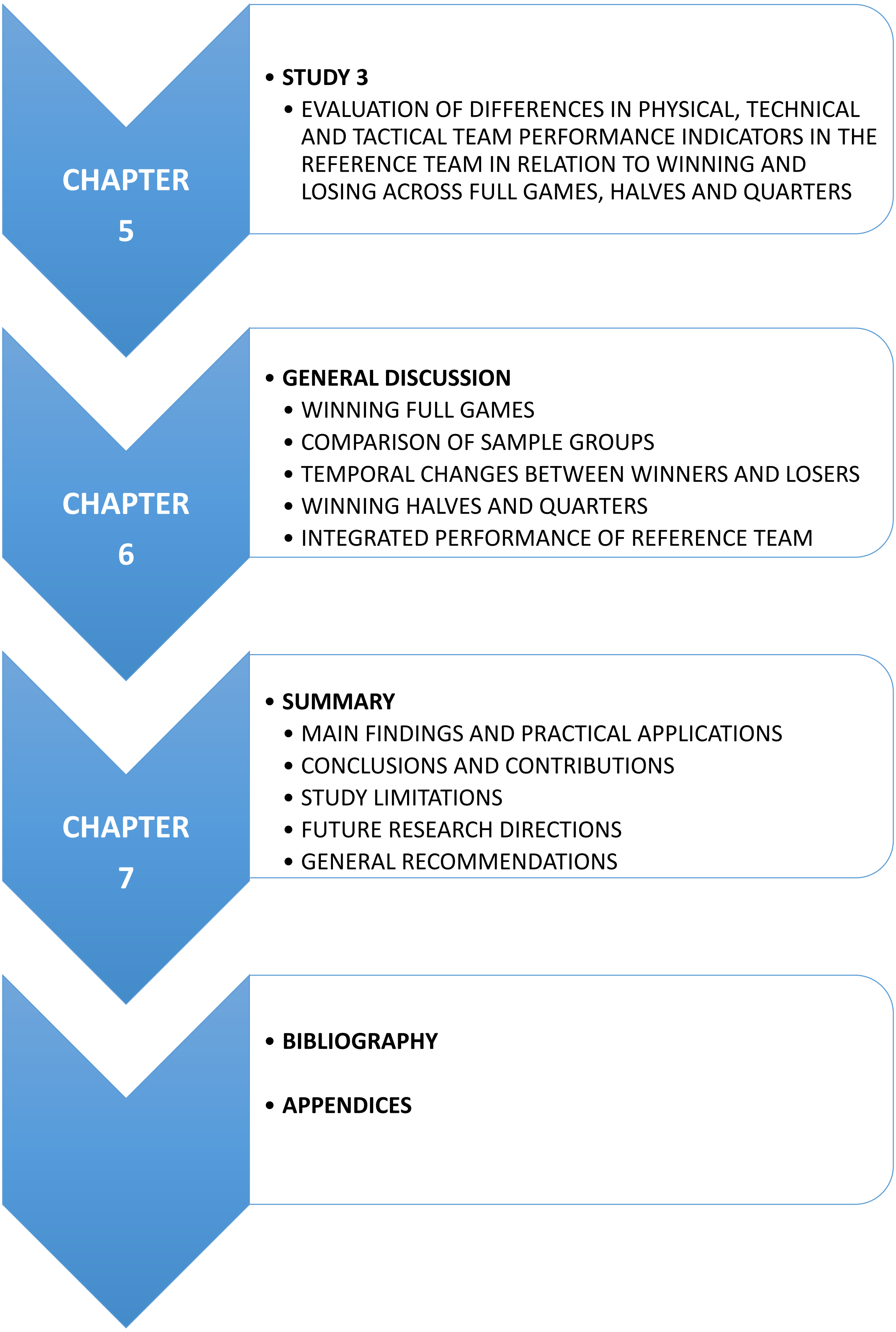


Figure 1.1 Overview of thesis structure.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

The literature review is comprised of two parts and commences with an overview of the GAA and characteristics of Gaelic football to establish the background and context for the research. Part 1 also references published studies and current knowledge regarding preparation and performance in Gaelic football. Part 2 documents the evolution of performance and match analysis and outlines the development of PIs within team sports. This section incorporates a critical review of the literature pertaining to identification of the PIs differentiating winners from losers in soccer, rugby, Australian football and Gaelic football. Part 2 culminates with the specific research opportunity for this PhD to address current knowledge gaps and previous methodological limitations. The chapter concludes with a study plan and summary of the analysis methods selected.

2.2 Part 1: Overview of the GAA and characteristics of Gaelic football

2.2.1 Background

The Gaelic Athletic Association (GAA) is Ireland's largest sporting organisation (59) and is recognised internationally as one of the great amateur sporting associations in the world (60). The GAA, which was established in 1884 to revive and nurture indigenous sports and pastimes incorporating Gaelic football, hurling, handball and rounders (60), currently supports over 2,200 community based clubs throughout the 32 counties of

Ireland (60). Gaelic games are also played by the global Irish diaspora (1), facilitated by the establishment of 400 international clubs (60). Of the four traditional sports, Gaelic football is the most popular and is second only to soccer in terms of team sports participation in Ireland (61).

Nationally, Gaelic football has a prominent media profile exemplified by spectator attendance figures for the AIC series (62), along with significant television viewing audiences, exceeding one million for both the 2019 All-Ireland final and replay (63,64). Moreover, live television streams are broadcast globally to accommodate interest from the Irish diaspora (2). Competitions are structured from under 6 (U6) to senior level. In addition to playing for a club, players can also represent their school, college, organisation, county, province or country. The latter three senior representative categories are generally recognised as indicative of elite level.

Inter-county competition formally begins in January with the NFL. The 32 teams are grouped in 4 divisions. Each team plays a minimum of 7 games, with the top 2 teams in Divisions 2, 3 and 4 contesting the league finals. In Division 1, the top 4 teams participate in semi-finals, with the winners progressing to compete in the NFL final. Although the NFL structure facilitates promotion and relegation, final league positions have had no bearing on championship rankings. However, NFL games are ideal for introducing new players and experimenting with preparation and performance strategies. Following the NFL, the major competition involves the provincial and AIC, which begin in May and conclude in August (formerly September) following the AIC final.

The four provincial championships are organised on a knockout-basis. The winners of each province progress directly to the AIC quarter-finals (Super 8s). Teams following their elimination from their provincial championship enter the AIC qualifiers. This effectively provides losing teams in the provincial championships with a second ('back door') opportunity to remain in the AIC and progress to the AIC quarter-finals if they defeat their opposition through progressive rounds of games.

2.2.2 Task and skill analysis

Gaelic football is a field invasion game, played with a round ball on a rectangular pitch measuring between 130-145 m in length and 80-90 m in width. It is a high scoring game (22) that has been described as a hybrid of Australian football, rugby and soccer (40,65). The primary objective is to gain possession of the ball and outscore the opposition (1). Success relies on a team's capacity to gain and retain possession of the ball. This requires individual players having appropriate catching, kicking and passing skill levels, along with shadowing, blocking and tackling abilities (22).

Scoring involves kicking the ball between the posts and below the crossbar for a goal (3 points) or kicking or hand passing the ball over the crossbar for 1 point. During play, possession can be gained from catching the ball or using the foot to lift the ball into the hands off the ground. Players can carry the ball when running, but need to intersperse bouncing and soloing (kicking the ball to one self before it bounces) at specific intervals (4 steps) or within a set time (3 sec). Possession is retained by passing the ball to a teammate using either the hand or foot. Other physical skills include high fielding, shoulder charging and blocking an opponent's hand or kick pass. Players can tackle (the ball) or shoulder charge an opponent in an attempt to dispossess them and regain possession. Although Gaelic football has unique characteristics, the ability to pass using either hand or foot and to tackle, demonstrates similarities with Australian football (22).

2.2.3 Team formations and positional categories

Senior inter-county games are played over two 35 min halves plus stoppage time. Teams consist of 15 players (14 outfield players and a goalkeeper) and may use up to 6 additional players from the nominated substitutes. There are 15 unique playing positions relating to defensive, midfield and attacking areas of the pitch. Figure 2.1 illustrates the traditional formation used by Gaelic football teams.

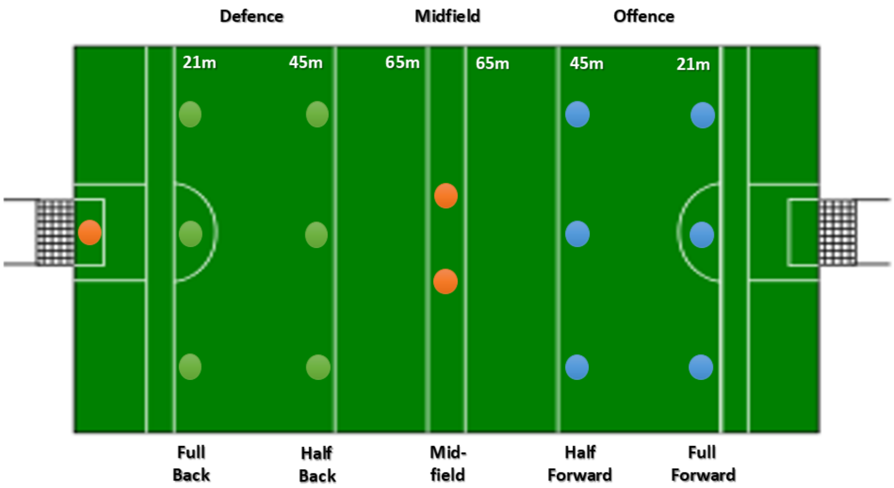


Figure 2.1 Traditional Gaelic football team formation.

Traditional team formations involved two defensive lines of three players, with each line being confronted by a trio of opposition forwards, the remaining two players from each team occupied the midfield positions (22). The defensive lines include three full backs (FB) and three half-backs (HB). The forward lines include three half forwards (HF) and three full forwards (FF). Two midfield (MF) players traditionally operated in the middle-third of the field (46,50,66,67). The first and second half of each game is initiated by a throw-in from the referee. Only the midfielders from each team are allowed to be in the middle third of the pitch for the throw-in (Figure 2.1). Generally, the FB and FF players were positioned in the attacking and defensive thirds of the field, respectively, whereas the HB, MF and HF players resided round the middle third positions, although they had a greater dispensation to roam. Modern managers and coaches have discarded the traditional rigid team configuration and have adopted formations and tactics that enable a more dynamic approach to defence and offence. For example, HF can be designated as sweepers, to provide cover to either the FB or HB players (Figure 2.2 A), and FF are sometimes used as a third MF player (Figure 2.2 B).

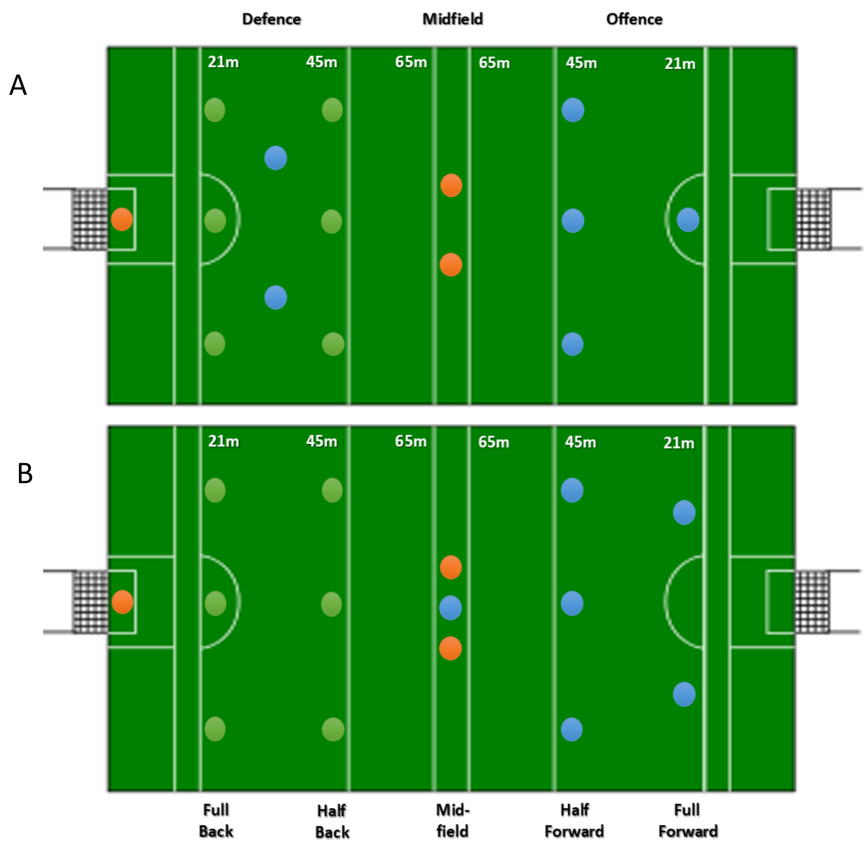


Figure 2.2 Gaelic football team formation with two forwards acting as defensive sweepers (A) or as one forward playing as a third midfielder (B).

2.2.4 Dynamics of match play

Gaelic football match play is characterised by turnovers and fast paced-transitions, as teams attack or counterattack and transfer the ball from their own defensive, midfield or attacking zones, and try to score in the opposition's defensive zone (Figure 2.1). This dynamic flow from defence to offence along with the high scoring nature of games (22) likely adds to the spectator appeal. The tactics adopted by modern Gaelic football teams, often involves withdrawing some or all of their attacking players to create a defensive screen positioned ~45 – 65 m from their goal (Figure 2.3). This replicates the evolving compact formations observed in other team sports such as soccer, Australian football and rugby, which encompass the congregation of players in defensive zones (18) and concentration of defensive actions in narrow bands around the central regions of the pitch (68). By increasing player density, compact defensive strategies enable teams to decrease the space available for the opposition to attack (18,68) (Figure 2.3).

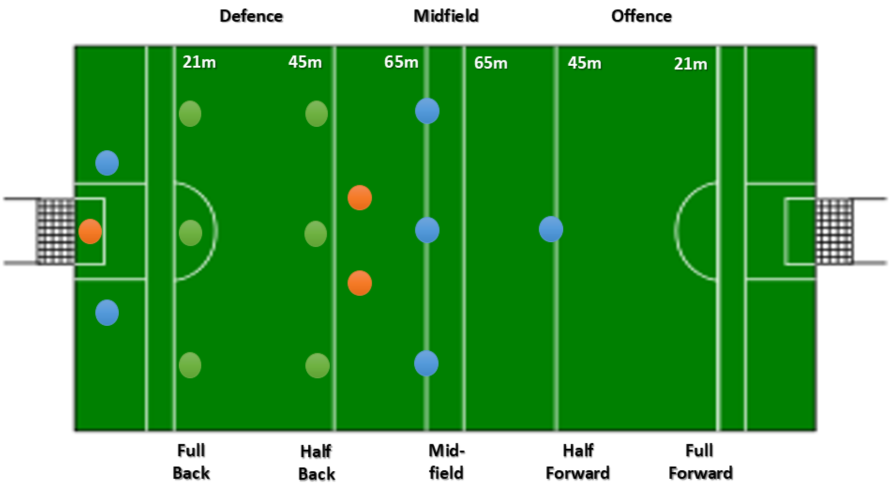


Figure 2.3 Team formation employing a defensive screen with 2 forwards adopting sweeping positions behind the full back line, 3 forwards setting a screen in midfield (65 m line), 1 forward providing an outlet in the offensive zone and 2 midfielders and 3 half backs setting a screen around the 45 m line.

2.2.5 Technical skills, tactical strategies and performance

The tactical strategies employed and technical skills demonstrated by elite Gaelic football teams have been investigated in the last 10 years. Bradley and O'Donoghue (2011) reported that the majority of successful counterattacks leading to scores in AIC games (n=15) during the 2007 and 2008 seasons originated in a team's defensive or midfield zone, commenced following a dispossession, were between 26 and 35 s in duration, involved ≥5 passes and penetrated into the opposition's 21 m defensive zone (38). Only 12% of counterattacks initiated with a kick pass resulted in a score compared to 25% when a hand pass initiated a counterattack. Hand passes likely enable a greater number of players to support the attacking play and for offensive players to initiate their penetrating runs (38).

In a subsequent historical comparison, Lynch and Carroll (2017) reported that teams competing in the AICSFF between 2014–2016, executed significantly more hand passes and less kick passes in both defence and midfield, than teams competing in finals during the 1980s (41). Interestingly, the kick pass success rate was substantially higher among contemporary players (81% vs. 55%) than those who played during the 1980s (41). This difference may be due to enhanced technical competency or to the fact that during the 1980s, the kick pass was often used to transfer the ball over a long distance with less emphasis being placed on retaining possession. There was a significant reduction in forward directed passes from the 1980s to 2014–2016 (84% vs. 63%) and a concomitant increase in both backward and lateral passes in the same period (41), suggesting that modern teams attempted to control the game by maintaining possession and 'switching' the direction of play to probe the opponent's defensive line (69). The reduction in forward kick passes combined with the increase in forward hand passes between 2014–2016 indicates that modern teams have adopted passing strategies that emphasise ball retention to create scoring opportunities that have a higher probability of success (38,41), in contrast to the more direct kick passing offensive strategy used in the 1980s (41).

In another study, Mangan et al., (2017) reported that over two-thirds (70%) of passes during NFL and AIC games between 2014 and 2016 were by hand with a retention rate of 97% (46). This is higher than the retention rate of 79% for kick passes in the same period. Less than one third of all kick outs were directed within the defensive 45 m zone. This 'short' kick out strategy resulted in a ball retention rate of 92% compared to 56% for kick outs directed beyond the 45 m line (46). The number of fouls, turnovers and tackles were aggregated into a composite PI termed 'defensive actions' (46). Although fewer defensive actions occurred in attack, than midfield or defence, there was obvious potential for teams to adopt a 'high press' (47) to regain possession and create more scoring opportunities.

When comparing Division 1 and Division 3 teams, McGahan et al., (2018) found that teams in the top division had a higher tackle count in midfield and defensive areas and had a similar number in attack, indicating that the higher standard of play was associated with more organised defensive strategies (47). Although the number of successful shots from play was similar, Division 3 teams were not exposed to the same frequency of tackles when attacking. They also had significantly more missed shots from play, perhaps due in part to inferior technical proficiency (47). Combined, the findings from these studies have provided greater insight into the offensive tactics and passing strategies used by contemporary teams.

2.2.6 Physical characteristics of play

Gaelic football is a contact sport. Players are permitted to tackle (the ball), shoulder charge an opponent, or block a hand or kick pass (22), in an attempt to dispossess them and regain possession. The physical nature of match play is increased by the convention of person-to-person marking (22) and may be exacerbated by intense tackling and high impact collisions (70). High muscularity and strength may be advantageous for players, with the latter also potentially protecting against injury (22). Muscular strength and power can also enhance the execution of other physical skills such as punt kicking and jumping to enable high fielding.

In addition to demonstrating proficiency in fundamental movement skills, players are also required to display considerable speed, strength, power and aerobic capacities. All outfield players perform repeated high-intensity activities incorporating accelerations, decelerations, jumps and changes in direction, in addition to multiple bouts of high and maximal speed running (sprinting). Speed over short distances is important and can facilitate direct contests for the ball, escaping tackles (22), evading an opponent or intercepting passes. Furthermore, the dynamic alteration in possession and transition between defence and offence during games, requires players to run repeatedly with or without the ball (22), often at high-speed.

Selected components of the physical profiles displayed by inter-county Gaelic footballers, from pre-season to in-season, are displayed in Table 2.1. When the data from these studies are combined and compared longitudinally from either ≤2005 or ≥2015, it is clear that the average modern player is slightly older (age; 24.2 vs. 25.9 y) and taller (height; 180.5 vs. 182.1 cm) but similar in body mass (84.0 vs. 84.2 kg). Estimates of aerobic capacity are only available from ≤2005, with a mean $\dot{V}O_{2max}$ of 52.9 $ml \cdot kg^{-1} \cdot min^{-1}$ being reported. Unfortunately, none of the studies listed differentiated between successful (winning) and unsuccessful (losing) players/teams or provided data from the later stages of the AIC. Knowledge of the physical profiles and fitness capacities of successful teams could provide relevant benchmarks for practitioners.

Table 2.1 Physical profile of senior inter-county players

Reference	Data Collection	Phase (month)	Players (n)	Age (year)	Height (cm)	Body Mass (kg)	$\dot{V}O_{2max}$ (ml·kg·$^{-1}$·min^{-1})
Cullen et al. (71)	2018	Pre-season (January) – In-season (September)	37	26.0 ± 4.0	181.0 ± 15.0	86.0 ± 4.0	-
Kelly and Collins (72)	≤2018	Pre-season (November) – In-season (March)	26	26.6 ± 6.0	183.5 ± 7.4	85.4 ± 10.2	-
Malone et al. (73)	≤2017	In-season (Pre-All Ireland Championship)	22	24.3 ± 6.1	180.2 ± 7.3	81.6 ± 7.5	-
Shovlin et al. (74)	2015	In-season (June)	148	26.6 ± 6.0	183.7 ± 5.9	83.6 ± 8.3	-
McIntyre (75)	≤2005	In-season (middle)	30	24.0 ± 6.0	179.0 ± 6.0	81.0 ± 9.0	48.7 ± 7.0*
Brick and O'Donoghue (76)	≤2003	Early-season (January)	25	23.6 ± 3.4	-	86.5 ± 8.6	57.0 ± 3.9*
Reeves and Collins (77)	≤2003	In-season (midway)	12	25.0 ± 3.5	182.0 ± 4.0	83.0 ± 2.8	-

Values are mean ± SD. *Estimated from progressive 20m shuttle run.

2.2.7 Activity profile of players and temporal changes in performance

The incorporation of player tracking technology (i.e., GPS devices) into the preparation programmes and performance analysis (PA) of elite Gaelic football teams has facilitated examination of the activity and running profiles of players. The average total distance covered during games ranges from ~8.2 to 8.9 km (43,48,50,71), and mean peak speeds between 8.4 m·s^{-1} (50) and 9.9 m·s^{-1} (71) have been reported. Similar to Australian football (78), the physical nature of Gaelic football and associated impacts may exacerbate high levels of fatigue and contribute to declines in physical performance, potentially affecting match outcome. In studies employing 1-5 Hz GPS devices, fatigue has been shown to impair activity profiles in Australian football through reductions in physical performance across halves and quarters (57,78). Similarly, a video-based time motion analysis study in soccer reported a reduction in high-intensity running (defined as ≥4.0 m·s^{-1}) through comparisons of the first and last 15 min periods (79), supporting the contention that fatigue levels increase towards the end of games (80).

Studies employing 4 Hz GPS devices in Gaelic football, have found that the total distance covered during games decreased in the second, third and fourth quarters, and high-speed running (≥4.7 m·s^{-1}) distance decreased in the second and fourth quarters (44). A positional hierarchy existed with middle-third players (i.e., HB, MF and HF) having superior physical performance compared to the inside (i.e., FB and FF) players (46,48,50). Middle-third players also experienced the greatest declines in high-speed running and sprinting (≥6.1 m·s^{-1}) between the first and second half (48) and between quarters of match play (50). Similarly, running performance was reported to decline in soccer players between match halves and across 15 min intervals although no significant differences were found in skill-related performance variables between these match periods (81). In contrast, in rugby league players, decrements in physical performance measured as distance travelled and number of collisions in the final stages of matches, were associated with significant declines in skill rating and number of skill involvements (82).

Though it is clear that decrements in physical performance of football players occur in the latter stages of matches, the influence and association of these decrements on skill-related variables in Gaelic football needs further investigation. Interpretations of the decrements in the activity profiles of individual players could be enhanced with additional insights provided from evaluation of overall team performance. Unfortunately, analysis of team performance has not been conducted to date within the published literature.

2.2.8 Physiological requirements and responses

The physiological requirements of outfield players are characterised by irregular changes of pace and anaerobic efforts interspersed with periods of light to moderate aerobic activity (22). Heart rate (HR) measurement provides an estimate of the physiological strain imposed during games (22). An early study involving inter-county players during competitive 'challenge' games (lasting 60 min) reported a mean HR of 160 ± 6 beats·min^{-1}, equating to ~80% HR maximum (83). Interestingly, the mean HR did not differ between the first and second half or between the first 10 min and last 10 min of the game, which may indicate the ability of the players evaluated to pace themselves (83).

It is not clear whether the results from competitive 'challenge' games are indicative of performance alterations in regulation 70 min games (+stoppages). It is plausible that reductions in mean HR would be more apparent in longer duration games, potentially due to the manifestation of fatigue. Ideally, physiological responses by modern day players should be examined in conjunction with activity profiles to provide greater clarity regarding the pacing qualities or performance decrements displayed. Nonetheless, the relatively high physiological load imposed on these elite Gaelic footballers, illustrated the importance of aerobic conditioning for sustaining performance levels throughout games.

2.2.9 Preparation of players; training and conditioning implications

Although the GAA is enshrined in amateur tradition, today's elite inter-county Gaelic football players adopt a quasi-professional training regime (2), incorporating scientific prescription of gym based conditioning, field practice and recovery strategies. There is accumulating evidence that training status and level of conditioning of the players, is likely to impact team performance and positively influence match outcome. The training loads reported recently using session-ratings of perceived exertion (RPE), depicting an average week (3475 ± 596 AU) (84) or from an intensive camp (5984 ± 554 AU) (73), are comparable to those in Australian football (85). In reviewing data from a full-season, it was found that high chronic training loads (≥4750 AU) were associated with superior tolerance to increased distances and exposures to maximal velocity running. These findings reinforce the need to regularly incorporate high training loads into training to adequately prepare players for competition and importantly, offer a potential protective effect against injury (84).

A significant association was found between competition and game based training in a study investigating positional differences in the running performance profiles of players and the relation between competitive matches and game-, skill- or conditioning-based training (67). The study findings were used to promote the use of game-based training to address the position specific physical requirements of competition (67). This practice can incorporate progressions of specific game scenarios at intensities replicating those experienced at the highest levels of match play. Although the findings from previous studies increase our understanding of the fitness components and training stimuli that should be incorporated into practice, studies to date, have not considered the associated training load or running profiles in relation to subsequent match outcome. The optimal practice design and training stimuli associated with successful match outcome is still to be elucidated.

The performance implications of appropriate physical conditioning have been highlighted in studies examining the impact of team rating and match outcome on running performance. Players from higher ranked teams covered more distance at high speed (>~4.7 $m \cdot s^{-1}$) compared to lower ranked players (43,44). The difference may have been due to superior levels of conditioning. However, in a related study (using a subset of the data), players from a team competing in Division 3 were found to cover more distance at high speed compared to players competing in a team participating in Division 1. A lower tackle count in the middle third and a preference to retain possession via hand passing in the lower division were postulated as possible explanations for this finding (47). In a study exploring the relation between running performance and technical variables, persistent fouling in the middle third was recently shown to have the largest negative impact on running (46). In contrast, the percentage of short kick outs performed by the opposition and total opposition possession time, positively increased the total distance and high-speed distance undertaken by players, highlighting the increased running requirements when not in possession of the ball (46).

It is also important to consider situational [13] and motivational factors [14] when interpreting performance data. Towards the end of Gaelic football matches (i.e., quarter 4), players have been found to run significantly less high-speed distance in big losses, defined as >6 points, compared to draws and wins [12]. Players competing in the latter stages of the AIC (i.e., August and September) covered significantly more total distance and distance at high speed in quarter 4 than during the previous months [15]. This finding suggests that progressive conditioning and/or the enhanced profile of the AIC competition results in superior levels of physical performance compared to those observed earlier in the season. Although reliability and validity assessments were conducted or referenced by the authors in these studies, the limitations in the data sampling (<5 Hz) capacity of the technology used were also acknowledged (45,47,84). Studies using superior microtechnology are warranted. Nonetheless, the findings may be generalised to inform the prescription of specific preparation programmes.

2.2.10 Team ratings and factors that influence success

Rating systems facilitate examination of differences in the performance levels and/or progress of players or teams. A modified version of the system, originally developed by Arpad Elo to rate the performance levels of chess players (86), has been used to classify the current performances of elite Gaelic football teams (87). This formula requires competing teams to possess a baseline rating, established from historical data. Following the conclusion of each round of games, the team rating is then either increased (in winners) or decreased (in losers) by a certain amount of rating points, which are calculated from an equation that compares the actual outcome to the expected outcome.

To evaluate the effectiveness of the modified Elo rating formula, a sample of 1101 senior inter-county matches (NFL and AIC) from 2010-2015 was examined (87). Using initial team ratings established from final league positions from 2009, the model correctly predicted the result in ~73% of 642 matches (87). The utility of this grading system has been further illustrated with the classification of teams into 4 specific tiers based on Elo points: tier 1 (≥1,728), tier 2 (1,511–1,727), tier 3 (1,348–1,510) and tier 4 (≤1,347) (43). Practically, the Elo rating system eliminates bias and enables teams to be compared objectively (87). It also enables longitudinal evaluation of team progression through comparisons of historical baseline positions and benchmarking against counties of a similar standard.

The relation between current Elo ratings and additional factors (i.e., population, registered player numbers, previous success at adult and underage levels, financial income from the GAA, team expenses and number of clubs in a county) were also examined. There was a strong positive association between previous success at senior, U21 and U18 level, and moderate association between population figures and the number of registered players in a county (87). Based on these findings, it was concluded that the development of underage players, particularly up to U18 and U21, should be promoted to facilitate success at senior level. Importantly, lower rated counties were cautioned against prioritising underage success over player development (87).

2.2.11 Score difference and average winning margin

An average winning margin of 6 points has been calculated in Gaelic football using results from NFL and AIC games (n=1194) played between 2010 and 2016 (44). This has enabled match outcome to be classified into 5 groups using the following score differentials: big loss (≥6 points), small loss (≤5 points), draw, small win (≤5 points) and big win (≥6 points) (44). This categorisation using an objective final score deficit (score difference) may be used to differentiate between winners and losers in various game contexts.

2.2.12 Summary Gaelic football characteristics and what does it take to win?

Part 1 of the literature review has provided an overview of the existing evidence and knowledge base pertaining to the characteristics of this invasion game, dynamics of match play, team formations and tactical strategies. In addition, technical skills, physical attributes, physiological responses and activity profiles have also been documented. Additional factors contributing to successful performance have been identified and the potential use of the ELO rating system for benchmarking and comparing performances of inter-county teams has also been noted.

Although an average winning margin has been presented and contemporary trends relating to kick out execution (i.e., short vs. long), passing preference (i.e., hand vs. foot), counterattacking, tackling and activity profiles have been introduced, the importance of each of these aspects of performance in contributing to winning needs further examination. Indeed, comprehensive knowledge of what it takes to win in Gaelic football, from a scientific evidence perspective, is limited. Practitioners in other elite sporting contexts use the 'what it takes to win' concept to illustrate the importance and interrelatedness of specific aspects of performance to successful outcome. In Gaelic football, different PIs can contribute to the effective transfer of possession, facilitate the transition from defence into offence and contribute to scores. However it is unclear which (if any) of these PIs can be used to accurately differentiate between winners and losers. Therefore, the next section of this literature review explores and critically examines the extensive range of PIs employed across the football codes following an overview of the evolution of performance and match analysis and development of PIs within team sports.

2.3 Part 2: Evolution of performance and match analysis and development of performance indicators within team sports

2.3.1 Origin and technological evolution of performance and match analysis

Match analysis relates to the objective evaluation of behavioural events of players individually or collectively (i.e., in a team) during competition (34). Although the origins of an early form of competition analysis 'sports notation' can be traced to the mid-nineteenth century, initial analytical reports for football (i.e., American, rugby and soccer) were not published until the early 1900s (88). Using coded notes and ideographic symbols written with pen and paper, newspaper sports reporters were key drivers in collecting comprehensive game data (e.g., time, pitch location and key events) for analytical purposes (88). This original coding of human behaviour enabled factors deemed relevant for sports performance evaluation to be accurately and objectively recorded (notated) real-time and later collated (34). The technique involving the examination of statistical details of performance was termed notational analysis (34,89). As notational analysis evolved, combinations of tally marks, codes and a schematic pitch representation were used to record events involving: the position (where?), the players involved (who?), the action (what?), the time (when?) and the outcome (success or fail?) (34).

Following general recognition of the utility by coaches in the United States, notational analysis was broadly applied in soccer (34). In the 1950s, Charles Reep developed a complete notation system and by 1968 had analysed more than 2000 games (90,91). The extensive use of hand notation systems facilitated the establishment of the original knowledge base in football. Early notational analysis required a considerable amount of learning and familiarisation for novices and the recording was often laboriously time consuming (90). The shorthand notation method was subsequently complimented with the introduction of audio-tape recorders. A combination of these methods was used by Reilly and Thomas in the 1970s during their pioneering investigations in motion analysis of ‘work-rate’ in different positional roles in soccer (24). The work of Reilly and Thomas became a standard against which other researchers could compare their methodologies and results (92).

The inauguration of the World Congress on Science and Football in 1987 and the development of sports science support for professional football teams operating at elite level in the 1980s and 1990s (89) likely contributed to the adoption of PA among the other football codes. During this period, game analysis embraced digitalisation, and further innovations involving video and computer-aided methods were utilised and described in soccer (93), Australian football (94) and Gaelic football (95). Developments in computerised notation alleviated some of the data processing load associated with earlier manual methods (91). It also enabled rapid access to performance data, incorporating technical and tactical evaluation and/or statistical compilation. Recent advancements in technology has facilitated the progression of computer and video based statistical analysis systems (e.g., Dartfish and Sportscode) and the introduction of semi-automated multiple camera systems (e.g., ProZone and Sport Universal Process AMISCO Pro) (96). Commercial access to the GPS networks has facilitated the incorporation of player tracking devices and subsequent research, initially in Australian football (97) and later in the other football codes.

The advancements in computer and video aided analysis systems have enhanced the objective evaluation of performance and contributed to and complimented the significant growth in the use of PA (33,34,98–100). The evolution of applied PA has coincided with the establishment of the International Society of Performance Analysis in Sport, the publication of the International Journal of Performance Analysis in Sport and formation of the World Congress of Performance analysis in Sport (99). Most elite soccer, rugby, Australian football and Gaelic football teams currently use a combination of video based analysis and player tracking to provide an objective evaluation of match performance. However, despite the widespread use of PA among elite sports teams, most of the published data is descriptive in nature. The lack of transferability and applicability of findings for practitioners working in applied settings has resulted in the emergence of a 'theory practice' gap (33). It has been suggested that researchers need to provide robust rationales for their investigations, highlight how knowledge regarding performance could be improved and how professional practice could be impacted (33).

The following literature review aims to highlight the context, importance and complexities of the performance data evaluated within match analysis research. In addition, the use of PIs within the football codes is explored through a critical evaluation of study methodologies, key findings and practical applications. Finally, a summary of emerging themes is presented, prior to highlighting the research context for the body of work undertaken as part of this PhD.

2.3.2 Analysis of team performance – outcome measures

From a team perspective, match analysis is used primarily to provide an objective assessment of performance and enable the evaluation of opposition strengths and weaknesses (6,100,101). Specifically, statistical information can be generated relating to each player's actions and to performance outcomes related to successful and unsuccessful teams (102). In football, winning is determined by scoring more than the opposition (34). By winning the primary objective may have been achieved, but it is important to appreciate the distinction between the performance and the outcome as coaches recognise that the best team (i.e., from a performance perspective) does not always win (34). Although match outcome is the primary criterion for assessing a team's performance and provides a general representation of the result, it does not differentiate between 'good' or 'bad' performance. Points difference in contrast, can be used to describe performances ranging from very poor to very good (14), assist with contextualising how well-matched competing teams were and enable examination of the effectiveness of the tactical strategies employed (103). Aspects of performance can be examined in relation to the overall result (i.e., win or lose) and the margin by which that outcome was achieved (19,103). The different approaches that have been used to analyse either win-loss (i.e., categorical) and/or score difference (i.e., continuous) as distinct outcome variables are highlighted in the ensuing studies following discussion of the term PI.

2.3.3 Use of performance indicators

A PI can be defined as a selection or combination of basic action variables that can be used to characterise certain aspects of performance. To be useful the PI should reflect successful performance or outcome (5). The terms: action variable, match or game statistic and PI, have often been used synonymously, and perhaps even misused (104) due to individual interpretations of researchers. For consistency of terminology, the variables examined in this review are referred to as PIs and where authors have identified key PIs these are classified as KPIs. The term PI is used throughout this review to refer to team PIs, which are normally derived from a combination of player PIs. However, where player PIs are examined specifically, this difference is highlighted. Among various invasion team-based sports PIs have generally been used to describe physical, technical and tactical aspects of performance. Unfortunately, some PIs have been examined as a result of their availability rather than to enhance understanding of performance (33).

2.3.4 Characteristics of performance indicators

In match analysis studies, PIs are often examined in their raw unprocessed form (e.g., number of kick or hand passes) or combined in the form of a derived PI (e.g., total number of passes), with the latter generated to provide potentially more insightful information (17). On occasion, it may also be appropriate to express certain PIs as percentages to facilitate descriptive analysis and interpretation of team performance (105). Reporting PIs, such as missed tackles as percentages, can reflect subtle differences which may not be highlighted to the same extent if only frequencies are used in the analysis (105). It is also important to consider the units of measurement in which PIs are reported (5,106). The analysis and interpretation of discrete PIs in their absolute form (i.e., frequency counts of kicks for a given match or time period) may be limited when trying to explain match outcome. This is due to the fact that this approach does not consider the influence of the OT on a RT's performance or address potential random variations between-match factors such as weather or game style (17). Performance data, transformed to better describe the specific nature of a given sport (106) in a process termed 'descriptive conversion', can be used to convert PIs into a relative form by subtracting the oppositions' value for a given PI from that of the RTs (17). From a coaching perspective, this also enables comparisons of the strengths and weaknesses of the OTs based on previous match evaluations (17).

2.3.5 Use of performance indicators within team sports

A comprehensive evaluation of all of the different methods used to investigate PIs within the various football codes is beyond the scope of this PhD thesis. A selection of studies utilising a diverse range of statistical models have however, been included in this literature review. An evaluation of relevant research pertaining to soccer, rugby league and Australian football is discussed prior to a review of studies investigating PIs in Gaelic football. Some of the original studies comparing successful and unsuccessful teams in soccer (107–110) examined PIs in matches from one-off tournaments. This was considered a limitation as there were inconsistencies relating to the teams analysed regarding the quality of their opposition and overall number of matches played (13). Analyses of limited data sets involving a single team, may be constrained by contextual variables and not truly representative of the competition examined. In contrast, evaluation of a large sample of matches from different teams facilitates a more robust evaluation of the PIs associated with successful performances (103). Only studies involving match samples from multiple teams, competing in extended league competitions across some of the professional football codes are included in this review. In addition to the competition, number of games and season(s) examined, the number of PIs evaluated, screening procedures and statistical techniques used, are highlighted in the tables contained within each of the ensuing team sport sections. Key PIs differentiating winners from losers in both univariate and multivariate analyses are outlined. When sufficient information has been reported by the authors, the proportion of variance explained by the model and the subsequent classification accuracy (i.e., model fit) is also presented. It is recommended that an evaluation of intra-observer reliability be performed when using computerised notation systems (111) and this approach has been promoted in the literature (6,13,34). In the review, each study methodology was evaluated to determine if a sufficient reliability assessment was conducted in relation to the data presented. Tables 2.4, 2.10 and 2.14 highlight the video source (i.e., database) used, the method and statistical technique employed to examine the reliability and/or validity of the data and a comment regarding the information reported by the authors.

2.3.6 Team performance indicators in soccer

A summary of the key studies investigating PIs in soccer is presented in Tables 2.2 and 2.3. Lago-Peñas et al., (2010; 2011) undertook two studies to differentiate winning, drawing and losing teams from 308 games played in the Spanish League (6) during the

2008-09 season and in 288 games played as part of the group stages of the UEFA Champions League (7) from 2007-10. Univariate differences in 'game related statistics' (PIs) were examined in the Spanish study (6) using a Kruskal Wallace H test as the assumptions of normality and homogeneity of variances were not met. A one-way analysis of variance (ANOVA) was used to investigate PIs in the UEFA study (7). In both studies, differences in technical PIs, characterised as contributing to goals scored (n=3), offence (range 6-7) or defence (n=6), were initially examined in conjunction with important contextual factors including match location (i.e., home or away) (6,7) and opposition quality (7). In the second study, 'assists' were not included, whereas passes and the percentage of successful passes were examined. With the exception of this latter PI (percentage of successful passes) represented as a distributional range, all other PIs were examined in their absolute forms.

In both studies, winners had a significantly higher mean number of shots, shots on goal and effectiveness defined as shots on goal×100⁄total shots. In addition, assists, offsides committed and crosses against were identified as important contributors to winning in the Spanish League (6). The total number of passes, successful passes (%) and ball possession were significant contributors to winning games in the Champions League (7). Losing teams in both studies were issued a greater number of red cards. In the Champions League losing teams were also issued a greater number of yellow cards (7). In the Spanish League losers executed a greater number of crosses and were penalised for being offside less than winning teams (6).

In subsequent discriminant analysis (DA), only the first discriminant function (DF) of the two identified was significant. The DFs explained 93.2% (6) and 90.7% (7) of the variance, respectively, resulting in an overall classification accuracy of 55.1% (6) and 79.9% (7) of winning, drawing and losing teams. Using a structural coefficient (SC) threshold ≥ 0.3 (112) the PIs identified as having the highest discriminatory power in the Spanish study (6) were shots on goal (0.75), crosses against (0.62), total shots (0.50), ball possession (0.39), crosses (-0.59) and venue (-0.56). Shots on goal (0.51), crosses (0.36), ball possession (0.36), venue (0.75) and quality of opposition (0.86) had the highest discriminatory power in relation to the Champions League (7). Venue was found to be a distinguishing contextual factor in both multivariate analyses. Venue was also a significant contextual factor in the univariate analysis reported from the Spanish study (6). It was not however, included in the univariate results presented in the UEFA study (7). Overall, the univariate analyses identified between 8 and 10 combined PIs and contextual factors that discriminated between winning, losing and drawing teams in the UEFA and Spanish studies, respectively (6,7). Between 5 and 6 PIs distinguished performance outcome using the multivariate models (6,7), indicating that the type of statistical analysis influenced the results obtained (6).

From a practical perspective, the reduction in the number of significant PIs highlighted in the multivariate analyses provided justification for the inclusion of this technique in condensing key performance information for coaches. The results were interpreted as highlighting the importance of retaining ball possession to create scoring chances, particularly shots on goal, in winning games (6,7). Caution is warranted in interpreting the main findings due to the use of absolute PI values. Failure to standardise data to account for the influence of the opposition and other contextual factors in each specific game is a limitation of these studies. Encouragingly, acceptable reliability of the data used in the analysis was demonstrated by the Kappa (K) values ranging from 0.92 – 0.95 (7) and 0.95 – 0.98 (6) reported from a comparison of 5 randomly selected matches coded with data provided by Gecasport (Table 2.4). The accuracy of the Gecasport data was referenced as being verified in previous research (113).

A similar combination of univariate and multivariate analyses was also used by Zhou et al., (2018) to differentiate the technical and physical characteristics exhibited by winners in a comprehensive sample of soccer games (Table 2.2), spanning 5 seasons (2012–17) from the Chinese Association Super League (9). The original sample of 1430 matches was reduced to 1218 following elimination of games that involved a red card. A 2 step cluster analysis, with Euclidean as the distances measure and Schwartz's Bayesian criterion, was then used to identify a final sample of 1056 'balanced' games that were associated with a difference of ≤ 2 goals. The model quality was rated as very good based on the 0.7 average silhouette coefficient reported (9).

Match location (i.e., home or away) and quality of the opposition (i.e., difference between end-of-season rankings of the competing teams) were examined in conjunction with 16 technical and 11 physical performance-related parameters (PIs), expressed in either percent units, original (raw) values or adjusted to 50% of ball possession of 'own' team (i.e., RT or OT) (9). An initial ANOVA found significantly higher values for winning teams in total shots, shots on target, 50–50 challenges won, offsides, sprinting distance

>23 km·h^{-1}, sprinting efforts, sprinting distance in ball possession and high-speed-running distance (between 19.1 – 23.0 km·h^{-1}) in possession of the ball. Crosses from winning teams were significantly lower than the number reported for both drawing and losing teams (9). Losing teams had a significantly higher number of passes, forward passes, sprinting distance out of ball possession and high-speed-running distance out of ball possession. Both venue and quality of opposition were significantly different between groups (9).

The subsequent DA revealed two DFs that were significant with the first (DF1) and second (DF2) functions explaining ~95% and ~5% of the variance, respectively (9). Using the same SC (>0.30) reported previously (6,7), the parameters with the greatest discriminatory power were shots on target (DF1: -0.33, DF2: 0.49), sprinting distance in ball possession (DF1: -0.32), quality of opposition (DF1: 0.40), passes (DF2: 0.40) and forward passes (DF2: 0.34) (9). Overall, the univariate analysis identified 13 combined PIs and contextual factors that distinguished between winning, losing and drawing teams, whereas only 5 PIs were found to differentiate performance outcome using the multivariate model. Shots on target and sprinting distance in ball possession were highlighted as the two most important PIs that discriminated outcome. The effectiveness of total passes and forward passes was also noted, albeit they were only significant in DF2 (9). The importance of shots on target and elements of ball possession among winners replicates similar findings reported in the two previous studies highlighted (6,10). Sprinting distance in ball possession was also identified as important to winning in this large sample (9).

The study highlighted the additional benefit of combining technical and physical PIs to develop a greater insight and enhanced understanding of match performance (9). Although the quality of the clustering analysis model was reported using the silhouette coefficient, the predictive power of the multivariate model was not evaluated or reported. The lack of validation and standardisation limits the interpretation and practical significance of the findings. Furthermore, there was also no assessment of internal reliability (Table 2.4) and the reference provided relating to previous evaluation of the reliability and validity of the AMISCO® system employed (114) did not contain any relevant supporting information.

In a large-scale retrospective study conducted in the Spanish League by Gomez et al., (2012), the independent and interactive effects of location and final outcome on 'game-related statistics' (PIs) according to the zone of the pitch in which they occurred, was examined in 1900 games played from 2003-04 to 2007-08 (8) (Table 2.3). A principal component analysis (PCA) with an orthogonal (Varimax) rotation was used to reduce the original PIs (PIx6: goals, shots, committed fouls, turnovers, ball recovers and crosses) by zone (Z) (Zx19; Z1.1 defence to Z5.5 attack) interactions (PIxZ=114) into smaller dimensions (PIx36) for inclusion in the final model (8). In contrast to the other studies (6,7,9) goals were included in this investigation as scores are often considered outcomes and not necessarily PIs (17). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.65 reported was deemed adequate by the authors, however, this was considered mediocre using criteria presented by Kaiser and Rice previously (115). All PIs were above the acceptable level of 0.5 within the anti-image correlation matrix and all commonalities had values below 0.5, which was considered acceptable by the authors (8). A criterion of 0.60 was employed to identify substantial loadings on the 4 discreet factors generated with eigenvalues >1.5. These were subsequently characterised as: factor 1: turnovers in zone 5.2 (i.e., offensive small area) and crosses in zone 4 (i.e., between the midfield circle and offensive semi-circle area); factor 2: goals and shots in zone 5.1 (i.e., offensive goal area), turnovers in zone 4 and ball recover in zone 2 (i.e., between the defensive semi-circle area and midfield circle); factor 3: goals and shots in zone 5.2; and factor 4: turnovers in zone 5.1 (8).

Subsequent mixed linear modelling (MLM) found significant main effects for game location and final outcome for all 4 factors, with higher effect sizes (ES) reported in factor 1 and factor 3 for game location (ES = 0.11) and final outcome (ES = 0.16), respectively. The interaction effect of location by outcome was only significant for factor 4 (8). Home teams and winning teams exhibited better values in all components. Winners were distinguished by their ability to be more effective at regaining possession in zone 2 and executing penetrative passes to zone 5.2 and zone 5.1 resulting in more shots and goals. The authors indicated that tactical strategies emphasising recovery of the ball in defence leading to penetrative offensive passes, through more effective decision making, should be developed and practiced (8).

Although the study by Gomez et al., (2012) illustrated the potential of using PCA to facilitate the reduction of a large number of PIs into a smaller number of dimensions, there was limited information provided relating to how this process was achieved. With the exception of factor 4 (i.e., turnovers), the newly generated composite factors were not characterised with novel PI names to assist with practical interpretation. Combined, the 4 factors only explained 22.3% of the total variance. The low score was postulated to have been a consequence of the uncorrelated nature of the original PIs while also reflecting the general complexity of football (8), although it is likely, that both the low KMO and communality scores contributed to this poor result. Subsequent analysis was limited considerably by the fact that ~80% of variance was not explained by the factors produced in the PCA. The lack of explained variance may have been influenced by the omission of PIs such as ball possession (6,7) and passing (9) that were previously found to be important. This may also help to explain the trivial ES obtained from the MLM. In addition to the omission of a test of the accuracy of the MLM, another potential limiting factor relates to the lack of consideration of opposition quality and failure to standardise the data. A comparable internal reliability protocol to that already outlined (6,7) was utilised (Table 2.4), resulting in K values of >0.95 being reported and a similar reference was made to previous verification of the accuracy of the data provided by the Gecasport system (6).

In soccer, the investigation of technical and physical PIs has mainly involved the use of DA (6,7,9) with the main DFs obtained reported to explain between ~91-96% of the variance in match outcome. The highest accuracy of the models examined was ~80% indicating that 4 out of every 5 match outcomes were correctly classified. The use of PCA to facilitate the reduction in a large number of PIs into smaller dimensions was also demonstrated (8). The investigators examining PIs in the Spanish (6,8) and Champions (7) Leagues reported internal reliability process results and referenced previous research. In contrast, the authors utilising data provided from the Chinese (9) League did not conduct any internal reliability and referenced research that did not support the reliability or validity of the data collection process. The failure to account for the influence of the opposition on the PIs investigated by standardising the data, is another significant limitation in these soccer studies.

Table 2.2 Use of discriminant analysis to examine performance indicators in soccer in relation to match outcome (win/loss)

Reference	League / Games / Season(s)	Univariate Analysis	Results Winners vs. Losers	Results Variance Accuracy	Main Differentiating PIs
Lago-Peñas et al. (6)	Spanish n = 380 2008-09	**PI x 16** T: Goals scored x 3 T: Offence x 6 T: Defence x 6 C: x 1; H vs. A **Kruskal Wallace H**	**PI x 10** **W:** Higher total shots, shots on goal, assists, effectiveness, offsides committed & crosses against **L:** Higher crosses, offsides received & red cards **C**: venue	**DF*1** **V = 93.2%** **A = 55.1%**	**PI x 6** Total shots, shots on goal, crosses, crosses against, ball possession & venue
Lago-Peñas et al. (7)	UEFA Champions n = 288 2007-08 to 2009-10	**PI x 18** T: Goals scored x 3 T: Offence x 7 T: Defence x 6 C: x 2; H vs. A, OQ **ANOVA**	**PI x 8** **W:** Higher total shots, shots on goal, passes, successful passes, effectiveness & ball possession **L:** Higher yellow & red cards	**DF*1** **V = 90.7%** **A = 79.7%**	**PI x 5** Shots on goal, crosses, ball possession, venue & quality of opposition
Zhou et al. (9)	Chinese n = 1056^ 2012-17	**PI x 29** T x 16 P x 11 C x 2; H vs. A, OQ **ANOVA**	**PI x 15** **W:** Higher shots, shots on target, 50–50 challenge won, offsides, sprinting distance, sprinting effort, sprinting distance in ball possession & high-speed running distance in ball possession & lower crosses **L:** Higher passes, forward passes, sprinting distance out of ball possession & high-speed running distance out of ball possession C: Venue & quality of opposition	**DF*1** **V = 95.5%** **DF*2** **V = 4.5%** **A = N/A**	**PI x 5** Shots on target, sprinting distance in ball possession, quality of opposition, passes & forward passes

PI = Performance Indicator, UEFA = Union of European Football Associations, ANOVA = Analysis of variance, T = Technical, P = Physical, C = Contextual, H = Home, A = Away, OQ = Opposition quality, W = Winners, L = Losers, DF* = Discriminant function (reported as significant), V = Variance, A = Accuracy, N/A = Not available, ^ = balanced games with difference between teams ≤ 2 goals.

Table 2.3 Use of principal component analysis and mixed linear modelling to examine performance indicators in soccer in relation to match outcome (win/loss)

Reference	League Games Season(s)	Original Screening	Analysis Outcome Measures	Results Variance Accuracy	Main Differentiating PIs
Gomez et al. (8)	Spanish n = 1900 2003-04 to 2007-08	**PI x 114** 6 Technical x 19 Zones **PCA** Kaiser-Meyer-Olkin = 0.65 Anti-Image Correlation Matrix >0.5 Communalities <0.5 **PI x 36**	**PCA** Orthogonal (Varimax) **PI x 4 Factors** Eigenvalue >1.5 Loadings ≥0.6 **Mixed Linear Model** Win / Draw / Lose Home vs. Away	**Variance = 22.3%** **Accuracy = N/A**	**PI x 4** Game location & final outcome main effects for factor 1: turnovers in zone 5.2 & crosses in zone 4; factor 2: goals & shots in zone 5.1, turnovers in zone 4 & ball recover in zone 2; factor 3: goals & shots in zone 5.2; & factor 4: turnovers in zone 5.1. Home & winning teams = better values, location x outcome significant for factor 4

PI = Performance indicator, PCA = Principal component analysis, N/A = Not available.

Table 2.4 Reliability techniques used to examine performance indicators in soccer

Reference	Data Source	Method	Result	Comment
Lago-Peñas et al. (6)	Gecasport (www.sdifutbol.com)	Authors coded 5 randomly selected matches, compared with data provided by Gecasport	Inter-rater: Cohen's Kappa **K** = range **0.95 - 0.98**	Accuracy of the system previously verified in research (113)
Lago-Peñas et al. (7)	Gecasport (www.sdifutbol.com)	Authors coded 5 randomly selected matches, compared with data provided by Gecasport	Inter-rater: Cohen's Kappa **K** = range **0.92 - 0.95**	Accuracy of the system previously verified in research (113)
Gomez et al. (8)	Gecasport (www.sdifutbol.com)	Authors coded 4 randomly selected matches from each season, 2 observations made	Inter-rater: Cohen's Kappa **K** = **>0.95**	Accuracy of the system previously verified (6)
Zhou et al. (9)	AMISCO® tracking system	-	-	Referenced previous evaluation of the reliability and validity of the system in measuring player movement (114), yet reference provided did not refer to this information

2.3.7 Team performance indicators in rugby league

A summary of selected studies investigating PIs in rugby league is presented in Tables 2.5 and 2.6. In recent studies conducted by Parmar et al., (2017, 2018), PIs were examined in relation to their contribution to match outcome and points difference using two different approaches in a sample of 545 games from the European Super League from 2012-14 (14,15). Using data provided by Opta, relative PIs were created from a combination of 'action' and 'form' variables, by subtracting the away team's performance from the home teams, or in the case of form by determining the differential in a series of current and historical measures (14,15). In addition to the 5 form variables, 24 PIs were selected for inclusion in regression analysis in the first study (14) based on their correlation coefficient with point's difference demonstrating an ES >0.3 (116). A combined total of 45 PIs were examined in the second study (15).

In the first investigation, a selection of PIs were incorporated into either a backwards logistic regression (LogR, n=11) or linear regression (LinR, n=19) model (117) following the stepwise elimination of the least important PIs using either the likelihood ratio or the significance value of the t-test statistic, respectively (14). Overall, 9 PIs were found to contribute significantly to predicting match outcome. These were score first, completed sets (i.e., where the team in attack reaches their fifth tackle without losing possession of the ball, or scores a try), current season final league position, metres gained, scoot metres (i.e., distance carried at onset of possession when the ball is not passed), time in possession, successful pass, scoot (i.e., number of direct carries) and previous season final league position. Similarly, 9 PIs were found to significantly predict points difference. These were score first, completed sets, breaks, current season final league position, unsuccessful pass, metres gained, total passes, cumulative league form and scoot (14).

Using training data from 2012 and 2013 and a process of cross validation, match outcome was correctly classified with an accuracy of 91.0% and this increased to 92.2% with the 2014 testing data (14). Similarly 86.5% of the variance in points difference was explained initially with the training data (2012-13) prior to the model performance increasing to 87.4% when cross validated with the 2014 testing data (14). Combined, the two regression analyses identified 13 'key' PIs as significant with 5 concordant and 5 discordant observations across the models considered to represent an interpretive challenge to practitioners lacking statistical expertise (14).

Match outcome was predicted using a machine learning (i.e., data mining) approach incorporating an exhaustive Chi-squared automatic interaction detection (CHAID) decision tree. Following a cross validation process employing either 75% (training) or 25% (testing) of the data (14) the overall accuracy was ~85%. From a practical perspective, metres gained, completed sets and first carry metres were found to be the most influential in predicting winners. The home team were likely to win on ~61% of occasions if the values for the relative metres gained were between −258 and 259 m. The likelihood of a positive outcome increased to 78% and ~92% if the performance of the opposition was matched or exceeded in relation to the number of completed sets, and achieved 25 or more first carry metres, respectively (14). Although both metres gained and completed sets contributed to overall success, they were considered outcome measures, and consequently did not inform the process or actions necessary to achieve these PIs. It has been suggested that future stepwise regression approaches should only include process PIs (14).

The analysis of multiple teams combined enabled general principles regarding facets of performance to be determined. However, in the absence of categorisation of different tactical approaches, the significance of some PIs may have been diminished if they were important to some teams and not to others (i.e., depending on their style of play). A methodology to facilitate identification of individual team differences was suggested (14). The exclusion of certain PIs and subsequent restriction in the number of explanatory PIs in the models may have resulted in misleading information regarding the importance (or not) of certain PIs. A solution using a dimension reduction technique such as PCA was proposed as a potential alternative to address the limitations of using stepwise reductionist methods (14).

The second investigation used PCA to reduce the original 45 PIs into 10 factors, which had eigenvalues >1 and these factors explained 73.4% of the variance. The PCA generated 4 general themes, characterised as possession, speed of play, form and infringement (15). To address the limitations of the stepwise reductionist methods utilised previously, the PCA factor scores were then analysed using both linear (i.e., points difference) and logistic (i.e., win/loss) forced-entry regression analyses, incorporating sampling on a random selection of 75% of the data and then cross-validated with the remaining 25% (15). The LogR predicted match outcome with an accuracy of between

86.0% and 88.4%, for the training and testing samples, respectively. The LinR generated 5 PIs that accounted for 81.8% of the variance in points difference. Making quick ground, amount of possession, form, quick play and losing possession early were the most influential PIs in both models, with defensive quickness also included in the LinR model (15). The resulting CHAID decision tree correctly classified between 76.0% and 78.8% of match outcomes in the training and test samples, respectively (15). The importance of making quick ground was again highlighted, increasing the chances of the home team winning to 72.7%. This value increased to 91.6% and 92.2% when possession was increased and when combined with form, respectively (15). Although general possession explained ~41% of variance, a distinction between possession and speed of play was considered important. Evaluation of the speed of play, which explained ~21% of variance, enabled the contribution of quick play, making quick ground and retaining possession following a kick, to gaining territory while the opposition may have been defensively disorganised to be examined, along with defensive quickness, which conversely related to limiting the effectiveness of the opposition's attacking ability (15).

In summary, the authors noted that when stepwise methods were utilised, a slight reduction in predictive ability was observed in the parsimonious models. Although this process may have refined the 'take home messages' and practical applications for practitioners, there was also potential for the contribution of excluded principal components to the outcome of close matches or to the provision of a competitive edge to be missed by adopting this approach (15). Nonetheless, the regression models utilised in both studies demonstrated slightly superior predictive ability (87% – 92%) compared to the decision tree (77% – 86%) technique, which was considered a more practical method based on the transferability of its visual results and easy interpretation for practitioners (15). The methodologies presented in these rugby league studies (14,15) highlight the potential of PCA and regression analysis to be combined to provide greater insights into relative PIs that contribute to match outcome and performance. Unfortunately, there was no descriptive information provided relating to the PIs examined in either study, nor was any internal assessment on the reliability of the data conducted, which represents a limitation.

Table 2.5 Use of backwards stepwise linear and logistic regression and decision trees to examine performance indicators in rugby league in relation to match outcome using score difference or win/loss, in 545 games from the European Super League from 2012-14

Reference	Original Screening	Analysis Outcome Measures	Results Accuracy	Main Differentiating PIs
Parmar et al. (14)	**PI x 29*^** Correlation Coefficient > 0.3 High Multicollinearity <1 Variance Inflation Factor >10	**PI x 20** BLogR: W / L BLinR: PtsD DT-CHAID: W / L	**BLogR: PI x 11** **TrainA = 91.0%** **TestA = 92.2%**	**PI x 9** BLogR: Score first, completed sets, current season final league position, metres gained, scoot metres, time in possession, successful pass, scoot & previous season final league position
		Regression Model Fit Train 2012-13 & Test 2014 Cross validation	**BLinR: PI x 10** **TrainA = 86.5%** **TestA = 87.4%**	**PI x 9** BLinR: Score first, completed sets, breaks, current season final league position, unsuccessful pass, metres gained, total passes, cumulative league form & scoot BLogR + BLinR = **13 KPI + 3 PI**
		DT-CHAID Model Fit Train 75% & Test 25%	**DT-CHAID: PI N/A** **TrainA = 85.4%** **TestA = 85.5%**	**PI x 3** DT-CHAID: Metres gained, completed sets & first carry metres

PI = Performance indicator, KPI = Key performance indictor, BLogR = Backwards logistic regression, BLinR = Backwards linear regression, PtsD = Points difference, DT-CHAID = Decision tree-chi-square automatic interaction detection, TrainA = Training accuracy, TestA = Testing accuracy, * = includes form variables, ^ = standardised against the opposition (home – away), N/A = Not available.

Table 2.6 Use of principal component analysis, forced entry regression and decision trees to examine performance indicators in rugby league in relation to match outcome using score difference or win/loss, in 545 games from the European Super League from 2012-14

Reference	**Original Screening**	**Analysis Outcome Measures**	**Results Variance Accuracy**	**Main Differentiating PIs**
Parmar et al. (15)	**PI x 45*^**	**PI x 45** PCA Orthogonal **PI x 10 Factors** Eigenvalue >1.0	**PI x 10** **PCA:** **V = 73.4%**	
		FELinR: Points Difference	**FELinR:** **V = 81.8%**	**PI x 6** Making quick ground, amount of possession, form, quick play, losing possession early & defensive quickness
		FELogR: Win/Loss Model Fit Random Split Train 75% & Test 25%	**FELogR:** **TrainA = 86.0%** **TestA = 88.4%**	**PI x 5** Making quick ground, amount of possession, form, quick play & losing possession early
		DT-CHAID: W / L	**DT-CHAID:** **TrainA = 76.0%** **TestA = 78.8%**	**PI x 3** Making quick ground, amount of possession & form

PI = Performance indicator, PCA = Principal component analysis, FELogR = Forced entry logistic regression, FELinR = Forced entry linear regression, W = Win, L = Loss, DT-CHAID = Decision tree-chi-square automatic interaction detection, V = Variance, TrainA = Training accuracy, TestA = Testing accuracy, * = includes form variables, ^ = standardised against the opposition (home – away).

2.3.8 Team performance indicators in Australian football

A summary of the main studies investigating PIs in Australian football is presented in Tables 2.7 to 2.9. To determine whether statistical methods, similar to those reported by Michael Lewis in Moneyball (2003) (118), could assist in optimising the recruitment of Australian Football League (AFL) players, Stewart et al., (2007) used an econometric approach to identify both team and player PIs that most closely related to the winning 'margin' (i.e., points difference) in 738 games from 2002-05 (18). Their original analysis employed models that predicted the probability of a team winning. However, models that predicted points difference instead were selected as these were found to produce superior results and points difference was deemed a more informative dependent variable (18). Using a series of ordinary least squares (OLS) regression models and F-tests, 31 of the original 51 PIs (expressed as the relative difference between winners and losers) were eliminated. The removed PIs either reflected the sum of other PIs (e.g., disposals = kicks and handballs) and their inclusion caused exact multicollinearity, or they did not have a statistically significant influence on winning margins. Some excluded PIs exactly predicted the winning points difference (e.g., goals, behinds and rushed behinds), and the omission of these PIs was subsequently considered a potential limitation in the ability of forward players to be rated highly in their model (18). The 20 remaining PIs were then ranked using correlation coefficients to determine those that most closely related to winning points difference. Inside 50s (0.53) and kicks (0.51) were found to have the strongest positive association with winning (18).

To address the primary purpose of their research, a second model was developed using a subset of the 20 PIs to quantify the relation between specific player statistics and team winning points differences (18). Following elimination of team statistics (e.g., kick ins, inside 50s, rebound 50s and switch of play) the model was created using the PI with the strongest correlation to points difference and progressively developed with additional PIs until there was no significant improvement in the power of the model, represented by the adjusted R^2 (18). Bounce (0.56), kick long (0.53) and centre clearances (0.51) had the highest coefficients.

The interpretation of the results with the linear model was essentially straightforward. For example, a team's winning points difference would be increased on average by 0.46 of a point for every additional kick executed in play with 0.99 points added to a team's points difference with each additional long kick (0.46 + 0.53) (18). In addition, the importance of the bounce in retaining possession, gaining territory and creating scoring opportunities was highlighted (18). Collectively, these player statistics explained only 41% of the overall variability indicating that other PIs influenced the point's difference obtained by a team. The research investigators conceded that the nature of sports such as Australian football presented difficulties in accurately measuring the player statistics that contributed to the effectiveness of a team winning (18). Although, this initial study highlighted the contribution of both individual player and collective team PIs to obtaining a positive score differential, it is unclear whether the accuracy of the model would have been enhanced with the inclusion of some or all of the team statistics previously eliminated or if the predicted power could have been improved by the employment of a non-linear model to better reflect the multi-dimensional nature of performance within the sport. Moreover, there was no internal assessment conducted on the reliability of the data used (Table 2.9).

In a more recent study Robertson et al., (2016) examined the influence of individual player performance distribution on match outcome by converting player scores in 13 commonly reported PIs to a percentage of the team total using 197 games from 2014 (16). The descriptive conversion of PI data for each team player facilitated the extraction of 11 features including minimum, maximum, mean, standard deviation and 7 heuristically selected percentile (P) levels (i.e., P5, P10, P25, P50, P75, P90 and P95), which enabled a profile of each PI for a specific team to be generated (16). Of the 143 original features, only 36 displayed significantly different means for match outcome (via ANOVA) and did not exhibit a multicollinearity problem (r = <0.80 with another feature) and were therefore propagated for modelling (16).

A generalised estimating equation (GEE) model using a binomial distribution and exchangeable correlation structure was employed (16) to facilitate the assessment of longitudinal data and account for the correlations between repeated measures on the same participants (119). In these circumstances, the classification accuracy of GEE was considered superior to other methods such as LogR (120). Following further data screening, 8 features were identified as contributing significantly to the model. The top 3 features related to goals; with lower P75, P90 and P95 values highlighted (16). The findings indicate that when the percentage contribution of individual players to team goals total was examined, winning teams had greater contributions to team goals from multiple players and were less reliant (i.e., compared to losing teams) on a couple of key goal scorers. In addition lower P90 and P95 values were illustrated for behinds and inside 50s, respectively, whereas higher P25 for marks and P25 and P50 values for disposals were demonstrated (16).

These results indicate that team success could be improved through inclusion of multiple goal kickers and utilising players who contributed to gaining more possessions (i.e., higher median player disposal) (16). Using a 10-fold cross-validation, the overall accuracy of the model was 63.9% (median), meaning that nearly two-thirds of matches were correctly classified. The model was rated fair by the authors (16). Only 8 out of 143 original features were used in the GEE model. It is possible that the application of different screening criteria may have resulted in the propagation of additional features for modelling and enhanced the model's accuracy. It is unclear whether the incorporation of absolute PIs as opposed to features derived from the relative player distributions may have enhanced the accuracy. Nonetheless, this second study emphasised the importance of considering individual player contributions in examining factors promoting overall team success.

Robertson et al., (2016) also investigated the relation between PIs and match outcome in 394 games from 2013-14 using a combination of linear modelling (LogR) and data mining (i.e., decision tree-CHAID) approaches, with the latter selected to characterise multiple patterns capable of explaining winning (17). The researchers omitted PIs such as goals, behinds and goal assists, as these were considered a function of score and therefore match outcome and did not reflect a PI *per se* (17). Subsequently, 17 commonly reported

PIs (14 raw and 3 derived) were examined in their relative form. However, following collinearity diagnostics, disposals (passes) were also omitted due their positive relationship ($r > 0.77$) with handballs and kicks (17). A one-way ANOVA incorporating a Bonferroni adjustment with a reduced p-value (0.003) revealed significant differences in 14 of the remaining 16 PIs (i.e., excluding hit-outs and free kicks differential), which were then used to develop the binary LogR (win = 1 and loss = 0) linear probability model (17).

Using 2013 (training) data, the first model included all 14 PIs. Those PIs found to contribute significantly to the outcome of the full model (e.g., kicks, marks, inside 50, marks inside 60, goal conversion and kick:handball ratio) were subsequently incorporated into the second and third models, with the final model limited to kicks and goal conversions (17). Using 5-fold cross validation, mean classification accuracies of 88.6%, 85.9% and 82.5% were reported for models 1–3, respectively. Only minor reductions in model performance were apparent (range -0.1% to -1.5%) when fitted to the 2014 (testing) data (17). The decision tree-CHAID data mining technique was then employed to further explore subsets of PIs. This approach similarly highlighted the important contribution of kicks and goal conversions to explaining match outcome. These PIs had an accuracy of 89.8% in explaining match outcome in contrast to the 81.5% reported using the 6 PIs, although reductions of between -10.6% and -2.6% were found when fitted to the 2014 data, respectively (17).

The different approaches utilising only two PIs returned a classification accuracy of >80%. Using two PIs may therefore be an alternative to comparisons of multiple PIs which provided unnecessarily detailed and occasional misleading results (17). The LogR resulted in very high classification rates with only minor reductions in performance during subsequent iterations with less PIs and during testing with 2014 data, which also evinced the contribution of kicks and goal conversions in explaining match outcome (17). Conversely, although the initial CHAID model (PI; n=6) demonstrated the highest classification accuracy of all of the models, it was the least generalisable. The performance of the initial CHAID model declined by ~10% when tested with 2014 data in comparison to the moderate reduction in accuracy reported in the model constructed using only kicks and goal conversions (17).

Although the CHAID approach highlighted the challenge of obtaining an accurate but not overfitted model often experienced by researchers in addressing classification issues, the analysis illustrated multiple PI profiles that progressed understanding of match outcome for this sample. Specifically, teams with additional kicks and superior goal conversion (>4.2%) defeated their opposition on 49 of 54 occasions (17). The authors acknowledged that the results supported previous findings highlighting the importance of kicks and inside 50s (18) despite differences in the current dependent variable (i.e., categorical vs. continuous) used. Both kicking and goal conversions could be practiced and improved through incorporation into the team warm-up (17).

This study extended previous findings and employed progressive analysis techniques. However, in addition to the absence of any reliability assessments on the PIs used, there was limited generalisability of results due to the use of grouped (all AFL) team data, which precluded elucidation of the technical and tactical strategies of the most successful sides. It is also possible that variations in coaching styles and/or rule changes could modify the importance of various PIs over time (17). The authors posited a number of recommendations for future analysis. These included; i) the combined use of win/loss and points difference, ii) a quarter-by-quarter approach, iii) use of additional PIs; e.g., metres gained, ball movement chains or player matchups, and iv) highlighted the potential for an integrated approach to employ non-linear models to investigate multiple PIs including the physiological characteristics required to demonstrate the PIs noted in their study (17).

In the most comprehensive study investigating PIs conducted to date in Australian football, Young et al., (2019) addressed some of the previous shortcomings associated with the use of small to moderate numbers of PIs and limited comparisons across seasons, which invariably restricted the development of previous models and their subsequent validation (19). To improve the modelling employed and to provide a more thorough understanding of winning performances, the relation between PIs and match outcome measures (i.e., win–loss and points difference) were examined in 3120 games from 2001-16 (19). The complete dataset consisted of 103 PIs of which 54 originated from the Champion Data statistics provided to the AFL and a further 49 secondary PIs were created, either from the difference to the oppositions PI value (i.e., reflecting a standardised/relative score) or by dividing 1 PI by another (e.g., inside 50s per shot) (19).

Collinearity screening was conducted using Pearson's (r) correlation matrix and this identified 6 pairs of PIs with coefficients ≥ 0.95. The PIs with the lowest correlation with point's difference were removed. These were identified as uncontested possessions relative, marks uncontested, marks uncontested relative, clearances relative, turnovers relative, and frees against relative. In addition, 6 score related PIs (i.e., goal assists, score assists, goal conversion both raw and relative) were also removed as these were related to the outcome measure. A total of 91 PIs were used in the final analysis (19). The match sample was partitioned in half to provide 3 timeframes (2001-08, 2009-16 and 2001-16). A feature selection process was employed to determine the top 45 PIs for each timeframe and outcome measure, with model training and testing conducted on a 70:30 ratio, using 10-fold cross-validation and bootstrapped with replacement sampling, respectively (19).

The decision tree models created using the C4.5 algorithm (121) and limited to 5 levels to reduce overfitting, were evaluated using the Gini index criterion. There were higher prediction accuracies for win-loss compared to points difference for each of the time frames (2001–08: 83.5% vs. 64.4%, 2009–16: 88.4% vs. 70.3% and 2001–16: 88.9% vs. 69.7%) analysed. The latter two models had a ~5% higher accuracy than the first model (19). All three models were comparable to those reported using an alternative method (17). The decision tree models identified multiple combinations of PIs that accounted for winning and losing. For example, by its prominent place on the first branch of the decision tree the PI 'metres gained relative' (i.e., representing the difference between metres gained by opposing teams), was highlighted in the model that predicted whether a match outcome was win–loss during 2009–2016, (19). This new PI was further investigated as an outcome measure. Subsequent modelling revealed that the most important factors for enhancing the PI 'metres gained relative' were the relative forms of inside 50s, inside 50s per shot, time in possession and turnovers forced score. The latter 3 PIs along with metres gained were also identified as important factors in the models predicting match outcome (19). Intercepts, disposals and turnovers were also important predictors of match outcome in their raw forms (19). Although no results relating to these PIs were presented in the main paper, the basis of this inference was provided in the supplementary table which highlighting the top 10 ranked coefficients from the generalised linear models (GLM) for points difference. Indeed, the absence of descriptive information relating to either the original dataset or the top 45 PIs used in modelling limited some aspects of the practical interpretation of this study.

The prediction accuracies for points difference revealed by the GLMs were higher than those reported from decision trees, supporting previous findings (17). They were however, similar across timeframes (2001–08; 7.0 points, 2009–16; 6.8 points and 2001–16; 7.4 points) and when converted to simple win-loss outcomes, correctly classified results in 95.1%, 94.5%, and 93.1% of matches across the three timeframes analysed, respectively. Further validation for the use of GLMs was provided by the partial interpretation of the relative importance of each PI as a predictor of point's difference. The highest coefficients were for the relative forms of inside 50s per shot (-7.40), inside 50s (5.11) and rebound 50s (4.84). The authors surmised that these PIs could be used to track team performance in games (19). In contrast to decision tree models, the authors posited that GLMs did not reveal the interrelatedness of PIs and could not provide benchmark values. Interpretation of PIs should therefore involve a combination of GLMs and decision tree modelling with relationships contextualised to the specific timeframe pertaining to the data (19).

The superior performance demonstrated by both the GLM and decision tree modelling techniques in this study compared to previous research in Australian football was likely attributed to a number of factors. These included the use of new PIs not previously examined and the increase in PIs and number of games (and seasons) incorporated, which potentially also enhanced the reliability of the model training and subsequent predictions (19). Although previous researchers have compared values of the PIs provided within the dataset generated by Champion Data with their own coding (16), a limitation of this study, similar to those reviewed previously (17,18) is that the reliability of the data was not ascertained independently. Notwithstanding the fact that this research represented the most comprehensive analysis conducted in Australian football to date, it was acknowledged that additional PIs, not examined may have provided further performance insights. The authors proposed the use of data reduction techniques incorporating PCA (19), similar to those previously used by researchers in soccer (8,122).

In summary, studies in Australian football have examined PIs in relation to match outcomes represented as points difference (18,19) or win-loss (16–19) using decision trees (17,19) and standard GLMs (19) in addition to multiple regression (18) and LogR (17). GEE models, considered an extension of the GLM, have also been used to explore the influence of individual player performance distribution from each PI on match outcome (16). Since the original work of Stewart et al., (2007), there has been an increase in the number and complexity of PIs collected and used in Australian football. This has been facilitated by recent innovations in technology, including the proliferation of wearable athlete tracking devices combined with greater access to statistical data (e.g., provided by the AFL via Champion Data) (17,19). Distinctive differences in PIs between successful (winning) and unsuccessful (losing) Australian football teams have been identified in the studies outlined (16–19). Indeed, the nature and combination of these differences may be more important than their magnitude (17). Nonetheless, the validity of the novel insights relating to the most influential PIs contributing to winning have also been improved through the enhanced modelling of extensive longitudinal data.

Table 2.7 Use of general linear modelling and general estimating equations to examine individual player and team performance indicators in Australian football in relation to match outcome; using score difference or win/loss

Reference	Games / Season(s)	Original Screening	Analysis Outcome Measure	Results Variance Accuracy	Main Differentiating PIs
Stewart et al. (18)	n = 738 2002-05	**PI x 51^** **GLM**: OLS & Correlation coefficients F - tests	**OLS** Points Difference Team **PI x 20** Player **PI x 11**	**V = 41.0***	**PI x 2** Team: Inside 50s & kicks **PI x 3** Player: Bounce, long kicks & center clearances
Robertson et al. (16)	n = 197 2014	**PI x 143** PI: 13 x 11 features **PI x 36** **ANOVA** R = <0.80	**PI x 8**^ features **GEE** Win/Loss Binomial distribution Exchangeable correlation structure Model fit = 10-fold cross validation	**A = 63.9***	**PI x 8** P: Lower P75, P90 & P95 for goals, lower P90 for behinds & lower P95 for inside 50s, higher P25 & P50 for disposals & higher P25 for marks

PI = Performance indicator, GLM = General linear model, OLS = Ordinary least squares, ANOVA = Analysis of variance, GEE = General estimating equations, P25, P50, P75, P90, P95 = Percentile X…, * = based on absolute/derived features of player PI, ^ = standardised against the opposition.

Table 2.8 Use of logistic regression and decision trees to examine performance indicators in Australian football in relation to match outcome; using score difference or win/loss

Reference	Games / Seasons	Original Screening	Analysis Outcome Measures	Results Accuracy	Main Differentiating PIs
Robertson et al. (17)	n = 394 2013-14	**PI x 17^** Spearman's correlation matrix Variance inflation factors **PI x 16^** ANOVA *Bonferroni* *P < 0.003*	Win/Loss **BinLogR** Model Fit 5-fold cross-validation Train 2013 (80%) & Test 2014 (20%)	**BinLogR:** **M1:** **TrainA = 88.6%** **TestA = 87.1%** **M2:** **TrainA = 85.9%** **TestA = 85.8%** **M3:** **TrainA = 82.5%** **TestA = 81.0%**	**M1: PI x 14** Kicks, marks, handball, tackles, inside 50's, clearances, clangers, contested possessions, uncontested possessions, contested marks, marks inside 50, goal conversion (%), kicks to handball ratio & contested to uncontested possession ratio (%) **M2: PI x 6** Kicks, marks, inside 50's, marks inside 50, goal conversion (%) & kicks to handball ratio **M3: PI x 2** Kicks & goal conversion
			DT-CHAID To prevent overfitting >10 cases *P* < 0.05 >10% gain ratio	**DT-CHAID 1:** **TrainA = 89.8%** **TestA = 79.2%** **DT-CHAID 2:** **TrainA = 81.5%** **TestA = 78.9%**	**DT-CHAID 1: PI x 6** Kicks, goal conversion, contested possessions, contested marks, handballs & inside 50's **DT-CHAID 2: PI x 2** Kicks & goal conversion

PI = Performance indicator, ANOVA = Analysis of variance, BinLogR = Binary logistic regression, DT-CHAID = Decision tree-chi-squared automatic interaction detection, M1-3 = Model 1-3, TrainA = Training accuracy, TestA = Test accuracy, ^ = Expressed in relative form (standardised against their opposition for a given match).

Table 2.9 Use of general linear models and decision trees to examine performance indicators in Australian football in relation to match outcome; using score difference or win/loss

Reference	Games / Seasons	Original Screening	Analysis Outcome Measures	Results Accuracy	Main Differentiating PIs
Young et al. (19)	n = 3120 2001-16	**PI x 103*** Pearson's (r) correlation matrix Coefficients > 0.95 **PI x 91*** Feature selection (gini index) PI x top 45 for each timeframe and outcome measure	**PI x 45*** Points Difference & Win/Loss 2001-08, 2009-16 & 2001-16 **DT-C4.5** Model Fit: 10-fold cross-validation Train: 2001-05, 2009-13 & 2001-10 (70%) / Test: 2006–08, 2014-16 & 2011–16 (30%) Bootstrapped & replacement sampling Points Difference Discretisation x4 equal bins $P < 0.05$, Limited to 5 levels Gini index GLM & RMSE	**DT-C4.5** **Win/Loss** **2001-08 = 83.5%** **2009-16 = 88.4%** **2001-16 = 88.9%** **Points Difference** **2001-08 = 64.4%** **2009-16 = 70.3%** **2001-16 = 69.7%** **GLM:** **RMSE for Points Difference** **2001-08 = 7.0** **2009-16 = 6.8** **2001-16 = 7.4** **Win/Loss** **2001-08 = 95.1%** **2009-16 = 94.5%** **2001-16 = 93.1%**	**PI x 4 (2009-16)** DT-C45: Metres gained, turnovers forced score, inside 50s per shot & time in possession (all in relative form) **PI x 3** GLM: inside 50s per shot, inside 50s & rebound 50s (all in relative form)

PI = Performance indicator, GLM = General linear model, DT-C45 = Decision tree based on C45 algorithm, RMSE = Root mean square error, * = some PIs standardised to represent difference to oppositions PI value.

Table 2.10 Reliability and validity techniques used to examine performance indicators in Australian football

Reference	Data Source	Method	Result	Comment
Stewart et al. (18)	ProWess Sports	-	-	No information provided
Robertson et al. (16)	www.afl.com. au/stats Champion Data	Inter-rater: 13 PI coded in 9 games from 1 round using team totals (n = 18), 2-way mixed single-measure (ICC 3,1) used to examine agreement between AFL and author-coded values RMSE values obtained for each PI to provide an absolute error estimate (using the AFL data as criterion measure)	Reliability Very high agreement for author vs. CD **ICC** range = **0.947–1.000** Validity Low absolute error for author coding vs. CD **RMSE** range = **0.0–4.5**	Due to high agreement and low error AFL reported values were used in analyses
Robertson et al. (17)	www.afl.com.au Champion Data	-	-	Validity of data high in previous research (123) Internal reliability not assessed
Young et al. (19)	Champion Data	-	-	Validity of data high in previous research (16,123) Internal reliability not assessed

PI = Performance indicator, AFL = Australian Football League, ICC = Intra-class correlation coefficients, RMSE = Root mean square error, CD = Champion Data.

2.3.9 Team performance indicators in Gaelic football

Studies differentiating successful and unsuccessful teams in Gaelic football are presented in Tables 2.11 to 2.13. The PIs investigated have involved five general aspects of play: possession, offence, defence, passing and dead ball distribution. An initial outline of the methodologies used in each study is presented prior to a combined discussion of the findings and their practical application. In addition to methodological limitations being highlighted, the techniques employed to assess reliability are also noted (Table 2.14).

Carroll (2013) examined elite inter-county Gaelic football games (n=57) and considered 12 PIs in relation to opposition effects (40). The PIs of 8 'top' teams, who had reached the quarter-final stage of the AIC at least twice in the preceding three seasons (between 2010-12), was compared to those of 'bottom' teams. In addition both top and bottom teams were compared against different qualities of opposition, i.e., top vs. bottom, top vs. top and bottom vs. bottom (40). Top teams had significantly higher attacks, shots, shot efficiency, percentage of both own and opposition kick outs won, fouls committed and points, and significantly lower turnovers against (40). In pondering possible explanations for the non-significant findings reported in the 4 other PIs, it was suggested that the hand pass to kick pass ratio did not actually represent a PI. Attacking and defensive efficiency were considered an inverse of each other, and therefore a significant or insignificant finding in one of these corresponded to a similar result in the other (40).

The remaining performance comparisons conducted using Mann Whitney U tests found that top teams had a superior attack efficiency, shots and percentage opposition kick outs won, when competing against bottom teams compared to other top teams. Only the frequency of goals was higher when bottom teams competed against each other, than when they played top teams (40). Although this study did not evaluate differences in PIs between winning and losing teams, the findings relating to top and bottom teams represented reference normative profiles from which teams could benchmark their own performances (40). A limitation is that individual PIs were not standardised.

The initial findings of Carroll were subsequently progressed by Allister et al., (2018) who investigated 'game-related statistics' (PIs) that specifically discriminated between winning and losing inter-county teams (20). The study used final score differences to compare performances in 28 games from the AIC. A combination of close (n=14: score difference ≤ 5 points) and unbalanced (n=14: score difference ≥ 6 points) games, from the 2015–17 seasons were examined (20). No information was provided regarding the stage of the AIC the games were played, i.e., provincial championship, qualifiers or finals. A total of 13 PIs (i.e., *total attacks*, total shots, *goals, fouls committed*, scorable fouls committed, yellow, red and black cards conceded, *attack efficiency, shot efficiency, own kick out win percentage and opposition kick out win percentage* and set piece scores) were identified and defined (20). Seven of the 7 PIs (italicised) were similar to those used previously (40). Univariate analysis, conducted using dependent t-tests, found significant differences between winners and losers in all games combined (i.e., total attacks, shot efficiency and goals); in close games (i.e., shot efficiency) and in unbalanced games (i.e., total attacks, shot efficiency, goals, yellow and black cards). Shot efficiency was the only PI significant across all contexts (20).

A subsequent multivariate discriminant analysis found that the DFs were significant for all games combined and in unbalanced contexts. The associated model accuracy determined via a reclassification process, was 71.4% and 78.6% for all games and unbalanced games, respectively (20). The model accuracy was only 50% for classifying outcome from close games. This low accuracy may have been due to minimal performance differences observed in close games or to the concealment of technical disparities due to alterations in the styles of play employed (20). Using a SC threshold ≥0.3, fouls committed (0.56), goals (0.39) and total attacks (0.31), had the highest discriminatory power in all games. Total attacks (0.85), shot efficiency (0.69), goals (0.54), attack efficiency (0.34), opposition kick-out win percentage (0.37) and yellow (0.32), black (−0.71) and red cards (−0.46) were, identified as the PIs relevant for unbalanced games. Shot efficiency (0.56), goals (0.50), total attacks (0.47), fouls committed (0.37) and black cards issued (0.43), were the PIs contributing to winning or losing performances in close games (20).

The finding that 8 out of 13 PIs were significantly different in unbalanced games demonstrates a clear distinction in performance levels for winners compared to losers. Of the 8 PIs, attacks, shot efficiency, goals and black cards, were similar to those associated with winning close games (20). The negative impact of a red card and the associated numerical disadvantage was previously shown in soccer to significantly reduce a team's likelihood of scoring and subsequently winning (124). The number of red cards received also distinguished losers from winners in the Spanish (6) and Champion's Leagues (7), potentially explaining the contribution of this PI to the model. Although the univariate analysis found that only shot efficiency differentiated winners from losers in close games, 5 PIs (nearly 40% of those studied) distinguished clear performance differences between groups in the multivariate model. Perhaps the model accuracy could have been improved by including a more extensive range of PIs (20). The methodology employed could also be enhanced by using a larger sample of games, or by using an alternative approach of comparing the differences between winners and losers, i.e., standardising the data.

In a recent comprehensive study, McGuckin et al., (2020) compared differences in PIs between winners and losers and examined determinants of successful possession in a sample of 59 games from the 2016 AIC (21). In developing their operational definitions, the authors consented to exclude possession restarts executed from the goalkeeper from their overall team possession count and instead referred to these as 'starter plays'. This was in contrast to the definition of possession used previously (46) in elite level competition. The new definition influenced the results of aggregated PIs such as productivity (i.e., scores/10 possessions) and turnover rate (i.e., number of turnovers/total possession), presented previously (125). Nonetheless, the analysis was focused on determining tactical factors that influenced possession and possession characteristics that contributed to match success (21).

Paired t-tests were used to evaluate differences in 7 of the PIs that were found to be normally distributed. The Wilcoxan signed-rank test was used for the 13 remaining comparisons. When classified according to aspects of play, 15 significant differences were evident among winners. These were possession (i.e., total possession, possession percentage and percentage success of possession originating in both defence and midfield), offence (i.e., attacks, shot count, territorial effectiveness (%), scores, points, scoring efficiency (%) and productivity), defence (i.e., turnovers and turnover rate (%)) and dead ball distribution (i.e., own kick outs won and opposition kick outs won) (21). Using univariate analysis winning teams were distinguished from losers by the number of possessions and being more effective in possession as demonstrated by a lower percentage turnover rate and a higher productivity rating (21). In subsequent analysis, a binary LogR model, developed using two-thirds of the possessions examined (n=4116) and tested using the remaining third (n=2058), found that longer possessions, possessions starting in the attacking third (i.e., compared to those originating in midfield and defence) and gaining possession from an opposition kick out, were the best predictors of leading to a shot (21).

The comprehensive descriptive statistics presented in this study provide a useful reference for coaches and support practitioners. However, limitations exist including a similar failure to standardise the data relative to the opposition. There was an absence of operational definitions for some of the PIs used, such as attack creation percentage (i.e., expressed as number of attacks divided by number of team possessions) and territorial effectiveness, which referred to attacking efficiency (i.e., expressed as number of shots divided by number of attacks). No information was provided in relation to the screening process used to select the predictor PIs for the LogR. Furthermore, there was no comparison between the performance of winners and losers in the final analysis of possessions leading to shots.

The practical findings from the three Gaelic football studies highlighted are discussed in relation to the five aspects of play outlined previously and where appropriate specific gaps in the literature are highlighted for potential consideration.

2.3.9.1 Possession

Possession is necessary to create scoring opportunities and scores and aspects of ball possession have previously been found to distinguish between winners and losers in soccer (6,7,9), rugby league (14,15) and Australian football (19). Surprisingly, possession characteristics were not examined in the initial Gaelic football studies (20,40). However, a recent study found that winners achieved more possessions, demonstrated higher productivity ratings and were more successful at translating possession originating in both defence and midfield into shots (21). The fact that there was no significant differences between the percentages of possession originating in either of the three pitch zones, indicates that overall effectiveness of the possession was important. In addition to documenting the origin of team possessions, further examination and analysis of the frequency of individual player possessions by area of pitch could also inform the tactical process of how the ball is transferred from the defensive to the offensive area by winning compared to losing teams.

2.3.9.2 Offence

Carrol (2013) found that top teams created significantly more attacking opportunities, executed more shots and had a superior shot efficiency compared to bottom teams (40). In a subsequent study, total attacks and goals discriminated between winners and losers across all, close and unbalanced games and in the univariate comparisons within all games and unbalanced games (20). The findings indicate that winning teams are more adept at identifying or creating scoring opportunities (20) and converting these chances into goals. In addition to the higher productivity scores reported (21), winners demonstrate an ability to be more effective with use of possession and attain greater offensive penetration. As goals (and indeed points) are considered outcome measures (17), the inclusion of this PI, albeit perhaps contentious, provided support for the importance of goals in contributing to winning.

In the same study, shot efficiency only distinguished winners from losers in close and unbalanced games, although it was significant across all three contexts in the univariate evaluation (20). This is not surprising as total shots and shots on goal (or target) discriminated winners from losers in soccer (6,7,9), as did goal conversions in Australian football (17). In Gaelic football, top teams obtained an average score of between 1-12 to 1-13 (15-16 scores), when playing against top or bottom teams in the 2011-12 AIC (40), whereas winners outscored losers by 1-17 (20 scores) to 1-11 (14 scores) in the 2016 AIC (21). The relative stability of the average shot count of ~30 reported for winners during this period (20,21,40) indicates that the proficiency of shooting has improved, evinced by a progressive increase from ~49% (40) to ~58% (20,21) and demonstrates the importance of effective offensive play. The improved shot efficiency may have resulted from improved coaching and/or a greater emphasis placed on offensive players to optimise their shot selection (20,21). Additional reference information relating to the origin of attacks, nature of scores (i.e., goals, points and points from play or from dead balls) and the average number of attacks required to score, would enhance understanding of general offensive play.

2.3.9.3 Defence

There were no significant differences reported in defensive efficiency between winners and losers. The sensitivity of this measure to reflect defensive play has been previously questioned (40). Alternatively, analysis of turnovers can be used to provide an indirect gauge of the defensive pressure applied and/or experienced by teams. Not surprisingly, winners conceded less turnovers than losers (21,40). Winners also had a lower turnover rate when expressed as a percentage of their overall possession (21). This illustrates more effective retention of possession and enhanced coordination of defensive actions to force turnovers from the opposition (21). Top teams commit significantly more fouls than bottom teams (40). Similarly fouls committed by winners is a significant discriminating factor in both close games and all games combined (20). This may help to explain the presence of tactical fouling in the modern game (20) and/or reflect the application of more aggressive defending or tackling. Although yellow, black and red cards were found to significantly discriminate between winners and losers (20), only red cards exhibited a consistent trend in the descriptive comparisons with losers receiving more than winners. Surprisingly, there was no evaluation of tackling conducted in any of the three studies reviewed. To improve understanding of differences in the defensive organisation between winners and losers, knowledge of the origin of tackles, fouls committed and turnovers generated could provide useful insights.

2.3.9.4 Passing

A significant gap currently exists relating to aspects of passing in relation to the potential for differentiation between winners and losers. Although, a hand pass to kick pass ratio was previously included as a PI, the importance of passing was not discussed (40). Excluding kick outs (i.e., restarts), this particular aspect of performance has not been considered to date. Analysis of effectiveness of hand and kick passing could inform differences relating to the technical execution and ability of successful compared to unsuccessful teams in retaining possession and transferring the ball between defensive and offensive zones.

2.3.9.5 Dead ball distribution

Initial analysis revealed that top teams retained a significantly higher percentage of their own kick outs (61% vs. 55%) and gained significantly more opposition kick outs (45% vs. 39%) when compared to bottom teams. A significant decline in the percentage of opposition kick outs won (45% vs. 38%) occurred when top teams played against each other, compared to when they played against bottom teams (40). Despite not dictating the restart, top teams clearly employed more effective strategies targeted at gaining possession from opposition kick outs compared to bottom teams. These tactics were somewhat negated and were obviously less effective when top teams competed against each other. This may have been due to a greater variety in the range of kick out plays rehearsed and optimised by opposing top teams.

The percentage of opposition kick outs won was also a discriminating factor in unbalanced games, although no significant differences were observed in the univariate analysis between winners and losers in either the percentage of opposition (24% vs. 23%) or own (77% vs. 76%) kick outs won (20). Analysis of the kick outs executed in the 2016 AIC, found that winning teams won significant more of the opposition's kick outs (8 vs. 5) than losing teams. However, they won significantly less of their own kick outs (16 vs. 18). Both findings could be explained in part by the higher volume of kick outs executed by losers compared to winners and their preference to utilise long kick outs (21). Winners had a higher scoring return from their kick outs and conceded less scores compared to losers. They were particularly more effective in converting short opposition kick outs won to scores (63% vs. 28%) (21). The fact that gaining an opposition kick out was one of the most significant predictors of a possession leading to a shot, highlights the potential of a high-press strategy to target and pressurise opposition kick outs, to generate turnovers and perhaps scores.

The kick out restart is clearly an important aspect of the game and presents an opportunity for both the team in possession to initiate an attack and for the opposition to gain possession and counterattack. The increase in the percentage of kick outs retained has coincided with the evolution in playing style in recent years (20). Teams now often opt for short kick outs to increase the probability of retaining possession. This has been facilitated by the development in goalkeeper coaching to enhance the standard of kicking from the ground (40). The greater emphasis placed on ball retention by coaches has resulted in the development and adoption of strategies which incorporate variations of short and long kick outs, with the latter encouraged through the introduction of the 'mark' in 2017. Nonetheless, evaluation of the effectiveness of the retention of possession through dead ball distribution can provide an indication of the tactical strategy and technical ability of teams.

In summary, the descriptive information and inferential statistics employed within the Gaelic football studies outlined have provided an initial reference point for coaches and applied practitioners. All three studies evinced both the inter- and intra-rater reliability assessments conducted, although the source of the data was only acknowledged in two of the studies (21,40). A major limitation in these studies involves the failure to standardise the PIs examined to account for the influence of the opposition, which may detract from the overall interpretation of the findings. In addition to the gaps in aspects of technical performance not yet examined, there is currently no information dedicated to the evaluation of physical PIs that distinguish between winning and losing teams.

Table 2.11 Use of inferential statistics to examine performance indicators in Gaelic football in relation to comparisons of top and bottom teams

Reference	Competition Games Season(s)	Univariate Analysis	Results & Comparisons
Carroll (20)	AIC n = 57 2011-12	**PI x 12** **Offence:** Attacks, attack efficiency, shots, shot efficiency, points, goals **Defence:** Defensive efficiency, turnovers against & fouls committed **Passing:** HP:FP ratio **Dead ball distribution:** % own kick outs won & % opposition kick outs won **Comparisons** Top^ vs. Bottom **Wilcoxan signed-rank** Top vs. Top, Top vs. Bottom Bottom vs. Top, Bottom vs. Bottom **Mann Whitney U**	**Top vs. Bottom**: **PI x 8** Attacks, shots, shot efficiency, turnovers against, % own kick outs won, % opposition kick outs won, fouls committed & points **Top vs. Top compared to Top vs. Bottom** **PI x 3** Attack efficiency, shots & % opposition kick outs won **Bottom vs. Top compared to Bottom vs. Bottom** **PI x 1** Goals

PI = Performance indicator, AIC = All-Ireland Championship, HP:FP = Hand pass:Foot pass, ^Top = Teams who reached at least the quarter-final stage twice in last 3 seasons (2010-12).

Table 2.12 Use of discriminant analysis to examine performance indicators in Gaelic football in relation to match outcome and score difference

Reference	Competition Games Season(s)	Univariate Analysis	Results Winners vs Losers	Results Accuracy	Main Differentiating PIs
Allister et al. (20)	AIC n = 28^ 2015-17	**PI x 13** **Offence:** Attacks, attack efficiency, shots, shot efficiency, set piece scores & goals **Defence:** fouls committed, scorable fouls committed, yellow, red & black cards conceded **Dead ball distribution:** % own kick out won & % opposition kick out won **3 Groups** All Close Unbalanced **Dependent t-test**	**PI x 3** **All**: Attacks, shot efficiency & goals **PI x 1** **Close**: Shot efficiency **PI x 5** **Unbalanced**: Attacks, shot efficiency, goals, yellow & black cards	**All: DF*** **CCA^2 = 0.486** **Medium ES** **A = 71.4%** **Close: DF** **CCA^2 = 0.416** **A = 50.0%** **Unbalanced: DF*** **CCA^2 = 0.835** **Very Large ES** **A = 78.6%**	**All: PI x 3** Fouls committed, goals & attacks **Close: PI x 5** Shot efficiency, goals, attacks, fouls committed & black cards **Unbalanced: PI x 8** Attacks, shot efficiency, goals, attack efficiency, opposition kick out win percentage & yellow, black & red cards

PI = Performance indicator, AIC = All-Ireland Championship, DF* = Discriminant function (reported as significant), CCA_2 = Canonical correlation^2, ES = Effect size, A = Accuracy, ^ = divided into close (difference between teams < 6 points) and unbalanced games (difference between teams ≥ 6 points).

Table 2.13 Examination of performance indicators in Gaelic football in relation to match outcome and possessions leading to a shot

Reference	Competition Games Season	Original Screening	Results Winners vs. Losers	Supplementary Analysis
McGuckin et al. (21)	AIC n = 59 2016	**PI x 20** **PI x 7 Paired t-test** **PI x 13 Wilcoxan signed-rank** **Possession:** Total possession, possession %, possession starting in DF%, possession starting in MF%, possession starting in AT%, % success of possession DF, % success of possession MF & % success of possession AT **Offence:** Attacks, attack creation (%), shot count, territorial effectiveness (%), scores, points, scoring efficiency (%) & productivity **Defence:** Turnovers & turnover rate (%) **Dead ball distribution:** Own kick out won & opposition kick out won	**PI x 15** **PI x 4** **Possession:** Total possession, possession %, % success of possession DF & % success of possession MF **PI x 7** **Offence:** Attacks, shot count, territorial effectiveness (%), scores, points, scoring efficiency (%) & productivity **PI x 2** **Defence:** Turnovers & turnover rate (%) **PI x 2** **Dead ball distribution:** Own kick out won & opposition kick out won	**6,174 possessions** 3,574 resulted in shot 2,600 did not **Binary Logistic Regression** No screening rational provided **PI x 8** Model Fit Train = 66% (4116) Test = 33% (2058) **Predictors of possession leading to shot:** Duration (longer), starting area (defence & midfield = negative therefore attack) & opposition kick out

AIC = All-Ireland Championship, PI = Performance indicator, DF = Defence, MF = Midfield, AT = Attack.

Table 2.14 Reliability and validity techniques used to examine performance indicators in Gaelic football

Reference	Data Source	Method	Result	Comment
Carroll (40)	Terrestrial television	For intra-rater: author (>1,000 hours' experience on system) viewed 2 randomly selected matches separated by 8 weeks, under the same conditions. For inter-rater, 1 randomly selected game was analysed by 2 observers and by the author. Low percentage errors were observed for all PIs (<5%)	Intra-rater & Inter-rater Low **percentage error <5%**	Reference provided to support rationale for technique used (126)
Allister et al. (20)	-	Intra-rater: 1 match randomly selected and analysed on 2 occasions separated by 5 weeks under same conditions. Inter-rater: A second match was analysed and results compared with those of another experienced operator (1000+ hours of software specific experience).	Intra-rater: High **ICC** values **>95%** Inter-rater: Cohen's Kappa **K** = range **0.93 - 0.96**	
McGuckin et al. (21)	Terrestrial television & Internal recordings	Intra-rater: 1 match randomly selected and analysed on 2 occasions separated by 4 weeks. Inter-rater: 1 match was analysed and results compared with those of another experienced operator (accredited ISPAS & Level 4 GAA analyst).	Intra-rater: **ICC** = **0.99** **95% CI: 0.990 - 1.000** Inter-rater: author vs. other **ICC** = **1.000** **95% CI: 0.998 - 1.000**	Inter-rater reliability in PIs where agreement was <100% indicated percentage errors between 2 (Team A possessions) – 181 (Team B kick out own) %

PIs = Performance indicators, ICC = Intraclass correlation coefficients, CI = Confidence interval.

2.3.10 Summary of team performance indicators

Across the football codes, researchers have identified numerous discrete player and team PIs and various combinations of these have been incorporated into statistical models in an attempt to explain the relationship of specific PIs with match outcome. Evaluation of the performance (i.e., accuracy) of these mathematical models can be used to determine the validity of inferences made regarding the contributions of specific PIs and their optimal ranges (19). Although linear techniques including DA and GLMs have often generated acceptable models, these methods may not account for multi-dimensional behavioural outputs that illustrate the complex, evolving configurations observed in invasion team sports (127). Consequently, their use could be considered suboptimal when employed (in isolation) to explain the relation between PIs and match outcomes in these contexts (17). To address this limitation, non-linear data mining techniques that have the potential to identify multiple patterns in data, such as decision trees have been proposed and employed (17,19). Nonetheless, in the studies reviewed in this chapter (14,17,19) the predictive accuracies of the non-linear approaches have been slightly inferior in comparison to the GLMs employed to analyse the same data. Therefore, the continued use of GLMs is considered appropriate. In addition, the potential for techniques such as PCA to facilitate the reduction of the large numbers of PIs included in longitudinal data sets into smaller composite dimensions that retain the complexity of their original PIs has also been highlighted (15).

Advancements in modelling through incorporation of large PI datasets relating to player actions and events captured over many seasons and employment of novel modelling algorithms have generally resulted in enhancing the predictive accuracy of models and provided valuable insights regarding aspects of performance that can be targeted and optimised (19). The use of interpretable modelling techniques enables researchers to explain and illustrate the practical significance of their findings through the identification and benchmarking of specific PIs and presentation of hypothetical scenarios. By improving the transferability of findings, recent studies have contributed to addressing the ‘theory-practice’ gap identified previously (33). Generally, results have been used to make inferences about which PIs contribute most to influencing scoring and successful match outcome (16). Understanding PIs can facilitate the creation of profiles to predict team behaviour and performance (103). Knowledge of PIs may also be used to inform in-game coach decision-making (17) or to identify strengths and weaknesses of an opposition team (10). Also, PIs can be used to assist in understanding the variability in performance, facilitate establishment of reference values for matches, inform practical guidelines for the development of physical, technical and tactical training/practice components and enable evaluation of the effectiveness of training interventions and tactical strategies (103). It is clear that the evaluation and interpretation of PIs relating to match outcome are useful from both a strategic development and tactical performance perspective (17). Moreover, the impact of rule changes such as the introduction of the mark on PIs should be evaluated through ongoing research to enable revised performance benchmarks to be established (20).

2.3.11 Research opportunity

In comparison to the professional football codes, analysis of match performance in Gaelic football, from a research perspective, could be characterised as emerging. However, learning and knowledge can be accelerated by addressing some of the methodological issues previously highlighted such as those outlined in soccer regarding lack of standardised operational definitions, absence of consideration of match context and measurement of discrete isolated PIs (33,98,99). The inadequate transferability of findings and subsequent limited impact on practice (128) was considered a result of not having fully described match performance (98). Consequently, there remained aspects of performance that needed to be examined and defined (33,128).

Numerous PIs can facilitate either the gaining of possession within the attacking zone or the transfer of possession from the defensive into the offensive areas. Therefore, investigation of an extensive range of PIs in Gaelic football using a methodology that addresses some of the limitations regarding match analysis within the football codes alluded to represents an opportunity to identify important aspects of general performance (i.e., offence, defence, possession, passing and dead ball distribution) and contribute to enhancing understanding of the specific factors associated with winning. The ensuing studies were designed and conducted to address the previously outlined 'theory-practice' gap (33) and present comprehensive information and practical recommendations to coaches and practitioners to inform and enhance preparation and performance in elite Gaelic football.

2.3.12 Study plan and analysis methods

Three studies, incorporating specific research questions, were designed to address existing performance knowledge gaps. Figure 2.4 illustrates the study plan and analysis methods conducted. In study 1 (Chapter 3), a combination of univariate comparisons and multivariate methods including: PCA, DA and LogR, were selected to identify technical and tactical PIs that differentiated between winners and losers in relation to the outcome of full games. The analysis initially explored the differences between all winners and losers, prior to the evaluation of three sub-samples. The analysis culminated with an examination of the temporal changes demonstrated by winners and losers, between the first and second halves and from the first to the fourth quarter.

Study 2 (Chapter 4) was designed to extend the full game technical and tactical analysis by using a combination of PCA and GEE to identify PIs that distinguished between winners and losers in relation to the outcome of halves and quarters. The temporal analysis from Chapter 3 was progressed through a comparison of the contribution of derived PIs to winning either the first or second half; or the first, second, third or fourth quarters. In study 3 (Chapter 5), the technical and tactical analysis was complimented with the additional examination of physical performance. This integrated analysis enabled further exploration and evaluation of differences between the winning and losing profiles in a RT, in relation to the outcome of full games, halves and quarters.

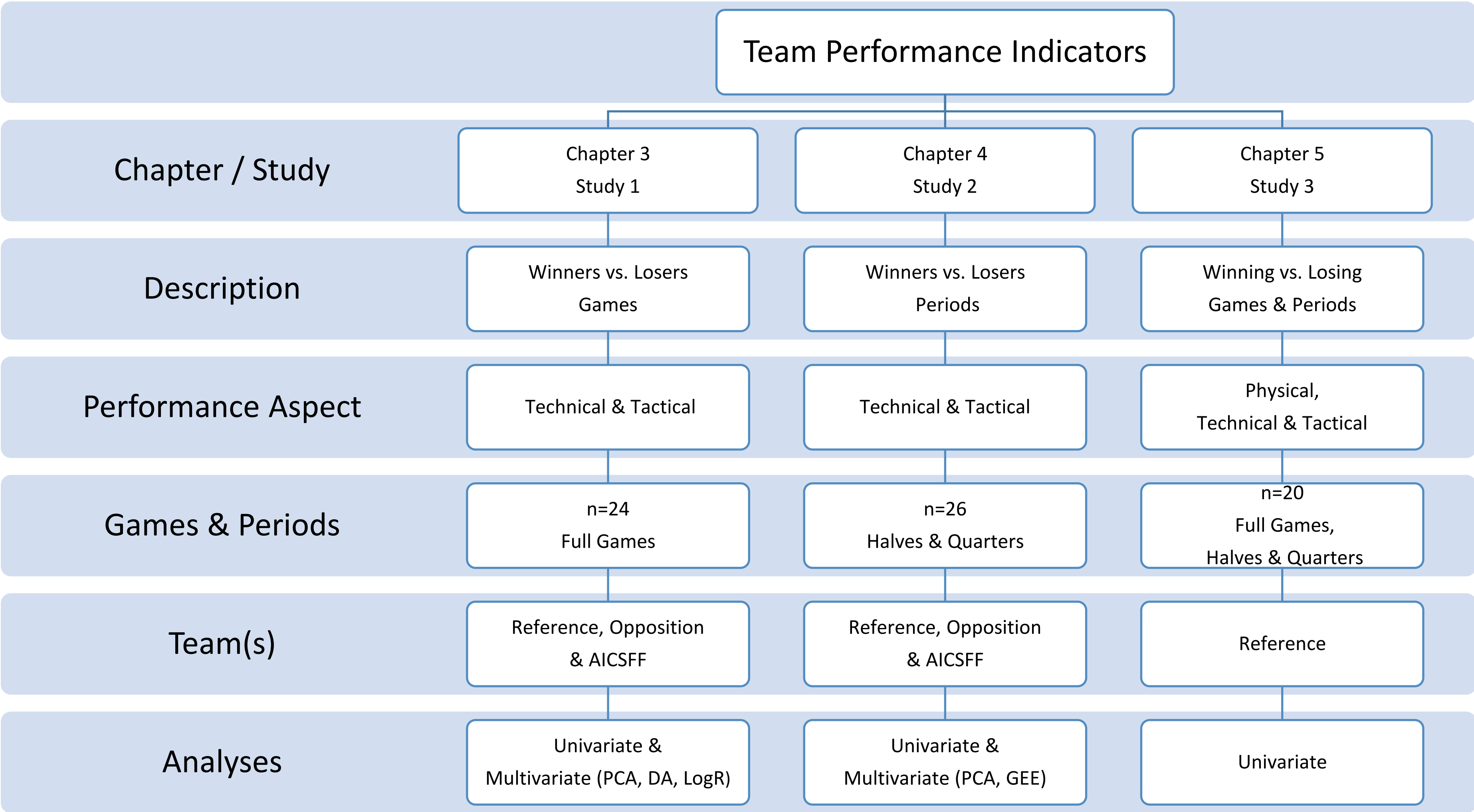


Figure 2.4 Summary of research methods and analysis. AICSFF = All Ireland Championship semi-finalists and finalists, PCA = Principal component analysis, DA = Discriminate analysis, LogR = Logistic regression, GEE = General estimating equations.

CHAPTER 3

STUDY 1: EVALUATION OF DIFFERENCES IN TECHNICAL AND TACTICAL TEAM PERFORMANCE INDICATORS BETWEEN WINNERS AND LOSERS IN RELATION TO THE OUTCOME OF FULL GAMES

3.1 Rationale

To understand the factors contributing to game outcome in elite Gaelic football competition, key indicators that define aspects of performance need to be investigated (5). Differences in PIs exhibited between winners and losers and/or opposing teams can be examined to enhance understanding of the factors which contribute to successful (win) or unsuccessful (lose) Gaelic football match outcomes. As each PI is directly influenced by the tactical strategies employed by both teams, the effectiveness of these strategies can be indirectly evaluated through analysis of overall technical performance.

Although previous studies have reported decrements in player physical profiles between match halves and towards the latter stages of games (48,129), the influence of these decrements on skill related (i.e., technical) performance have not been investigated. Unfortunately, no published studies have examined temporal changes in technical and tactical performance during elite Gaelic football games. Additional insights may be ascertained by examining whether aspects of technical performance differed in winners and losers, between the first and second halves or between the start (i.e., first quarter) and end of the game (i.e., last quarter).

Several PIs, differentiating winners from losers , have previously been identified using various univariate (20,21,40) and multivariate analyses incorporating DA (20) or LogR (21). The DA technique is considered more powerful than LogR. However, LogR is commonly used as a robust alternative because it is not constrained by stringent assumptions (130). The dimensionality of large datasets can be reduced through PCA, a statistical technique that increases interpretability and minimises information loss. It is an ideal approach to reducing Gaelic football PIs commonly examined, into smaller composite dimensions (131) prior to the differentiating evaluation. These PIs should be expressed in their relative form (17), defined as 'descriptive conversion' (106), to account for the influence of the opposition and between-match contextual factors. This simple process enables new PIs to be established, which represents the difference between opposing teams (e.g., winners and losers) or specific time periods (e.g., first and second halves).

Knowledge of factors contributing to winning and losing games and benchmarking with teams competing in the AICSFF, may inform the development of preparation strategies and prescription of field practice. Moreover, examination of technical and tactical performance across match periods could provide coaches and practitioners with further insights relating to the preparation strategies required to win games.

3.1.1 Study purpose

The primary purpose of this study was to evaluate team technical and tactical performance to identify traditional or novel PIs that differentiated between winning and losing games in elite Gaelic football. A secondary objective was to examine temporal changes in technical and tactical performance between the first and second half of play and from the first to the fourth quarter in winning and losing teams.

3.1.2 Aims

1) To compare differences in the technical and tactical PIs that distinguish between winning and losing in a sample of games from the NFL (Division 1) and AIC.

2) To examine temporal changes in technical and tactical performance between the first and second half of play and from the first to the fourth quarter in winning and losing teams.

3) To identify novel PIs by using data reduction techniques to combine existing PIs.

4) To identify composite variables that distinguish between winners and losers using both LogR and DA.

5) To compare the classification accuracy of the LogR and DA models, using a leave-one-out cross-validation (LOOC) approach.

3.1.3 Hypotheses

1) Winning teams demonstrate superior technical and tactical performance across different aspects of play including: possession, offence, defence, passing and dead ball distribution profiles, in comparison to losing teams.

2) Winning teams maintain technical and tactical performance levels across halves and quarters, whereas losing teams demonstrate declines in technical and tactical performance across these match periods.

3) The complexity of large data sets can be reduced by using PCA to combine discrete PIs, enabling novel PIs capable of distinguishing between winning and losing to be identified and characterised.

4) Both LogR and DA can identify PIs that differentiate between winners and losers.

5) The LOOC technique demonstrates sufficient classification accuracy in the PIs found to differentiate between winners and losers.

3.2 Methods

3.2.1 Match sample

The technical and tactical PIs from winning and losing elite Gaelic football teams were examined in 26 inter-county games from 2014-2015. Tables 3.1 (2014) and 3.2 (2015) provide the chronological order (i.e., from top to bottom) of the RT's (Team A; Derry) contests with their OTs (Team B) and their progression through the NFL and AIC. In addition to the venue and attendance record, the pre-game Tier (T1-4) status and Elo rating of opposing teams is highlighted, along with match outcome and score. Information from 2 additional games included from the AICSFF in each year is also incorporated.

Overall, 1049 technical performance profiles from players who participated in these games, were collated and examined. The RT competed against 13 OTs during 16 Division 1 NFL and 6 AIC games (win=8, loss=12, draw=2). The match sample included a semi-final and final from the NFL. Unfortunately, the RT did not progress to the final stages of the AIC in either year. Therefore, to evaluate performance at the highest level of competition and to enable benchmarking, the sample included 2 semi-finals and 2 finals from the AIC. The other 2 AIC semi-finals involved extra time and replays and were not included. As winners and losers could not be differentiated from draws, 2 NFL games from rounds 1 and 3 from 2014 (Table 3.1) and 2015 (Table 3.2) respectively, were excluded from the original sample, which resulted in 24 games, incorporating 972 individual player profiles, being included in the analysis. Using a points difference previously established (44), 14 games were associated with a small winning margin (≤5 points), and the remaining 10 games involved a large winning margin (between 6-15 points). Games were played between 1300 and 2100 h. Team ratings were determined using the Elo rating system for Gaelic football (87) and the total playing time including stoppages was used in the analysis. Quarters were calculated by dividing each half by two. For example, a first half lasting 36 min, resulted in quarter 1 and quarter 2 being 18 min in duration, whereas a second half lasting 38 min led to quarter 3 and quarter 4 being 19 min in duration.

3.2.2 Experimental procedures - video analysis and coding

Match footage was sourced from a combination of internal team video recordings from the RT and OTs and from external media broadcasters (BBC, Premier Sports, RTÉ, Setanta Sports, SKY and TG4). In 16 of the 26 games, two video sources were obtained, which enabled cross-checking of events. In some of these games and the remaining 10 games, a very small number of events (mean ± SD; 4 ± 5, range; 0 - 22) were estimated due to television replays, obscured vision and/or footage quality. Each game was transferred from a DVD to a Toshiba Satellite Pro (Tokyo, Japan) laptop computer (Intel Core i5-5200U CPU) operating Microsoft Windows 10 (Washington, USA). The footage was then imported using Dartfish (v8) TeamPro software (Fribourg, Switzerland).

A custom built tagging panel (Figure 3.1) was used to code the games and document PIs. All games were coded by the same individual (>15 years' experience analysing elite sports performance). The mean (± SD) number of events per game was

1163 ± 63 (range; 1044 – 1308), with each event involving a minimum of 3 and maximum of 11 tagging inputs. Events included frequency counts, duration (for possession), pitch location (origin) and outcome. After each game was coded, the events were visually inspected to detect and correct operational tagging errors (Figure 3.2). Each individual event was then examined and checked for accuracy. The sequence of events was observed and adjusted, where necessary to ensure that the tagging timeline captured all related events. Once the data validation was concluded, the coding events were then exported into Microsoft Excel (Microsoft, USA), transformed and collated for specific match periods.

3.2.3 Variables and definitions

The 83 technical and tactical PIs (35 raw and 48 derived) selected for examination in the present study, were identified from a review of Gaelic football literature (20,38,40,41,46,47,125) and subsequently validated by an expert team of coaches and support staff (5,105,132). Previous researchers examined between 13 (20) and 20 (21) PIs to distinguish between winners and losers, however, not all aspects of performance were examined. To address this limitation, an extensive range of traditional and novel PIs were selected to ensure the 'practical translation and relativity' of the results (133). The PIs were categorised into 5 general themes as presented in Table 3.3, incorporating: possession (n=13), offence (n=19), defence (n=21), passing (n=15) and dead ball distribution (n=15), to facilitate practical performance analysis and to provide a comprehensive reference for coaches and practitioners. Contextual information was also evaluated from 3 match characteristics (i.e., playing time, ball in play and stoppage time) and 5 game statistics involving: Elo ratings and substitutions, in addition to black, yellow and red cards received. Operational definitions for these combined match and game statistics (n=8) and PIs (n=83) were then devised and referenced during event tagging to ensure consistency and accuracy of coding (20,38,134). The operational definitions used for the game statistics and the PIs associated with each of the five aspects of play are presented in Tables 3.4 – 3.9.

Table 3.1 Match sample 2014, n=13

Context				Team A					Team B			
Date	**NFL /AIC**	**Venue**	**Gate**	**Result**	**Tier**	**Elo**	**Team**	**Score**	**Score**	**Team**	**Elo**	**Tier**
01/02	NFL - RD1	Celtic Park	5,126	Draw	T2	1627	Derry	1-15	2-12	Tyrone	1891	T1
09/02	NFL - RD2	Fitzgerald stadium	3,496	Win	T2	1639	Derry	0-16	0-14	Kerry	1898	T1
02/03	NFL - RD3	Celtic Park	1,610	Win	T2	1689	Derry	3-16	0-12	Westmeath	1450	T3
09/03	NFL - RD4	Páirc Uí Rinn	6,070	Loss	T2	1703	Derry	3-14	2-18	Cork	1939	T1
16/03	NFL - RD5	Celtic Park	6,212	Win	T2	1696	Derry	1-16	0-13	Dublin	2108	T1
30/03	NFL - RD6	Celtic Park	2,429	Win	T1	1760	Derry	2-17	3-9	Kildare	1693	T2
06/04	NFL - RD7	MacHale Park	9,292	Loss	T1	1779	Derry	1-7	2-12	Mayo	2008	T1
13/04	NFL - SF	Croke Park	28,903	Win	T1	1766	Derry	2-15	1-16	Mayo	2021	T1
27/04	NFL - F	Croke Park	38,841	Loss	T1	1811	Derry	1-10	3-19	Dublin	2076	T1
25/05	UC - QF	Celtic Park	15,883	Loss	T1	1798	Derry	0-11	1-11	Donegal	1783	T1
21/06	AIQ - RD1	Celtic Park	2,093	Loss	T1	1742	Derry	2-14	2-16	Longford	1289	T4
31/08	AI - SF	Croke Park	81,500	Win	T1	1754	Donegal	3-14	0-17	Dublin	1968	T1
21/09	AI - F	Croke Park	82,184	Loss	T1	1864	Donegal	0-12	2-9	Kerry	1883	T1

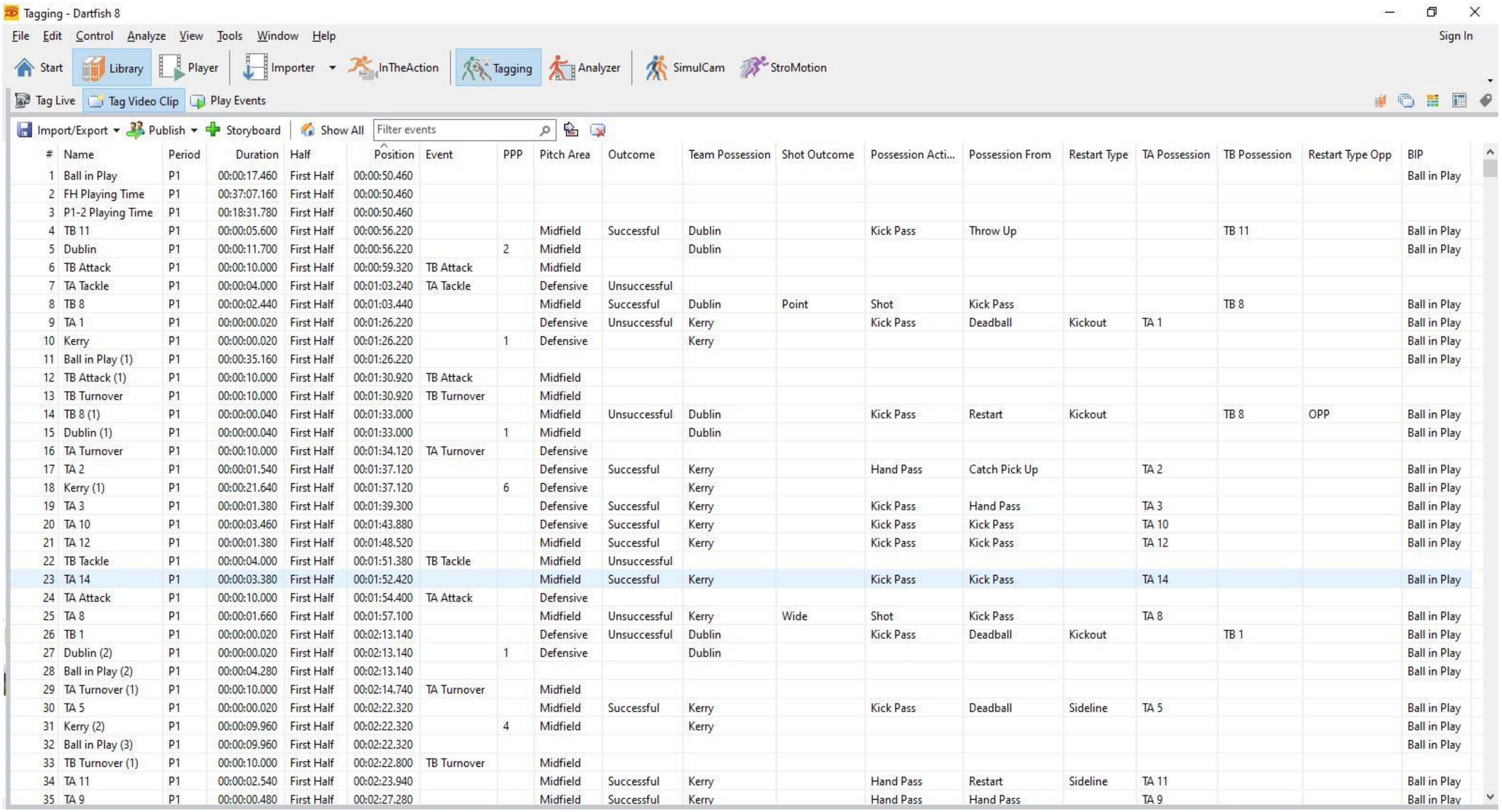
NFL = National Football League, AIC = All-Ireland Championship, RD = Round, UC = Ulster Championship, AIQ = All-Ireland qualifier, AI = All-Ireland, QF = Quarter-final, SF = Semi-final, F = Final, T = Tier, Elo = Team rating points.

Table 3.2 Match sample 2015, n=13

Context				Team A					Team B			
Date	**NFL /AIC**	**Venue**	**Gate**	**Result**	**Tier**	**Elo**	**Team**	**Score**	**Score**	**Team**	**Elo**	**Tier**
31/01	NFL - RD1	MacCumhaill Park	4,530	Loss	T2	1668	Derry	0-12	1-15	Donegal	1985	T1
08/02	NFL - RD2	Celtic Park	2,991	Loss	T2	1661	Derry	0-13	1-17	Kerry	2053	T1
28/02	NFL - RD3	Healy Park	3,735	Draw	T2	1650	Derry	1-8	0-11	Tyrone	1779	T1
08/03	NFL - RD4	Celtic Park	3,716	Loss	T2	1663	Derry	1-13	2-12	Mayo	1991	T1
15/03	NFL - RD5	St. Tiarnach's Park	2,900	Loss	T2	1652	Derry	0-10	0-15	Monaghan	1836	T1
28/03	NFL - RD6	Croke Park	19,224	Loss	T2	1638	Derry	0-4	0-8	Dublin	2051	T1
05/04	NFL - RD7	Owenbeg	909	Win	T2	1632	Derry	2-15	1-11	Cork	1978	T1
07/06	UC - QF	Celtic Park	10,541	Win	T2	1694	Derry	0-12	0-11	Down	1586	T2
27/06	UC - SF	St. Tiarnach's Park	19,237	Loss	T2	1713	Derry	0-10	1-9	Donegal	1968	T1
11/07	AIQ - RD2	Owenbeg	3,797	Win	T2	1697	Derry	1-16	0-10	Wexford	1356	T3
18/07	AIQ - RD3	Pearse Stadium	4,600	Loss	T2	1708	Derry	0-8	1-11	Galway	1672	T2
23/08	AI - SF	Croke Park	53,044	Loss	T2	1701	Tyrone	1-11	0-18	Kerry	1889	T1
20/09	AI - F	Croke Park	82,300	Loss	T1	1927	Kerry	0-9	0-12	Dublin	1981	T1

NFL = National Football League, AIC = All-Ireland Championship, RD = Round, UC = Ulster Championship, AIQ = All-Ireland qualifier, AI = All-Ireland, QF = Quarter-final, SF = Semi-final, F = Final, T = Tier, Elo = Team rating points.

Figure 3.1 Dartfish tagging panel.



#	Name	Period	Duration	Half	Position	Event	PPP	Pitch Area	Outcome	Team Possession	Shot Outcome	Possession Acti...	Possession From	Restart Type	TA Possession	TB Possession	Restart Type Opp	BIP
1	Ball in Play	P1	00:00:17.460	First Half	00:00:50.460													Ball in Play
2	FH Playing Time	P1	00:37:07.160	First Half	00:00:50.460													
3	P1-2 Playing Time	P1	00:18:31.780	First Half	00:00:50.460													
4	TB 11	P1	00:00:05.600	First Half	00:00:56.220			Midfield	Successful	Dublin		Kick Pass	Throw Up			TB 11		Ball in Play
5	Dublin	P1	00:00:11.700	First Half	00:00:56.220		2	Midfield		Dublin								Ball in Play
6	TB Attack	P1	00:00:10.000	First Half	00:00:59.320	TB Attack		Midfield										
7	TA Tackle	P1	00:00:04.000	First Half	00:01:03.240	TA Tackle		Defensive	Unsuccessful									
8	TB 8	P1	00:00:02.440	First Half	00:01:03.440			Midfield	Successful	Dublin	Point	Shot	Kick Pass			TB 8		Ball in Play
9	TA 1	P1	00:00:00.020	First Half	00:01:26.220			Defensive	Unsuccessful	Kerry		Kick Pass	Deadball	Kickout	TA 1			Ball in Play
10	Kerry	P1	00:00:00.020	First Half	00:01:26.220		1	Defensive		Kerry								Ball in Play
11	Ball in Play (1)	P1	00:00:35.160	First Half	00:01:26.220													Ball in Play
12	TB Attack (1)	P1	00:00:10.000	First Half	00:01:30.920	TB Attack		Midfield										
13	TB Turnover	P1	00:00:10.000	First Half	00:01:30.920	TB Turnover		Midfield										
14	TB 8 (1)	P1	00:00:00.040	First Half	00:01:33.000			Midfield	Unsuccessful	Dublin		Kick Pass	Restart	Kickout		TB 8	OPP	Ball in Play
15	Dublin (1)	P1	00:00:00.040	First Half	00:01:33.000		1	Midfield		Dublin								Ball in Play
16	TA Turnover	P1	00:00:10.000	First Half	00:01:34.120	TA Turnover		Defensive										
17	TA 2	P1	00:00:01.540	First Half	00:01:37.120			Defensive	Successful	Kerry		Hand Pass	Catch Pick Up		TA 2			Ball in Play
18	Kerry (1)	P1	00:00:21.640	First Half	00:01:37.120		6	Defensive		Kerry								Ball in Play
19	TA 3	P1	00:00:01.380	First Half	00:01:39.300			Defensive	Successful	Kerry		Kick Pass	Hand Pass		TA 3			Ball in Play
20	TA 10	P1	00:00:03.460	First Half	00:01:43.880			Defensive	Successful	Kerry		Kick Pass	Kick Pass		TA 10			Ball in Play
21	TA 12	P1	00:00:01.380	First Half	00:01:48.520			Midfield	Successful	Kerry		Kick Pass	Kick Pass		TA 12			Ball in Play
22	TB Tackle	P1	00:00:04.000	First Half	00:01:51.380	TB Tackle		Midfield	Unsuccessful									
23	TA 14	P1	00:00:03.380	First Half	00:01:52.420			Midfield	Successful	Kerry		Kick Pass	Kick Pass		TA 14			Ball in Play
24	TA Attack	P1	00:00:10.000	First Half	00:01:54.400	TA Attack		Defensive										
25	TA 8	P1	00:00:01.660	First Half	00:01:57.100			Midfield	Unsuccessful	Kerry	Wide	Shot	Kick Pass		TA 8			Ball in Play
26	TB 1	P1	00:00:00.020	First Half	00:02:13.140			Defensive	Unsuccessful	Dublin		Kick Pass	Deadball	Kickout		TB 1		Ball in Play
27	Dublin (2)	P1	00:00:00.020	First Half	00:02:13.140		1	Defensive		Dublin								Ball in Play
28	Ball in Play (2)	P1	00:00:04.280	First Half	00:02:13.140													Ball in Play
29	TA Turnover (1)	P1	00:00:10.000	First Half	00:02:14.740	TA Turnover		Midfield										
30	TA 5	P1	00:00:00.020	First Half	00:02:22.320			Midfield	Successful	Kerry		Kick Pass	Deadball	Sideline	TA 5			Ball in Play
31	Kerry (2)	P1	00:00:09.960	First Half	00:02:22.320		4	Midfield		Kerry								Ball in Play
32	Ball in Play (3)	P1	00:00:09.960	First Half	00:02:22.320													Ball in Play
33	TB Turnover (1)	P1	00:00:10.000	First Half	00:02:22.800	TB Turnover		Midfield										
34	TA 11	P1	00:00:02.540	First Half	00:02:23.940			Midfield	Successful	Kerry		Hand Pass	Restart	Sideline	TA 11			Ball in Play
35	TA 9	P1	00:00:00.480	First Half	00:02:27.280			Midfield	Successful	Kerry		Hand Pass	Hand Pass		TA 9			Ball in Play

Figure 3.2 Dartfish tagging output example.

3.2.4 Intra-rater reliability

To determine intra-rater reliability, two games were randomly selected and coded twice over a 4-week period. Using a convention outlined by previous researchers (135), a two-way mixed effects model, evaluating absolute agreement between the mean of four full-game measurements, was selected to compute the intraclass correlation coefficient (ICC). The lowest ICC recorded was 0.93 (the number of unsuccessful hand passes), all other PIs had an ICC >0.93 (mean 0.98), demonstrating excellent reliability (136) (Appendix D).

3.2.5 Statistical analysis

3.2.5.1 Univariate comparisons

The relative difference between winners and losers was analysed in 8 combined game statistics and 83 PIs using Statistical Package for Social Science (SPSS) for Windows (Version 24; SPSS Inc., Chicago, USA). For 5 of the game statistics and each PI, a new PI representing the relative difference between winners and losers was created, e.g., the 'difference' in team possession between winners and losers was represented by *dteam possession*. This enabled a preliminary univariate analysis to be conducted comparing all winners (n=24) with losers (n=24). Further differences between winners and losers were examined in 3 sub-samples of games from 1) the AICSFF (n=4), 2) when the RT won (n=8) and 3) when the OTs won (n=12). In addition, temporal differences between the first and second halves and from the first to the fourth quarter, were examined in winners and losers. Differences that were found to be normally distributed based on the Shapiro-Wilk test were analysed using a one-sample t-test. Differences which did not meet the normality assumption were examined using a Wilcoxan signed-rank test. Descriptive statistics are presented as mean ± SD and statistical significance was accepted at $p \leq 0.05$.

3.2.5.2 Multivariate comparisons

Differences between all winners and losers were further examined using multivariate techniques. Prior to the PCA being employed, preliminary screening excluded 48 PIs due to observed functional dependencies and distributional range (Appendix E). A correlation matrix was subsequently used to identify and provisionally remove any of the 35 remaining PIs that were highly correlated with others. The PCA was then conducted on the differences between winners and losers using an orthogonal rotation (Varimax with Kaiser normalisation). Previously excluded PIs were then progressively incorporated into the PCA, using a trial and error approach, to optimise the KMO measure of sampling adequacy. The KMO statistic of 0.73 achieved was deemed sufficient and all individual KMO values were above the acceptable limit of 0.5 (115). Overall, 18 PIs were retained with an average communality of 0.82 (range 0.58 – 0.94). The PCA produced 4 components with eigenvalues greater than Kaiser's criterion of 1 (137). The associated regression factors were then evaluated using DA (SPSS) and LogR (RStudio Team 2015; Integrated Development for R. RStudio, Inc., Boston, USA), with both models incorporating a LOOC to compare how well these techniques correctly classified winners and losers.

Table 3.3 Technical and tactical performance indicators across five themes, n=83

Possession (n=13)	**Offence (n=19)**	**Defence (n=21)**	**Passing (n=15)**	**Dead ball distribution (n=15)**
Team possession (n)	Attack total (n)	Turnover total (won) (n)	Pass total (n)	Dead ball total (n)
Team possession (%)	Attack origin - defence (n)	Turnover origin - defence (n)	Pass total successful (n)	Dead ball kick pass successful (n)
Team possession (min:s)	Attack origin - midfield (n)	Turnover origin - midfield (n)	Pass total successful (%)	Dead ball kick pass successful (%)
Team possession average (s)	Attack origin - attack (n)	Turnover origin - attack (n)	Pass total unsuccessful (n)	Dead ball kick pass unsuccessful (n)
Team possession origin - defence (n)	Attack efficiency (%)	Tackle total (n)	Pass total unsuccessful (%)	Dead ball kick pass unsuccessful (%)
Team possession origin - midfield (n)	Shot total (n)	Tackle successful (n)	Hand pass (n)	Dead ball free kick total (n)
Team possession origin - attack (n)	Shot from play (n)	Tackle successful (%)	Hand pass successful (n)	Dead ball free kick successful (n)
Team player possession total (n)	Shot from play (%)	Tackle unsuccessful (n)	Hand pass successful (%)	Dead ball free kick successful (%)
Team player possession total (min:s)	Shot from dead ball (n)	Tackle unsuccessful (%)	Hand pass unsuccessful (n)	Dead ball free kick unsuccessful (n)
Player possession average (s)	Shot from dead ball (%)	Tackle origin - defence (n)	Hand pass unsuccessful (%)	Dead ball free kick unsuccessful (%)
Player possession origin - defence (n)	Shot efficiency (%)	Tackle origin - midfield (n)	Kick pass (n)	Dead ball kick out total (n)
Player possession origin - midfield (n)	Score total (points + goals)	Tackle origin - attack (n)	Kick pass successful (n)	Dead ball kick out successful (n)
Player possession origin - attack (n)	Number of scores (n)	Free kick total (won) (n)	Kick pass successful (%)	Dead ball kick out successful (%)
	Attack per score average	Free kick origin - defence (n)	Kick pass unsuccessful (n)	Dead ball kick out unsuccessful (n)
	Productivity (score/10 possessions)	Free kick origin - midfield (n)	Kick pass unsuccessful (%)	Dead ball kick out unsuccessful (%)
	Point (n)	Free kick origin - attack (n)		
	Point from play (n)	Defensive actions total (n)		
	Point from dead ball (n)	Defensive actions - defence (n)		
	Goal (n)	Defensive actions - midfield (n)		
		Defensive actions - attack (n)		
		Defensive efficiency (%)		

Table 3.4 Game statistics and operational definitions used for match context

Context	Description
Playing time (min:s)	Duration of game including ball in play time and stoppage time due to injuries or dead balls.
Ball in play time (min:s)	Duration in which the ball is active within the boundaries of the field.
Stoppage time (min:s)	Duration when ball is not active.
Yellow card (n)	When a player is shown a yellow card.
Black card (n)	When a player is shown a black card.
Red card (n)	When a player is shown a red card and/or black card and not replaced.
Substitution (n)	When a player is replaced during the game.
Elo rating (pt)	An objective rating of a team's current performance based on historical data.
Tier (T)	Teams were classified within 4 tiers based on their Elo rating; tier 1 (≥1,728 Elo points), tier 2 (1,511–1,727 Elo points), tier 3 (1,348–1,510 Elo points), and tier 4 (≤1,347 Elo points) (87).

Table 3.5 Performance indicators and operational definitions used for possession

Possession	Description
Player possession	When a player controls the ball with either hand or foot (includes kick outs from goalkeeper). Possession persists until the player scores or fails in an attempted pass or shot, or the player is dispossessed and does not regain possession.
(n, min:s, s) (origin = D, M, A)	The total count of player possessions, the total time in player possession and the average time per possession (total possessions/total time). Each player possession is classified as originating in defence, midfield or attack.
Team possession	Team possession starts with control of the ball and persists until the team scores or a player loses possession.
(n, %, min:s, s) (origin = D, M, A)	The total count and percentage of team possession (relative to total time of opposition possession), total time in team possession and the average time per team possession (total possessions/total time). Each team possession is classified as originating in defence, midfield or attack.

Table 3.6 Performance indicators and operational definitions used for offence

Offence	**Description**
Attack	When a ball is passed across the opposition's 45 m line or shot attempted from outside the 45 m line. If the ball re-enters the middle zone and is then passed, carried back, or shot attempted into the attacking zone, it is considered the same attack. A new attack can start within the attacking zone if a turnover is gained during play from a kick out, sideline kick or technical foul. Attack ceases with loss of possession.
(n, origin = D, M, A)	Total count of attacks. Each attack is classified as originating in defence, midfield or attack.
Attacking efficiency (%)	Number of shots expressed as a percentage of the total number of team attacks.
Shot	An action that sends the ball directly towards the opposing teams' goal in an attempt to score a point or goal.
(n, *successful, unsuccessful)*	Total count of shots. Shot successful if score obtained. Shot unsuccessful if no score obtained.
Shot from play	A shot executed during open play.
(n, *%)*	Expressed as total count of shots from play and percentage of overall shots.
Shot from dead ball	A shot executed during a set play, e.g., penalty kick, 45 m kick, free kick or sideline kick.
(n, *%)*	Expressed as total count of shots from dead ball and percentage of overall shots.
Shot efficiency (%)	Number of scores expressed as a percentage of the total number of team shots.
Total score (pt)	Combined total score from points and goals.
Total number of scores (n)	Combined total number of scores from points and goals.
Average attack/ score	Mean number of attacks required to score.
Productivity (scores/10 possession)	Number of points scored per 10 possessions.
Point (pt)	When the ball is kicked, or struck with the hand(s) over the crossbar and between the two posts (1 point).
Goal (g)	When the ball is kicked under the crossbar and between the two posts (3 points).

Table 3.7 Performance indicators and operational definitions used for defence

Defence	**Description**
Turnover	When possession transfers from one team to another during play (excluding kick outs resulting from scores or the ball going wide past the end line).
(n, origin = D, M, A)	Total count of turnovers. Each turnover is classified as originating in defence, midfield or attack.
Tackle	When a player attempts to dispossess an opponent who is in possession of the ball. Minor physical contact on an opposing player's body is not counted, but contact on the ball is.
(n, *successful, unsuccessful; n, %)* *(origin* = D, M, A*)*	Total count of tackles. Each tackle classified as successful if player is dispossessed and loses possession, commits a technical foul or fails to execute a pass or shot resulting in a score. Tackle classified as unsuccessful if player retains possession or scores. Expressed as count and percentage. Each tackle is classified as originating from defence, midfield or attack.
Foul, free kick	Any action that is considered by the referee to be an infringement on the rules, resulting in a free kick.
(n, origin = D, M, A)	Total count of fouls/free kicks. Each foul/free kick is classified as originating in defence, midfield or attack.
Defensive actions	Number of fouls committed, turnovers won and tackles made combined per pitch zone.
(n, origin = D, M, A)	Total count of defensive actions. Each defensive action is classified as originating in defence, midfield or attack.
Defensive efficiency (%)	Number of opposition attacks which do not result in a shot as a percentage of their total attacks.

Table 3.8 Performance indicators and operational definitions used for passing

Passing	**Description**
Pass total	Combined total of hand pass and kick pass.
(n, successful, unsuccessful; n, %)	Total count of passes recorded. Each pass classified as successful, i.e., possession was retained, or unsuccessful, i.e., possession was lost (expressed as count and percentage).
Hand pass	Transfer of ball between players using the hand/fist.
(n, successful, unsuccessful; n, %)	Combined total of hand pass. Hand pass classified as successful, i.e., possession was retained, or unsuccessful, i.e., possession was lost (expressed as count and percentage).
Kick pass	Transfer of ball between players using the foot.
(n, successful, unsuccessful; n, %)	Combined total of kick pass. Kick pass classified as successful, i.e., possession was retained, or unsuccessful, i.e., possession was lost (expressed as count and percentage).

Table 3.9 Performance indicators and operational definitions used for dead balls

Dead ball	Description
Dead ball (n)	When a player releases possession from a dead ball kick out, free kick, sideline kick, 45 m kick or penalty kick. Expressed as total count of dead balls.
Dead ball kick pass	When a player releases possession from a dead ball kick out, sideline kick or free kick.
(n, *successful, unsuccessful; n, %)*	Total count of dead ball kick passes. Each dead ball kick pass classified as successful, i.e., possession was retained, or unsuccessful, i.e., possession was lost (expressed as count and percentage).
Dead ball free kick pass	When possession is released from a dead ball free kick.
(n, *successful, unsuccessful; n, %)*	Total count of dead ball free kick passes. Each dead ball free kick pass classified as successful, i.e., possession was retained, or unsuccessful, i.e., possession was lost (expressed as count and percentage).
Dead ball kick out	When a player releases possession from a dead ball kick out.
(n, *successful, unsuccessful; n, %)*	Total count of dead ball kick outs. Each dead ball kick out classified as successful, i.e., possession was retained, or unsuccessful, i.e., possession was lost (expressed as count and percentage).

3.3 Results

3.3.1 Winning games: winners vs. losers, n=24

Results from the univariate analyses of game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 3.10 to 3.15. Each table includes the mean result from both the winners and losers and the relative difference between these two groups. Significant differences are illustrated in the tables and highlighted within the text.

3.3.1.1 Match characteristics and game statistics: winners vs. losers

The average (mean ± SD) playing, ball in play and stoppage times were 74:12 ± 1:38, 37:08 ± 3:25 and 37:04 ± 4:09 min:s, respectively. There were no significant differences in the Elo ratings, number of substitutions made, or cards received, between winners and losers as outlined in Table 3.10.

Table 3.10 Elo ratings, number of substitutions and cards received, between winners (n=24) and losers (n=24)

	Group		
Game statistic	**Winners**	**Losers**	**Difference**
Substitution (n)	5.0 ± 1.2	5.5 ± 0.6	-0.5 ± 1.3
Yellow card (n)	1.7 ± 1.4	1.2 ± 1.1	0.5 ± 1.1
Black card (n)	0.4 ± 0.6	0.6 ± 0.7	-0.3 ± 0.9
Red card/BCNR (n)	0.2 ± 0.4	0.2 ± 0.4	0.0 ± 0.6
Elo rating (points)	1822.1 ± 184.6	1753.6 ± 174.6	68.5 ± 263.7

Values are mean ± SD; BCNR = Black card not replaced.

3.3.1.2 Performance characteristics: winners vs. losers

There were no differences in any of the measured team or individual possession indices (Table 3.11). In offensive play, the shots (p = 0.049), shot efficiency (p = 0.000), total score (p = 0.000), total number of scores (p = 0.000), average attack per score (p = 0.000), productivity (p = 0.000), points (p = 0.000), points from play (p = 0.002), and goals (p = 0.002) of winners was superior to losers (Table 3.12). When compared to losing teams, winning teams obtained a higher (p = 0.010) number of turnovers (Table 3.13). There were no differences in the number of tackles, defensive actions or defensive efficiency between winners and losers. Winners had a higher percentage of hand pass success (p = 0.040) and a lower number (p = 0.036) and percentage (p = 0.040) of unsuccessful hand passes than losers (Table 3.14). Winners also performed less kick outs (p = 0.010), resulting in fewer successful kick outs (p = 0.001) and successful dead ball kick passes (p = 0.036) overall (Table 3.15).

Table 3.11 Team and individual possession characteristics

	Group		
Performance indicator	**Winners**	**Losers**	**Difference**
Team possession			
Total number (n)	71.6 ± 7.7	71.8 ± 8.6	-0.1 ± 8.4
Proportion of total (%)	51.1 ± 4.2	48.9 ± 4.2	2.1 ± 8.3
Total time (s)	973.9 ± 110.2	936.2 ± 140.5	37.7 ± 158.7
Time per possession (s)	13.8 ± 2.2	13.3 ± 3.0	0.5 ± 2.4
Origin defence (n)	40.4 ± 6.4	42.2 ± 6.7	-1.8 ± 10.0
Origin midfield (n)	22.9 ± 5.4	21.8 ± 7.1	1.1 ± 8.7
Origin attack (n)	8.3 ± 2.7	7.8 ± 2.6	0.6 ± 3.7
Player possession			
Total number (n)	298.8 ± 36.6	297.3 ± 38.6	1.5 ± 51.6
Total time in possession (s)	636.2 ± 92.2	608.6 ± 115.4	27.6 ± 114
Time per possession (s)	2.1 ± 0.2	2.0 ± 0.2	0.1 ± 0.3
Origin defence (n)	82.4 ± 15.8	84.7 ± 21.9	-2.3 ± 30.1
Origin midfield (n)	146.7 ± 30.4	144.2 ± 34.5	2.5 ± 40.3
Origin attack (n)	70.6 ± 14.3	68.4 ± 19.5	2.2 ± 28.3

Values are mean ± SD.

Table 3.12 Selected indices of offensive play

Performance indicator	Group		Difference
	Winners	Losers	
Attack			
Total number (n)	41.4 ± 6.6	38.4 ± 5.7	3.0 ± 8.6
Origin defence (n)	21.6 ± 5.0	20.4 ± 5.8	1.3 ± 5.2
Origin midfield (n)	18.0 ± 5.0	16.6 ± 4.8	1.4 ± 7.3
Origin attack (n)	1.8 ± 1.4	1.4 ± 1.4	0.3 ± 2.1
Efficiency (%)	71.6 ± 10.3	68.3 ± 8.0	3.3 ± 11.8
Shot			
Total number (n)	29.5 ± 5.7[a]	26.2 ± 4.8	3.3 ± 7.8
From play (n)	22.8 ± 6.4	19.7 ± 5.0	3.0 ± 7.5
From play (%)	76.1 ± 9.9	74.8 ± 8.3	1.3 ± 10.3
From dead ball (n)	6.8 ± 2.1	6.5 ± 2.0	0.3 ± 2.7
From dead ball (%)	23.9 ± 9.9	25.2 ± 8.3	-1.3 ± 10.3
Efficiency (%)	53.2 ± 11.5[a]	45.6 ± 9.5	7.6 ± 9.2
Score			
Total combined	18.1 ± 4.8[b]	13.0 ± 4.2	5.1 ± 3.6
Total number (n)	15.5 ± 3.5[a]	11.9 ± 3.1	3.6 ± 2.9
Average attack/score (n)	2.9 ± 1.0[a]	3.5 ± 1.3	-0.6 ± 0.7
Productivity	2.5 ± 0.7[a]	1.8 ± 0.6	0.7 ± 0.6
Point (n)	14.1 ± 3.1[a]	11.3 ± 2.9	2.8 ± 3.2
Point from play (n)	9.5 ± 3.1[a]	7.3 ± 2.6	2.3 ± 3.1
Point from dead ball (n)	4.6 ± 2.0	4.0 ± 2.3	0.6 ± 2.8
Goal (n)	1.3 ± 1.0[b]	0.6 ± 0.9	0.8 ± 1.1

Values are mean ± SD; $p \leq 0.05$ vs. losers using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 3.13 Selected indices of defensive play

Performance indicator	Group: Winners	Losers	Difference
Turnovers			
Total number (n)	32.5 ± 7.5[a]	28.7 ± 6.5	3.8 ± 6.7
Origin defence (n)	17.6 ± 3.5	16.1 ± 5.1	1.5 ± 4.4
Origin midfield (n)	13.1 ± 5.4	11.3 ± 4.8	1.9 ± 7.6
Origin attack (n)	1.8 ± 1.5	1.3 ± 1.3	0.5 ± 2.2
Tackles			
Total number (n)	90.9 ± 23.1	92.9 ± 16.3	-2.0 ± 27.7
Successful (n)	10.0 ± 3.7	9.8 ± 3.5	0.3 ± 3.5
Successful (%)	10.9 ± 3.1	10.7 ± 3.9	0.2 ± 3.4
Unsuccessful (n)	80.8 ± 20.7	83.1 ± 16.1	-2.3 ± 26.0
Unsuccessful (%)	89.1 ± 3.1	89.3 ± 3.9	-0.2 ± 3.4
Origin defence (n)	37.3 ± 14.0	39.4 ± 8.9	-2.0 ± 15.8
Origin midfield (n)	41.7 ± 16.8	39.4 ± 10.9	2.3 ± 19.4
Origin attack (n)	11.9 ± 7.1	14.1 ± 6.6	-2.3 ± 10.9
Free kick won			
Total number (n)	19.4 ± 5.7	18.7 ± 7.1	0.7 ± 8.2
Origin defence (n)	4.9 ± 2.2	4.0 ± 2.6	0.9 ± 3.0
Origin midfield (n)	9.0 ± 3.7	9.7 ± 5.2	-0.7 ± 6.6
Origin attack (n)	5.4 ± 2.0	5.0 ± 2.6	0.4 ± 2.6
Defensive actions			
Total number (n)	142.2 ± 27.8	141.4 ± 22.3	0.8 ± 35.4
Origin defence (n)	60.0 ± 15.9	61.0 ± 12.7	-1.1 ± 18.6
Origin midfield (n)	64.5 ± 20.8	60.2 ± 15.9	4.4 ± 28.0
Origin attack (n)	17.7 ± 9.9	20.2 ± 8.0	-2.5 ± 14.3
Defensive efficiency (%)	31.8 ± 8.0	28.4 ± 10.3	3.3 ± 11.8

Values are mean ± SD; $p \leq 0.05$ vs. losers using a one-sample t-test ([a]).

Table 3.14 Successful and unsuccessful hand and kick pass

Performance indicator	Group		Difference
	Winners	**Losers**	
Combined hand and kick pass			
Total number (n)	247.7 ± 37.1	248.6 ± 39.2	-1.0 ± 49.2
Successful (n)	227.0 ± 38.5	226.5 ± 41.2	0.5 ± 50.2
Successful (%)	91.4 ± 3.1	90.8 ± 3.3	0.7 ± 3.2
Unsuccessful (n)	20.6 ± 6.2	22.1 ± 6.2	-1.5 ± 6.4
Unsuccessful (%)	8.6 ± 3.1	9.2 ± 3.3	-0.7 ± 3.2
Hand pass			
Total number (n)	168.6 ± 36.6	170.2 ± 42.0	-1.6 ± 44.3
Successful (n)	164.6 ± 35.8	165.3 ± 42.3	-0.7 ± 44.3
Successful (%)	97.6 ± 1.2[a]	96.9 ± 1.7	0.7 ± 1.7
Unsuccessful (n)	4.0 ± 2.0[a]	4.9 ± 2.0	-0.9 ± 2.0
Unsuccessful (%)	2.4 ± 1.2[a]	3.1 ± 1.7	-0.7 ± 1.7
Kick pass			
Total number (n)	79.0 ± 14.0	78.4 ± 13.7	0.6 ± 15.9
Successful (n)	62.4 ± 13.9	61.2 ± 11.2	1.2 ± 17.3
Successful (%)	78.7 ± 7.0	78.2 ± 6.0	0.5 ± 8.8
Unsuccessful (n)	16.6 ± 5.9	17.2 ± 6.2	-0.6 ± 6.5
Unsuccessful (%)	21.3 ± 7.0	21.8 ± 6.0	-0.5 ± 8.8

Values are mean ± SD; $p \leq 0.05$ vs. losers using a one-sample t-test ([a]).

Table 3.15 Dead ball distribution

Performance indicator	Group: Winners	Group: Losers	Difference
Dead ball			
Total number (n)	42.7 ± 7.4	46.8 ± 7.3	-4.1 ± 10.6
^Dead ball kick pass			
Successful (n)	28.0 ± 4.6[a]	31.1 ± 5.9	-3.0 ± 6.8
Successful (%)	78.8 ± 8.1	77.2 ± 8.0	1.6 ± 10.8
Unsuccessful (n)	7.9 ± 3.7	9.3 ± 3.8	-1.4 ± 5.2
Unsuccessful (%)	21.2 ± 8.1	22.8 ± 8.0	-1.6 ± 10.8
Dead ball free kick pass			
Total number (n)	13.5 ± 4.6	13.5 ± 6.3	-0.1 ± 7.3
Successful (n)	12.7 ± 4.2	12.7 ± 5.4	0.0 ± 6.7
Successful (%)	94.4 ± 5.5	95.5 ± 6.2	-1.0 ± 7.9
Unsuccessful (n)	0.8 ± 0.8	0.8 ± 1.2	0.0 ± 1.2
Unsuccessful (%)	5.6 ± 5.5	4.5 ± 6.2	1.0 ± 7.9
Dead ball kick out			
Total number (n)	20.3 ± 4.2[a]	24.0 ± 3.9	-3.8 ± 6.5
Successful (n)	13.4 ± 3.2[a]	16.0 ± 4.0	-2.5 ± 3.3
Successful (%)	67.3 ± 14.4	66.2 ± 12.6	1.0 ± 16.5
Unsuccessful (n)	6.9 ± 3.5	8.1 ± 3.2	-1.2 ± 5.1
Unsuccessful (%)	32.7 ± 14.4	33.8 ± 12.6	-1.0 ± 16.5

Values are mean ± SD; $p \leq 0.05$ vs. losers using a one-sample t-test ([a]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs.

3.3.1.3 Multivariate analysis: winners vs. losers

The 4 eigenvectors produced by the PCA explained 81.9% of the total variance (Figure 3.3) and the component loadings after rotation are illustrated in Table 3.16. The dominant PIs in each component were used to subjectively characterise new PIs reflecting: 1) midfield-counterattacking, 2) defensive free kick efficiency, 3) defensive-counterattacking and 4) possession. The LogR revealed that defensive-counterattacking (β-coefficient = -3.22, SE = 1.36, p = 0.018) significantly contributed to outcome (lose vs. win) and was retained in the model (odds ratio; 0.0398, 0.0012-0.2980; 95% CI), with the log likelihood function being 8.00, $\chi^2(1) = 16.00$, $p < 0.001$. Using lose as positive, the area under the curve was 0.88. The R^2 value was 0.48 (approaching a large effect). The DA performed on this variable, revealed 1 DF (win or lose), which explained 100% of the variance, canonical $R^2 = 0.47$, significantly differentiating the groups, $\Lambda = 0.53$, $\chi^2(1) = 13.77$, $p < 0.001$. The LOOC returned and accuracy of 87.5% in both models, indicating that defensive-counterattacking differentiated winners from losers in 21 out of 24 games.

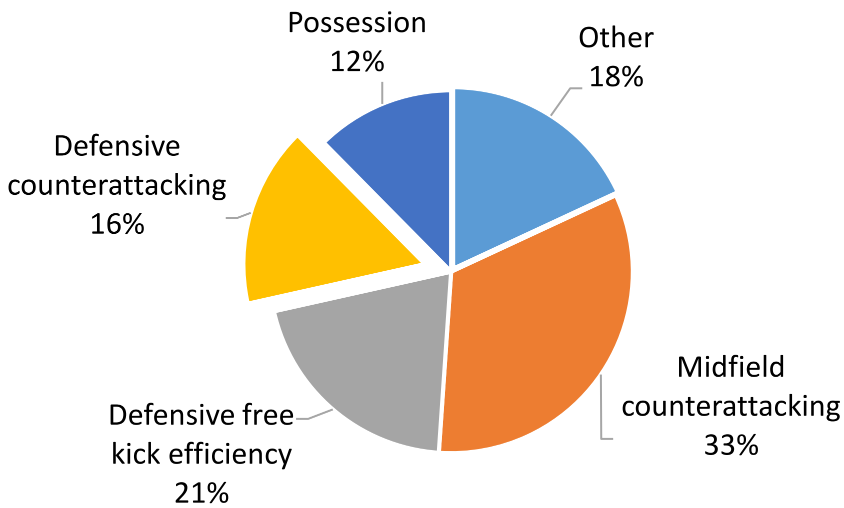


Figure 3.3 Variance explained by each of the principal components.

Table 3.16 Summary of exploratory principal component analysis using 18 performance indicators created from the differences between independent winners (n=12) and losers (n=12)

	Rotated component loadings			
Performance indicator	**Midfield counter-attacking**	**Defensive free kick efficiency**	**Defensive counter-attacking**	**Possession**
dAttack origin MF	**0.958**	0.123	0.060	-0.014
dTeam possession origin MF	**0.913**	0.320	0.031	0.077
dTurnover origin MF	**0.880**	-0.136	0.353	-0.130
dPlayer possession origin AT	**0.608**	**-0.639**	0.209	0.110
dTackle origin AT	**0.458**	**-0.740**	-0.133	-0.325
dShot from play	**0.664**	-0.315	**0.589**	0.135
dPoint from play	0.309	0.074	**0.686**	-0.138
dAttack origin DF	-0.155	**-0.544**	**0.618**	-0.362
dTurnover origin DF	**-0.561**	0.117	**0.601**	**0.452**
dPlayer possession time	0.017	0.091	**0.404**	**0.824**
dDead ball FK pass unsuccessful	0.156	**0.551**	-0.192	**0.518**
dDead ball FK pass successful	0.081	**0.873**	-0.104	0.126
dFree kick origin DF	-0.353	**0.759**	0.136	0.208
dPlayer possession origin DF	**-0.759**	**0.425**	0.008	0.325
dTackle origin MF	0.165	-0.307	0.235	**-0.739**
dDead ball kick out successful	-0.159	0.048	**-0.893**	-0.161
dTackle origin DF	**-0.694**	0.305	0.039	-0.083
dTeam possession origin DF	**-0.833**	0.383	-0.259	0.157
Eigenvalue	5.94	3.67	2.90	2.23
% of variance	33.01	20.41	16.12	12.38

Component loadings ≥±0.4 appear in bold. DF = defence, MF = midfield, AT = attack, FK = free kick.

3.3.2 Winning games: winners vs. losers (AICSFF, RT vs. OTs and OTs vs. RT)

3.3.2.1 Match characteristics: all

Table 3.17 summarises the match characteristics relating to winning for the RT (n=8), OTs (n=12) and for teams competing in the AICSFF (n=4).

Table 3.17 Match characteristics associated with winning for the reference (n=8) and opposition (n=12) teams and also for teams competing in the AICSFF (n=4)

	Team		
Characteristic	**AICSFF**	**Reference**	**Opposition**
Playing time (min:s)	75:17 ± 0:57	73:51 ± 1:49	74:05 ± 1:37
Ball in play time (min:s)	37:27 ± 1:31	36:09 ± 3:09	37:42 ± 4:01
Stoppage time (min:s)	37:49 ± 1:20	37:42 ± 3:55	36:22 ± 4:58

Values are mean ± SD.

3.3.3 Winning games: AICSFF winners vs. losers, n=4

Results from the univariate analyses of game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 3.18 to 3.23. Each table includes the mean result from both the winners and losers and the relative difference between these two groups. Significant differences are illustrated in the tables and highlighted within the text.

3.3.3.1 Game statistics: AICSFF winners vs. losers

There was no difference in any game statistics in the AICSFF (Table 3.18).

Table 3.18 Game statistics between winners and losers from the AICSFF

	Group		
Game statistic	**Winners**	**Losers**	**Difference**
Substitution (n)	6.0 ± 0.0	5.3 ± 1.0	0.8 ± 1.0
Yellow card (n)	3.0 ± 0.8	2.0 ± 0.8	1.0 ± 0.8
Black card (n)	1.0 ± 0.8	0.5 ± 0.6	0.5 ± 1.3
Red card/BCNR (n)	0.5 ± 0.6	0.0 ± 0.0	0.5 ± 0.6
Elo rating (points)	1876.8 ± 93.3	1865 ± 117.4	11.8 ± 167.2

Values are mean ± SD; BCNR = Black card not replaced.

3.3.3.2 Performance characteristics: AICSFF winners vs. losers

There was no difference in team or player possession (Table 3.19) or defensive characteristics (Table 3.21). Winners had a higher total score ($p = 0.011$) and productivity ($p = 0.013$) compared to losers (Table 3.20). Winners had a higher percentage of successful hand passes ($p = 0.020$) and lower percentage of unsuccessful hand passes ($p = 0.020$) than losers (Table 3.22). Winners also had fewer successful dead ball kick passes ($p = 0.008$) (Table 3.23).

Table 3.19 Possession for winners and losers from the All-Ireland semi-finals and finals

Performance indicator	Group		Difference
	Winners	Losers	
Team possession			
Total number (n)	72.5 ± 7.9	73.5 ± 5.7	-1.0 ± 2.4
Proportion of total (%)	52.0 ± 2.9	48.0 ± 2.9	4.1 ± 5.8
Total time (s)	1005.7 ± 83.2	925.9 ± 69.1	79.9 ± 111.1
Time per possession (s)	14.1 ± 2.4	12.6 ± 1.0	1.5 ± 1.8
Origin defence (n)	42.3 ± 7.4	42.5 ± 8.2	-0.3 ± 14.4
Origin midfield (n)	21.5 ± 6.6	24.0 ± 3.4	-2.5 ± 9.5
Origin attack (n)	8.8 ± 3.8	7.0 ± 2.6	1.8 ± 5.4
Player possession			
Total number (n)	304.5 ± 41.3	289 ± 11.2	15.5 ± 47.1
Total time in possession (s)	630.8 ± 22.9	598.2 ± 72.8	32.6 ± 63.3
Time per possession (s)	2.1 ± 0.2	2.1 ± 0.2	0.0 ± 0.4
Origin defence (n)	82.0 ± 13.3	83.3 ± 22.5	-1.3 ± 35.0
Origin midfield (n)	157.5 ± 45.3	143.0 ± 4.9	14.5 ± 47.2
Origin attack (n)	65.0 ± 10.4	62.8 ± 17.7	2.3 ± 21.9

Values are mean ± SD.

Table 3.20 Offensive play for winners and losers from the All-Ireland semi-finals and finals

Performance indicator	Group		Difference
	Winners	**Losers**	
Attack			
Total number (n)	42.3 ± 6.7	41.8 ± 6.6	0.5 ± 11.8
Origin defence (n)	21.3 ± 2.9	20.5 ± 2.1	0.8 ± 4.0
Origin midfield (n)	18.5 ± 6.8	19.3 ± 3.9	-0.8 ± 9.8
Origin attack (n)	2.5 ± 2.4	2.0 ± 1.8	0.5 ± 2.9
Efficiency (%)	69.6 ± 11.2	66.4 ± 9.6	3.3 ± 6.7
Shot			
Total number (n)	29.0 ± 3.7	27.8 ± 6.5	1.3 ± 9.0
From play (n)	22.3 ± 4.0	22.0 ± 6.0	0.3 ± 8.4
From play (%)	76.5 ± 6.8	79.2 ± 7.3	-2.7 ± 12.3
From dead ball (n)	6.8 ± 1.7	5.8 ± 2.1	1.0 ± 3.4
From dead ball (%)	23.5 ± 6.8	20.9 ± 7.3	2.7 ± 12.3
Efficiency (%)	51.0 ± 15.2	44.8 ± 3.0	6.2 ± 15.8
Score			
Total combined	17.0 ± 4.7[a]	13.0 ± 3.4	4.0 ± 1.4
Total number (n)	14.5 ± 3.5	12.5 ± 3.3	2.0 ± 3.2
Average attack/score (n)	3.1 ± 1.0	3.5 ± 0.8	-0.4 ± 0.7
Productivity	2.4 ± 0.8[a]	1.8 ± 0.5	0.6 ± 0.2
Point (n)	13.3 ± 3.8	12.3 ± 3.4	1.0 ± 4.9
Point from play (n)	8.8 ± 3.0	10.0 ± 3.4	-1.3 ± 3.5
Point from dead ball (n)	4.5 ± 1.0	2.3 ± 1.3	2.3 ± 1.7
Goal (n)	1.3 ± 1.5	0.3 ± 0.5	1.0 ± 1.8

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using a one-sample t-test ([a]).

Table 3.21 Defensive play for winners and losers from the All-Ireland semi-finals and finals

	Group		
Performance indicator	**Winners**	**Losers**	**Difference**
Turnovers			
Total number (n)	32.8 ± 7.5	31.3 ± 5.7	1.5 ± 7.0
Origin defence (n)	17.8 ± 1.5	16.0 ± 5.8	1.8 ± 5.7
Origin midfield (n)	12.5 ± 5.3	13.0 ± 4.8	-0.5 ± 9.7
Origin attack (n)	2.5 ± 2.4	2.3 ± 2.1	0.3 ± 3.3
Tackles			
Total number (n)	100.8 ± 11.0	94.3 ± 7.8	6.5 ± 16.4
Successful (n)	12.5 ± 1.3	12.3 ± 3.9	0.3 ± 2.9
Successful (%)	12.6 ± 2.4	13.1 ± 4.1	-0.5 ± 2.0
Unsuccessful (n)	88.3 ± 11.5	82.0 ± 8.8	6.3 ± 14.6
Unsuccessful (%)	87.4 ± 2.4	87.0 ± 4.1	0.5 ± 2.0
Origin defence (n)	44.0 ± 17.5	40.3 ± 7.2	3.8 ± 23.4
Origin midfield (n)	44.5 ± 9.3	42.3 ± 7.3	2.3 ± 14.7
Origin attack (n)	12.3 ± 4.9	11.8 ± 5.3	0.5 ± 9.5
Free kick won			
Total number (n)	18.5 ± 5.2	18.0 ± 2.6	0.5 ± 5.1
Origin defence (n)	4.8 ± 2.1	4.3 ± 2.4	0.5 ± 2.6
Origin midfield (n)	9.3 ± 2.5	10.8 ± 1.5	-1.5 ± 3.3
Origin attack (n)	4.5 ± 1.0	3.0 ± 0.8	1.5 ± 1.3
Defensive actions			
Total number (n)	151.5 ± 11	144.3 ± 14.9	7.3 ± 23.9
Origin defence (n)	64.8 ± 17.8	61.0 ± 13.6	3.8 ± 30.1
Origin midfield (n)	67.8 ± 14.2	64.5 ± 9.1	3.3 ± 23.0
Origin attack (n)	19.0 ± 9.3	18.8 ± 7.7	0.3 ± 14.9
Defensive efficiency (%)	33.6 ± 9.6	30.4 ± 11.2	3.3 ± 6.7

Values are mean ± SD.

Table 3.22 Passing for winners and losers from the All-Ireland semi-finals and finals

	Group		
Performance indicator	**Winners**	**Losers**	**Difference**
Combined hand and kick pass			
Total number (n)	253.3 ± 43.5	236.0 ± 11.6	17.3 ± 49.0
Successful (n)	231.3 ± 49.0	216.0 ± 6.6	15.3 ± 51.4
Successful (%)	90.8 ± 4.1	91.6 ± 1.7	-0.8 ± 3.3
Unsuccessful (n)	22.0 ± 6.3	20.0 ± 5.1	2.0 ± 5.5
Unsuccessful (%)	9.2 ± 4.1	8.4 ± 1.7	0.8 ± 3.3
Hand pass			
Total number (n)	166.0 ± 37.0	159.5 ± 15.3	6.5 ± 23.8
Successful (n)	161.8 ± 36.2	154.5 ± 15.1	7.3 ± 23.7
Successful (%)	97.5 ± 1.4[a]	96.9 ± 1.4	0.6 ± 0.3
Unsuccessful (n)	4.3 ± 2.6	5.0 ± 2.3	-0.8 ± 0.5
Unsuccessful (%)	2.5 ± 1.4[a]	3.2 ± 1.4	-0.6 ± 0.3
Kick pass			
Total number (n)	87.3 ± 21.5	76.5 ± 21.8	10.8 ± 31.6
Successful (n)	69.5 ± 23.2	61.5 ± 16.9	8.0 ± 34.0
Successful (%)	78.8 ± 8.5	80.7 ± 6.3	-1.9 ± 11.2
Unsuccessful (n)	17.8 ± 7.1	15.0 ± 7.1	2.8 ± 5.1
Unsuccessful (%)	21.2 ± 8.5	19.4 ± 6.3	1.8 ± 11.1

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using a one-sample t-test ([a]).

Table 3.23 Dead ball distribution for winners and losers from the All-Ireland semi-finals and finals

Performance indicator	Group		Difference
	Winners	Losers	
Dead ball			
Total number (n)	43.5 ± 6.0	47.5 ± 4.0	-4.0 ± 7.3
^Dead ball kick pass			
Successful (n)	28.3 ± 4.3[a]	33.8 ± 3.8	-5.5 ± 1.7
Successful (%)	77.0 ± 5.0	81.2 ± 7.8	-4.2 ± 10.8
Unsuccessful (n)	8.5 ± 2.5	8.0 ± 3.5	0.5 ± 5.7
Unsuccessful (%)	23.0 ± 5.0	18.8 ± 7.8	4.2 ± 10.9
Dead ball free kick pass			
Total number (n)	12.8 ± 3.8	13.3 ± 3.0	-0.5 ± 2.4
Successful (n)	12.3 ± 3.4	13.0 ± 2.6	-0.8 ± 2.6
Successful (%)	96.5 ± 4.2	98.5 ± 3.0	-2.0 ± 4.2
Unsuccessful (n)	0.5 ± 0.6	0.3 ± 0.5	0.3 ± 0.5
Unsuccessful (%)	3.5 ± 4.2	1.5 ± 3.0	2.0 ± 4.2
Dead ball kick out			
Total number (n)	22.5 ± 5.1	24.3 ± 1.7	-1.8 ± 6.5
Successful (n)	14.5 ± 3.1	16.8 ± 2.1	-2.3 ± 1.5
Successful (%)	64.8 ± 8.2	69.5 ± 12	-4.8 ± 15.6
Unsuccessful (n)	8.0 ± 2.9	7.5 ± 3.1	0.5 ± 5.8
Unsuccessful (%)	35.2 ± 8.2	30.5 ± 12	4.8 ± 15.6

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using a one-sample t-test ([a]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs.

3.3.4 Winning games: winners vs. losers (RT vs. OTs; n=8 and OTs vs. RT; n=12)

Results from the univariate analyses of the match characteristics, game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 3.24 to 3.29. Each table includes the mean results from both the RT and OTs and the relative difference between these two groups, associated with two contexts, 1) when the RT won and 2) when the OTs won. Significant differences are illustrated in the tables and highlighted within the text.

3.3.4.1 Match characteristics: winners vs. losers; RT vs. OTs. and OTs vs. RT

There were no significant differences in any game statistics between the RT and their OTs (Table 3.24).

3.3.4.2 Performance characteristics: winners vs. losers; RT vs. OTs. and OTs vs. RT

The main differences observed between the RT and OTs when winning, are highlighted below by aspect of play.

3.3.4.2.1 Possession

In winning, the RT had more total time in both team (p = 0.007) and player (p = 0.008) possession and a higher frequency of team (p = 0.007) possessions (Table 3.25) than OTs. In contrast, OTs had fewer team (p = 0.005) and player (p = 0.003) possessions than the RT. The OTs had fewer team possessions originating in defence (p = 0.028) and player possessions originating in midfield (p = 0.041), whereas the RT had more player possessions originating in defence (p = 0.007).

3.3.4.2.2 Offence

In winning, OTs had a greater number of attacks (p = 0.015) and attacks originating in defence (p = 0.004) than the RT (Table 3.26). Shot efficiency was also higher in both the RT (p = 0.006) and OT (p = 0.018) when winning. Both the RT and OTs had higher total scores (RT: p = 0.006, OT: p = 0.002), total number of scores (RT: p = 0.005, OT: p = 0.001), points (RT: p = 0.012, OT: p = 0.003), and points from play (RT: p = 0.004, OT: p = 0.005), combined with lower average attacks per score (RT: p = 0.001, OT: p = 0.033) when winning. Productivity (p = 0.000) and number of goals scored (p = 0.021) were also higher in OTs when winning.

3.3.4.2.3 Defence

In winning, the OTs obtained a significantly higher total number of turnovers (p = 0.024). Turnover origin was higher in midfield (p = 0.050) for the OTs and in defence (p = 0.022) for the RT (Table 3.27). The RT performed less tackles (p = 0.003) and the OTs performed more tackles (p = 0.035) in defensive play. Similarly, the RT performed fewer unsuccessful tackles (p = 0.003), whereas the OTs performed more unsuccessful tackles (p = 0.026).

The RT performed fewer tackles in midfield (p = 0.005) and attack (p = 0.002), whereas the OTs performed more tackles in midfield (p = 0.005). The OTs won fewer free kicks overall ($p = 0.049$) and free kicks originating in midfield ($p = 0.006$). In contrast, the RT won more free kicks originating in defence ($p = 0.010$). The RT performed fewer defensive actions ($p = 0.009$) and OTs more ($p = 0.005$) defensive actions, respectively. Likewise, the RT performed fewer defensive actions originating in midfield ($p = 0.004$) and attack ($p = 0.012$), whereas the OTs performed a greater number of defensive actions originating in midfield ($p = 0.002$).

3.3.4.2.4 Passing

The OTs performed fewer total passes ($p = 0.001$) and had less total successful ($p = 0.006$) passes in winning compared to the RT (Table 3.28). They also had fewer total hand passes ($p = 0.006$) and successful hand passes ($p = 0.006$). The RT had a higher percentage of successful hand passes ($p = 0.008$) and lower percentage of unsuccessful hand passes ($p = 0.008$). There were no significant differences in kick pass characteristics between either the RT or OTs.

3.3.4.2.5 Dead ball distribution

In winning, the OTs had a fewer number ($p = 0.001$) of dead balls (Table 3.29) and fewer successful ($p = 0.003$) and unsuccessful ($p = 0.015$) dead ball kick passes. The RT had more free kick passes ($p = 0.032$) and more successful free kick passes ($p = 0.023$). In contrast, the OTs had fewer free kick passes ($p = 0.016$) and less successful free kick passes ($p = 0.019$). The OTs had fewer kick outs ($p = 0.012$) and unsuccessful kick outs ($p = 0.037$), whereas the RT had fewer successful kick outs ($p = 0.041$).

Table 3.24 Game statistics for the reference team and opposition teams

	Group					
	Reference Win			Opposition Win		
Game statistic	Reference	Opposition	Difference	Opposition	Reference	Difference
Substitution (n)	4.9 ± 1.5	5.6 ± 0.5	-0.8 ± 1.2	4.8 ± 1.2	5.6 ± 0.5	-0.8 ± 1.2
Yellow card (n)	2.3 ± 1.5	1.4 ± 1.4	0.9 ± 1.5	0.8 ± 1.0	0.8 ± 0.8	0.0 ± 0.7
Black card (n)	0.1 ± 0.4	0.5 ± 0.8	-0.4 ± 0.9	0.3 ± 0.5	0.8 ± 0.8	-0.4 ± 0.8
Red card/BCNR (n)	0.3 ± 0.5	0.3 ± 0.5	0.0 ± 0.5	0.0 ± 0.0	0.3 ± 0.5	-0.3 ± 0.5
Elo rating (points)	1696.6 ± 48.4	1761.3 ± 280.3	-64.6 ± 287.3	1887.6 ± 224.0	1711.3 ± 59.3	176.3 ± 241.9

Values are mean ± SD; BCNR = Black card not replaced.

Table 3.25 Possession for the reference team and opposition teams

Performance indicator	Group					
	Reference Win			Opposition Win		
	Reference	Opposition	Difference	Opposition	Reference	Difference
Team possession						
Total number (n)	77.5 ± 6.1[a]	70.4 ± 11.1	7.1 ± 10.0	67.4 ± 6.2[a]	72.1 ± 8.0	-4.7 ± 4.6
Proportion of total (%)	54.6 ± 3.5	45.4 ± 3.5	9.2 ± 6.9	48.4 ± 3.0	51.6 ± 3.0	-3.2 ± 6.0
Total time (s)	1004.8 ± 120.4[a]	836.0 ± 120.2	168.8 ± 126.1	942.8 ± 110.3	1006.5 ± 134.4	-63.8 ± 121.6
Time per possession (s)	13.1 ± 2.1	12.3 ± 3.8	0.7 ± 3.2	14.1 ± 2.3	14.2 ± 2.7	0.0 ± 1.9
Origin defence (n)	43.9 ± 5.5	39.5 ± 4.0	4.4 ± 5.8	37.4 ± 5.7[a]	43.9 ± 7.6	-6.5 ± 8.9
Origin midfield (n)	24.8 ± 4.3	21.8 ± 10.0	3.0 ± 8.9	22.2 ± 5.9	21.1 ± 6.0	1.1 ± 8.6
Origin attack (n)	8.9 ± 2.1	9.1 ± 2.5	-0.3 ± 3.8	7.8 ± 2.9	7.1 ± 2.5	0.8 ± 3.3
Player possession						
Total number (n)	311.4 ± 42.1	269.5 ± 39.8	41.9 ± 53.5	288.4 ± 31.2[a]	318.5 ± 31.6	-30.1 ± 28.1
Total time in possession (s)	655.0 ± 95.3[a]	534.9 ± 84.3	120.1 ± 93.4	625.5 ± 107.0	661.2 ± 122.0	-35.7 ± 99.8
Time per possession (s)	2.1 ± 0.3	2.0 ± 0.2	0.1 ± 0.4	2.2 ± 0.2	2.1 ± 0.2	0.1 ± 0.3
Origin defence (n)	92.9 ± 13.8[a]	74.4 ± 12.4	18.5 ± 13.7	75.6 ± 14.9	92.0 ± 25.1	-16.4 ± 30.2
Origin midfield (n)	146.1 ± 29.5	118.4 ± 28.7	27.8 ± 40.6	143.4 ± 27.7[a]	161.8 ± 33.6	-18.3 ± 27.4
Origin attack (n)	72.4 ± 11.8	76.8 ± 14.1	-4.4 ± 23.2	71.3 ± 17.1	64.8 ± 22.5	6.6 ± 33.9

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using a one-sample t-test ([a]).

Table 3.26 Offensive play for the reference team and opposition teams

Performance indicator	Group					
	Reference Win			Opposition Win		
	Reference	Opposition	Difference	Opposition	Reference	Difference
Attack						
Total number (n)	39.6 ± 4.1	41.0 ± 4.5	-1.4 ± 5.7	42.3 ± 8.0[a]	35.6 ± 5.0	6.8 ± 8.1
Origin defence (n)	19.5 ± 3.3	21.8 ± 6.5	-2.3 ± 6.0	23.2 ± 6.1[a]	19.4 ± 6.2	3.8 ± 3.6
Origin midfield (n)	18.5 ± 2.6	17.5 ± 6.2	1.0 ± 5.1	17.6 ± 5.8	15.2 ± 3.9	2.4 ± 8.0
Origin attack (n)	1.6 ± 1.1	1.8 ± 1.8	-0.1 ± 2.6	1.6 ± 1.2	1.0 ± 0.9	0.6 ± 1.6
Efficiency (%)	76.6 ± 12.4	66.8 ± 7.5	9.8 ± 12.5	68.9 ± 7.9	69.9 ± 8.1	-1.0 ± 11.3
Shot						
Total number (n)	30.3 ± 5.1	27.4 ± 4.3	2.9 ± 6.2	29.2 ± 6.8	24.8 ± 4.5	4.3 ± 8.9
From play (n)	22.8 ± 5.4	20.6 ± 5.0	2.1 ± 5.0	22.9 ± 8.0	18.3 ± 4.7	4.6 ± 8.8
From play (%)	74.5 ± 8.2	74.7 ± 9.6	-0.2 ± 7.9	77.1 ± 12.1	73.5 ± 7.9	3.6 ± 11.3
From dead ball (n)	7.5 ± 1.9	6.8 ± 2.1	0.8 ± 2.6	6.3 ± 2.4	6.5 ± 2.1	-0.3 ± 2.7
From dead ball (%)	25.5 ± 8.2	25.3 ± 9.6	0.2 ± 7.9	23.0 ± 12.1	26.5 ± 7.9	-3.6 ± 11.3
Efficiency (%)	55.9 ± 5.5[a]	46.5 ± 5.8	9.4 ± 6.8	52.2 ± 13.6[a]	45.2 ± 12.9	7.0 ± 8.7
Score						
Total combined	19.5 ± 4.1[a]	13.9 ± 3.2	5.6 ± 4.1	17.6 ± 5.5[b]	12.5 ± 5.2	5.1 ± 3.8
Total number (n)	16.8 ± 2.2[a]	12.6 ± 2.1	4.1 ± 2.9	14.9 ± 4.1[a]	11.2 ± 3.6	3.8 ± 3.0
Average attack/score (n)	2.4 ± 0.4[a]	3.3 ± 0.4	-0.9 ± 0.4	3.1 ± 1.3[a]	3.6 ± 1.8	-0.6 ± 0.8
Productivity	2.5 ± 0.5	2.0 ± 0.5	0.5 ± 0.6	2.6 ± 0.7[a]	1.8 ± 0.7	0.9 ± 0.6
Point (n)	15.4 ± 1.5[a]	12.0 ± 2.3	3.4 ± 2.8	13.6 ± 3.6[a]	10.5 ± 3.0	3.1 ± 2.8
Point from play (n)	10.1 ± 2.0[a]	7.4 ± 2.1	2.8 ± 1.8	9.4 ± 3.8[a]	6.3 ± 2.1	3.1 ± 3.0
Point from dead ball (n)	5.3 ± 1.3	4.6 ± 2.1	0.6 ± 2.6	4.2 ± 2.5	4.2 ± 2.5	0.0 ± 3.2
Goal (n)	1.4 ± 1.1	0.6 ± 1.1	0.8 ± 1.2	1.3 ± 0.9[b]	0.7 ± 1.0	0.7 ± 0.8

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 3.27 Defensive play for the reference team and opposition teams

	Group					
	Reference Win			Opposition Win		
Performance indicator	**Reference**	**Opposition**	**Difference**	**Opposition**	**Reference**	**Difference**
Turnovers						
Total number (n)	32.1 ± 7.3	29.9 ± 8.1	2.3 ± 5.1	32.7 ± 8.2[b]	27.0 ± 5.6	5.7 ± 7.5
Origin defence (n)	19.0 ± 3.3[a]	15.1 ± 5.6	3.9 ± 3.7	16.6 ± 4.0	16.8 ± 4.9	-0.2 ± 4.0
Origin midfield (n)	11.6 ± 4.8	13.4 ± 4.8	-1.8 ± 3.8	14.3 ± 5.8[a]	9.3 ± 4.3	5.1 ± 8.0
Origin attack (n)	1.5 ± 1.2	1.4 ± 1.4	0.1 ± 2.4	1.8 ± 1.5	1.0 ± 1.0	0.8 ± 1.9
Tackles						
Total number (n)	74.0 ± 17.2[a]	104.1 ± 14.4	-30.1 ± 19.7	98.8 ± 24.2[a]	84.9 ± 15.7	13.9 ± 20.1
Successful (n)	8.4 ± 3.6	9.1 ± 3.4	-0.8 ± 3.3	10.3 ± 3.9	9.4 ± 3.5	0.9 ± 4.0
Successful (%)	10.9 ± 3.5	8.9 ± 3.5	2.0 ± 3.2	10.4 ± 3.2	11.2 ± 3.8	-0.7 ± 3.5
Unsuccessful (n)	65.6 ± 14.4[a]	95.0 ± 14.6	-29.4 ± 18.9	88.5 ± 21.8[a]	75.5 ± 14.9	13.0 ± 17.5
Unsuccessful (%)	89.1 ± 3.5	91.1 ± 3.5	-2.0 ± 3.2	89.6 ± 3.2	88.8 ± 3.8	0.7 ± 3.5
Origin defence (n)	36.1 ± 10.2	37.5 ± 8.6	-1.4 ± 8.2	35.9 ± 15.4	40.3 ± 10.1	-4.4 ± 17.6
Origin midfield (n)	29.3 ± 6.7[a]	45.8 ± 8.6	-16.5 ± 11.6	49.0 ± 19.1[a]	34.2 ± 11.3	14.8 ± 14.7
Origin attack (n)	8.6 ± 5.2[a]	20.9 ± 5.0	-12.3 ± 7.3	13.9 ± 8.4	10.4 ± 4.0	3.5 ± 8.8
Free kick won						
Total number (n)	23.8 ± 4.2	16.6 ± 6.7	7.1 ± 8.9	16.8 ± 5.3[a]	20.3 ± 8.4	-3.6 ± 5.6
Origin defence (n)	5.1 ± 1.5[a]	2.8 ± 1.8	2.4 ± 1.9	4.8 ± 2.7	4.8 ± 3.0	0.1 ± 3.5
Origin midfield (n)	12.1 ± 3.6	7.0 ± 5.3	5.1 ± 7.0	6.9 ± 2.6[a]	11.2 ± 5.6	-4.3 ± 4.3
Origin attack (n)	6.5 ± 1.5	6.9 ± 2.6	-0.4 ± 2.2	5.0 ± 2.4	4.4 ± 2.3	0.6 ± 3.2
Defensive actions						
Total number (n)	122.8 ± 27.2[a]	157.9 ± 19.3	-35.1 ± 27.5	152.0 ± 26.5[a]	129.5 ± 19.6	22.5 ± 22.6
Origin defence (n)	62.0 ± 13.4	59.3 ± 13.5	2.8 ± 10.2	57.0 ± 17.4	62.3 ± 12.9	-5.3 ± 19.4
Origin midfield (n)	47.9 ± 14.1[a]	71.3 ± 10.4	-23.4 ± 16.0	74.6 ± 20.2[a]	51.3 ± 16.0	23.3 ± 19.4
Origin attack (n)	12.9 ± 6.5[b]	27.4 ± 7.0	-14.5 ± 10.4	20.4 ± 11.4	15.9 ± 5.2	4.5 ± 11.7
Defensive efficiency (%)	33.3 ± 7.5	23.5 ± 12.4	9.8 ± 12.5	30.1 ± 8.1	31.1 ± 7.9	-1.0 ± 11.3

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 3.28 Passing for the reference team and opposition teams

	Group					
	Reference Win			Opposition Win		
Performance indicator	**Reference**	**Opposition**	**Difference**	**Opposition**	**Reference**	**Difference**
Combined hand and kick pass						
Total number (n)	256.4 ± 42.0	223.1 ± 43.3	33.3 ± 56.3	240.0 ± 33.3[a]	269.8 ± 31.1	-29.8 ± 22.8
Successful (n)	233.5 ± 44.1	199.6 ± 46.7	33.9 ± 57.8	221.3 ± 33.7[a]	247.9 ± 33.0	-26.6 ± 27.2
Successful (%)	90.8 ± 3.5	89.0 ± 3.7	1.8 ± 2.6	92.1 ± 2.7	91.7 ± 3.0	0.3 ± 3.5
Unsuccessful (n)	22.9 ± 7.2	23.5 ± 6.3	-0.6 ± 3.6	18.7 ± 5.4	21.9 ± 6.8	-3.3 ± 7.8
Unsuccessful (%)	9.2 ± 3.5	11.0 ± 3.7	-1.8 ± 2.6	7.9 ± 2.7	8.3 ± 3.0	-0.4 ± 3.5
Hand pass						
Total number (n)	175.0 ± 44.3	142.8 ± 45.2	32.3 ± 55.7	165.3 ± 33.7[a]	192.1 ± 34.9	-26.8 ± 20.6
Successful (n)	171.3 ± 42.6	137.3 ± 45.4	34.0 ± 54.1	161.2 ± 33.3[a]	187.6 ± 34.7	-26.4 ± 21.5
Successful (%)	97.9 ± 1.1[a]	95.8 ± 2.2	2.1 ± 1.5	97.5 ± 1.2	97.6 ± 1.0	-0.2 ± 1.4
Unsuccessful (n)	3.8 ± 2.4	5.5 ± 2.1	-1.8 ± 2.3	4.1 ± 1.7	4.5 ± 1.8	-0.4 ± 2.1
Unsuccessful (%)	2.1 ± 1.1[a]	4.2 ± 2.2	-2.1 ± 1.5	2.5 ± 1.2	2.4 ± 1.0	0.2 ± 1.4
Kick pass						
Total number (n)	81.4 ± 10.6	80.4 ± 14.1	1.0 ± 7.7	74.8 ± 12.8	77.8 ± 11.5	-3.0 ± 12.9
Successful (n)	62.3 ± 7.0	62.4 ± 12.9	-0.1 ± 11.0	60.2 ± 14.2	60.3 ± 8.7	-0.2 ± 14.7
Successful (%)	76.9 ± 6.6	77.5 ± 6.6	-0.5 ± 7.7	79.8 ± 7.2	77.9 ± 5.8	2.0 ± 9.2
Unsuccessful (n)	19.1 ± 6.9	18.0 ± 6.2	1.1 ± 5.4	14.6 ± 4.2	17.4 ± 6.4	-2.8 ± 7.2
Unsuccessful (%)	23.1 ± 6.6	22.6 ± 6.6	0.5 ± 7.7	20.2 ± 7.2	22.2 ± 5.8	-2.0 ± 9.2

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using a one-sample t-test ([a]).

Table 3.29 Dead ball distribution for the reference team and opposition teams

	Group					
	Reference Win			Opposition Win		
Performance indicator	Reference	Opposition	Difference	Opposition	Reference	Difference
Dead ball						
Total number (n)	49.1 ± 4.1	44.0 ± 7.5	5.1 ± 9.0	38.2 ± 6.3[a]	48.5 ± 7.8	-10.3 ± 7.9
^Dead ball kick pass						
Successful (n)	31.5 ± 5.0	28.9 ± 5.2	2.6 ± 7.1	25.7 ± 3.0[a]	31.7 ± 6.8	-6.0 ± 5.4
Successful (%)	75.8 ± 9.0	78.1 ± 9.1	-2.3 ± 7.9	81.4 ± 7.9	75.3 ± 7.3	6.1 ± 11.3
Unsuccessful (n)	10.1 ± 4.2	8.4 ± 4.2	1.8 ± 3.3	6.3 ± 3.1[a]	10.3 ± 3.6	-4.1 ± 4.9
Unsuccessful (%)	24.2 ± 9.0	21.9 ± 9.1	2.3 ± 7.9	18.6 ± 7.9	24.7 ± 7.3	-6.1 ± 11.3
Dead ball free kick pass						
Total number (n)	17.3 ± 3.8[a]	10.8 ± 5.7	6.5 ± 6.9	11.2 ± 3.8[a]	15.5 ± 7.1	-4.3 ± 5.3
Successful (n)	16.1 ± 3.1[a]	10.0 ± 4.9	6.1 ± 6.0	10.5 ± 3.6[a]	14.4 ± 6.0	-3.9 ± 4.9
Successful (%)	94.1 ± 4.2	95.1 ± 7.8	-0.9 ± 8.4	93.9 ± 6.7	94.7 ± 5.9	-0.8 ± 8.9
Unsuccessful (n)	1.1 ± 0.8	0.8 ± 1.2	0.4 ± 1.4	0.7 ± 0.8	1.1 ± 1.4	-0.4 ± 1.2
Unsuccessful (%)	5.9 ± 4.2	5.0 ± 7.8	0.9 ± 8.4	6.1 ± 6.7	5.3 ± 5.9	0.8 ± 8.9
Dead ball kick out						
Total number (n)	21.8 ± 3.0	23.8 ± 3.4	-2.0 ± 5.5	18.6 ± 4.3[b]	24.2 ± 4.9	-5.6 ± 7.2
Successful (n)	13.4 ± 4.1[a]	16.8 ± 4.7	-3.4 ± 3.8	13.1 ± 2.8	15.2 ± 4.2	-2.1 ± 3.4
Successful (%)	61.6 ± 15.8	69.9 ± 13.4	-8.3 ± 10.7	71.9 ± 14.3	62.7 ± 12.3	9.2 ± 16.8
Unsuccessful (n)	8.4 ± 3.8	7.0 ± 3.0	1.4 ± 3.2	5.5 ± 3.1[a]	9.0 ± 3.4	-3.5 ± 5.1
Unsuccessful (%)	38.4 ± 15.8	30.1 ± 13.4	8.3 ± 10.7	28.1 ± 14.3	37.3 ± 12.3	-9.2 ± 16.8

Values are mean ± SD; $p \leq 0.05$ vs. losing team (between) using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs.

3.4 Winning games: temporal changes in winners and losers across halves and quarters

Results from the univariate analyses of match characteristics, game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 3.30 to 3.42. Table 3.30 highlights the overall match characteristics for the first and second halves and for the first and fourth quarters. Tables 3.31 and 3.32 illustrate the games statistics and relative differences between the two halves and quarters for both winners and losers, respectively. Tables 3.33 to 3.42 include the mean results from both winners and losers and the relative difference between either the two halves or quarters for each group. Significant differences are illustrated in the tables and highlighted within the text.

3.4.1 Match characteristics: temporal changes between halves and quarters

With respect to match periods, there was no significant difference in average playing time between the first and second halves or between the first and fourth quarters, respectively (Table 3.30). There was a significant decrease in ball in play times from the first to the second half (p = 0.004) and from the first to the fourth quarter (p = 0.021). This was associated with a significant increase in stoppage time across both halves (p = 0.003) and quarters (p = 0.010).

In both winners (W) and losers (L) there was a significant increase in the number of substitutions made in the second half (W: p = 0.000, L: p = 0.000) and in the fourth quarter (W: p = 0.000, L: p = 0.000) (Tables 3.31 and 3.32). There was a significant increase in the number of yellow cards issued to winners in both the second half (p = 0.030) and the fourth quarter (p = 0.003), but not in losers. The number of black cards issued to winners and losers was also significantly higher in the second half (W: p = 0.032, L: p = 0.009) and only in losers in the fourth quarter (p = 0.017). There were no significant differences in the number of red cards received between halves or quarters in winners or losers.

3.4.2 Performance characteristics: temporal changes between halves and quarters

The main differences observed between the first and second halves and from the first to the fourth quarter in winners and losers, are highlighted below by aspect of play.

3.4.2.1 Possession

There was no significant difference in any possession PIs between the first and second halves in winners (Table 3.33). However, the total duration of both team (p = 0.026) and individual (p = 0.034) player possession in the second half was significantly reduced in losers. There was a significant decline in team possessions originating in both defence (p = 0.015) and midfield (p = 0.030) in losers. The total number of player possessions (p = 0.027) and player possessions originating in midfield (p = 0.003) also decreased in losers in the second half.

Both winners and losers had a significant decline in team possession (W: p = 0.003, L: p = 0.022) in the fourth quarter (Table 3.34). This coincided with a decline in team possessions originating in defence in losers (*p* = 0.005). The total number of player possessions (*p* = 0.045) also decreased significantly in losers in the fourth quarter, manifesting in a significant decline in player possessions originating in defence (*p* = 0.019) and midfield (*p* = 0.019). This is in contrast to the decline in player possessions originating in attack (*p* = 0.017) experienced by winners.

3.4.2.2 Offence

Among winners, the number of attacks was significantly lower in both the second half (*p* = 0.006) and fourth quarter (*p* = 0.000) (Tables 3.35 and 3.36). In addition, the number of attacks originating in midfield was significantly lower in winners in both the second half (*p* = 0.013) and fourth quarter (*p* = 0.000). The number of attacks originating in defence in the second half was significantly lower in losers (*p* = 0.027). Losers had a significant increase in the number of shots in the second half (*p* = 0.028). This resulted in a significantly enhanced attacking efficiency in both the second half (*p* = 0.012) and the fourth quarter (*p* = 0.016).

3.4.2.3 Defence

There was no significant difference in turnovers between the first and second halves (Table 3.37). Winners had a significantly lower number of turnovers in the fourth quarter (*p* = 0.005) (Table 3.38). The number of turnovers gained in midfield declined significantly in winners in the second half (*p* = 0.019), whereas the number of turnovers gained in defence decreased significantly in losers in both the second half (*p* = 0.002) and fourth quarter (*p* = 0.001). The percentage of successful tackles executed by winners was also significantly lower in the second half (p = 0.044). This decrease coincided with a significant reduction in the number of tackles originating in attack in the fourth quarter (p = 0.036). The overall defensive efficiency in winners was significantly lower in both the second half (p = 0.012) and fourth quarter (p = 0.019). In losers, the total number of combined defensive actions (p = 0.050) and number of defensive actions occurring in defence (p = 0.028) was significantly lower in the fourth quarter.

3.4.2.4 Passing

There was no significant difference in the passing characteristics between any match periods in winners (Tables 3.39 and 3.40). There was a significant reduction in the total number of combined hand and kick passes executed by losers across both halves (p = 0.011) and quarters (p = 0.029), resulting from the significant decline in both the number of hand (p = 0.014) and kick passes (p = 0.044) performed. In losers, there was also a significant reduction in the number of successful combined passes in the second half (p = 0.031), reflected largely in the significant decrease in the number of successful hand passes performed in both the second half (p = 0.018) and in the fourth quarter (p = 0.049). Similarly, the number of unsuccessful combined passes declined significantly in both the second half (p = 0.032) and fourth quarter (p = 0.002) in losers. This coincided with a significant decrease in the number of unsuccessful kick passes performed by losers in the fourth quarter (p = 0.004) and was reflected in a significant increase in the percentage success of kick passes (p = 0.031) in this period.

3.4.2.5 Dead ball distribution

Winners had a significant reduction in the number ($p = 0.026$) and percentage ($p = 0.029$) of unsuccessful dead ball free kick passes in the second half (Table 3.41). This was reflected in a significant increase in the percentage success of dead ball free kick passes ($p = 0.029$). Winners had a significant increase in the number of unsuccessful dead ball kick outs ($p = 0.022$) executed in the second half. In contrast, losers had a significant reduction in both the number ($p = 0.001$) and percentage ($p = 0.001$) of unsuccessful dead ball kick outs and in both the number ($p = 0.020$) and percentage ($p = 0.013$) of unsuccessful dead ball kick passes in the fourth quarter (Table 3.42). This resulted in a significant increase in their percentage dead ball kick out ($p = 0.001$) and kick pass success ($p = 0.013$).

Table 3.30 Match characteristics, halves and quarters, n=24

	Period					
	Half			Quarter		
Characteristic	**First**	**Second**	**Difference**	**1**	**4**	**Difference**
Playing time (min:s)	36:50 ± 0:53	37:21 ± 1:11	-0:31 ± 1:19	18:25 ± 0:26	18:40 ± 0:35	-0:15 ± 0:39
Ball in play time (min:s)	19:16 ± 2:10[a]	17:52 ± 1:51	1:25 ± 2:10	9:31 ± 1:11[a]	8:36 ± 1:21	1:25 ± 1:49
Stoppage time (min:s)	17:34 ± 2:30[a]	19:29 ± 2:31	-1:55 ± 2:51	8:54 ± 1:18[a]	10:04 ± 1:39	-1:10 ± 2:03

Values are mean ± SD; $p \leq 0.05$ vs. second half or fourth quarter using a one-sample t-test ([a]).

Table 3.31 Game statistics, full-game winners, n=24

	Period					
	Half			Quarter		
Game statistic	**First**	**Second**	**Difference**	**1**	**4**	**Difference**
Substitution (n)	0.3 ± 0.6[b]	4.7 ± 1.2	-4.4 ± 1.5	0.2 ± 0.5[a]	3.2 ± 1.1	-3.0 ± 1.3
Yellow card (n)	0.6 ± 0.6[b]	1.0 ± 1.0	-0.4 ± 0.9	0.2 ± 0.4[b]	0.8 ± 0.9	-0.6 ± 0.9
Black card (n)	0.0 ± 0.2[b]	0.3 ± 0.6	-0.3 ± 0.6	0.0 ± 0.2	0.3 ± 0.5	-0.2 ± 0.6
Red card/BCNR (n)	0.0 ± 0.2	0.1 ± 0.3	-0.1 ± 0.4	0.0 ± 0.0	0.1 ± 0.3	-0.1 ± 0.3

Values are mean ± SD; $p \leq 0.05$ vs. second half or fourth quarter using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]); BCNR = Black card not replaced.

Table 3.32 Game statistics, full-game losers, n=24

	Period					
	Half			Quarter		
Game statistic	**First**	**Second**	**Difference**	**1**	**4**	**Difference**
Substitution (n)	0.7 ± 0.9[b]	4.8 ± 1.1	-4.1 ± 1.9	0.2 ± 0.4[b]	2.5 ± 1.0	-2.3 ± 1.1
Yellow card (n)	0.6 ± 0.8	0.6 ± 0.8	0.0 ± 1.2	0.3 ± 0.5	0.4 ± 0.8	-0.1 ± 1.1
Black card (n)	0.1 ± 0.3[b]	0.5 ± 0.6	-0.4 ± 0.6	0.1 ± 0.3[b]	0.4 ± 0.6	-0.3 ± 0.6
Red card/BCNR (n)	0.0 ± 0.2	0.2 ± 0.4	-0.1 ± 0.4	0.0 ± 0.0	0.1 ± 0.3	-0.1 ± 0.3

Values are mean ± SD; $p \leq 0.05$ vs. second half or fourth quarter using Wilcoxon signed-rank test ([b]); BCNR = Black card not replaced.

Table 3.33 Team and individual possession characteristics across halves in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**First Half**	**Second Half**	**Difference**	**First Half**	**Second Half**	**Difference**
Team possession						
Total number (n)	36.5 ± 5.2	35.1 ± 4.2	1.5 ± 5.6	36.3 ± 4.8	35.5 ± 5.1	0.8 ± 4.9
Proportion of total (%)	49.4 ± 8.7	52.9 ± 7.6	-3.5 ± 14.1	50.6 ± 8.7	47.1 ± 7.6	3.5 ± 14.1
Total time (s)	485.4 ± 83.0	488.6 ± 98.2	-3.2 ± 144.7	504.9 ± 124.0[a]	431.3 ± 76.8	73.6 ± 151
Time per possession (s)	13.4 ± 2.2	14.2 ± 3.6	-0.8 ± 3.9	14.3 ± 4.6	12.4 ± 2.8	1.9 ± 4.7
Origin defence (n)	19.8 ± 3.6	20.6 ± 4.0	-0.8 ± 4.0	22.3 ± 4.1[a]	19.9 ± 4.1	2.5 ± 4.6
Origin midfield (n)	12.6 ± 3.8	10.3 ± 3.6	2.3 ± 5.0	10.2 ± 4.2[b]	11.6 ± 4.4	-1.4 ± 4.9
Origin attack (n)	4.2 ± 2.3	4.2 ± 2.2	0.0 ± 3.5	3.8 ± 1.4	4.0 ± 2.4	-0.3 ± 2.9
Player possession						
Total number (n)	149.8 ± 21.9	149.0 ± 31.9	0.8 ± 40.7	158.1 ± 32.7[a]	139.2 ± 21.3	18.9 ± 39.3
Total time in possession (s)	320.6 ± 69.8	315.6 ± 66.5	5.1 ± 100.5	329.5 ± 96.5[a]	277.4 ± 59.9	52.1 ± 113.3
Time per possession (s)	2.1 ± 0.3	2.1 ± 0.3	0.0 ± 0.3	2.1 ± 0.3	2.0 ± 0.3	0.1 ± 0.4
Origin defence (n)	40.1 ± 10.8	41.3 ± 8.2	-1.2 ± 11.1	45.1 ± 12.3	39.6 ± 13.3	5.5 ± 13.3
Origin midfield (n)	72.3 ± 13.0	74.3 ± 26.6	-2.0 ± 28.8	80.8 ± 27.7[a]	63.4 ± 12.2	17.4 ± 25.3
Origin attack (n)	37.3 ± 8.8	33.3 ± 11.3	4.0 ± 14.4	32.2 ± 10.7	36.2 ± 13.5	-4.0 ± 14.6

Values are mean ± SD; $p \leq 0.05$ vs. second half using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 3.34 Team and individual possession characteristics across quarters in winners and losers

	Group					
	Winners			Losers		
Performance indicator	Quarter 1	Quarter 4	Difference	Quarter 1	Quarter 4	Difference
Team possession						
Total number (n)	19.2 ± 2.9[a]	17.0 ± 2.0	2.1 ± 3.1	18.9 ± 2.8[a]	17.0 ± 3.1	2.0 ± 3.9
Proportion of total (%)	49.8 ± 9.4	53.6 ± 9.9	-3.7 ± 16.6	50.2 ± 9.4	46.4 ± 9.9	3.7 ± 16.6
Total time (s)	239.1 ± 45.8	239.9 ± 65.4	-0.7 ± 80.5	245.5 ± 68.3	206.2 ± 53.8	39.3 ± 104
Time per possession (s)	12.6 ± 2.5	14.3 ± 4.3	-1.7 ± 4.6	13.2 ± 4.1	12.4 ± 3.4	0.8 ± 6.0
Origin defence (n)	10.0 ± 2.3	10.3 ± 2.3	-0.3 ± 3.2	11.3 ± 2.8[a]	9.1 ± 2.8	2.2 ± 3.5
Origin midfield (n)	7.1 ± 2.7	4.7 ± 2.3	2.5 ± 3.4	5.5 ± 3.5	5.6 ± 2.4	0.0 ± 4.0
Origin attack (n)	2.0 ± 1.5	2.1 ± 1.2	-0.1 ± 2.0	2.0 ± 1.0	2.3 ± 1.9	-0.2 ± 2.2
Player possession						
Total number (n)	76.3 ± 13.1	72.7 ± 18.9	3.6 ± 23.3	79.4 ± 20.0[a]	67.3 ± 14.3	12.1 ± 28.0
Total time in possession (s)	153.4 ± 33.2	150.5 ± 41	2.9 ± 52.4	159.6 ± 52.2	129.1 ± 38.2	30.4 ± 72.7
Time per possession (s)	2.0 ± 0.2	2.1 ± 0.3	-0.1 ± 0.3	2.0 ± 0.4	1.9 ± 0.3	0.1 ± 0.5
Origin defence (n)	20.9 ± 7.0	20.6 ± 6.3	0.3 ± 9.3	22.6 ± 7.9[a]	17.9 ± 6.9	4.8 ± 9.2
Origin midfield (n)	35.8 ± 8.0	36.8 ± 16.3	-0.9 ± 17.7	40.4 ± 17[a]	31.0 ± 7.6	9.4 ± 18.2
Origin attack (n)	19.6 ± 5.9[a]	15.4 ± 6.3	4.3 ± 8.1	16.4 ± 5.9	18.5 ± 7.9	-2.0 ± 8.8

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 3.35 Offensive play across halves in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**First half**	**Second half**	**Difference**	**First half**	**Second half**	**Difference**
Attack						
Total number (n)	22.1 ± 3.9[a]	19.3 ± 4.1	2.8 ± 4.6	19.1 ± 3.3	19.3 ± 3.3	-0.2 ± 3.4
Origin defence (n)	11.1 ± 2.9	10.5 ± 2.7	0.5 ± 2.5	11.0 ± 3.4[a]	9.3 ± 3.4	1.7 ± 3.5
Origin midfield (n)	10.2 ± 3.4[a]	7.9 ± 3.0	2.3 ± 4.1	7.6 ± 3.1	9.0 ± 3.1	-1.5 ± 3.9
Origin attack (n)	0.9 ± 0.9	0.9 ± 1.1	0.0 ± 1.4	0.5 ± 0.6	0.9 ± 1.1	-0.4 ± 1.1
Efficiency (%)	69.8 ± 11.9	74.3 ± 13.9	-4.6 ± 15.3	63.6 ± 10.2[a]	72.8 ± 12.3	-9.2 ± 16.4
Shot						
Total number (n)	15.3 ± 3.3	14.2 ± 3.5	1.1 ± 3.8	12.1 ± 2.8[a]	14.0 ± 3.4	-1.9 ± 4.0
From play (n)	11.9 ± 3.5	10.9 ± 3.8	1.0 ± 3.6	9.0 ± 3.2	10.7 ± 3.3	-1.7 ± 4.2
From play (%)	77.1 ± 14.0	75.2 ± 10.9	2.0 ± 15.9	72.5 ± 12.8	75.9 ± 11.1	-3.4 ± 17.1
From dead ball (n)	3.4 ± 1.9	3.3 ± 1.4	0.1 ± 2.6	3.1 ± 1.2	3.3 ± 1.6	-0.2 ± 2.0
From dead ball (%)	22.9 ± 14.0	24.8 ± 10.9	-2.0 ± 15.9	27.5 ± 12.8	24.1 ± 11.1	3.4 ± 17.1
Efficiency (%)	51.4 ± 15.0	55.3 ± 15.2	-4.0 ± 18.9	48.3 ± 13.6	43.7 ± 15.1	4.6 ± 22.0
Score						
Total combined	8.8 ± 3.1	9.3 ± 3.0	-0.5 ± 3.7	6.4 ± 2.4	6.7 ± 3.1	-0.3 ± 3.5
Total number (n)	7.8 ± 2.4	7.7 ± 2.2	0.1 ± 3.0	5.9 ± 2.1	6.0 ± 2.2	-0.1 ± 3.0
Average attack/score (n)	3.3 ± 2.2	2.8 ± 1.1	0.6 ± 2.1	4.0 ± 3.2	4.0 ± 3.0	0.1 ± 4.3
Productivity	2.4 ± 0.8	2.7 ± 0.9	-0.3 ± 1.1	1.8 ± 0.8	1.9 ± 0.9	-0.1 ± 1.1
Point (n)	7.3 ± 2.3	6.8 ± 2.1	0.5 ± 3.2	5.6 ± 2.1	5.7 ± 2.0	0.0 ± 2.9
Point from play (n)	4.8 ± 1.9	4.8 ± 1.9	0.0 ± 2.3	3.6 ± 2.0	3.7 ± 1.6	-0.1 ± 2.5
Point from dead ball (n)	2.5 ± 1.5	2.0 ± 1.0	0.5 ± 1.7	2.0 ± 1.2	2.0 ± 1.6	0.1 ± 1.7
Goal (n)	0.5 ± 0.7	0.8 ± 0.8	-0.3 ± 1.1	0.3 ± 0.5	0.3 ± 0.6	-0.1 ± 0.7

Values are mean ± SD; $p \leq 0.05$ vs. second half using a one-sample t-test ([a]).

Table 3.36 Offensive play across quarters in winners and losers

Performance indicator	Group					
	Winners			Losers		
	Quarter 1	Quarter 4	Difference	Quarter 1	Quarter 4	Difference
Attack						
Total number (n)	11.3 ± 2.6[a]	8.3 ± 2.7	3.0 ± 3.3	9.9 ± 2.5	9.0 ± 1.8	0.8 ± 3.1
Origin defence (n)	5.1 ± 1.7	4.6 ± 2.2	0.5 ± 2.0	5.5 ± 2.2	4.5 ± 2.0	1.0 ± 2.7
Origin midfield (n)	5.8 ± 2.4[a]	3.4 ± 1.7	2.3 ± 2.8	4.1 ± 2.8	4.1 ± 1.7	0.0 ± 3.3
Origin attack (n)	0.4 ± 0.7	0.3 ± 0.4	0.2 ± 0.8	0.3 ± 0.4	0.4 ± 0.7	-0.2 ± 0.6
Efficiency (%)	67.6 ± 15.0	80.0 ± 30.4	-12.4 ± 34.9	65.6 ± 14.9[a]	79.8 ± 20.1	-14.2 ± 26.9
Shot						
Total number (n)	7.6 ± 2.5	6.5 ± 2.9	1.1 ± 3.0	6.5 ± 2.3	7.2 ± 2.3	-0.7 ± 3.4
From play (n)	5.8 ± 2.5	4.6 ± 3.0	1.2 ± 3.4	4.7 ± 2.5	5.3 ± 2.5	-0.6 ± 4.0
From play (%)	74.9 ± 16.1	68.0 ± 18.8	7.0 ± 26.9	68.6 ± 20.4	72.5 ± 22.1	-3.9 ± 36
From dead ball (n)	1.8 ± 1.1	1.9 ± 1.1	-0.1 ± 1.9	1.8 ± 0.8	1.9 ± 1.5	-0.1 ± 1.8
From dead ball (%)	25.1 ± 16.1	32.0 ± 18.8	-7.0 ± 26.9	31.4 ± 20.4	27.5 ± 22.1	3.9 ± 36.0
Efficiency (%)	56.3 ± 15.3	62.3 ± 24.1	-6.0 ± 23.8	50.7 ± 20.8	38.6 ± 18.4	12.1 ± 33.2
Score						
Total combined	4.7 ± 2.1	4.4 ± 2.3	0.3 ± 2.7	3.5 ± 1.6	3.2 ± 2.3	0.3 ± 2.9
Total number (n)	4.2 ± 1.6	3.6 ± 1.4	0.6 ± 1.8	3.3 ± 1.6	2.7 ± 1.3	0.6 ± 2.2
Average attack/score (n)	3.2 ± 2.4	2.6 ± 1.1	0.6 ± 2.4	3.5 ± 2.2	4.4 ± 2.7	-0.9 ± 3.8
Productivity	2.4 ± 1.0	2.6 ± 1.4	-0.2 ± 1.5	1.9 ± 1.1	2.0 ± 1.6	0.0 ± 2.0
Point (n)	4.0 ± 1.5	3.3 ± 1.3	0.7 ± 2.0	3.1 ± 1.7	2.4 ± 1.0	0.7 ± 2.1
Point from play (n)	2.5 ± 1.4	2.1 ± 1.0	0.5 ± 1.6	2.0 ± 1.6	1.5 ± 1.0	0.5 ± 2.2
Point from dead ball (n)	1.4 ± 0.9	1.2 ± 0.8	0.3 ± 1.3	1.2 ± 0.9	1.0 ± 1.0	0.2 ± 1.4
Goal (n)	0.3 ± 0.5	0.4 ± 0.6	-0.1 ± 0.9	0.1 ± 0.3	0.3 ± 0.6	-0.1 ± 0.6

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 3.37 Defensive play across halves in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**First half**	**Second half**	**Difference**	**First half**	**Second half**	**Difference**
Turnovers						
Total number (n)	17.5 ± 4.7	15.0 ± 4.8	2.5 ± 6.0	15.1 ± 4.0	13.5 ± 3.7	1.6 ± 4.3
Origin defence (n)	9.1 ± 2.4	8.5 ± 2.3	0.7 ± 3.2	9.3 ± 3.5[a]	6.8 ± 2.7	2.6 ± 3.6
Origin midfield (n)	7.5 ± 3.4[b]	5.6 ± 3.2	2.0 ± 3.8	5.3 ± 2.6	6.0 ± 3.0	-0.7 ± 3.0
Origin attack (n)	0.8 ± 1.0	1.0 ± 1.2	-0.1 ± 1.7	0.5 ± 0.6	0.8 ± 1.0	-0.3 ± 1.0
Tackles						
Total number (n)	46.0 ± 13.6	44.8 ± 14.7	1.2 ± 16.2	47.5 ± 12.7	45.4 ± 9.1	2.0 ± 14.9
Successful (n)	5.6 ± 2.2	4.4 ± 2.6	1.2 ± 3.1	5.2 ± 2.5	4.6 ± 2.1	0.6 ± 3.0
Successful (%)	12.4 ± 4.2[a]	9.5 ± 4.8	2.8 ± 6.5	11.4 ± 5.2	10.3 ± 4.8	1.1 ± 6.5
Unsuccessful (n)	40.4 ± 12.6	40.4 ± 13.1	0.0 ± 15.1	42.3 ± 12.5	40.8 ± 8.8	1.4 ± 14.3
Unsuccessful (%)	87.6 ± 4.2[a]	90.5 ± 4.8	-2.8 ± 6.5	88.6 ± 5.2	89.7 ± 4.8	-1.2 ± 6.4
Origin defence (n)	17.5 ± 6.6	19.9 ± 11.1	-2.4 ± 11.8	20.4 ± 7.3	19.0 ± 5.6	1.5 ± 9.5
Origin midfield (n)	22.0 ± 10.4	19.6 ± 8.5	2.4 ± 8.8	20.8 ± 8.0	18.5 ± 6.9	2.3 ± 10.1
Origin attack (n)	6.5 ± 4.5	5.3 ± 4.9	1.2 ± 6.1	6.2 ± 3.7	7.9 ± 4.2	-1.7 ± 4.5
Free kick won						
Total number (n)	9.9 ± 4.0	9.5 ± 3.0	0.5 ± 4.2	8.8 ± 3.9	9.9 ± 4.3	-1.0 ± 4.0
Origin defence (n)	2.2 ± 1.4	2.7 ± 1.6	-0.5 ± 2.1	1.9 ± 1.5	2.1 ± 1.7	-0.3 ± 1.8
Origin midfield (n)	4.8 ± 2.5	4.2 ± 2.1	0.6 ± 2.7	4.5 ± 3.2	5.2 ± 3.0	-0.7 ± 3.3
Origin attack (n)	2.9 ± 1.7	2.5 ± 1.2	0.3 ± 2.2	2.5 ± 1.5	2.5 ± 1.9	-0.1 ± 2.1
Defensive actions						
Total number (n)	72.4 ± 14.7	69.8 ± 17.3	2.6 ± 16.0	72.3 ± 15.9	69.2 ± 10.7	3.1 ± 15.6
Origin defence (n)	29.0 ± 7.4	30.9 ± 11.9	-1.9 ± 11.8	32.4 ± 8.7	28.6 ± 6.8	3.8 ± 9.1
Origin midfield (n)	34.1 ± 11.3	30.5 ± 12.0	3.6 ± 10.6	31.0 ± 11.0	29.2 ± 9.0	1.8 ± 12.2
Origin attack (n)	9.3 ± 5.2	8.4 ± 6.9	0.8 ± 7.1	8.8 ± 4.4	11.4 ± 5.5	-2.5 ± 5.9
Defensive efficiency (%)	36.4 ± 10.2[a]	27.2 ± 12.4	9.2 ± 16.4	30.2 ± 11.9	26.2 ± 12.9	4.1 ± 15.1

Values are mean ± SD; $p \leq 0.05$ vs. second half using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 3.38 Defensive play across quarters in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**Quarter 1**	**Quarter 4**	**Difference**	**Quarter 1**	**Quarter 4**	**Difference**
Turnovers						
Total number (n)	8.8 ± 2.9[a]	6.6 ± 2.9	2.2 ± 3.4	8.0 ± 2.6	6.5 ± 2.2	1.5 ± 3.5
Origin defence (n)	4.4 ± 1.5	3.9 ± 1.6	0.5 ± 2.2	4.7 ± 2.0[a]	2.9 ± 1.6	1.8 ± 2.4
Origin midfield (n)	4.0 ± 2.3[a]	2.4 ± 2.0	1.6 ± 2.7	3.0 ± 2.4	3.2 ± 1.9	-0.2 ± 2.7
Origin attack (n)	0.3 ± 0.6	0.3 ± 0.4	0.1 ± 0.8	0.3 ± 0.4	0.4 ± 0.8	-0.2 ± 0.8
Tackles						
Total number (n)	23.9 ± 7.7	21.3 ± 7.2	2.7 ± 9.9	24.5 ± 6.2	22.2 ± 5.8	2.3 ± 8.0
Successful (n)	2.8 ± 1.5	2.1 ± 1.6	0.8 ± 2.3	2.4 ± 1.4	2.5 ± 1.3	-0.1 ± 1.6
Successful (%)	11.6 ± 4.8	9.7 ± 7.2	1.9 ± 10.2	9.8 ± 5.5	11.2 ± 4.5	-1.4 ± 5.7
Unsuccessful (n)	21.1 ± 6.8	19.2 ± 6.5	1.9 ± 9.2	22.1 ± 5.9	19.7 ± 5.3	2.4 ± 7.4
Unsuccessful (%)	88.4 ± 4.8	90.3 ± 7.2	-1.9 ± 10.2	90.2 ± 5.5	88.8 ± 4.5	1.4 ± 5.7
Origin defence (n)	9.0 ± 4.7	9.6 ± 5.4	-0.6 ± 7.1	10.6 ± 4.1	9.2 ± 4.8	1.5 ± 6.9
Origin midfield (n)	11.5 ± 5.9	9.5 ± 4.3	2.0 ± 6.0	10.9 ± 4.5	8.8 ± 4.1	2.1 ± 6.5
Origin attack (n)	3.4 ± 2.8[b]	2.1 ± 2.2	1.3 ± 3.3	3.0 ± 2.2	4.2 ± 2.9	-1.3 ± 3.8
Free kick won						
Total number (n)	5.0 ± 2.4	5.0 ± 1.7	0.0 ± 2.7	4.4 ± 2.4	5.0 ± 2.8	-0.6 ± 2.6
Origin defence (n)	0.9 ± 0.8	1.3 ± 1.1	-0.4 ± 1.2	0.9 ± 1.0	1.0 ± 1.1	-0.2 ± 1.2
Origin midfield (n)	2.4 ± 1.6	2.1 ± 1.3	0.3 ± 1.8	2.3 ± 1.8	2.6 ± 1.8	-0.4 ± 1.8
Origin attack (n)	1.6 ± 1.1	1.5 ± 0.9	0.1 ± 1.5	1.3 ± 1.0	1.3 ± 1.3	0.0 ± 1.7
Defensive actions						
Total number (n)	37.1 ± 9.0	32.9 ± 8.5	4.2 ± 11.7	37.4 ± 7.9[a]	33.8 ± 6.4	3.6 ± 8.5
Origin defence (n)	14.7 ± 5.2	14.9 ± 5.8	-0.2 ± 7.4	17.1 ± 5.3[a]	13.8 ± 5.2	3.4 ± 7.0
Origin midfield (n)	17.8 ± 6.8	14.6 ± 5.8	3.2 ± 7.8	16.3 ± 5.4	14.4 ± 5.6	1.8 ± 7.5
Origin attack (n)	4.6 ± 3.2	3.4 ± 3.1	1.2 ± 4.0	4.0 ± 2.7	5.6 ± 3.8	-1.6 ± 4.7
Defensive efficiency (%)	34.4 ± 14.9[a]	23.9 ± 15.3	10.5 ± 20.5	32.4 ± 15.0	28.0 ± 22.8	4.4 ± 26.1

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 3.39 Passing across halves in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**First half**	**Second half**	**Difference**	**First half**	**Second half**	**Difference**
Combined hand and kick pass						
Total number (n)	123.8 ± 20.4	123.9 ± 31.6	-0.2 ± 38.1	134.7 ± 32.0[a]	114.0 ± 20.5	20.7 ± 36.7
Successful (n)	113.0 ± 19.0	114.0 ± 32.6	-1.0 ± 36.9	122.5 ± 34.0[a]	104.0 ± 21.5	18.4 ± 39.1
Successful (%)	91.4 ± 2.6	91.3 ± 4.4	0.1 ± 3.2	90.1 ± 4.8	90.9 ± 4.1	-0.8 ± 6.0
Unsuccessful (n)	10.7 ± 3.5	9.9 ± 3.6	0.8 ± 3.5	12.2 ± 4.1[a]	9.9 ± 3.9	2.3 ± 4.9
Unsuccessful (%)	8.7 ± 2.6	8.7 ± 4.4	0.0 ± 3.2	9.9 ± 4.8	9.1 ± 4.1	0.8 ± 6.0
Hand pass						
Total number (n)	83.3 ± 17.3	85.4 ± 30.3	-2.1 ± 33.0	93.9 ± 31.9[a]	76.3 ± 19.8	17.5 ± 32.3
Successful (n)	81.1 ± 16.8	83.5 ± 29.6	-2.4 ± 32.3	91.0 ± 31.8[a]	74.3 ± 19.9	16.8 ± 32.2
Successful (%)	97.5 ± 1.8	97.8 ± 1.7	-0.3 ± 2.4	96.6 ± 1.9	97.0 ± 2.5	-0.4 ± 2.9
Unsuccessful (n)	2.1 ± 1.5	1.9 ± 1.4	0.3 ± 2.0	2.8 ± 1.4	2.1 ± 1.5	0.8 ± 2.2
Unsuccessful (%)	2.5 ± 1.8	2.2 ± 1.7	0.3 ± 2.4	3.4 ± 1.9	3.0 ± 2.5	0.4 ± 2.9
Kick pass						
Total number (n)	40.5 ± 9.7	38.5 ± 5.8	2.0 ± 7.8	40.8 ± 7.7[a]	37.6 ± 7.9	3.2 ± 7.3
Successful (n)	31.9 ± 8.9	30.5 ± 6.5	1.4 ± 7.1	31.4 ± 7.8	29.8 ± 6.4	1.6 ± 8.9
Successful (%)	78.5 ± 6.5	78.8 ± 8.8	-0.3 ± 6.3	76.7 ± 9.7	79.4 ± 7.4	-2.7 ± 12.3
Unsuccessful (n)	8.6 ± 3.1	8.0 ± 3.4	0.5 ± 2.7	9.4 ± 4.1	7.8 ± 3.6	1.5 ± 4.5
Unsuccessful (%)	21.5 ± 6.5	21.2 ± 8.8	0.3 ± 6.3	23.3 ± 9.7	20.7 ± 7.4	2.7 ± 12.3

Values are mean ± SD; $p \leq 0.05$ vs. second half using a one-sample t-test ([a]).

Table 3.40 Passing across quarters in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**Quarter 1**	**Quarter 4**	**Difference**	**Quarter 1**	**Quarter 4**	**Difference**
Combined hand and kick pass						
Total number (n)	63.5 ± 12.3	60.3 ± 17.9	3.2 ± 21.9	67.2 ± 18.7[a]	54.8 ± 13.7	12.4 ± 26.1
Successful (n)	57.3 ± 12.1	55.4 ± 18.5	1.9 ± 21.6	60.7 ± 19.9	50.5 ± 14.0	10.2 ± 27.4
Successful (%)	90.2 ± 5.0	91.0 ± 5.0	-0.8 ± 6.7	89.2 ± 5.6	91.6 ± 5.0	-2.4 ± 7.1
Unsuccessful (n)	6.2 ± 3.0	4.9 ± 2.2	1.3 ± 3.8	6.5 ± 2.6[a]	4.3 ± 2.5	2.2 ± 3.0
Unsuccessful (%)	9.8 ± 5.0	9.0 ± 5.0	0.8 ± 6.7	10.8 ± 5.6	8.4 ± 5.0	2.4 ± 7.1
Hand pass						
Total number (n)	42.3 ± 11.0	41.6 ± 16.3	0.6 ± 19.3	46.9 ± 18.9[a]	37.0 ± 12.0	9.9 ± 23.1
Successful (n)	40.9 ± 10.7	40.5 ± 16.1	0.5 ± 19	45.5 ± 18.5[a]	35.9 ± 11.9	9.6 ± 22.7
Successful (%)	96.9 ± 2.9	96.8 ± 4.1	0.0 ± 5.0	97.3 ± 2.0	97.1 ± 3.8	0.1 ± 4.8
Unsuccessful (n)	1.3 ± 1.1	1.2 ± 1.1	0.2 ± 1.6	1.3 ± 1.0	1.0 ± 1.2	0.3 ± 1.6
Unsuccessful (%)	3.2 ± 2.9	3.2 ± 4.1	0.0 ± 5.0	2.8 ± 2.0	2.9 ± 3.8	-0.1 ± 4.8
Kick pass						
Total number (n)	21.2 ± 6.0	18.6 ± 3.9	2.6 ± 6.4	20.3 ± 5.0[a]	17.8 ± 4.7	2.5 ± 5.6
Successful (n)	16.4 ± 5.4	14.9 ± 4.7	1.5 ± 5.7	15.1 ± 5.1	14.5 ± 3.8	0.6 ± 6.6
Successful (%)	77.1 ± 9.9	79.0 ± 11.8	-1.9 ± 15.2	73.9 ± 14.5[a]	82.1 ± 10.5	-8.2 ± 17.6
Unsuccessful (n)	4.8 ± 2.6	3.7 ± 1.9	1.1 ± 3.2	5.2 ± 3.0[a]	3.3 ± 2.3	1.9 ± 2.9
Unsuccessful (%)	22.9 ± 9.9	21.0 ± 11.8	1.9 ± 15.2	26.1 ± 14.5[a]	17.9 ± 10.5	8.2 ± 17.6

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 3.41 Dead ball distribution across halves in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**First half**	**Second half**	**Difference**	**First half**	**Second half**	**Difference**
Dead ball						
Total number (n)	21.3 ± 4.5	21.4 ± 4.3	-0.1 ± 4.9	22.9 ± 4.7	23.9 ± 4.1	-1.0 ± 4.9
^Dead ball kick pass						
Successful (n)	14.3 ± 3.2	13.8 ± 3.0	0.5 ± 4.2	14.7 ± 4.7	16.4 ± 3.2	-1.8 ± 5.4
Successful (%)	80.2 ± 8.1	77.8 ± 10.6	2.4 ± 9.0	73.8 ± 12.9	80.8 ± 11.9	-7.0 ± 18.6
Unsuccessful (n)	3.6 ± 1.9	4.3 ± 2.3	-0.7 ± 1.9	5.1 ± 2.6	4.2 ± 2.8	1.0 ± 3.8
Unsuccessful (%)	19.8 ± 8.1	22.2 ± 10.6	-2.4 ± 9.0	26.2 ± 12.9	19.2 ± 11.9	7.0 ± 18.6
Dead ball free kick pass						
Total number (n)	6.9 ± 3.3	6.5 ± 2.4	0.4 ± 3.5	6.3 ± 3.8	7.2 ± 3.7	-0.9 ± 4.0
Successful (n)	6.3 ± 3.1	6.3 ± 2.4	0.0 ± 3.5	6.0 ± 3.7	6.8 ± 3.1	-0.8 ± 4.2
Successful (%)	91.4 ± 9.4[a]	97.3 ± 6.5	-5.8 ± 12	94 ± 11.2	96.1 ± 6.9	-2.0 ± 11.9
Unsuccessful (n)	0.6 ± 0.6[b]	0.2 ± 0.5	0.4 ± 0.8	0.4 ± 0.6	0.5 ± 0.8	-0.1 ± 0.9
Unsuccessful (%)	8.6 ± 9.4[a]	2.7 ± 6.5	5.8 ± 12.0	6.0 ± 11.2	3.9 ± 6.9	2.0 ± 11.9
Dead ball kick out						
Total number (n)	9.5 ± 2.0	10.8 ± 3.2	-1.2 ± 3.2	12.0 ± 2.2	12.0 ± 3.0	0.0 ± 3.5
Successful (n)	6.6 ± 1.4	6.8 ± 2.4	-0.2 ± 2.2	7.4 ± 1.7	8.5 ± 3.0	-1.1 ± 2.8
Successful (%)	71.2 ± 16.0	65.2 ± 18.1	6.0 ± 17.0	62.8 ± 15.9	71.3 ± 20.2	-8.5 ± 26
Unsuccessful (n)	2.9 ± 1.9[a]	4.0 ± 2.2	-1.0 ± 2.1	4.6 ± 2.3	3.5 ± 2.5	1.2 ± 3.6
Unsuccessful (%)	28.8 ± 16.0	34.8 ± 18.1	-6.0 ± 17.0	37.2 ± 15.9	28.7 ± 20.2	8.5 ± 26.0

Values are mean ± SD; $p \leq 0.05$ vs. second half using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs.

Table 3.42 Dead ball distribution across quarters in winners and losers

	Group					
	Winners			Losers		
Performance indicator	**Quarter 1**	**Quarter 4**	**Difference**	**Quarter 1**	**Quarter 4**	**Difference**
Dead ball						
Total number (n)	11.2 ± 2.6	11.0 ± 2.6	0.3 ± 3.4	11.7 ± 2.6	11.6 ± 2.9	0.1 ± 3.0
^Dead ball kick pass						
Successful (n)	7.1 ± 2.0	7.0 ± 2.1	0.2 ± 3.0	7.2 ± 3.0	8.2 ± 2.3	-1.0 ± 3.2
Successful (%)	76.7 ± 14	77.8 ± 15.4	-1.1 ± 18.9	71.9 ± 19.1[a]	85.5 ± 14.5	-13.6 ± 24.6
Unsuccessful (n)	2.3 ± 1.6	2.1 ± 1.5	0.2 ± 2.1	2.8 ± 1.8[a]	1.5 ± 1.5	1.2 ± 2.4
Unsuccessful (%)	23.3 ± 14.0	22.2 ± 15.4	1.1 ± 18.9	28.1 ± 19.1[a]	14.6 ± 14.5	13.6 ± 24.6
Dead ball free kick pass						
Total number (n)	3.2 ± 1.8	3.3 ± 1.2	-0.1 ± 1.6	3.0 ± 2.5	3.6 ± 2.3	-0.6 ± 2.7
Successful (n)	2.9 ± 1.6	3.2 ± 1.2	-0.3 ± 1.6	2.9 ± 2.5	3.4 ± 2.1	-0.5 ± 2.6
Successful (%)	89.8 ± 15.1	96.9 ± 11.2	-6.6 ± 21.1	96.4 ± 12	95.0 ± 10.2	0.5 ± 14.8
Unsuccessful (n)	0.3 ± 0.5	0.1 ± 0.3	0.3 ± 0.6	0.1 ± 0.3	0.3 ± 0.5	-0.2 ± 0.6
Unsuccessful (%)	10.2 ± 15.1	3.1 ± 11.2	6.6 ± 21.1	3.6 ± 12.0	5.0 ± 10.2	-0.5 ± 14.8
Dead ball kick out						
Total number (n)	5.2 ± 2.0	5.5 ± 2.0	-0.3 ± 2.8	6.2 ± 1.7	5.5 ± 2.5	0.8 ± 2.6
Successful (n)	3.3 ± 1.3	3.4 ± 1.7	-0.1 ± 2.4	3.6 ± 1.2	4.4 ± 2.1	-0.8 ± 2.2
Successful (%)	68.3 ± 22.8	65.3 ± 22.1	3.0 ± 29.1	61.5 ± 22.7[a]	83.3 ± 20.2	-21.8 ± 28.6
Unsuccessful (n)	1.8 ± 1.6	2.0 ± 1.5	-0.2 ± 2.0	2.6 ± 1.7[a]	1.0 ± 1.3	1.5 ± 2.0
Unsuccessful (%)	31.7 ± 22.8	34.7 ± 22.1	-3.0 ± 29.1	38.5 ± 22.7[a]	16.7 ± 20.2	21.8 ± 28.6

Values are mean ± SD; $p \leq 0.05$ vs. second half using a one-sample t-test ([a]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs.

3.5 Results summary: winning games

This is the first study in Gaelic football to use PCA on an extensive range of variables to establish four novel PIs (i.e., midfield-counterattacking, defensive free kick efficiency, defensive-counterattacking and possession), which explained ~82% of the variance. Defensive-counterattacking differentiated winners from losers with a classification accuracy of 87.5%. Univariate comparisons revealed differences in 14 PIs (in: offence, defence, passing and dead ball distribution), which distinguished between winners and losers when all games were combined, as summarised in Table 3.43. In addition to demonstrating enhanced shooting efficiency, winners were more productive with their possession, generated more turnovers and displayed superior competency in hand passing. When the match sample was further analysed by sub-group, 5 differences were found in PIs (in: offence, passing and dead ball distribution) between winning and losing teams competing in the AICSFF (Table 3.44), with superior productivity and increased hand passing competency, similarly distinguishing winners from losers.

Further sub-group comparisons revealed that in winning the RT demonstrated 24 differences in PIs compared to the OTs across the 5 aspects of play examined, whereas 34 differences in PIs were demonstrated by the OTs when winning compared to the RT (Table 3.45). Specifically, the RT achieved more team and player possessions and were more competent in their hand passing. The RT also performed less overall defensive actions and tackles in attack and midfield, but won more turnovers and free kicks in defence. In contrast, the OTs displayed less possession in winning and demonstrated fewer overall and successful combined passes and hand passes. The OTs performed more defensive actions and tackles overall and in midfield, which helped to generate more turnovers overall and in midfield. The OTs attacked more from defence, whereas both teams displayed superior shot efficiency in winning.

This is also the first study to examine temporal differences in technical and tactical PIs between winners and losers. Among winning and losing teams, there were differences in 10 PIs and 16 PIs, respectively between the first and second halves (Table 3.46). In the second half, winning teams executed fewer attacks overall and from midfield. Defensive efficiency declined in winners and this was reflected in less effective tackling and turnovers in midfield. In the second half, losing teams demonstrated fewer turnovers and possessions from defence and subsequently initiated fewer attacks from this zone. However, losing teams gained more possessions in midfield, executed more shots and enhanced their attacking efficiency. In losing teams, the numbers of combined, hand and kick passes all decreased, with the success rate of both combined and hand passing also declining. When the fourth quarter was compared to the first, there were differences in 7 PIs in winners and 23 PIs in losers (Table 3.47). In the fourth quarter, winning teams had less team possessions overall and player possession in attack and they executed fewer attacks overall and from midfield. Defensive efficiency declined in winners, and this was reflected in less tackling in attack and a decrease in turnovers overall and in midfield. In defence, losing teams achieved fewer team and player possessions and had fewer defensive actions and turnovers. Losing teams improved their attacking efficiency and kick pass competence but had fewer overall combined, hand and kick passes.

Table 3.43 Summary of differences demonstrated by winners of full games compared to losers in AIC and NFL games, n=24

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
	Shot ↑ number & efficiency **Score** ↑ total ↑ number ↑ productivity ↑ goals ↑ points ↑ points from play ↓ average attack/score	**Turnover** ↑ number	**Hand pass** ↑ % successful ↓ number & % unsuccessful	**Dead ball kick pass** ↓ number successful **Kick out** ↓ total & number successful

Table 3.44 Summary of differences demonstrated by winners of full games compared to losers in AICSFF games, n=4

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
	Score ↑ total ↑ productivity		**Hand pass** ↑ % successful ↓ % unsuccessful	**Dead ball kick pass** ↓ number successful

Table 3.45 Summary of differences demonstrated by the reference team when winning (n=8) vs. the opposition teams and by the opposition teams when winning (n=12) vs. the reference team

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
Team RT: ↑ no. & time OT: ↓ no. & in DF **Player** RT: ↑ time & in DF OT: ↓ no. & in MF	**Attack** OT: ↑ no. & from DF **Shot** RT: ↑ efficiency OT: ↑ efficiency **Score** RT: ↑ total, no., points & points from play & ↓ average AT/score OT: ↑ total & no., productivity, goals, points, points from play, & ↓ average AT/score	**Turnover** RT: ↑ in DF OT: ↑ no. & in MF **Tackle** RT: ↓ no. & no. unsuccessful & ↓ no. in MF & AT OT: ↑ no. & no. unsuccessful & ↑ no. in MF **Free kick won** RT: ↑ in DF OT: ↓ no. & in MF **Defensive actions** RT: ↓ no. & in MF & AT OT: ↑ no. & in MF	**Combined** OT: ↓ no. & no. successful **Hand pass** RT = ↑ % successful & ↓ % unsuccessful OT = ↓ no. & no. successful	**Dead ball** OT: ↓ no. **Dead ball kick pass** OT: ↓ no. & no. unsuccessful **Dead ball free kick pass** RT: ↑ no. & no. successful OT: ↓ no. & no. successful **Kick out** RT: ↓ no. successful OT: ↓ no. & no. unsuccessful

RT = reference team, OT = opposition teams, ↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield, AT = attack.

Table 3.46 Summary of differences demonstrated by winners and losers in the second half compared to the first half, n=24

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
Team L: ↓ time & no. in DF & ↑ no. in MF **Player** L: ↓ no. & time & no. in MF	**Attack** W: ↓ no. & no. from MF L: ↓ no. from DF & ↑ efficiency **Shot** L: ↑ no.	**Turnovers** W: ↓ no. in MF L: ↓ no. in DF **Tackles** W: ↓ % successful & ↑ % unsuccessful **Efficiency** W: ↓	**Combined** L: ↓ no. & no. successful & no. unsuccessful **Hand pass** L: ↓ no. & no. successful **Kick pass** L: ↓ no.	**Dead ball free kick pass** W: ↑ % successful & ↓ no. & % unsuccessful **Kick out** W: ↑ no. unsuccessful

W = winners, L = losers, ↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield, AT = attack.

Table 3.47 Summary of differences demonstrated by winners and losers in the fourth quarter compared to the first quarter, n=24

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
Team W: ↓ no. L: ↓ no. & no. in DF **Player** W: ↓ no. in AT L: ↓ no. & no. in DF & MF	**Attack** W: ↓ no. & no. from MF L: ↑ efficiency	**Turnovers** W: ↓ no. & no. in MF L: ↓ no. in DF **Tackles** W: ↓ no. in AT **Actions** L: ↓ no. & no. in DF **Efficiency** W: ↓	**Combined** L: ↓ no. & no. unsuccessful **Hand pass** L: ↓ no. & no. successful **Kick pass** L: ↓ no. & ↑ % successful & ↓ no. & % unsuccessful	**Dead ball kick pass** L: ↑ % successful & ↓ no. & % unsuccessful **Kick out** L: ↑ % successful & ↓ no. & % unsuccessful

W = winners, L = losers, ↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield, AT = attack.

3.6 Study 1 summary and preface to study 2

The first study has explored a comprehensive range of technical and tactical team PIs across five broad aspects of play (i.e., possession, offence, defence, passing and dead ball distribution). Both traditional and novel PIs were used to examine and subsequently distinguish between winning and losing teams in elite Gaelic football. In addition, using sub-group analysis, specific differences were highlighted regarding the PIs that differentiated between winners and losers in the AICSFF and between the RT and OTs. Furthermore, to compliment the understanding of what it takes to win games, temporal differences in winners and losers (of full games) were evaluated between the first and second halves and from the first to the fourth quarter.

The practical benefit of using a dimensionality (data) reduction technique (PCA) was demonstrated through the generation of four novel component variables, one of which, defensive-counterattacking, was found to effectively differentiate between winners and losers. The results obtained from the different analyses methods employed highlighted the value of combining univariate and multivariate techniques. Overall, this study focused on the technical and tactical team PIs which differentiated between winning and losing in relation to full games. Gaelic football games are contested over two designated halves, which are often further dissected into quarters by coaches and practitioners to facilitate a detailed period analysis. Therefore, further insights and performance knowledge could be gained through a more thorough examination of the technical and tactical PIs which differentiate winners from losers in match halves and quarters.

CHAPTER 4

STUDY 2: EVALUATION OF DIFFERENCES IN TECHNICAL AND TACTICAL TEAM PERFORMANCE INDICATORS BETWEEN WINNERS AND LOSERS IN RELATION TO THE OUTCOME OF HALVES AND QUARTERS

4.1 Rationale

In the first study, the team PIs associated with winning Gaelic football games were presented. As full-game data sets were examined, it was not possible to determine whether significant differences in aspects of technical and tactical performance existed between winners and losers in relation to the outcome of halves and quarters, to date no published studies have examined this.

In addition, defensive-counterattacking, established from the primary PCA, was shown to differentiate winners from losers using full game profiles. It is unclear whether this PI and/or other derived components from a secondary PCA could be used to differentiate winners from losers across either halves or quarters. Moreover, further insights could be revealed by extending the temporal analysis previously conducted within winners and losers in study 1, to determine whether any of the new derived components (PIs) from the secondary PCA interacted with match period (time).

4.1.1 Study purpose

The primary purpose of this study was to evaluate team technical and tactical performance to identify traditional or novel PIs that differentiated between winning and losing halves and quarters in elite Gaelic football. A secondary objective was to examine whether novel PIs contributed more to winning specific halves (i.e., first or second) or quarters (i.e., 1,2,3 or 4).

4.1.2 Study aims

1) To compare relative differences in technical and tactical PIs that distinguish between winning and losing halves and quarters in elite Gaelic football teams.

2) To generate novel PIs by using PCA to combine discrete PIs into new composite variables.

3) To identify composite variables that distinguish between winners and losers using GEE.

4) To determine whether derived components contributed more to winning specific halves or periods.

5) To compare the classification accuracy of the GEE, using the LOOC approach.

4.1.3 Hypotheses

1) In winning halves and quarters, teams demonstrate superior technical and tactical performance across different aspects of play including; possession, offence, defence, passing and dead ball distribution profiles, in comparison to losing teams.

2) The complexity of large data sets can be reduced by using PCA to combine discrete PIs, enabling novel PIs capable of distinguishing between winning and losing in halves and quarters to be identified and characterised.

3) GEE can identify PIs that differentiate between winners and losers across halves and quarters.

4) The LOOC technique demonstrates sufficient classification accuracy in the PIs found to differentiate between winners and losers across halves and quarters.

5) Novel component PIs contribute more to winning specific periods.

4.2 Methods

4.2.1 Match sample

The technical and tactical PIs from 13 Gaelic football teams were examined during 16 inter-county Division 1 NFL and 10 AIC games (Tables 3.1 and 3.2). Team ratings were determined using the Elo rating system for Gaelic football (87). As winners and losers could not be differentiated from match periods which ended in a draw, 3 halves and 19 quarters were excluded, resulting in 49 halves and 85 quarters being analysed. Both playing time and stoppage time was included in the total duration of each half. Quarters were calculated by dividing each half by 2, for example a first half lasting 36 min, resulted in quarter 1 and quarter 2 being 18 min in duration.

4.2.2 Experimental procedures and operational definitions

The experimental procedures and operational definitions used in this study have been described in detail in Chapter 3 (Tables 3.4 – 3.9). In summary, match footage from internal team video recordings and from external media broadcasters was imported and coded using a custom built tagging panel in Dartfish (v8) TeamPro software (Fribourg, Switzerland). Following data validation, the coding events were then exported into Microsoft Excel (Microsoft, USA) and transformed and collated for specific match periods to facilitate statistical analysis.

4.2.3 Intra-rater reliability

To determine intra-rater reliability, two games were randomly selected and coded twice over a 4-week period. Using the convention outlined previously (135), a two-way mixed effects model, evaluating absolute agreement between the mean of either 8 halves or 16 quarter measurements (Appendix D), was selected to compute the ICC. The lowest ICC recorded for halves was 0.90 (attack origin defence), whereas the lowest score for quarters was 0.89 (attack origin attack). All other PIs had an ICC >0.90 (mean 0.98), demonstrating excellent reliability (136).

4.2.4 Statistical analysis

The relative differences in game statistics and PIs between winners and losers were analysed across match halves and quarters using SPSS for Windows (Version 24; SPSS Inc., Chicago, USA) with statistical significance accepted at $p \leq 0.05$. The distribution of differences between winners and losers was assessed for normality using the Shapiro-Wilk test. Data that met the normality assumption were analysed using a one-sample t-test. A Wilcoxon signed-rank test was used to evaluate differences that did not meet the normality assumption. Descriptive statistics are presented as mean ± SD.

Preliminary screening excluded 48 PIs from the initial PCA due to observed functional dependencies and distributional range. A correlation matrix was subsequently used to identify and provisionally remove any of the 35 remaining PIs that were highly intercorrelated. The PCA was then conducted on the differences between winners and losers using an orthogonal rotation (Varimax with Kaiser normalisation). Previously excluded PIs were then progressively incorporated into the PCA, using a trial and error approach, to optimise the sampling adequacy (KMO). The KMO statistics of 0.72 and 0.74 achieved for halves and quarters, respectively were deemed sufficient and all individual KMO values were above the acceptable limit of 0.5 (115). Overall, the number of PIs retained ranged from 25 (halves) to 27 (quarters). An average communality of 0.84 (range 0.48 – 0.95) for halves and 0.81 (range 0.55 – 0.96) for quarters was reported. The PCA for both halves and quarters produced six components with eigenvalues greater than Kaiser's criterion of 1 (137).

The associated regression factors were then evaluated using GEE models to determine if these novel components could differentiate winners from losers across specific match periods. The SPSS technique GENLIN (link=logit, distribution=binomial, working correlation structure=independent) was employed. To account for multiple correlated observations, match period (half or quarter) was treated as the repeated measure. The model goodness of fit incorporated the Quasi likelihood under Independence Model Criterion (QIC). Four correlation structures were examined and the lowest QIC values were reported by the independent model. The QIC for the main and interaction effects for halves was 45.43 and 40.79, respectively. The corresponding values for quarters were 87.66 and 81.56, respectively. Two of the original components that were not significant and demonstrated a high correlation with other parameter estimates were removed from the GEE models in the analysis of both halves (offensive dead ball efficiency and high-press efficiency) and quarters (low-press efficiency and defensive-counterattacking goals). For halves, one additional component (midfield-counterattacking) was also removed from the interaction analysis due to over specification of the model, whereas all four components were incorporated into the interaction analysis for quarters.

4.3 Results

Results from the univariate analyses of match characteristics, game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 4.1 to 4.8. Table 4.1 highlights the overall match characteristics for all halves and quarters combined. Tables 4.2 and 4.3 illustrate the games statistics and relative differences between winners and losers across halves or quarters, respectively. Tables 4.4 to 4.8 include the mean results from both winners and losers and the relative difference between the two groups across both halves and quarters. Significant differences are illustrated in the tables and highlighted within the text.

4.3.1 Match characteristics and game statistics: winning halves and quarters

The average; playing time, ball in play time and stoppage times for the halves (n=49) and quarters (n=85) are summarised in Table 4.1. There were no significant differences in the number of substitutions or black, yellow or red cards received by opposing teams (Tables 4.2 and 4.3). However, there was a significant difference between the Elo ratings of winners compared to losers ($p < 0.05$) when examined across quarters, but not halves.

Table 4.1 Match characteristics for halves (n=49) and quarters (n=85)

	Period	
Characteristic	**Halves**	**Quarters**
Playing time (min:s)	37:09 ± 1:04	18:32 ± 0:32
Ball in play time (min:s)	18:31 ± 2:05	9:16 ± 1:13
Stoppage time (min:s)	18:38 ± 2:35	9:16 ± 1:28

Values are mean ± SD.

Table 4.2 Game statistics for halves (n=49)

	Group		
Game statistic	**Winners**	**Losers**	**Difference**
Substitution (n)	2.6 ± 2.3	2.8 ± 2.3	-0.2 ± 1.3
Yellow card (n)	0.9 ± 0.9	0.6 ± 0.8	0.2 ± 0.9
Black card (n)	0.2 ± 0.5	0.3 ± 0.5	0.0 ± 0.7
Red card/BCNR (n)	0.1 ± 0.3	0.1 ± 0.3	0.0 ± 0.4
Elo rating (points)	1799.5 ± 164.3	1773.4 ± 181.3	26.1 ± 261.9

Values are mean ± SD; BCNR = Black card not replaced.

Table 4.3 Game statistics for quarters (n=85)

	Group		
Game statistic	**Winners**	**Losers**	**Difference**
Substitution (n)	1.3 ± 1.5	1.4 ± 1.4	-0.1 ± 1.3
Yellow card (n)	0.3 ± 0.6	0.3 ± 0.6	0.0 ± 0.7
Black card (n)	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.5
Red card / BCNR (n)	0.0 ± 0.2	0.0 ± 0.2	0.0 ± 0.3
Elo rating (points)	1816.9 ± 167.3[a]	1753.2 ± 186.5	63.7 ± 258.7

Values are mean ± SD; $p \leq 0.05$ vs. losers using a one-sample t-test ([a]) BCNR = Black card not replaced.

4.3.2 Performance characteristics: winning halves and quarters

4.3.2.1 Possession

During both halves (H) and quarters (Q), the percentage (H: p = 0.006, Q: p = 0.001), total time (H: p = 0.006, Q: p = 0.000), and average duration (H: p = 0.001, Q: p = 0.002) of team possession was significantly higher in winners (Table 4.4). Winners also had a significantly higher number (H: p = 0.038, Q: p = 0.001) and total time (H: p = 0.018, Q: p = 0.001) of individual player possessions than losers during both halves and quarters. During quarters, winners had significantly less team possessions originating in defence (p = 0.002) and significantly more beginning in midfield (p = 0.008), leading to significantly more player possessions in both midfield (p = 0.001) and attack (p = 0.008). Winners also had a significantly higher number of player possessions originating in midfield (p = 0.023) during halves.

4.3.2.2 Offence

Across both halves and quarters; attacks originating in defence (H: p = 0.020, Q: p = 0.030), attack efficiency (H: p = 0.023, Q: p = 0.002), shots (H: p = 0.011, Q: p = 0.000), shots from play (H: p = 0.021, Q: p = 0.000), shot efficiency (H: p = 0.000, Q: p = 0.000), total scores (H: p = 0.000, Q: p = 0.000), total number of scores (H: p = 0.000, Q: p = 0.000), average attack per score (H: p = 0.000, Q: p = 0.000), productivity (H: p = 0.000, Q: p = 0.000), points (H: p = 0.000, Q: p = 0.000), points from play (H: p = 0.001, Q: p = 0.000), points from dead balls (H: p = 0.007, Q: p = 0.002), and goals (H: p = 0.000, Q: p = 0.000) of winners, was significantly different from losers (Table 4.5). The total number of attacks

(p = 0.000) and attacks originating in midfield (p = 0.013) during quarters was also significantly higher in winners than losers.

4.3.2.3 Defence

When compared to losing teams, winning teams had a significantly higher number of turnovers in both match periods (H: p = 0.001, Q: p = 0.000). Turnover origin was significantly higher in defence during halves (p = 0.003) and in defence (p = 0.000) and midfield (p = 0.000) during quarters (Table 4.6). Defensive efficiency was significantly higher in winners than losers during both halves (p = 0.023) and quarters (p = 0.002). There were no significant difference in tackles, free kicks won or defensive actions between winners and losers.

4.3.2.4 Passing

Across both halves and quarters, winners had a significantly higher combined number of total passes (H: p = 0.040, Q: p = 0.005), higher number (H: p = 0.028, Q: p = 0.001) and percentage (H: p = 0.008, Q: p = 0.000) of successful passes, and also a significantly lower percentage (H: p = 0.008, Q: p = 0.000) of combined unsuccessful passes (Table 4.7). Winners also had a higher number of both overall (H: p = 0.024, Q: p = 0.002) and successful (H: p = 0.020, Q: p = 0.002) hand passes. In quarters, there was a significantly higher percentage of kick pass success (p = 0.001) and consequently a significantly lower number (p = 0.000) and percentage (p = 0.001) of unsuccessful kick passes in winners than losers. In quarters, winners also had fewer unsuccessful passes (p = 0.000).

4.3.2.5 Dead ball distribution

Winners had significantly fewer successful dead ball kick passes (H: $p = 0.000$, Q: $p = 0.009$) and successful kick outs (H: $p = 0.000$, Q: $p = 0.000$) across halves and quarters, resulting from significantly fewer overall dead balls (H: $p = 0.001$, Q: $p = 0.000$) and kick outs (H: $p = 0.000$, Q: $p = 0.000$), executed compared to losers during halves and quarters (Table 4.8). However, during quarters winners had a significantly higher percentage dead ball kick pass success ($p = 0.004$) and a lower frequency ($p = 0.000$) and percentage ($p = 0.004$) of unsuccessful dead ball kick passes. Similarly, in quarters winners had a higher percentage of kick out success ($p = 0.036$) and a lower frequency ($p = 0.000$) and percentage ($p = 0.036$) of unsuccessful kick outs.

Table 4.4 Possession across halves and quarters in winners and losers

Performance indicator	Period					
	Halves			Quarters		
	Winners	Losers	Difference	Winners	Losers	Difference
Team possession						
Total number (n)	35.8 ± 4.6	36.7 ± 5.1	-1.0 ± 5.1	18.0 ± 2.9	17.8 ± 3.0	0.2 ± 3.3
Proportion of total (%)	53.2 ± 7.8[a]	46.8 ± 7.8	6.4 ± 15.5	53.3 ± 8.3[a]	46.7 ± 8.3	6.5 ± 16.7
Total time (s)	504.1 ± 98.3[a]	442.8 ± 91.8	61.3 ± 150.4	254.2 ± 58.2[a]	221.5 ± 47.3	32.7 ± 80.8
Time per possession (s)	14.4 ± 3.8[a]	12.2 ± 2.8	2.2 ± 4.1	14.4 ± 4.1[a]	12.8 ± 3.4	1.7 ± 4.8
Origin defence (n)	20.0 ± 3.8	21.2 ± 4.1	-1.1 ± 6.1	9.8 ± 2.5[a]	11.1 ± 2.6	-1.3 ± 3.8
Origin midfield (n)	11.4 ± 4.2	11.4 ± 3.8	0.0 ± 5.9	6.0 ± 2.8[a]	4.9 ± 2.5	1.2 ± 4.0
Origin attack (n)	4.3 ± 1.9	4.2 ± 2.5	0.2 ± 3.2	2.2 ± 1.4	1.9 ± 1.6	0.4 ± 2.2
Player possession						
Total number (n)	154.8 ± 28.2[a]	141.1 ± 27.4	13.7 ± 45.2	78.6 ± 16.5[a]	69.8 ± 13.2	8.8 ± 23.5
Total time in possession (s)	326.8 ± 78.4[a]	289.2 ± 66.2	37.6 ± 107.4	165.7 ± 45.7[a]	143.5 ± 34.4	22.2 ± 57.8
Time per possession (s)	2.1 ± 0.3	2.0 ± 0.3	0.1 ± 0.4	2.1 ± 0.4	2.0 ± 0.3	0.1 ± 0.5
Origin defence (n)	41.3 ± 8.7	41.3 ± 13.5	0.0 ± 17.6	20.2 ± 6.0	21.2 ± 7.6	-0.9 ± 10.3
Origin midfield (n)	77.5 ± 23.2[a]	66.4 ± 20.9	11.1 ± 32.9	39.2 ± 13.8[a]	32.7 ± 8.6	6.5 ± 17.1
Origin attack (n)	36.0 ± 10.6	33.3 ± 10.7	2.7 ± 18.3	19.2 ± 6.9[a]	15.9 ± 6.4	3.2 ± 10.9

Values are mean ± SD; $p \leq 0.05$ vs. losers using a one-sample t-test ([a]).

Table 4.5 Offensive play across halves and quarters in winners and losers

	Period					
	Halves			Quarters		
Performance indicator	**Winners**	**Losers**	**Difference**	**Winners**	**Losers**	**Difference**
Attack						
Total number (n)	20.6 ± 4.0	19.2 ± 3.7	1.4 ± 5.8	10.8 ± 2.4[a]	9.4 ± 2.4	1.4 ± 3.4
Origin defence (n)	10.8 ± 2.7[a]	9.7 ± 3.0	1.1 ± 3.1	5.6 ± 1.9[a]	5.1 ± 2.2	0.5 ± 2.1
Origin midfield (n)	8.9 ± 3.5	8.7 ± 3.1	0.2 ± 5.1	4.7 ± 2.2[a]	3.8 ± 2.0	0.9 ± 3.3
Origin attack (n)	0.9 ± 1.0	0.8 ± 1.1	0.1 ± 1.5	0.4 ± 0.7	0.4 ± 0.8	0.0 ± 1.0
Efficiency (%)	72.1 ± 12.4[a]	67.2 ± 12.1	4.8 ± 14.4	74.1 ± 17.4[a]	65.5 ± 21.2	8.6 ± 25.4
Shot						
Total number (n)	14.8 ± 3.5[a]	12.8 ± 3.0	2.0 ± 5.3	7.9 ± 2.3[a]	6.0 ± 2.0	1.9 ± 3.3
From play (n)	11.2 ± 3.7[b]	9.6 ± 3.0	1.6 ± 4.7	6.1 ± 2.6[a]	4.5 ± 2.0	1.6 ± 3.1
From play (%)	74.4 ± 11.4	74.0 ± 12.2	0.4 ± 14.4	75.4 ± 16.9	73.5 ± 20.1	1.9 ± 23.3
From dead ball (n)	3.6 ± 1.6	3.2 ± 1.6	0.4 ± 2.2	1.8 ± 1.1	1.5 ± 1.1	0.3 ± 1.5
From dead ball (%)	25.6 ± 11.4	26.0 ± 12.2	-0.4 ± 14.4	24.6 ± 16.9	26.5 ± 20.1	-1.9 ± 23.3
Efficiency (%)	55.1 ± 13[a]	44.6 ± 15.1	10.4 ± 15.8	58.6 ± 18.7[a]	44.3 ± 20.4	14.3 ± 26.3
Score						
Total combined	9.4 ± 2.8[b]	6.1 ± 2.4	3.3 ± 2.3	5.3 ± 2.2[b]	2.7 ± 1.3	2.6 ± 1.7
Total number (n)	8.0 ± 2.0[b]	5.6 ± 2.0	2.4 ± 2.2	4.4 ± 1.4[b]	2.5 ± 1.2	1.9 ± 1.3
Average attack/score (n)	2.7 ± 0.8[b]	4.3 ± 3.3	-1.6 ± 2.8	2.7 ± 1.0[b]	4.4 ± 2.7	-1.9 ± 2.4
Productivity	2.7 ± 0.8[a]	1.7 ± 0.7	1 ± 0.7	3.0 ± 1.3[b]	1.5 ± 0.8	1.4 ± 1.1
Point (n)	7.3 ± 2.0[b]	5.4 ± 2.0	1.9 ± 2.5	4.0 ± 1.3[b]	2.4 ± 1.2	1.5 ± 1.5
Point from play (n)	4.7 ± 1.9[a]	3.6 ± 1.7	1.1 ± 2.3	2.7 ± 1.3[b]	1.6 ± 1.2	1.1 ± 1.5
Point from dead ball (n)	2.6 ± 1.3[b]	1.8 ± 1.3	0.7 ± 1.8	1.3 ± 1.0[b]	0.8 ± 0.8	0.4 ± 1.2
Goal (n)	0.7 ± 0.7[b]	0.2 ± 0.5	0.5 ± 0.8	0.4 ± 0.6[b]	0.1 ± 0.3	0.4 ± 0.6

Values are mean ± SD; $p \leq 0.05$ vs. losers using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 4.6 Defensive play across halves and quarters in winners and losers

	Period					
	Halves			Quarters		
Performance indicator	**Winners**	**Losers**	**Difference**	**Winners**	**Losers**	**Difference**
Turnovers						
Total number (n)	16.6 ± 4.7[a]	14.4 ± 4.3	2.2 ± 4.3	8.8 ± 2.8[b]	6.6 ± 2.4	2.1 ± 2.7
Origin defence (n)	9.0 ± 2.6[a]	7.9 ± 3.0	1.2 ± 2.6	4.7 ± 1.9[b]	3.9 ± 1.9	0.9 ± 2.2
Origin midfield (n)	6.7 ± 3.6	5.8 ± 2.8	0.9 ± 4.8	3.6 ± 2.1[a]	2.4 ± 1.6	1.3 ± 2.8
Origin attack (n)	0.9 ± 1.1	0.8 ± 1.1	0.1 ± 1.5	0.4 ± 0.7	0.4 ± 0.8	0.0 ± 1.1
Tackles						
Total number (n)	45.0 ± 12.4	47.0 ± 13.0	-1.9 ± 18.9	22.2 ± 7.5	23.8 ± 7.3	-1.5 ± 10.5
Successful (n)	5.1 ± 2.4	5.0 ± 2.4	0.1 ± 2.7	2.6 ± 1.7	2.4 ± 1.6	0.2 ± 1.9
Successful (%)	11.3 ± 4.5	10.9 ± 5.3	0.4 ± 6.0	11.6 ± 6.7	10.2 ± 6.3	1.4 ± 7.9
Unsuccessful (n)	39.9 ± 11.2	42.0 ± 12.4	-2.1 ± 17.9	19.6 ± 6.7	21.4 ± 6.8	-1.8 ± 9.6
Unsuccessful (%)	88.7 ± 4.5	89.1 ± 5.3	-0.4 ± 6.0	88.4 ± 6.7	89.8 ± 6.3	-1.4 ± 7.9
Origin defence (n)	18.9 ± 7.6	18.8 ± 6.1	0.1 ± 9.9	9.5 ± 5.1	10.0 ± 4.2	-0.5 ± 6.6
Origin midfield (n)	19.6 ± 8.0	21.3 ± 9.6	-1.7 ± 12.9	9.6 ± 4.7	10.5 ± 5.8	-0.9 ± 7.5
Origin attack (n)	6.5 ± 5.0	6.9 ± 3.8	-0.3 ± 7.0	3.2 ± 2.7	3.2 ± 2.5	0.0 ± 3.9
Free kick won						
Total number (n)	9.5 ± 3.2	10.3 ± 4.1	-0.8 ± 5.1	4.6 ± 2.3	4.5 ± 2.3	0.2 ± 3.3
Origin defence (n)	2.3 ± 1.3	2.2 ± 1.7	0.1 ± 1.9	1.1 ± 0.9	0.9 ± 1.1	0.1 ± 1.4
Origin midfield (n)	4.4 ± 2.3	5.2 ± 2.9	-0.9 ± 3.9	2.2 ± 1.6	2.3 ± 1.8	-0.1 ± 2.5
Origin attack (n)	2.8 ± 1.4	2.8 ± 1.9	0.0 ± 2.2	1.4 ± 1.1	1.3 ± 1.1	0.1 ± 1.4
Defensive actions						
Total number (n)	72.0 ± 15.5	71.2 ± 14.9	0.8 ± 22.0	35.5 ± 9.1	35.2 ± 8.7	0.3 ± 12.1
Origin defence (n)	30.7 ± 9.3	29.7 ± 7.2	1.1 ± 11.7	15.4 ± 6.0	15.4 ± 5.0	0.0 ± 7.8
Origin midfield (n)	31.6 ± 10.9	31.7 ± 11.1	-0.1 ± 16.7	15.6 ± 6.3	15.1 ± 6.8	0.5 ± 9.3
Origin attack (n)	9.7 ± 6.3	9.9 ± 4.8	-0.2 ± 8.8	4.5 ± 3.5	4.7 ± 3.4	-0.3 ± 5.1
Defensive efficiency (%)	32.8 ± 12.1[a]	27.9 ± 12.4	4.8 ± 14.4	34.5 ± 21.2[a]	25.9 ± 17.4	8.6 ± 25.4

Values are mean ± SD; $p \leq 0.05$ vs. losers using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 4.7 Passing across halves and quarters in winners and losers

	Period					
	Halves			Quarters		
Performance indicator	**Winners**	**Losers**	**Difference**	**Winners**	**Losers**	**Difference**
Combined hand and kick pass						
Total number (n)	129.3 ± 28.3[a]	116.3 ± 26.6	13.0 ± 43.2	65.3 ± 16.0[a]	58.4 ± 12.5	6.9 ± 21.9
Successful (n)	119.0 ± 28.8[a]	104.9 ± 27.1	14.1 ± 43.5	60.5 ± 16.4[a]	52.4 ± 12.9	8.2 ± 22.6
Successful (%)	91.5 ± 3.9[a]	89.7 ± 4.3	1.8 ± 4.6	92.1 ± 4.2[a]	89.1 ± 5.5	3.1 ± 6.4
Unsuccessful (n)	10.3 ± 3.7	11.4 ± 4.0	-1.1 ± 3.9	4.8 ± 2.1[a]	6.1 ± 2.6	-1.3 ± 2.9
Unsuccessful (%)	8.5 ± 3.9[a]	10.3 ± 4.3	-1.8 ± 4.6	7.9 ± 4.2[a]	10.9 ± 5.5	-3.1 ± 6.4
Hand pass						
Total number (n)	89.7 ± 26.2[a]	77.1 ± 25.4	12.6 ± 37.7	45.9 ± 14.9[a]	39.0 ± 12.1	6.9 ± 19.6
Successful (n)	87.6 ± 25.9[a]	74.8 ± 25.1	12.8 ± 37.4	44.8 ± 14.8[a]	37.9 ± 12.1	6.9 ± 19.6
Successful (%)	97.6 ± 1.7	97.0 ± 2.3	0.6 ± 2.5	97.5 ± 2.5	96.8 ± 3.7	0.6 ± 4.7
Unsuccessful (n)	2.1 ± 1.4	2.2 ± 1.6	-0.2 ± 1.7	1.1 ± 1.0	1.1 ± 1.1	0.0 ± 1.5
Unsuccessful (%)	2.4 ± 1.7	3.0 ± 2.3	-0.6 ± 2.5	2.5 ± 2.5	3.2 ± 3.7	-0.6 ± 4.7
Kick pass						
Total number (n)	39.6 ± 8.5	39.2 ± 7.7	0.4 ± 10.2	19.4 ± 5.0	19.5 ± 4.2	-0.1 ± 5.7
Successful (n)	31.3 ± 8.5	30.1 ± 6.8	1.3 ± 11.4	15.7 ± 5.0	14.5 ± 3.9	1.2 ± 6.3
Successful (%)	78.6 ± 8.6	76.7 ± 8.6	1.9 ± 11.9	80.3 ± 10.2[a]	74.6 ± 11.0	5.8 ± 14.9
Unsuccessful (n)	8.3 ± 3.4	9.2 ± 4.0	-0.9 ± 4.0	3.7 ± 1.9[a]	5.0 ± 2.5	-1.3 ± 2.8
Unsuccessful (%)	21.4 ± 8.6	23.3 ± 8.6	-1.9 ± 11.9	19.7 ± 10.2[a]	25.4 ± 11.0	-5.8 ± 14.9

Values are mean ± SD; $p \leq 0.05$ vs. losers using a one-sample t-test ([a]).

Table 4.8 Dead ball distribution across halves and quarters in winners and losers

	Period					
	Halves			Quarters		
Performance indicator	Winners	Losers	Difference	Winners	Losers	Difference
Dead ball						
Total number (n)	21.1 ± 3.9[a]	24.2 ± 4.1	-3.1 ± 6.1	10.2 ± 2.7[a]	11.9 ± 2.6	-1.7 ± 4
^Dead ball kick pass						
Successful (n)	13.3 ± 2.8[a]	16.1 ± 4.0	-2.7 ± 4.7	6.7 ± 2.2[a]	7.7 ± 2.5	-1 ± 3.4
Successful (%)	77.6 ± 11.0	76.9 ± 13.4	0.7 ± 17	81.0 ± 15.0[a]	74.0 ± 15.3	6.9 ± 21.6
Unsuccessful (n)	4.1 ± 2.2	4.9 ± 2.9	-0.8 ± 3.7	1.7 ± 1.4[a]	2.7 ± 1.7	-1 ± 2.3
Unsuccessful (%)	22.4 ± 11.0	23.1 ± 13.4	-0.7 ± 17	19.0 ± 15.0[a]	26.0 ± 15.3	-7 ± 21.6
Dead ball free kick pass						
Total number (n)	6.4 ± 2.6	7.5 ± 3.6	-1.1 ± 4.5	3.2 ± 1.9	3.2 ± 2.1	0 ± 2.9
Successful (n)	5.9 ± 2.3	7.1 ± 3.4	-1.2 ± 4.3	2.9 ± 1.8	3.0 ± 2.0	-0.1 ± 2.8
Successful (%)	92.1 ± 10.3	94.7 ± 9.6	-2.6 ± 12.8	91.8 ± 16.9	95.3 ± 12.3	-2.3 ± 21.3
Unsuccessful (n)	0.6 ± 0.7	0.5 ± 0.8	0.1 ± 0.9	0.2 ± 0.4	0.2 ± 0.5	0.1 ± 0.6
Unsuccessful (%)	7.9 ± 10.3	5.3 ± 9.6	2.6 ± 12.8	8.2 ± 16.9	4.7 ± 12.3	2.3 ± 21.3
Dead ball kick out						
Total number (n)	9.9 ± 2.5[a]	12.2 ± 2.6	-2.3 ± 4.2	4.5 ± 1.7[a]	6.7 ± 1.9	-2.2 ± 2.7
Successful (n)	6.4 ± 2.0[a]	7.9 ± 2.3	-1.5 ± 2.2	3.1 ± 1.4[b]	4.3 ± 1.7	-1.1 ± 1.9
Successful (%)	67.1 ± 18.4	66.5 ± 19.1	0.6 ± 25.8	72.6 ± 22.4[a]	65.3 ± 21.5	7.3 ± 31.7
Unsuccessful (n)	3.4 ± 2.1	4.3 ± 2.8	-0.8 ± 3.8	1.4 ± 1.3[a]	2.4 ± 1.7	-1.0 ± 2.3
Unsuccessful (%)	32.9 ± 18.4	33.5 ± 19.1	-0.6 ± 25.8	27.4 ± 22.4[a]	34.7 ± 21.5	-7.3 ± 31.7

Values are mean ± SD; $p \leq 0.05$ vs. losers using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs.

4.3.3 Multivariate analysis: winning halves and quarters

The six eigenvectors produced by the PCA explained 83.5% and 81.0% of the total variance for halves (Figure 4.1) and quarters (Figure 4.2), respectively. The component loadings after rotation for each period, are illustrated in Tables 4.9 and 4.10, respectively. The dominant PIs in each component were used to characterise the new PIs presented.

Using a GEE model, the parameter estimates for all main effects were found to significantly contribute to winning halves: midfield-counterattacking (β =1.501, $\chi^2(1)$ = 6.993, p = 0.008), possession (β = 2.216, $\chi^2(1)$ = 10.566 , p = 0.001), low-press efficiency (β = 1.133, $\chi^2(1)$ = 4.589, p = 0.032), and tackle pressure (β = 1.665, $\chi^2(1)$ = 5.200, p = 0.023). Although there was no significant main effect for time, the interaction analysis found that two components; possession (β = -5.469, $\chi^2(1)$ = 7.334, p = 0.007) and tackle pressure (β = -3.512, $\chi^2(1)$ = 6.039, p = 0.014), contributed significantly more to winning in the second half compared to the first half. Using the LOOC, the overall classification accuracy of the model for halves was 77.6%.

Similarly, the parameter estimates for all main effects were found to significantly contribute to winning quarters: midfield-counterattacking (β = 1.774, $\chi^2(1)$ = 17.095, p = 0.000), possession (β = 1.089, $\chi^2(1)$ = 13.079, p = 0.000), offensive dead ball efficiency (β = 0.563, $\chi^2(1)$ = 4.749, p = 0.029), and high-press efficiency (β = -0.509, $\chi^2(1)$ = 4.515, p = 0.034). Although there was no significant main effect for time, the interaction analysis revealed that two components; high-press efficiency (β = 6.143, $\chi^2(1)$ = 13.057, p = 0.000) and midfield-counterattacking (β = 5.915, $\chi^2(1)$ = 5.330, p = 0.021) contributed significantly more to winning in quarters 1 and 2, respectively, in comparison to quarter 4. Using the LOOC, the overall classification accuracy of the model for quarters was 76.5%.

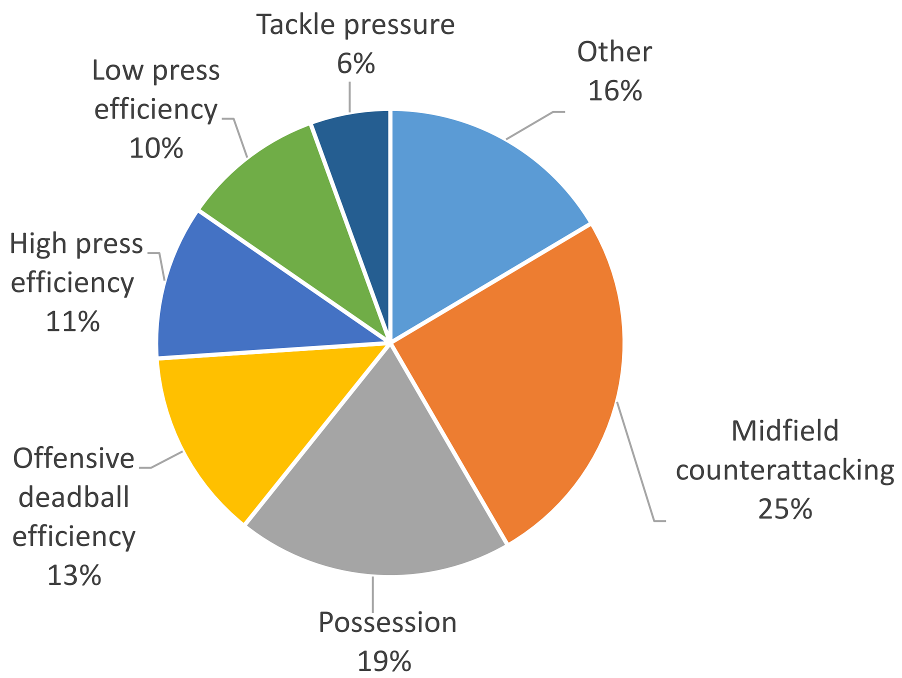


Figure 4.1 Variance explained by the principal components derived for halves.

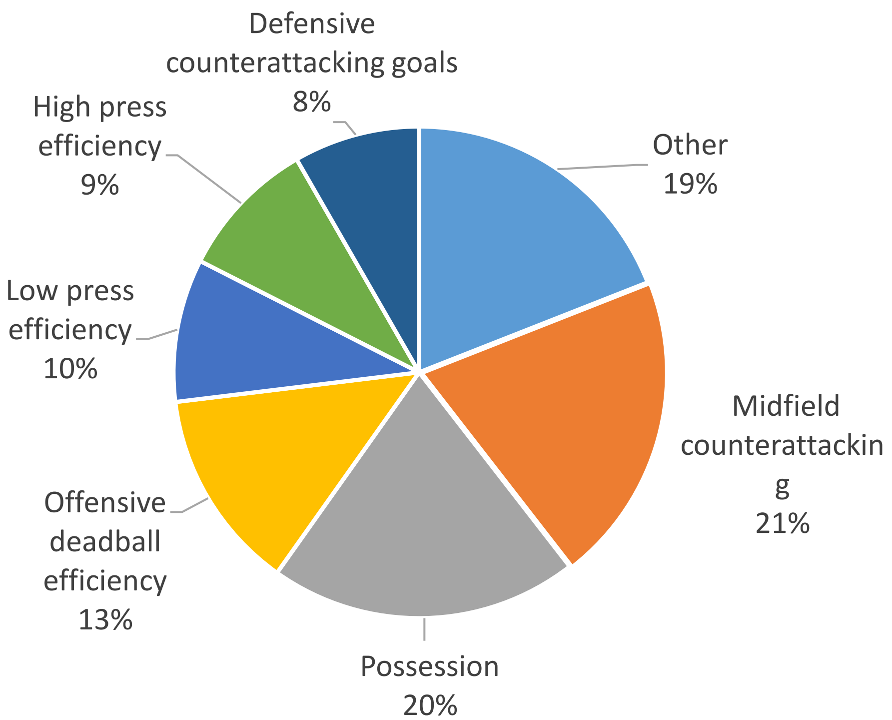


Figure 4.2 Variance explained by the principal components derived for quarters.

Table 4.9 Summary of exploratory principal component analysis created from the differences between winners and losers across halves

Principal component / Performance indicator	Midfield counter-attacking	Possession	Offensive dead ball efficiency	High-press efficiency	Low-press efficiency	Tackle pressure
dTurnover origin midfield	**0.937**	-0.064	0.143	0.007	-0.184	0.003
dAttack origin midfield	**0.899**	-0.188	0.182	-0.017	-0.084	-0.166
dTeam possession origin midfield	**0.857**	-0.103	0.113	-0.065	0.051	-0.286
dShot from play	**0.855**	0.273	-0.014	0.237	-0.061	0.126
dPoint from play for	**0.628**	0.310	**-0.445**	0.106	0.152	0.061
dPlayer possession origin attack	**0.529**	**0.453**	0.211	0.300	-0.366	-0.071
dTackle origin attack	0.385	-0.137	0.169	0.175	**-0.693**	0.323
dAttack origin attack	0.210	0.080	0.223	**0.906**	-0.072	-0.116
dPoint from dead ball for	0.203	0.217	**0.848**	-0.041	0.065	0.097
dTurnover origin attack	0.174	0.032	0.202	**0.931**	-0.102	-0.022
dShot from dead ball	0.154	-0.119	**0.873**	0.162	0.067	-0.037
dTeam possession origin attack	0.136	0.129	**0.742**	**0.558**	-0.070	-0.123
dTotal team player possession (s)	0.089	**0.903**	0.152	-0.001	0.098	-0.182
dTeam possession (s)	0.056	**0.956**	0.082	0.038	0.021	-0.154
dTeam possession average (s)	-0.010	**0.951**	-0.078	0.089	-0.178	0.069
dFree kick origin attack	-0.030	0.107	**0.803**	0.330	0.142	-0.201
dHand pass success	-0.044	**0.916**	-0.004	0.073	-0.069	-0.110
dTackle unsuccessful	-0.089	**-0.490**	-0.108	-0.128	-0.244	**0.749**
dHand pass unsuccessful	-0.149	0.136	-0.217	0.094	**-0.607**	-0.106
dFree kick origin defence	-0.294	-0.064	0.066	0.069	**0.764**	-0.085
dTurnover origin defence	-0.336	**0.532**	0.095	-0.171	**0.550**	0.179
dTackle origin defence	**-0.406**	-0.134	-0.181	-0.270	0.351	**0.545**
dPlayer possession origin defence	**-0.664**	0.378	0.050	-0.253	0.313	-0.253
dDead ball kick out unsuccessful	**-0.791**	-0.239	-0.125	-0.274	0.067	0.136
dTeam possession origin defence	**-0.830**	0.038	-0.185	-0.235	0.369	-0.052
Eigenvalue	6.29	4.78	3.30	2.67	2.46	1.39
% of variance	25.18	19.11	13.20	10.69	9.82	5.55

Component loadings ≥±0.4 appear in bold. Performance indicator = frequency, unless stated.

Table 4.10 Summary of exploratory principal component analysis created from the differences between winners and losers across quarters

Principal component / Performance indicator	**Midfield counter-attacking**	**Possession**	**Offensive dead ball efficiency**	**Low-press efficiency**	**High-press efficiency**	**Defensive counter-attacking goals**
dTurnover origin midfield	**0.929**	0.024	0.185	-0.193	0.013	-0.037
dAttack origin midfield	**0.862**	-0.011	0.111	-0.153	-0.015	-0.369
dTeam possession origin midfield	**0.820**	0.083	0.128	-0.034	-0.053	**-0.507**
dShot from play	**0.754**	0.315	-0.035	-0.122	0.069	0.315
dPoint from play for	**0.592**	0.237	-0.211	0.341	0.047	0.209
dPlayer possession origin attack	0.396	**0.450**	0.298	**-0.556**	0.136	0.192
dTackle origin attack	0.364	-0.305	-0.006	**-0.615**	0.351	0.013
dFree kick origin midfield	0.337	0.106	-0.023	0.107	-0.156	-0.791
dGoal for	0.222	0.137	-0.074	0.042	-0.279	**0.626**
dPlayer possession origin midfield	0.181	**0.829**	-0.056	0.148	0.165	-0.131
dTurnover origin attack	0.159	0.131	0.263	-0.119	**0.881**	-0.024
dAttack origin attack	0.150	0.122	0.283	-0.213	**0.855**	-0.115
dPoint from dead ball for	0.150	0.039	**0.840**	-0.050	-0.098	-0.029
dTotal team player possession (s)	0.146	**0.907**	0.125	0.030	-0.062	-0.006
dShot from dead ball	0.141	0.021	**0.866**	0.018	0.230	-0.090
dTeam possession origin attack	0.128	0.105	**0.783**	-0.112	**0.509**	0.081
dTeam possession (s)	0.112	**0.955**	0.120	0.059	0.011	0.050
dTeam possession averages (s)	0.003	**0.859**	-0.147	-0.120	0.114	0.329
dFree kick origin attack	-0.029	0.088	**0.863**	0.095	0.239	0.015
dHand pass success	-0.032	**0.924**	0.028	0.013	0.090	0.172
dTackle unsuccessful	-0.040	**-0.723**	-0.282	0.024	0.051	0.340
dFree kick origin defence	-0.097	0.081	0.189	**0.732**	-0.110	-0.075
dTackle origin defence	-0.184	-0.291	-0.363	**0.642**	0.011	0.159
dTurnover origin defence	-0.185	0.360	0.145	**0.471**	-0.292	**0.537**
dPlayer possession origin defence	**-0.633**	0.338	0.034	**0.444**	-0.190	0.160
dDead ball kick out unsuccessful	**-0.763**	-0.279	-0.241	0.101	-0.220	-0.056
dTeam possession origin defence	**-0.797**	0.017	-0.168	0.380	-0.331	0.011
Eigenvalue	5.52	5.49	3.58	2.54	2.49	2.24
% of Variance	20.45	20.33	13.25	9.41	9.21	8.31

Component loadings ≥±0.4 appear in bold. Performance indicator = frequency, unless stated.

4.3.4 Results summary: winning halves and quarters

This is the first investigation in Gaelic football to use PCA combined with GEE to identify novel components, which distinguished between winners and losers across halves and quarters. Of the six components identified by the PCA to explain >80% of the variance, five were similar across both halves and quarters (i.e., midfield-counterattacking, possession, offensive dead ball efficiency, high and low-press efficiency). In addition, tackle pressure was identified from the PCA analysis of halves, whereas defensive-counterattacking goals scored was included for quarters. Using four components for both halves (i.e., midfield-counterattacking, possession, low-press efficiency and tackle pressure) and quarters (i.e., midfield-counterattacking, possession, offensive dead ball efficiency and high-press efficiency), the models differentiated between winners and losers with a classification accuracy of 77.6% and 76.5%, respectively. The temporal analysis revealed that two components; possession and tackle pressure, contributed more to winning in the second half compared to the first half. In contrast, high-press efficiency and midfield-counterattacking contributed significantly more to winning in quarters 1 and 2, respectively, in comparison to quarter 4.

Univariate analysis indicated that 32 and 48 PIs differentiated winners from losers during halves and quarters, respectively, across the five aspects of play (i.e., possession, offence, defence, passing and dead ball distribution). Across halves, winners had a higher percentage and time in team possession, demonstrated superior defensive efficiency and generated more turnovers overall and in defence, which contributed to an increased initiation of attacks from this zone, as summarised in Table 4.11. Winners executed more shots overall and from play and demonstrated a superior shot and attacking efficiency and productivity. Winners also displayed enhanced passing competence with increased frequency and success of both combined and hand passes.

In quarters, winners had a higher percentage and time in team possession and more player possessions in both midfield and attack, as summarised in Table 4.12. Winners demonstrated superior defensive efficiency and generated more turnovers overall and in defence and midfield, which contributed to an increased initiation of attacks from these zones. Winners executed more shots overall and from play and demonstrated a superior shot and attacking efficiency and productivity. Winners also displayed enhanced passing competence with increased frequency and success of both combined and hand passes and increased success rate of kick passes. Winners also demonstrated a superior success rate in dead ball kick passes and kick outs.

Table 4.11 Summary of differences demonstrated by winners vs. losers in winning halves, n=49

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
Team ↑ %, time & time/possession **Player** ↑ no., time & no. in MF	**Attack** ↑ no. from DF & efficiency **Shot** ↑ no., no. from play & efficiency **Score** ↑ total, no., productivity, goals, points, points from play & dead ball, & ↓ average AT/score	**Turnovers** ↑ no. & no. in DF **Efficiency** ↑	**Combined** ↑ no. & no. & % successful & ↓ % unsuccessful **Hand pass** ↑ no. & no. successful	**Dead ball** ↓ no. **Dead ball kick pass** ↓ no. successful **Kick out** ↓ no. & no. successful

↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield, AT = attack.

Table 4.12 Summary of differences demonstrated by winners vs. losers in winning quarters, n=85

Aspect of play				
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**
Team ↑ %, time, time/possession & no. in MF & ↓ no. in DF **Player** ↑ no., time & no. in MF & AT	**Attack** ↑ no. & no. from DF & MF & efficiency **Shot** ↑ no., no. from play & efficiency **Score** ↑ total, no., productivity, goals, points, points from play & dead ball, & ↓ average AT/score	**Turnovers** ↑ no. & no. in DF & MF **Efficiency** ↑	**Combined** ↑ no. & no. & % successful & ↓ no. & % unsuccessful **Hand pass** ↑ no. & no. successful **Kick pass** ↑ % successful & ↓ no. & % unsuccessful	**Dead ball** ↓ no. **Dead ball kick pass** ↓ no. successful & ↑ % successful & ↓ no. & % unsuccessful **Kick out** ↓ no. & no. successful & ↑ % successful & ↓ no. & % unsuccessful

↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield, AT = attack.

4.3.5 Study 2 summary and preface to study 3

The second study has further explored the comprehensive range of technical and tactical team PIs across the five broad aspects of play (i.e. possession, offence, defence, passing and dead ball distribution). Both traditional and novel PIs were used to examine and subsequently distinguish between winners and losers across halves and quarters in elite Gaelic football. Using the same data reduction technique employed in study 1 (PCA), six component variables were generated for both halves and quarters. Temporal differences in some of these novel PIs were demonstrated using the GEE and the contribution of these PIs to winning specific match periods was highlighted.

Both studies 1 and 2 have explored team technical and tactical performance and highlighted PIs that extend knowledge of what it takes to win. However, due to the unavailability of opposition physical metrics, these studies did not consider team physical performance. It is therefore unclear what influence (if any) team physical performance has on technical and tactical performance and the subsequent outcome of games (and match periods). To date no studies have examined this. Consequently, further insights and performance knowledge could be gained through an integrated examination of the physical, technical and tactical PIs which differentiate between winning and losing teams in relation to the outcome of games and specific match periods (i.e., halves and quarters).

CHAPTER 5

STUDY 3: EVALUATION OF DIFFERENCES IN PHYSICAL, TECHNICAL AND TACTICAL TEAM PERFORMANCE INDICATORS IN THE REFERENCE TEAM IN RELATION TO WINNING AND LOSING ACROSS FULL GAMES, HALVES AND QUARTERS

5.1 Rationale

In Gaelic football, differences in the physical, technical and tactical PIs demonstrated between winning and losing can be examined to enhance understanding of the factors that contribute to successful (win) or unsuccessful (lose) match outcomes. As each PI is directly influenced by the tactical strategies employed by both the RT and OTs, the effectiveness of these strategies can be indirectly examined through analysis of overall team performance. Declines in possession characteristics and passing profiles were revealed in losers in the temporal analysis conducted in study 1. Moreover, decrements in physical performance profiles between match halves and towards the latter stages of games have also previously been reported (48,129). However, the influence of the declines in physical performance on skill (i.e., technical) related PIs has not been previously evaluated in Gaelic football.

Consequently, examination of differences between winning and losing in aspects of physical, technical and tactical performance between the first and second halves or between the start (i.e., first quarter) and end of the game (i.e., last quarter), may assist in explaining match outcome. It is also worth evaluating whether or not differences (if any) are more apparent in games lost compared to games won. Therefore, to extend the previous analysis conducted in this project and published studies pertaining to specific aspects of both team (20,21,39,47) and player performances (45,67,71) an integrated approach is warranted.

5.1.1 Study purpose

The primary purpose of this study was to examine physical, technical and tactical performance to identify PIs that differentiated between winning and losing games and specific match periods in an elite Gaelic football team (RT). A secondary objective was to determine if temporal changes in PIs occurred between the first and second halves and from the first to the fourth quarter and whether performance decrements were more pronounced in losing games compared to winning.

5.1.2 Study aims

1) To compare relative differences in physical, technical and tactical performance that distinguish between winning and losing in a RT across games and specific match periods.

2) To compare temporal differences in physical, technical and tactical performance in a RT across halves and quarters and also between winning and losing.

5.1.3 Hypotheses

1) In winning games and match periods, the RT demonstrates superior technical and tactical performance across different aspects of play including: possession, offence, defence, passing and dead ball distribution profiles, in comparison to losing.

2) In winning games and match periods, the RT demonstrates superior physical performance, evinced by greater distances covered in HIR and VHIR, in comparison to losing.

3) In winning games, the RT maintains physical, technical and tactical performance levels across halves and quarters, whereas a decline in performance is observed across these same periods in losing.

5.2 Methods

5.2.1 Match sample

The physical, technical and tactical PIs from the RT were examined in 22 games throughout 2 competitive seasons (Tables 3.1 and 3.2). The RT competed against 13 teams during 16 inter-county Division 1 NFL and 6 AIC games (win=8, loss=12, draw=2). As winners and losers could not be differentiated from match periods which ended in a draw, 2 games were excluded and the final analysis involved 20 games (RT vs. 12 teams). A small winning or losing margin of ≤5 points was associated with 11 games, whereas the remaining 9 games involved a large win or loss (between 6-15 points).

5.2.2 Participants

Data from 51 outfield players and 2 goalkeepers (mean ± SD; age, 24.5 ± 3.6 y; height, 181.9 ± 5.3 cm; mass, 83.5 ± 7.2 kg; estimated $\dot{V}O_2max$, 56.5 ± 3.3 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) were examined, incorporating 405 individual game files. The experimental procedures were approved by the University Research Ethics Committee (Appendix A). Participants were provided with a plain language statement outlining the nature and demands of the study as well as the inherent risks. Written informed consent was obtained prior to participation.

5.2.3 Physical measures and capacity

The players reported for physical evaluation(s) on two occasions, during February 2014 and in March 2015. The body mass (kg) and height (cm) of each player was measured using a portable stadiometer (SECA, Leicester Height Measure) and scales (SECA, 803), respectively. Following a standardised warm-up, a 20m progressive shuttle running test was used to obtain an estimation of $\dot{V}O_2max$. This was achieved by relating the number of levels and shuttles completed to a predicted value (138). For those players that participated in both physical assessment sessions, the mean score was used to provide an average value for inclusion in the physical summary.

5.2.4 Experimental procedures and operational definitions

The experimental procedures and operational definitions used in the tactical and technical evaluation of the RT were outlined in Chapter III. In relation to the evaluation of physical performance, microtechnology devices were used to measure activity profiles and PlayerLoad™. The streamlined GPS units sampled at 10 Hz (OptimEye S5, Firmware v6.92, Catapult Sports, Australia) and incorporated a tri-axial piezoelectric accelerometer with a frequency of 100 Hz and gyroscope capable of measuring 200-2000 degrees per second (Figure 5.1A). These sensors provided information relating to distance, speed, acceleration, deceleration, direction, orientation and angular motion. To enable player-tracking, the devices, with a mass of 67 g and dimensions of 96.5 x 52 x 14 mm (139), were inserted into a custom-made vest (Catapult Sports, Australia), which was worn under the player's shirt (Figure 5.1B). This bespoke harness enabled the units to be positioned between the scapulae, overlying the upper thoracic spine of the player, which limited restriction of upper body movement (97).

Figure 5.1 OptimEye S5 Catapult GPS device (A) inserted into bespoke harness (B).

Figure 5.2 Neil Gallagher (Donegal) and Enda Lynn (Derry) wearing GPS tracking devices during the 2015 Ulster Senior Football Championship Semi-Final (27/06/2015). Picture: Oliver McVeigh/SPORTSFILE.

Each player was familiarised with the harness and device and where possible the same player used the same device to minimise error (97). The units were activated outdoors for a minimum of 15 min to enable acquisition of satellite signal(s) (140), prior to being given to the players. Each player was subsequently examined to ensure that the devices were fitted securely in the correct position. Once instrumented, the players were tracked by the Global navigation satellite system (GNSS), which encompassed both the United States Navstar and Russian GLObal NAvigation satellite system (GLONASS) constellations (141).

5.2.5 Familiarisation and pilot study

Familiarisation with wearing the harness containing the tracking devices and preparation procedures was achieved by providing opportunities for players to experience the technology and related protocols during scheduled field training sessions and in two practice games (O'Fiach Cup, December 2013). The players used the same garment size (i.e., small, medium, large or extra-large) for both training and games. In addition, a pilot study was designed to test and review match day procedures and timelines. This preliminary investigation was conducted during the pre-season McKenna Cup competition, which was held in January 2014, prior to the commencement of the NFL. In this pilot phase, the RT competed in four games against OTs prior to being eliminated at the semi-final stage of the competition. Two of the OTs also wore the tracking devices whilst playing against the RT, which facilitated real-time (during play) and post-game analysis. In total, 50 files were obtained from 36 outfield players across five positions; full back (n=12), half back (n=12), midfield (n=4), half forward (n=10) and full forward (n=12), as described previously (66). This enabled comparisons to be conducted between players and across match periods (Appendix F).

5.2.6 Match measures

Locomotor activities ($m{\cdot}s^{-1}$) were collated and classified as; standing (≥0.00 – <0.19), walking (≥0.19 – <2.00), jogging (≥2.00 – <4.00), running (≥4.00 – <5.50), high-speed running (≥5.50 – <7.00), and maximal speed running (≥7.00), resembling activity profiles and thresholds reported previously in Australian football (56,57), hurling (142) and soccer (52–55,79). Consequently, the values of ≥5.5 and ≥7.0 $m{\cdot}s^{-1}$ used to classify high- and maximal-speed running, respectively are higher than the equivalent ≥4·7 and ≥6.1 $m{\cdot}s^{-1}$ reported previously in Gaelic football (46–48,50). The starting speed for each activity zone represented the end point for the preceding zone, ensuring that all data was included in the analysis. A dwell time of 0.3 s (i.e., requiring 3 consecutive data points to enable entry into an activity zone), was used to detect and record entries into each velocity zone. This minimum effort duration ensured that random errors or spikes in speed were not included (140) as bouts of maximum-speed running (129). Other match measures included low-intensity activity (LIA, standing, walking and jogging, <4.0 $m{\cdot}s^{-1}$), high-intensity running (HIR, ≥4.0 $m{\cdot}s^{-1}$), very high-intensity running (VHIR, ≥5.5 $m{\cdot}s^{-1}$) and PlayerLoad™. This index of external load was calculated as the square root of the sum of the squared instantaneous rate of change in acceleration in the forward, vertical and sideward directions and divided by a scaling factor of 100 (143).

5.2.7 Data verification and processing

After each game data was downloaded using the proprietary Catapult Sprint (v5.1.7) software, exported into Microsoft Excel and transformed for evaluation. To assess the quality of the GPS signal, the number of satellites and the horizontal dilution of precision (HDOP) scores were examined (129,144). The mean (±SD) number of GPS satellites acquired during the first and second halves was 13.8 ± 1.4 and 13.8 ± 1.1, respectively. This information only referred to the GPS satellites (controlled by the USA) tracking the devices as the software did not enable reporting of the number of satellites also connected to the GLONASS (Russian) system. The actual number of satellites tracking the devices during games would have been considerably higher than the results reported above (potentially >20).

The corresponding mean (±SD) HDOP scores of 0.67 ± 0.15 and 0.68 ± 0.17 for the first and second halves, reflected the geometrical arrangement of the satellites and indicated the acceptable accuracy of the signal (97,129). The data from all starting and substitute players were collated for the full duration of their involvement in each game to enable team performance to be evaluated. A small number of physical data files (n=11, 0.03%) were unusable due to; a player taking the tracking device off following the warm-up or during play (n=3), the device stopped working (n=5), or the file was corrupted and unreadable (n=3). Data was estimated for one player who did not wear the device during the game by using the results from another player from the same positional line. Results for the remaining 10 players were estimated using their own relative data from useable match periods. Overall, ~1.53% of the GPS and ~0.78% of the accelerometer data was estimated.

5.2.8 Reliability

The intra-rater reliability assessment used in the tactical and technical evaluation in this study was outlined in Chapters 3 and 4. The reliability and validity of the player tracking technology used to quantify velocity, distance and PlayerLoad™ has been reported previously (145,146). In addition, internal observations utilising a protocol similar to that outlined previously (147) were used to validate the OptimEye S5 player tracking devices. The bias for estimating total distance in each trial (n=86) of a 135 m team sports specific circuit was trivial at 1.5 + 0.3% versus the criterion method (trundle wheel).

5.2.9 Statistical analysis

Data analyses were performed using SPSS software version 24 (IBM SPSS Inc, Chicago, IL, USA). Normality of distribution for all PIs was assessed using the Shapiro-Wilk test. Differences in team technical, tactical and physical PIs were evaluated throughout full games, halves and quarters, using an independent t-test to compare results from winning with losing. In addition, relative differences between the first and second halves and between quarter 1 and quarter 4 were analysed irrespective of match outcome and then in relation to winning and losing using a one-sample t-test or Wilcoxan signed-rank test. Descriptive statistics are presented as mean ± SD and a p value of ≤ 0.05 was considered statistically significant.

5.3 Results

5.3.1 Winning periods

Results from the univariate analyses of match characteristics, game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 5.1 to 5.7. Table 5.1 highlights the overall match characteristics and game statistics for full games, halves and quarters across all periods and in both winning and losing contexts. In Tables 5.2 to 5.7, PI results are outlined in the same format and each table is presented over two pages. Significant differences are illustrated in the tables and highlighted within the text.

5.3.1.1 Match characteristics: all periods

Table 5.1 summarises the match characteristics and statistics for the full games, halves and quarters. There were no significant differences in total playing time, ball in play time or stoppage time between periods won compared to periods lost. In winning full games, the RT obtained more yellow cards (p = 0.034) and fewer black cards (p = 0.024) compared to when losing.

5.3.1.2 Performance characteristics: all periods

5.3.1.3 Period summary - possession

There was no significant difference in possession characteristics between winning and losing in full games (Table 5.2). Percentage possession was higher in winning halves (p = 0.003) and quarters (p = 0.003). In winning quarters, there was an increase in both the overall time (p = 0.010) and average duration (p = 0.014) of team possessions, whereas team possessions originating in defence were lower (p = 0.022). There was also an increase in the frequency (p = 0.018) and overall time (p = 0.018) of player possessions, in addition to player possessions originating in both midfield (p = 0.024) and attack (p = 0.046).

5.3.1.4 Period summary - offence

In winning full games, there was a higher number of attacks originating in midfield (p = 0.050) as shown in Table 5.3. Across full games (FG), halves (H) and quarters (Q), winning was associated with a higher shot efficiency (FG: p = 0.022, H: p = 0.014, Q: p = 0.002) and productivity rating (FG: p = 0.019, H: p = 0.000, Q: p = 0.000) in addition to higher shots (FG: p = 0.021, H: p = 0.000, Q: p = 0.000), total scores (FG: p = 0.005, H: p = 0.000, Q: p = 0.000), total number of scores (FG: p = 0.001, H: p = 0.000, Q: p = 0.000), points (FG: p = 0.001, H: p = 0.000, Q: p = 0.000) and points from play (FG: p = 0.001, H: p = 0.001, Q: p = 0.001).

In winning both halves and quarters, there was also an increase in the number of attacks (H: p = 0.018, Q: p = 0.003), attack efficiency (H: p = 0.000, Q: p = 0.011), shots from play (H: p = 0.001, Q: p = 0.001), points from dead balls (H: p = 0.009, Q: p = 0.022) and goals (H: p = 0.021, Q: p = 0.001), and this was associated with an overall significant decrease in the average attack per score (H: p = 0.042, Q: p = 0.001). In winning quarters, attacks originating in defence (p = 0.048) were also significantly higher compared to losing.

5.3.1.5 Period summary - defence

The RT won more free kicks in attack (p = 0.036) in winning full games (Table 5.4). There were no significant differences in defensive characteristics during halves. In winning quarters, there was a higher number of turnovers won overall (p = 0.004) and turnovers originating in midfield (p = 0.007). Defensive efficiency was also higher (p = 0.008) in winning quarters.

5.3.1.6 Period summary - passing

There were no significant differences in passing characteristics in the RT during full games or halves (Table 5.5). In winning quarters, the RT performed more combined hand and kick passes (p = 0.048). Additionally, there was a higher number (p = 0.022) and percentage (p = 0.008) of total successful passes and conversely a lower number (p = 0.013) and percentage (p = 0.008) of total unsuccessful passes. There was an increase in the number (p = 0.027) and success rate (p = 0.022) of hand passes. The percentage kick pass success was higher (p = 0.006), whereas the number (p = 0.018) and percentage (p = 0.006) of unsuccessful kick passes was lower.

5.3.1.7 Period summary - dead ball distribution

There was no significant difference in dead ball distribution characteristics between winning and losing in full games (Table 5.6). There were fewer dead balls executed when winning both halves (p = 0.023) and quarters (p = 0.006). In winning halves, the number of successful dead ball kick passes was less (p = 0.034). In winning quarters the percentage of dead ball kick pass success (p = 0.047) was higher and both the number (p = 0.004) and percentage (p = 0.047) of unsuccessful dead ball kick passes was lower. In winning both halves and quarters, the total number of kick outs (H: p = 0.005, Q: p = 0.000) and success rate (H: p = 0.047, Q: p = 0.023) was lower. In winning quarters, the number of unsuccessful kick outs was lower (p = 0.001).

5.3.1.8 Physical characteristics

The RT performed less running (p = 0.022) and covered less total distance (p = 0.028) in winning compared to losing full games (Table 5.7). Less total distance was also covered when winning halves (p = 0.025) due primarily to a decrease in overall LIA (p = 0.021) and walking (p = 0.018). Walking distance was also lower in winning quarters (p = 0.044).

Table 5.1 Match characteristics and game statistics for the reference team across full games (n=20; win=8/lose=12), halves (n=38; win=19/lose=19) and quarters (n=68; win=34/lose=34)

	Period								
	Full Game			Half			Quarter		
Characteristic	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Playing time (min:s)	73:59 ± 1:39	73:51 ± 1:49	74:05 ± 1:37	37:01 ± 1:04	36:59 ± 1:02	37:03 ± 1:07	18:28 ± 0:31	18:31 ± 0:31	18:25 ± 0:32
Ball in play time (min:s)	37:05 ± 3:41	36:09 ± 3:09	37:42 ± 4:01	18:25 ± 2:02	18:11 ± 2:22	18:38 ± 1:41	9:12 ± 1:13	9:13 ± 1:18	9:10 ± 1:10
Stoppage time (min:s)	36:54 ± 4:31	37:42 ± 3:55	36:22 ± 4:58	18:27 ± 2:39	18:48 ± 2:50	18:25 ± 2:23	9:16 ± 1:29	9:17 ± 1:33	9:15 ± 1:26
Statistic									
Substitution (n)	5.3 ± 1.0	4.9 ± 1.5	5.6 ± 0.5	2.7 ± 2.3	2.4 ± 2.4	3.1 ± 2.2	1.4 ± 1.4	1.4 ± 1.6	1.4 ± 1.3
Yellow card (n)	1.4 ± 1.3	2.3 ± 1.5*	0.8 ± 0.8	0.7 ± 0.9	0.9 ± 1.0	0.5 ± 0.7	0.3 ± 0.6	0.4 ± 0.6	0.3 ± 0.6
Black card (n)	0.5 ± 0.7	0.1 ± 0.4*	0.8 ± 0.8	0.3 ± 0.5	0.1 ± 0.3	0.4 ± 0.6	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.4
Red card/BCNR (n)	0.3 ± 0.4	0.3 ± 0.5	0.3 ± 0.5	0.1 ± 0.3	0.1 ± 0.3	0.2 ± 0.4	0.0 ± 0.2	0.1 ± 0.2	0.0 ± 0.2

Values are mean ± SD; $p \leq 0.05$ vs. losing using an independent t-test (*); Draws excluded from win/loss comparison during halves (n=2) and quarters (n=12); BCNR = Black card not replaced.

Table 5.2 Possession for the reference team and players across periods

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	Win	Lose	All	Win	Lose	All	Win	Lose
Team possession									
Total number (n)	74.3 ± 7.6	77.5 ± 6.1	72.1 ± 8.0	37.3 ± 4.6	37.1 ± 4.9	37.6 ± 4.3	18.6 ± 2.9	18.4 ± 3.4	18.7 ± 2.5
Proportion (%)	52.8 ± 3.4	54.6 ± 3.5	51.6 ± 3.0	52.8 ± 8.1	56.6 ± 6.2*	49.1 ± 8.1	52.0 ± 8.6	55.1 ± 8.0*	49.0 ± 8.1
Total time (s)	1005.8 ± 125.7	1004.8 ± 120.4	1006.5 ± 134.4	499.4 ± 103.5	530.4 ± 110.8	468.5 ± 88.0	246.3 ± 55.7	263.5 ± 58.9*	229.1 ± 47.1
Time/possession (s)	13.7 ± 2.5	13.1 ± 2.1	14.2 ± 2.7	13.7 ± 3.9	14.8 ± 4.7	12.5 ± 2.5	13.7 ± 4.1	14.9 ± 4.9*	12.4 ± 2.8
Origin defence (n)	43.9 ± 6.7	43.9 ± 5.5	43.9 ± 7.6	21.8 ± 4.3	20.9 ± 3.7	22.8 ± 4.7	11.1 ± 2.7	10.4 ± 2.5*	11.9 ± 2.7
Origin midfield (n)	22.6 ± 5.5	24.8 ± 4.3	21.1 ± 6.0	11.6 ± 3.6	11.8 ± 4.2	11.3 ± 3.1	5.5 ± 2.4	5.9 ± 2.6	5.1 ± 2.0
Origin attack (n)	7.8 ± 2.4	8.9 ± 2.1	7.1 ± 2.5	3.9 ± 1.8	4.4 ± 1.6	3.5 ± 1.8	1.9 ± 1.3	2.1 ± 1.3	1.7 ± 1.2

Table 5.2 Possession for periods continued

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	Win	Lose	All	Win	Lose	All	Win	Lose
Player possession									
Total number (n)	315.7 ± 35.3	311.4 ± 42.1	318.5 ± 31.6	157.1 ± 27.9	162.4 ± 28.7	151.7 ± 26.8	78.0 ± 15.2	82.3 ± 15.9*	73.7 ± 13.3
Total time in possession (s)	658.7 ± 109.4	655.0 ± 95.3	661.2 ± 22.0	326.6 ± 79.9	347.6 ± 91.3	305.6 ± 62.2	159.5 ± 40.9	171.1 ± 45.3*	147.9 ± 32.6
Time/possession (s)	2.1 ± 0.2	2.1 ± 0.3	2.1 ± 0.2	2.1 ± 0.3	2.1 ± 0.4	2.0 ± 0.2	2.0 ± 0.3	2.1 ± 0.4	2.0 ± 0.2
Origin defence (n)	92.4 ± 0.8	92.9 ± 3.8	92.0 ± 25.1	46.2 ± 12.6	44.9 ± 7.8	47.5 ± 16.2	22.9 ± 7.5	22.4 ± 6.1	23.4 ± 8.7
Origin midfield (n)	155.5 ± 2.2	146.1 ± 29.5	161.8 ± 3.6	78.0 ± 22.6	81.4 ± 2.9	74.5 ± 2.4	38.1 ± 11.2	41.1 ± 2.8*	35.0 ± 8.4
Origin attack (n)	67.8 ± 18.9	72.4 ± 11.8	64.8 ± 22.5	32.9 ± 10.9	36.1 ± 9.9	29.7 ± 11.2	17.0 ± 7.1	18.7 ± 6.7*	15.3 ± 7.1

Values are mean ± SD; $p \le 0.05$ vs. losing using an independent t-test (*).

Table 5.3 Offensive play for the reference team across periods

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Attack									
Total number (n)	37.2 ± 5.0	39.6 ± 4.1	35.6 ± 5.0	18.5 ± 3.2	19.7 ± 2.8*	17.3 ± 3.2	9.3 ± 2.1	10.1 ± 2.1*	8.6 ± 1.8
Origin defence (n)	19.5 ± 5.1	19.5 ± 3.3	19.4 ± 6.2	9.4 ± 2.9	10.1 ± 2.5	8.7 ± 3.2	5.0 ± 2.0	5.5 ± 1.8*	4.6 ± 2.1
Origin midfield (n)	16.5 ± 3.8	18.5 ± 2.6*	15.2 ± 3.9	8.4 ± 2.9	8.8 ± 3.1	8.1 ± 2.7	4.0 ± 1.8	4.3 ± 2.0	3.7 ± 1.6
Origin attack (n)	1.3 ± 1.0	1.6 ± 1.1	1.0 ± 0.9	0.6 ± 0.8	0.8 ± 0.9	0.4 ± 0.5	0.3 ± 0.5	0.3 ± 0.6	0.3 ± 0.5
Efficiency (%)	72.5 ± 10.3	76.6 ± 12.4	69.9 ± 8.1	72.1 ± 12.9	77.3 ± 11.7*	66.9 ± 12.0	72.8 ± 18.2	78.3 ± 19.4*	67.3 ± 15.2
Shot									
Total number (n)	27.0 ± 5.3	30.3 ± 5.1*	24.8 ± 4.5	13.3 ± 3.3	15.2 ± 2.8*	11.5 ± 2.7	6.7 ± 2.1	7.7 ± 2.0*	5.7 ± 1.7
From play (n)	20.1 ± 5.3	22.8 ± 5.4	18.3 ± 4.7	9.8 ± 3.0	11.3 ± 2.5*	8.3 ± 2.7	5.0 ± 2.2	5.9 ± 2.2*	4.1 ± 1.8
From play (%)	73.9 ± 7.8	74.5 ± 8.2	73.5 ± 7.9	73.1 ± 10.1	74.6 ± 7.8	71.6 ± 12.0	73.2 ± 16.2	75.4 ± 14.2	70.9 ± 17.9
From dead ball (n)	6.9 ± 2.0	7.5 ± 1.9	6.5 ± 2.1	3.5 ± 1.4	3.8 ± 1.4	3.2 ± 1.3	1.7 ± 1.0	1.8 ± 1.1	1.6 ± 1.0
From dead ball (%)	26.1 ± 7.8	25.5 ± 8.2	26.5 ± 7.9	26.9 ± 10.1	25.4 ± 7.8	28.4 ± 12.0	26.8 ± 16.2	24.6 ± 14.2	29.1 ± 17.9
Efficiency (%)	49.5 ± 11.6	55.9 ± 5.5*	45.2 ± 12.9	49.9 ± 15.2	55.9 ± 1.9*	43.9 ± 16.1	51.3 ± 20.3	58.8 ± 8.4*	43.8 ± 19.5

Table 5.3 Offensive play for periods continued

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Score									
Total combined	15.3 ± 5.8	19.5 ± 4.1*	12.5 ± 5.2	7.6 ± 3.5	9.8 ± 3.0*	5.4 ± 2.3	4.0 ± 2.4	5.4 ± 2.4*	2.6 ± 1.2
Total number (n)	13.4 ± 4.1	16.8 ± 2.2*	11.2 ± 3.6	6.7 ± 2.6	8.4 ± 2.0*	4.9 ± 1.9	3.4 ± 1.6	4.4 ± 1.5*	2.4 ± 1.2
Average attack/ score (n)	3.1 ± 1.5	2.4 ± 0.4	3.6 ± 1.8	3.7 ± 3.5	2.5 ± 1.0*	4.9 ± 4.6	3.2 ± 1.7	2.5 ± 1.0*	3.9 ± 2.0
Productivity	2.1 ± 0.8	2.5 ± 0.5*	1.8 ± 0.7	2.0 ± 0.9	2.7 ± 0.8*	1.4 ± 0.6	2.2 ± 1.3	3.0 ± 1.4*	1.4 ± 0.6
Point (n)	12.5 ± 3.5	15.4 ± 1.5*	10.5 ± 3.0	6.2 ± 2.3	7.7 ± 1.7*	4.7 ± 1.9	3.1 ± 1.5	3.9 ± 1.3*	2.4 ± 1.2
Point from play (n)	7.9 ± 2.8	10.1 ± 2.0*	6.3 ± 2.1	3.9 ± 1.9	4.9 ± 1.7*	2.9 ± 1.6	2.0 ± 1.3	2.6 ± 1.3*	1.5 ± 1.1
Point from dead ball (n)	4.6 ± 2.1	5.3 ± 1.3	4.2 ± 2.5	2.3 ± 1.3	2.8 ± 0.9*	1.8 ± 1.4	1.1 ± 0.9	1.4 ± 0.8*	0.9 ± 0.8
Goal (n)	1.0 ± 1.1	1.4 ± 1.1	0.7 ± 1.0	0.4 ± 0.6	0.7 ± 0.7*	0.2 ± 0.5	0.3 ± 0.6	0.5 ± 0.7*	0.1 ± 0.2

Values are mean ± SD; $p \leq 0.05$ vs. losing using an independent t-test (*).

Table 5.4 Defensive play for the reference team across periods

	Period								
	Full Game			Half			Quarter		
Performance indicator	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Turnovers									
Total number (n)	29.1 ± 6.7	32.1 ± 7.3	27.0 ± 5.6	14.5 ± 4.2	15.7 ± 4.4	13.2 ± 3.6	7.1 ± 2.7	8.1 ± 2.9*	6.2 ± 2.1
Origin defence (n)	17.7 ± 4.4	19.0 ± 3.3	16.8 ± 4.9	8.7 ± 3.0	9.1 ± 3.1	8.4 ± 3.1	4.4 ± 2.0	4.8 ± 2.1	4.0 ± 1.9
Origin midfield (n)	10.2 ± 4.5	11.6 ± 4.8	9.3 ± 4.3	5.1 ± 3.0	5.9 ± 3.2	4.3 ± 2.6	2.4 ± 1.6	2.9 ± 1.6*	1.9 ± 1.5
Origin attack (n)	1.2 ± 1.1	1.5 ± 1.2	1.0 ± 1.0	0.6 ± 0.8	0.7 ± 1.0	0.5 ± 0.6	0.3 ± 0.6	0.3 ± 0.6	0.3 ± 0.5
Tackles									
Total number (n)	80.6 ± 16.8	74.0 ± 17.2	84.9 ± 15.7	39.7 ± 10.6	38.5 ± 10.4	40.9 ± 10.9	20.4 ± 6.5	20.1 ± 6.6	20.8 ± 6.5
Successful (n)	9.0 ± 3.5	8.4 ± 3.6	9.4 ± 3.5	4.5 ± 2.4	4.3 ± 2.5	4.7 ± 2.3	2.2 ± 1.5	2.3 ± 1.7	2.2 ± 1.4
Successful (%)	11.1 ± 3.6	10.9 ± 3.5	11.2 ± 3.8	11.1 ± 4.8	10.7 ± 4.8	11.5 ± 5.0	10.7 ± 6.6	10.9 ± 7.0	10.5 ± 6.2
Unsuccessful (n)	71.6 ± 15.1	65.6 ± 14.4	75.5 ± 14.9	35.2 ± 9.4	34.2 ± 8.8	36.2 ± 10.1	18.2 ± 5.8	17.8 ± 5.9	18.6 ± 5.9
Unsuccessful (%)	89.0 ± 3.6	89.1 ± 3.5	88.8 ± 3.8	88.9 ± 4.8	89.3 ± 4.8	88.5 ± 5.0	89.3 ± 6.6	89.1 ± 7.0	89.5 ± 6.2
Origin defence (n)	38.7 ± 10.1	36.1 ± 10.2	40.3 ± 10.1	19.0 ± 7.0	18.9 ± 7.4	19.2 ± 6.7	9.9 ± 4.6	9.4 ± 4.8	10.5 ± 4.3
Origin midfield (n)	32.2 ± 9.8	29.3 ± 6.7	34.2 ± 11.3	15.9 ± 6.2	14.5 ± 4.8	17.2 ± 7.2	8.1 ± 3.9	8.0 ± 3.4	8.2 ± 4.4
Origin attack (n)	9.7 ± 4.5	8.6 ± 5.2	10.4 ± 4.0	4.8 ± 3.2	5.1 ± 4.1	4.5 ± 2.1	2.4 ± 2.2	2.7 ± 2.5	2.1 ± 1.7

Table 5.4 Defensive play for periods continued

	Period								
	Full Game			Half			Quarter		
Performance indicator	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Free kick won									
Total number (n)	21.7 ± 7.1	23.8 ± 4.2	20.3 ± 8.4	11.2 ± 3.7	10.8 ± 3.1	11.6 ± 4.3	5.3 ± 2.5	5.3 ± 2.4	5.2 ± 2.6
Origin defence (n)	4.9 ± 2.4	5.1 ± 1.5	4.8 ± 3.0	2.6 ± 1.5	2.4 ± 1.1	2.7 ± 1.9	1.1 ± 1.1	1.1 ± 1.0	1.2 ± 1.2
Origin midfield (n)	11.6 ± 4.8	12.1 ± 3.6	11.2 ± 5.6	6.0 ± 2.8	5.5 ± 2.5	6.5 ± 3.1	2.8 ± 1.8	2.8 ± 1.7	2.9 ± 2.0
Origin attack (n)	5.3 ± 2.2	6.5 ± 1.5*	4.4 ± 2.3	2.7 ± 1.4	3.0 ± 1.1	2.4 ± 1.6	1.3 ± 1.0	1.4 ± 1.0	1.1 ± 0.9
Defensive actions									
Total number (n)	126.8 ± 22.5	122.8 ± 7.2	129.5 ± 9.6	63.0 ± 13.1	62.9 ± 13.7	63.2 ± 12.8	31.7 ± 7.8	32.1 ± 8.3	31.3 ± 7.5
Origin defence (n)	62.2 ± 12.7	62.0 ± 13.4	62.3 ± 12.9	30.9 ± 8.3	31.1 ± 9.4	30.8 ± 7.4	15.8 ± 5.6	15.6 ± 5.9	16.1 ± 5.4
Origin midfield (n)	50.0 ± 15	47.9 ± 14.1	51.3 ± 16.0	24.8 ± 8.8	24.3 ± 8.2	25.3 ± 9.5	12.3 ± 5.2	12.9 ± 4.7	11.7 ± 5.6
Origin attack (n)	14.7 ± 5.8	12.9 ± 6.5	15.9 ± 5.2	7.3 ± 4.3	7.5 ± 5.1	7.1 ± 3.4	3.6 ± 2.7	3.6 ± 3.0	3.5 ± 2.5
Defensive efficiency (%)	32.0 ± 7.6	33.3 ± 7.5	31.1 ± 7.9	31.3 ± 12.4	33.2 ± 14.2	29.4 ± 10.3	33.3 ± 17.5	38.9 ± 9.2*	27.8 ± 13.8

Values are mean ± SD; $p \leq 0.05$ vs. losing using an independent t-test (*).

Table 5.5 Passing for the reference team across periods

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Combined hand and kick pass									
Total number (n)	264.5 ± 5.5	256.4 ± 42.0	269.8 ± 31.1	131.5 ± 27.6	136.1 ± 29.4	126.9 ± 25.6	65.5 ± 14.5	68.9 ± 15.8*	62.0 ± 12.2
Successful (n)	242.2 ± 37.4	233.5 ± 44.1	247.9 ± 33.0	120.2 ± 28.7	125.3 ± 30.5	115.1 ± 26.6	59.8 ± 15.2	63.9 ± 16.4*	55.6 ± 12.9
Successful (%)	91.4 ± 3.2	90.8 ± 3.5	91.7 ± 3.0	90.9 ± 4.1	91.5 ± 4.2	90.3 ± 4.0	90.6 ± 5.1	92.2 ± 4.5*	89.0 ± 5.3
Unsuccessful (n)	22.3 ± 6.8	22.9 ± 7.2	21.9 ± 6.8	11.3 ± 4.1	10.8 ± 4.0	11.8 ± 4.1	5.7 ± 2.5	5.0 ± 2.3*	6.5 ± 2.4
Unsuccessful (%)	8.7 ± 3.2	9.2 ± 3.5	8.3 ± 3.0	9.1 ± 4.1	8.5 ± 4.2	9.7 ± 4.0	9.4 ± 5.1	7.8 ± 4.5*	11.0 ± 5.3
Hand pass									
Total number (n)	185.3 ± 38.8	175.0 ± 44.3	192.1 ± 34.9	91.5 ± 26.5	95.6 ± 28.3	87.5 ± 24.6	45.6 ± 14	49.4 ± 15.5*	41.9 ± 11.4
Successful (n)	181.1 ± 37.9	171.3 ± 42.6	187.6 ± 34.7	89.4 ± 26.1	93.8 ± 27.8	85.1 ± 24.4	44.6 ± 13.8	48.4 ± 15.2*	40.8 ± 11.3
Successful (%)	97.7 ± 1.0	97.9 ± 1.1	97.6 ± 1.0	97.7 ± 1.6	98.1 ± 1.4	97.2 ± 1.6	97.5 ± 2.5	98.0 ± 2.3	97.1 ± 2.7
Unsuccessful (n)	4.2 ± 2.0	3.8 ± 2.4	4.5 ± 1.8	2.1 ± 1.3	1.8 ± 1.4	2.4 ± 1.3	1.1 ± 1.0	1.0 ± 1.0	1.1 ± 1.0
Unsuccessful (%)	2.3 ± 1.0	2.1 ± 1.1	2.4 ± 1.0	2.3 ± 1.6	1.9 ± 1.4	2.8 ± 1.6	2.5 ± 2.5	2.0 ± 2.3	2.9 ± 2.7

Table 5.5 Passing for periods continued

Performance indicator	**Period**								
	Full Game			**Half**			**Quarter**		
	All	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Kick pass									
Total number (n)	79.2 ± 11.0	81.4 ± 10.6	77.8 ± 11.5	40.0 ± 6.8	40.5 ± 6.5	39.4 ± 7.3	19.9 ± 4.3	19.6 ± 4.3	20.1 ± 4.4
Successful (n)	61.1 ± 7.9	62.3 ± 7.0	60.3 ± 8.7	30.7 ± 6.1	31.5 ± 5.5	30.0 ± 6.7	15.2 ± 3.9	15.6 ± 3.5	14.8 ± 4.4
Successful (%)	77.5 ± 6.0	76.9 ± 6.6	77.9 ± 5.8	77.0 ± 7.9	77.9 ± 7.9	76.0 ± 8.0	76.5 ± 10.4	80.0 ± 9.0*	73.1 ± 10.7
Unsuccessful (n)	18.1 ± 6.5	19.1 ± 6.9	17.4 ± 6.4	9.2 ± 3.7	9.1 ± 3.7	9.4 ± 3.7	4.7 ± 2.3	4.0 ± 2.2*	5.3 ± 2.3
Unsuccessful (%)	22.5 ± 6.0	23.1 ± 6.6	22.2 ± 5.8	23.0 ± 7.9	22.1 ± 7.9	24.0 ± 8.0	23.5 ± 10.4	20.0 ± 9.0*	26.9 ± 10.7

Values are mean ± SD; $p \leq 0.05$ vs. losing using an independent t-test (*).

Table 5.6 Dead ball distribution for the reference team across periods

	Period								
	Full Game			Half			Quarter		
Performance indicator	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Dead ball									
Total number (n)	48.8 ± 6.5	49.1 ± 4.1	48.5 ± 7.8	24.7 ± 3.8	23.3 ± 3.3*	26.1 ± 3.7	12.2 ± 2.5	11.4 ± 2.5*	13.1 ± 2.2
^Dead ball kick pass									
Successful (n)	31.6 ± 6.0	31.5 ± 5.0	31.7 ± 6.8	16.0 ± 3.9	14.6 ± 2.6*	17.3 ± 4.6	7.9 ± 2.6	7.5 ± 2.3	8.2 ± 2.8
Successful (%)	75.5 ± 7.8	75.8 ± 9.0	75.3 ± 7.3	75.5 ± 10.8	75.8 ± 10.1	75.3 ± 11.7	74.9 ± 15.7	78.6 ± 14.7*	71.1 ± 16.1
Unsuccessful (n)	10.3 ± 3.7	10.1 ± 4.2	10.3 ± 3.6	5.2 ± 2.5	4.8 ± 2.2	5.6 ± 2.7	2.7 ± 1.7	2.1 ± 1.4*	3.2 ± 1.7
Unsuccessful (%)	24.5 ± 7.8	24.2 ± 9.0	24.7 ± 7.3	24.5 ± 10.8	24.2 ± 10.1	24.7 ± 11.7	25.1 ± 15.7	21.4 ± 14.7*	28.9 ± 16.1
Dead ball FK pass									
Total number (n)	16.2 ± 6.0	17.3 ± 3.8	15.5 ± 7.1	8.4 ± 3.3	7.7 ± 2.6	9.2 ± 3.8	3.9 ± 2.3	3.9 ± 2.1	4.0 ± 2.5
Successful (n)	15.1 ± 5.0	16.1 ± 3.1	14.4 ± 6.0	7.8 ± 3.0	7.1 ± 2.3	8.6 ± 3.5	3.7 ± 2.2	3.6 ± 2.0	3.8 ± 2.4
Successful (%)	94.5 ± 5.2	94.1 ± 4.2	94.7 ± 5.9	94.0 ± 8.5	93.2 ± 8.6	94.8 ± 8.7	93.9 ± 12.3	92.1 ± 14.2	95.7 ± 10
Unsuccessful (n)	1.1 ± 1.2	1.1 ± 0.8	1.1 ± 1.4	0.6 ± 0.8	0.6 ± 0.7	0.6 ± 1.0	0.3 ± 0.5	0.3 ± 0.5	0.2 ± 0.6
Unsuccessful (%)	5.5 ± 5.2	5.9 ± 4.2	5.3 ± 5.9	6.0 ± 8.5	6.8 ± 8.6	5.2 ± 8.7	6.1 ± 12.3	7.9 ± 14.2	4.3 ± 10

Table 5.6 Dead ball distribution for periods continued

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	Win	Lose	All	Win	Lose	All	Win	Lose
Dead ball kick out									
Total number (n)	23.2 ± 4.3	21.8 ± 3.0	24.2 ± 4.9	11.6 ± 2.7	10.4 ± 1.8*	12.7 ± 2.9	6.0 ± 2.0	4.9 ± 1.6*	7.1 ± 1.8
Successful (n)	14.5 ± 4.1	13.4 ± 4.1	15.2 ± 4.2	7.1 ± 2.4	6.4 ± 2.0*	7.9 ± 2.5	3.7 ± 1.6	3.3 ± 1.5*	4.2 ± 1.6
Successful (%)	62.3 ± 13.4	61.6 ± 15.8	62.7 ± 12.3	62.4 ± 17.5	62.3 ± 17.9	62.5 ± 17.6	64.7 ± 21.4	68.5 ± 21.1	61.0 ± 21.4
Unsuccessful (n)	8.8 ± 3.5	8.4 ± 3.8	9.0 ± 3.4	4.4 ± 2.3	4.0 ± 2.1	4.8 ± 2.5	2.3 ± 1.6	1.6 ± 1.3*	2.9 ± 1.7
Unsuccessful (%)	37.7 ± 13.4	38.4 ± 15.8	37.3 ± 12.3	37.6 ± 17.5	37.7 ± 17.9	37.5 ± 17.6	35.3 ± 21.4	31.5 ± 21.1	39.0 ± 21.4

Values are mean ± SD; $p \leq 0.05$ vs. losing using an independent t-test (*); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs; FK = Free kick.

Table 5.7 Physical characteristics for the reference team across periods

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Stand (m)	604 ± 157	643 ± 224	577 ± 92	306 ± 89	310 ± 112	303 ± 61	152 ± 52	156 ± 65	148 ± 35
Walk (m)	39036 ± 5517	36850 ± 5866	40493 ± 4989	19466 ± 2776	18419 ± 2842*	20512 ± 2336	9691 ± 1333	9367 ± 1409*	10015 ± 1184
Jog (m)	38592 ± 2168	37728 ± 2028	39168 ± 2144	19225 ± 1341	19087 ± 1138	19362 ± 1536	9575 ± 846	9617 ± 802	9534 ± 899
Run (m)	20919 ± 1575	19964 ± 1278*	21556 ± 1464	10420 ± 930	10170 ± 807	10670 ± 998	5261 ± 589	5264 ± 582	5259 ± 606
High-speed run (m)	9469 ± 1268	9061 ± 924	9742 ± 1425	4689 ± 691	4583 ± 466	4795 ± 861	2393 ± 412	2335 ± 327	2452 ± 480
Maximum-speed run (m)	2224 ± 575	2322 ± 491	2158 ± 637	1107 ± 308	1147 ± 288	1067 ± 329	562 ± 172	561 ± 160	563 ± 186

Table 5.7 Physical characteristics for periods continued

Performance indicator	Period								
	Full Game			Half			Quarter		
	All	**Win**	**Lose**	**All**	**Win**	**Lose**	**All**	**Win**	**Lose**
Total distance (m)	111194 ± 7910	106572 ± 6820*	114276 ± 7251	55397 ± 4174	53898 ± 4110*	56896 ± 3766	27714 ± 2250	27356 ± 2058	28072 ± 2404
Low-intensity activity (m)	78231 ± 6132	75221 ± 5952	80238 ± 5605	38996 ± 3197	37817 ± 3071*	40176 ± 2939	19418 ± 1551	19140 ± 1461	19697 ± 1609
High-intensity running (m)	32612 ± 2939	31346 ± 2011	33456 ± 3226	16216 ± 1639	15900 ± 1243	16532 ± 1940	8217 ± 987	8160 ± 913	8273 ± 1067
Very high-intensity running (m)	11693 ± 1684	11383 ± 1118	11900 ± 1997	5796 ± 890	5730 ± 642	5861 ± 1098	2955 ± 521	2896 ± 423	3015 ± 604
PlayerLoad™ (AU)	10545 ± 547	10310 ± 408	10701 ± 587	5251 ± 304	5202 ± 310	5300 ± 297	2631 ± 187	2629 ± 180	2633 ± 197

Values are mean ± SD; $p \leq 0.05$ vs. losing using an independent t-test (*).

5.3.2 Temporal changes across halves

Results from the univariate analyses of match characteristics, game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 5.8 to 5.14. Table 5.8 highlights the mean results and relative differences between the first and second halves in the overall match characteristics and game statistics for all games and in both winning and losing contexts. In Tables 5.9 to 5.14, PI results are outlined in the same format and each table is presented over two pages. Significant differences are illustrated in the tables and highlighted within the text.

5.3.2.1 Match characteristics: temporal changes across halves

Table 5.8 shows the match characteristics and game statistics across halves and by game outcome. Across all games, there was a decrease in ball in play time (p = 0.023) and a significant increase in stoppage time (p = 0.032) between the first and second halves. In games that were lost, there was an increase in playing time (p = 0.028) in the second half, a decrease in ball in play time (p = 0.004) and an increase in stoppage time (p = 0.002). There was an increase in substitutions in the second half across all games (p = 0.000), and in both games won (p = 0.000) and lost (p = 0.002). There was no difference in cards received between halves.

5.3.2.2 Performance characteristics: temporal changes across halves

5.3.2.3 Half summary – possession

There was a decrease in the frequency of team possessions originating in defence (p = 0.041) in the second half in games that were lost (Table 5.9). There was an increase in the frequency of team possessions originating in midfield in games lost (p = 0.014) and a decrease in games won (p = 0.028). There was also a decrease in the frequency of player possessions originating in midfield in the second half across all games (p = 0.030) and also in games that were lost (p = 0.033).

5.3.2.4 Half summary – offence

Across all games, there were no differences in offensive characteristics between the first and second halves (Table 5.10). In games won, attacks originating in defence (p = 0.016) increased in the second half, whereas attacks originating in midfield (p = 0.007) decreased. Conversely, attacks originating in midfield (p = 0.039) increased in the second half of games lost and there was an increase in attacking efficiency (p = 0.018) and shots from play (p = 0.036) in this period. There were no differences in scoring PIs between halves in any context.

5.3.2.5 Half summary – defence

Table 5.11 shows the decrease in turnovers originating in defence in the second half in games that were lost (p = 0.015). There was also a decrease in the frequency of successful tackles (p = 0.014) across all games. This coincided with a reduction in the percentage of successful tackles (p = 0.009) and an increase in the percentage of unsuccessful tackles (p = 0.009) in the second half. The same trend for the percentage of successful (p = 0.020) and unsuccessful tackles (p = 0.020) was reported in games won. There was also a decrease in the number of free kicks won (p = 0.049) and free kicks originating in midfield (p = 0.012) in the second halves of games won. There were no differences in defensive actions or defensive efficiency between halves in any match context.

5.3.2.6 Half summary – passing

Table 5.12 shows the decrease in the total number of combined hand and kick passes in the second half across all games (p = 0.048) and also in games lost (p = 0.038). There was also a decrease in frequency of hand passes in games lost (p = 0.040), whereas there was no difference in any passing characteristics in games won. There were no differences in kick pass characteristics between halves in any match context.

5.3.2.7 Half summary – dead ball distribution

There were no significant differences in any dead ball characteristics across halves (Table 5.12).

5.3.2.8 Half summary – physical characteristics

There were no significant differences between the first and second half in locomotor activities, collated match distances or PlayerLoad™ across all games or in relation to winning (Table 5.14). In games lost, there was an increase in the distance covered at rest/standing (p = 0.029) in the first compared to the second half and there was a decrease in high-speed running (p = 0.037) in the second half.

Table 5.8 Match characteristics and game statistics for the reference team across halves in all games (n=20) and by match outcome (win: n=8; lose: n=12)

	Group								
	All			Win			Lose		
Characteristic	**First half**	**Second half**	**Difference FH - SH**	**First half**	**Second half**	**Difference FH – SH**	**First half**	**Second half**	**Difference FH - SH**
Playing time (min:s)	36:49 ± 0:57	37:10 ± 1:09	-0:21 ± 1:19	37:06 ± 1:06	36:44 ± 1:09	0:22 ± 1:20	36:38 ± 0:50[a]	37:27 ± 1:06	-0.49 ± 1:07
Ball in play time (min:s)	19:02 ± 2:12[a]	18:03 ± 1:53	0:59 ± 1:47	18:11 ± 1:53	17:57 ± 1:53	0:14 ± 2:05	19:35 ± 2:17[a]	18:06 ± 1:58	-1:29 ± 1:26
Stoppage time (min:s)	17:47 ± 2:39[a]	19:07 ± 2:32	-1:19 ± 2:34	18:55 ± 2:20	18:47 ± 2:25	0:08 ± 2:42	17:02 ± 2:40[a]	19:20 ± 2:41	-2:18 ± 2:01
Statistic									
Substitution (n)	0.7 ± 0.9[b]	4.7 ± 1.3	-4.0 ± 1.9	0.3 ± 0.7[a]	4.6 ± 1.4	-4.4 ± 1.7	0.9 ± 0.9[b]	4.7 ± 1.2	-3.8 ± 2.1
Yellow card (n)	0.5 ± 0.7	0.9 ± 1.0	-0.4 ± 1.0	0.8 ± 0.7	1.5 ± 1.2	-0.8 ± 1.3	0.3 ± 0.7	0.5 ± 0.5	-0.2 ± 0.8
Black card (n)	0.1 ± 0.3	0.4 ± 0.6	-0.3 ± 0.7	0.0 ± 0.0	0.1 ± 0.4	-0.1 ± 0.4	0.2 ± 0.4	0.6 ± 0.7	-0.4 ± 0.8
Red card/BCNR (n)	0.1 ± 0.2	0.2 ± 0.4	-0.2 ± 0.5	0.1 ± 0.4	0.1 ± 0.4	0.0 ± 0.5	0.0 ± 0.0	0.3 ± 0.5	-0.3 ± 0.5

Values are mean ± SD; $p \leq 0.05$ vs. second half using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]); BCNR = Black card not replaced.

Table 5.9 Possession for the reference team and players across halves

Performance indicator	Group								
	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH - SH
Team possession									
Total number (n)	38.2 ± 4.6	36.1 ± 4.4	2.2 ± 4.8	40.6 ± 3.2	36.9 ± 4.5	3.8 ± 4.9	36.6 ± 4.8	35.5 ± 4.3	1.1 ± 4.6
Proportion (%)	54.3 ± 8.0	51.2 ± 7.7	3.1 ± 14.2	54.8 ± 6.4	54.3 ± 7.7	0.6 ± 12.5	53.9 ± 9.1	49.1 ± 7.4	4.8 ± 15.5
Total time (s)	529.7 ± 104.9	476.1 ± 94.0	53.6 ± 154.6	502.2 ± 60.9	502.6 ± 116.2	-0.5 ± 141.1	548.1 ± 125.4	458.4 ± 76.3	89.7 ± 158.3
Time/possession (s)	14.3 ± 4.3	13.4 ± 3.5	0.8 ± 5.8	12.4 ± 1.3	14.1 ± 4.7	-1.7 ± 5.2	15.5 ± 5.1	13.0 ± 2.5	2.5 ± 5.7
Origin defence (n)	22.7 ± 4.2	21.3 ± 4.3	1.4 ± 5.2	21.1 ± 3.5	22.8 ± 3.3	-1.6 ± 3.9	23.7 ± 4.4[a]	20.3 ± 4.7	3.4 ± 5.1
Origin midfield (n)	11.2 ± 4.0	11.4 ± 3.6	-0.3 ± 5.2	14.4 ± 2.3[a]	10.4 ± 3.5	4.0 ± 4.1	9.0 ± 3.4[a]	12.1 ± 3.6	-3.1 ± 3.7
Origin attack (n)	4.4 ± 1.8	3.4 ± 1.6	1.0 ± 2.4	5.1 ± 2.0	3.8 ± 1.2	1.4 ± 2.6	3.9 ± 1.4	3.2 ± 1.9	0.8 ± 2.3

Table 5.9 Possession for halves continued

Performance indicator	All: First half	All: Second half	All: FH – SH	Win: First half	Win: Second half	Win: FH – SH	Lose: First half	Lose: Second half	Lose: FH - SH
Player possession									
Total number (n)	166.7 ± 25.2	149.0 ± 27.2	17.8 ± 38.9	160.4 ± 17.5	151.0 ± 36.0	9.4 ± 37.9	170.9 ± 29.2	147.6 ± 21.2	23.3 ± 40.1
Total time in possession (s)	347.8 ± 89.6	308.8 ± 61.2	39.0 ± 108.7	329.9 ± 53.8	325.1 ± 69.8	4.8 ± 80.3	359.8 ± 107.9	297.9 ± 55.3	61.9 ± 121.9
Time/possession (s)	2.1 ± 0.3	2.1 ± 0.3	0.0 ± 0.4	2.1 ± 0.2	2.2 ± 0.4	-0.1 ± 0.3	2.1 ± 0.4	2.0 ± 0.2	0.0 ± 0.4
Origin defence (n)	47.3 ± 11.1	45.1 ± 13.7	2.2 ± 13.8	45.0 ± 11.6	47.9 ± 5.1	-2.9 ± 11.5	48.8 ± 11.1	43.3 ± 17.3	5.5 ± 14.7
Origin midfield (n)	85.0 ± 24.9[a]	70.6 ± 16.5	14.4 ± 27.4	75.4 ± 10.4	70.8 ± 23.6	4.6 ± 21.5	91.3 ± 29.9[a]	70.4 ± 10.7	20.9 ± 29.8
Origin attack (n)	34.5 ± 11.4	33.3 ± 13.4	1.2 ± 16.1	40.0 ± 10.5	32.4 ± 10.1	7.6 ± 16.9	30.8 ± 10.9	33.9 ± 15.6	-3.1 ± 14.8

Values are mean ± SD; $p \leq 0.05$ vs. second half using a one-sample t-test ([a]).

Table 5.10 Offensive play for the reference team across halves

Performance indicator	Group								
	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH - SH
Attack									
Total number (n)	19.2 ± 3.6	18.1 ± 2.7	1.1 ± 4.0	21.3 ± 3.3	18.4 ± 1.9	2.9 ± 3.4	17.8 ± 3.3	17.8 ± 3.1	-0.1 ± 4.0
Origin defence (n)	10.1 ± 3.4	9.4 ± 3.0	0.7 ± 3.7	8.9 ± 1.7[b]	10.6 ± 1.9	-1.8 ± 1.5	10.8 ± 4.0	8.6 ± 3.3	2.3 ± 3.9
Origin midfield (n)	8.3 ± 3.5	8.2 ± 2.4	0.1 ± 4.7	11.3 ± 1.7[a]	7.3 ± 2.3	4.0 ± 3.0	6.3 ± 3.0[a]	8.8 ± 2.4	-2.5 ± 3.7
Origin attack (n)	0.8 ± 0.9	0.5 ± 0.5	0.4 ± 1.1	1.1 ± 1.1	0.5 ± 0.5	0.6 ± 1.4	0.6 ± 0.7	0.4 ± 0.5	0.2 ± 0.8
Efficiency (%)	69.8 ± 12.2	75.2 ± 13.4	-5.3 ± 15.2	78.2 ± 10.1	74.8 ± 17.5	3.5 ± 13.1	64.2 ± 10.3[a]	75.4 ± 10.6	-11.2 ± 14.1
Shot									
Total number (n)	13.4 ± 3.4	13.7 ± 3.5	-0.3 ± 4.4	16.5 ± 2.4	13.8 ± 3.5	2.8 ± 3.4	11.3 ± 2.1	13.6 ± 3.7	-2.3 ± 3.9
From play (n)	9.7 ± 3.1	10.4 ± 3.5	-0.7 ± 3.9	12.3 ± 2.6	10.5 ± 3.7	1.8 ± 3.4	8.0 ± 2.0[b]	10.3 ± 3.6	-2.3 ± 3.4
From play (%)	72.1 ± 8.9	75.1 ± 11.4	-3.1 ± 13.2	74.2 ± 9.8	74.4 ± 11.3	-0.2 ± 12.4	70.7 ± 8.5	75.6 ± 11.9	-4.9 ± 13.9
From dead ball (n)	3.7 ± 1.3	3.3 ± 1.4	0.4 ± 1.8	4.3 ± 1.7	3.3 ± 0.7	1.0 ± 1.8	3.3 ± 1.0	3.3 ± 1.7	0.0 ± 1.8
From dead ball (%)	27.9 ± 8.9	24.9 ± 11.4	3.1 ± 13.2	25.8 ± 9.8	25.6 ± 11.3	0.2 ± 12.4	29.3 ± 8.5	24.4 ± 11.9	4.9 ± 13.9
Efficiency (%)	49.0 ± 13.5	49.9 ± 16.6	-0.9 ± 19.9	52.0 ± 7.8	60.0 ± 10.6	-8.0 ± 14.4	47.0 ± 16.3	43.1 ± 16.8	3.8 ± 22.1

Table 5.10 Offensive play for halves continued

Performance indicator	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH - SH
Score									
Total combined	7.5 ± 3.2	7.8 ± 3.9	-0.3 ± 4.0	10.0 ± 2.4	9.5 ± 3.5	0.5 ± 4.4	5.8 ± 2.4	6.7 ± 3.9	-0.8 ± 3.9
Total number (n)	6.6 ± 2.4	6.8 ± 2.8	-0.2 ± 3.2	8.5 ± 1.3	8.3 ± 2.3	0.3 ± 3.1	5.3 ± 2.1	5.8 ± 2.8	-0.5 ± 3.3
Average attack/ score (n)	3.8 ± 3.5	3.6 ± 3.4	0.2 ± 4.5	2.5 ± 0.3	2.4 ± 0.9	0.1 ± 0.9	4.6 ± 4.4	4.4 ± 4.2	0.2 ± 5.9
Productivity	2.0 ± 0.8	2.2 ± 1.1	-0.2 ± 1.2	2.5 ± 0.6	2.6 ± 1.0	-0.1 ± 1.2	1.6 ± 0.8	1.9 ± 1.2	-0.3 ± 1.2
Point (n)	6.2 ± 2.2	6.3 ± 2.4	-0.2 ± 3.0	7.8 ± 1.0	7.6 ± 1.9	0.1 ± 2.7	5.1 ± 2.2	5.4 ± 2.4	-0.3 ± 3.3
Point from play (n)	3.7 ± 1.7	4.2 ± 2.0	-0.6 ± 2.5	4.9 ± 1.5	5.3 ± 1.8	-0.4 ± 2.6	2.8 ± 1.3	3.5 ± 1.9	-0.7 ± 2.6
Point from dead ball (n)	2.5 ± 1.1	2.1 ± 1.4	0.4 ± 1.3	2.9 ± 1.0	2.4 ± 0.5	0.5 ± 0.9	2.3 ± 1.1	1.9 ± 1.7	0.3 ± 1.6
Goal (n)	0.5 ± 0.7	0.5 ± 0.7	-0.1 ± 0.9	0.8 ± 0.7	0.6 ± 0.7	0.1 ± 1.0	0.3 ± 0.6	0.4 ± 0.7	-0.2 ± 0.8

Values are mean ± SD; $p \leq 0.05$ vs. second half using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 5.11 Defensive play for the reference team across halves

Performance indicator	Group: All First half	All Second half	All FH – SH	Win First half	Win Second half	Win FH – SH	Lose First half	Lose Second half	Lose FH - SH
Turnovers									
Total number (n)	15.5 ± 4.2	13.6 ± 4.0	1.9 ± 4.7	17.3 ± 3.9	14.9 ± 5.0	2.4 ± 5.2	14.3 ± 4.1	12.8 ± 3.1	1.5 ± 4.6
Origin defence (n)	9.7 ± 3.1	8.0 ± 2.9	1.8 ± 4.1	9.3 ± 2.4	9.8 ± 2.3	-0.5 ± 3.4	10.0 ± 3.5[a]	6.8 ± 2.7	3.3 ± 3.9
Origin midfield (n)	5.0 ± 2.8	5.2 ± 3.1	-0.2 ± 3.8	7.0 ± 2.6	4.6 ± 3.1	2.4 ± 3.2	3.7 ± 2.0	5.6 ± 3.2	-1.9 ± 3.2
Origin attack (n)	0.8 ± 0.9	0.5 ± 0.7	0.3 ± 1.2	1.0 ± 1.2	0.5 ± 0.8	0.5 ± 1.6	0.6 ± 0.7	0.4 ± 0.7	0.2 ± 0.9
Tackles									
Total number (n)	41.2 ± 12.4	39.4 ± 8.8	1.9 ± 13.4	39.0 ± 12.5	35.0 ± 10.4	4.0 ± 15.2	42.7 ± 12.7	42.3 ± 6.4	0.4 ± 12.5
Successful (n)	5.4 ± 2.7[b]	3.7 ± 1.7	1.7 ± 2.9	5.5 ± 3.1	2.9 ± 1.6	2.6 ± 3.4	5.3 ± 2.5	4.2 ± 1.6	1.1 ± 2.4
Successful (%)	12.8 ± 4.7[a]	9.2 ± 4.3	3.7 ± 5.6	13.4 ± 5.0[a]	7.7 ± 3.2	5.7 ± 5.4	12.5 ± 4.6	10.2 ± 4.7	2.3 ± 5.6
Unsuccessful (n)	35.9 ± 11.0	35.7 ± 8.1	0.2 ± 11.9	33.5 ± 10.0	32.1 ± 8.9	1.4 ± 12.3	37.4 ± 11.8	38.1 ± 6.8	-0.7 ± 12.2
Unsuccessful (%)	87.2 ± 4.7[a]	90.8 ± 4.2	-3.7 ± 5.6	86.7 ± 5.0[a]	92.3 ± 3.2	-5.7 ± 5.4	87.5 ± 4.6	89.8 ± 4.7	-2.4 ± 5.6
Origin defence (n)	19.6 ± 7.5	19.1 ± 6.6	0.6 ± 9.8	17.5 ± 7.2	18.6 ± 8.7	-1.1 ± 12.2	21.0 ± 7.6	19.3 ± 5.2	1.7 ± 8.2
Origin midfield (n)	17.0 ± 6.1	15.3 ± 6.2	1.7 ± 7.4	16.1 ± 4.3	13.1 ± 4.9	3.0 ± 6.3	17.5 ± 7.1	16.7 ± 6.8	0.8 ± 8.1
Origin attack (n)	4.7 ± 3.0	5.1 ± 3.5	-0.4 ± 4.7	5.4 ± 4.2	3.3 ± 2.0	2.1 ± 4.0	4.2 ± 1.9	6.3 ± 3.8	-2.1 ± 4.5

Table 5.11 Defensive play for halves continued

Performance indicator	Group								
	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH - SH
Free kick won									
Total number (n)	11.0 ± 4.3	10.7 ± 3.7	0.3 ± 4.0	13.1 ± 3.3[a]	10.6 ± 1.5	2.5 ± 3.0	9.6 ± 4.5	10.8 ± 4.8	-1.2 ± 4.0
Origin defence (n)	2.4 ± 1.5	2.6 ± 1.6	-0.2 ± 2.0	2.4 ± 1.3	2.8 ± 1.2	-0.4 ± 2.0	2.3 ± 1.7	2.4 ± 1.9	-0.1 ± 2.0
Origin midfield (n)	5.8 ± 3.1	5.8 ± 2.8	0.1 ± 3.5	7.3 ± 1.9[a]	4.9 ± 2.2	2.4 ± 2.0	4.8 ± 3.5	6.3 ± 3.1	-1.5 ± 3.5
Origin attack (n)	2.9 ± 1.3	2.4 ± 1.4	0.5 ± 1.5	3.5 ± 1.1	3.0 ± 0.8	0.5 ± 1.1	2.4 ± 1.4	2.0 ± 1.5	0.4 ± 1.8
Defensive actions									
Total number (n)	64.3 ± 14.3	62.6 ± 11.5	1.7 ± 12.9	63.5 ± 15.5	59.3 ± 15	4.3 ± 13.7	64.8 ± 14.2	64.8 ± 8.4	0.0 ± 12.7
Origin defence (n)	32.0 ± 8.4	30.2 ± 8.1	1.8 ± 10.3	29.8 ± 7.8	32.3 ± 10.6	-2.5 ± 12.9	33.4 ± 8.7	28.8 ± 6.0	4.6 ± 7.6
Origin midfield (n)	25.5 ± 8.1	24.5 ± 9.2	1.0 ± 8.8	26.4 ± 7.6	21.5 ± 8.7	4.9 ± 8.2	24.8 ± 8.7	26.5 ± 9.4	-1.7 ± 8.4
Origin attack (n)	6.9 ± 3.3	7.9 ± 5.0	-1.0 ± 6.2	7.4 ± 4.5	5.5 ± 3.4	1.9 ± 4.5	6.5 ± 2.3	9.4 ± 5.5	-2.9 ± 6.6
Defensive efficiency (%)	35.0 ± 10.3	27.8 ± 12.9	7.2 ± 17.1	36.9 ± 10.4	29.5 ± 14.6	7.4 ± 20.2	33.8 ± 10.5	26.7 ± 12.3	7.1 ± 15.6

Values are mean ± SD; $p \leq 0.05$ vs. second half using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 5.12 Passing for the reference team across halves

Performance indicator	Group: All First half	All Second half	All FH – SH	Win First half	Win Second half	Win FH – SH	Lose First half	Lose Second half	Lose FH - SH
Combined hand and kick pass									
Total number (n)	141.2 ± 25.1[a]	123.3 ± 26.7	17.9 ± 37.7	131.3 ± 17	125.1 ± 35.7	6.1 ± 36.8	147.8 ± 28.0[a]	122.1 ± 20.3	25.7 ± 37.8
Successful (n)	129.2 ± 27.0	113 ± 27.7	16.3 ± 40.0	119.9 ± 16.4	113.6 ± 37.7	6.3 ± 37.9	135.4 ± 31.4	112.5 ± 20.5	22.9 ± 41.5
Successful (%)	91.1 ± 4.2	91.1 ± 4.1	0.0 ± 5.2	91.3 ± 2.5	89.8 ± 5.4	1.4 ± 4.1	91.0 ± 5.1	92.0 ± 3.0	-1.0 ± 5.8
Unsuccessful (n)	12.0 ± 4.3	10.4 ± 3.9	1.6 ± 4.6	11.4 ± 3.3	11.5 ± 4.2	-0.1 ± 2.5	12.3 ± 5.0	9.6 ± 3.6	2.8 ± 5.4
Unsuccessful (%)	8.9 ± 4.2	8.9 ± 4.1	0.0 ± 5.2	8.7 ± 2.5	10.2 ± 5.4	-1.4 ± 4.1	9.1 ± 5.1	8.0 ± 3.0	1.0 ± 5.8
Hand pass									
Total number (n)	100.3 ± 25.1	85.0 ± 25.7	15.4 ± 32.9	90.0 ± 15.9	85.0 ± 35.1	5.0 ± 31.7	107.2 ± 28.3[a]	84.9 ± 18.9	22.3 ± 33.1
Successful (n)	98.1 ± 25.0	83.0 ± 25.3	15.1 ± 33.0	88.4 ± 15.1	82.9 ± 34.2	5.5 ± 31.3	104.5 ± 28.6	83.1 ± 18.9	21.4 ± 33.8
Successful (%)	97.7 ± 1.5	97.6 ± 1.6	0.1 ± 2.2	98.3 ± 1.1	97.5 ± 1.7	0.8 ± 1.5	97.3 ± 1.7	97.7 ± 1.6	-0.4 ± 2.5
Unsuccessful (n)	2.3 ± 1.3	2.0 ± 1.3	0.3 ± 1.7	1.6 ± 1.1	2.1 ± 1.6	-0.5 ± 1.2	2.7 ± 1.4	1.8 ± 1.2	0.8 ± 1.8
Unsuccessful (%)	2.3 ± 1.5	2.4 ± 1.6	-0.1 ± 2.2	1.7 ± 1.1	2.5 ± 1.7	-0.8 ± 1.5	2.7 ± 1.7	2.3 ± 1.6	0.4 ± 2.5

Table 5.12 Passing for halves continued

Performance indicator	Group: All First half	Second half	FH – SH	Win First half	Second half	FH – SH	Lose First half	Second half	FH - SH
Kick pass									
Total number (n)	40.9 ± 7.1	38.4 ± 6.5	2.5 ± 8.1	41.3 ± 8.5	40.1 ± 4.1	1.1 ± 8.1	40.6 ± 6.5	37.2 ± 7.7	3.4 ± 8.3
Successful (n)	31.2 ± 6.6	30.0 ± 5.4	1.2 ± 9.1	31.5 ± 6.0	30.8 ± 4.7	0.8 ± 8.3	30.9 ± 7.2	29.4 ± 6.0	1.5 ± 9.9
Successful (%)	76.3 ± 8.8	78.3 ± 7.5	-2.0 ± 10.9	76.8 ± 5.5	76.7 ± 9.6	0.1 ± 8.1	76.0 ± 10.6	79.4 ± 5.9	-3.4 ± 12.5
Unsuccessful (n)	9.7 ± 4.0	8.4 ± 3.4	1.3 ± 3.8	9.8 ± 3.4	9.4 ± 4.1	0.4 ± 3.0	9.7 ± 4.6	7.8 ± 3.0	1.9 ± 4.3
Unsuccessful (%)	23.7 ± 8.8	21.7 ± 7.5	2.0 ± 10.9	23.2 ± 5.5	23.3 ± 9.6	-0.1 ± 8.1	24.1 ± 10.6	20.6 ± 5.9	3.4 ± 12.5

Values are mean ± SD; $p \leq 0.05$ vs. second half using a one-sample t-test ([a]).

Table 5.13 Dead ball distribution for the reference team across halves

Performance indicator	Group								
	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH - SH
Dead ball									
Total number (n)	24.6 ± 4.6	24.2 ± 3.2	0.5 ± 4.5	25.4 ± 2.9	23.8 ± 1.8	1.6 ± 2.7	24.1 ± 5.5	24.4 ± 3.8	-0.3 ± 5.4
^Dead ball kick pass									
Successful (n)	15.7 ± 4.7	16.0 ± 3.2	-0.3 ± 5.3	16.4 ± 3.5	15.1 ± 1.9	1.3 ± 2.7	15.2 ± 5.4	16.5 ± 3.8	-1.3 ± 6.5
Successful (%)	74.6 ± 12.9	76.6 ± 9.4	-2.0 ± 15.8	77.5 ± 10.4	74.1 ± 8.4	3.4 ± 5.8	72.7 ± 14.4	78.3 ± 10.0	-5.6 ± 19.3
Unsuccessful (n)	5.3 ± 2.8	5.0 ± 2.2	0.4 ± 3.4	4.8 ± 2.3	5.4 ± 2.1	-0.6 ± 1.2	5.7 ± 3.2	4.7 ± 2.3	1.0 ± 4.2
Unsuccessful (%)	25.4 ± 12.9	23.4 ± 9.4	2.0 ± 15.8	22.5 ± 10.5	25.9 ± 8.4	-3.4 ± 5.8	27.3 ± 14.4	21.7 ± 10.0	5.6 ± 19.3
Dead ball FK pass									
Total number (n)	8.1 ± 3.8	8.1 ± 3.4	0.0 ± 4.0	9.6 ± 2.8	7.6 ± 1.7	2.0 ± 2.6	7.1 ± 4.1	8.4 ± 4.2	-1.3 ± 4.3
Successful (n)	7.6 ± 3.7	7.5 ± 2.8	0.1 ± 4.2	8.9 ± 2.5	7.3 ± 1.7	1.6 ± 2.9	6.8 ± 4.1	7.7 ± 3.4	-0.9 ± 4.7
Successful (%)	94.2 ± 8.5	94.4 ± 8.6	-0.3 ± 12.8	92.8 ± 6.5	95.5 ± 9.1	-2.7 ± 13.2	95.1 ± 9.7	93.7 ± 8.6	1.3 ± 12.8
Unsuccessful (n)	0.5 ± 0.7	0.6 ± 0.9	-0.1 ± 1.2	0.8 ± 0.7	0.4 ± 0.7	0.4 ± 1.2	0.3 ± 0.7	0.8 ± 1.1	-0.4 ± 1.1
Unsuccessful (%)	5.8 ± 8.5	5.6 ± 8.6	0.3 ± 12.8	7.2 ± 6.5	4.5 ± 9.1	2.7 ± 13.2	4.9 ± 9.7	6.3 ± 8.6	-1.3 ± 12.8

Table 5.13 Dead ball distribution for halves continued

	Group								
	All			Win			Lose		
Performance indicator	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH - SH
Dead ball kick out									
Total number (n)	11.6 ± 2.6	11.7 ± 2.7	-0.1 ± 3.1	10.3 ± 1.9	11.5 ± 1.6	-1.3 ± 1.9	12.4 ± 2.7	11.8 ± 3.4	0.7 ± 3.6
Successful (n)	6.9 ± 1.7	7.6 ± 3.2	-0.7 ± 3.0	6.5 ± 1.8	6.9 ± 2.8	-0.4 ± 2.3	7.2 ± 1.7	8.0 ± 3.4	-0.8 ± 3.4
Successful (%)	61.6 ± 17.3	63.8 ± 18.9	-2.2 ± 24.0	64.4 ± 16.9	59.1 ± 18.3	5.4 ± 15.2	59.8 ± 18.0	67.0 ± 19.5	-7.2 ± 28.0
Unsuccessful (n)	4.7 ± 2.5	4.1 ± 2.2	0.6 ± 3.2	3.8 ± 2.1	4.6 ± 2.1	-0.9 ± 1.9	5.3 ± 2.7	3.8 ± 2.3	1.5 ± 3.6
Unsuccessful (%)	38.4 ± 17.3	36.2 ± 18.9	2.2 ± 24.0	35.6 ± 16.9	40.9 ± 18.3	-5.4 ± 15.2	40.2 ± 18.0	33 ± 19.5	7.2 ± 28.0

Values are mean ± SD; ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs; FK = Free kick.

Table 5.14 Physical characteristics for the reference team across halves

Performance indicator	Group								
	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH – SH
Stand (m)	300 ± 109	304 ± 66	-4 ± 89	345 ± 163	298 ± 68	47 ± 110	269 ± 35[a]	308 ± 67	-39 ± 53
Walk (m)	19511 ± 2817	19525 ± 2746	-14 ± 713	18604 ± 3006	18245 ± 2890	359 ± 612	20116 ± 2638	20378 ± 2392	-262 ± 687
Jog (m)	19468 ± 1294	19124 ± 1403	344 ± 1608	19044 ± 1595	18684 ± 1021	360 ± 1749	19750 ± 1028	19418 ± 1582	333 ± 1587
Run (m)	10582 ± 989	10337 ± 859	246 ± 975	10147 ± 1041	9817 ± 669	330 ± 1195	10873 ± 879	10683 ± 813	190 ± 851
High-speed run (m)	4869 ± 728	4600 ± 672	269 ± 596	4601 ± 509	4460 ± 652	141 ± 718	5048 ± 814[a]	4694 ± 697	354 ± 516
Maximum-speed run (m)	1099 ± 283	1125 ± 326	-26 ± 204	1165 ± 273	1157 ± 256	7 ± 197	1055 ± 292	1103 ± 375	-48 ± 215

Table 5.14 Physical characteristics across halves continued

Performance indicator	Group								
	All			Win			Lose		
	First half	Second half	FH – SH	First half	Second half	FH – SH	First half	Second half	FH – SH
Total distance (m)	55999 ± 4442	55195 ± 3962	803 ± 2877	53906 ± 4496	52666 ± 3170	1240 ± 3743	57394 ± 3988	56882 ± 3599	512 ± 2269
Low-intensity activity (m)	39279 ± 3332	38953 ± 3113	326 ± 1996	37993 ± 3512	37227 ± 2788	766 ± 2189	40135 ± 3054	40103 ± 2861	32 ± 1898
High-intensity running (m)	16550 ± 1737	16062 ± 1558	489 ± 1501	15912 ± 1503	15434 ± 1245	478 ± 1890	16976 ± 1812	16480 ± 1652	496 ± 1272
Very high-intensity running (m)	5968 ± 901	5725 ± 902	243 ± 643	5765 ± 652	5617 ± 730	148 ± 818	6103 ± 1039	5797 ± 1026	306 ± 527
PlayerLoad™ (AU)	5330 ± 296	5215 ± 322	115 ± 288	5209 ± 260	5101 ± 257	108 ± 317	5410 ± 301	5291 ± 349	120 ± 281

Values are mean ± SD; $p \leq 0.05$ vs. second half using a one-sample t-test ([a]).

5.3.3 Temporal changes across quarters

Results from the univariate analyses of match characteristics, game statistics and the five groups of PIs, classified according to general aspects of game play, are presented in Tables 5.15 to 5.28. Table 5.15 highlights the mean results for quarters 1 to 4 and the relative differences between the first and fourth quarter in the overall match characteristics and game statistics for all games. Table 5.16 outlines the mean results and the relative differences between the first and fourth quarter in both winning and losing contexts. In Tables 5.17 to 5.28, PI results are outlined in the same format and each table is presented over two pages. Significant differences are illustrated in the tables and highlighted within the text.

5.3.3.1 Match characteristics: temporal changes across quarters

Tables 5.15 and 5.16 summarise the match characteristics and game statistics across quarters and by game outcome. There was an increase in substitutions from quarter 1 to quarter 4, across all games (p = 0.000), and both in games won (p = 0.002) and lost (p = 0.003). In games lost, there was also an increase in total playing time (p = 0.027) and stoppage time (p = 0.031) in quarter 4 compared to quarter 1.

5.3.3.2 Performance characteristics: temporal changes across quarters

5.3.3.3 Quarter summary – possession

There was a decrease in team possession (Tables 5.17 and 5.18), from quarter 1 to quarter 4, across all games (p = 0.007) and in games won (p = 0.032). In quarter 4, there was also a decrease in team possessions originating in midfield in games won (p = 0.003) and originating in defence in games lost (p = 0.035). There were no significant differences in player possessions across quarters or by match outcome.

5.3.3.4 Quarter summary – offence

There were no significant differences in offensive characteristics across quarters in all games combined or in games that were lost (Tables 5.19 and 5.20). In games won, there was a decrease in the frequency of attacks (p = 0.019) and in attacks originating in midfield (p = 0.001) from quarter 1 to quarter 4.

5.3.3.5 Quarter summary – defence

There were no significant differences in defensive characteristics across quarters in all games combined (Table 5.21). In games won, there was a decrease in the frequency of free kicks obtained originating in midfield (p = 0.008) in quarter 4. In games lost, there was a decrease in turnovers originating in defence (p = 0.014) and an increase in tackles originating in attack (p = 0.046).

5.3.3.6 Quarter summary – passing

In quarter 4, there was a reduction in the number of unsuccessful combined hand and kick passes (p = 0.029) and in kick passes (p = 0.040) across all games (Table 5.23). There were no significant differences in passing characteristics between winning and losing (Table 5.24).

5.3.3.7 Quarter summary – dead ball distribution

There were no significant differences in dead ball distribution across quarters in all games combined (Table 5.25). In games won, there was a decrease in the frequency of dead ball free kick passes (p = 0.050) in quarter 4. In games lost, there was an increase in the percentage of kick outs retained (p = 0.030) and a decrease in both the number (p = 0.025) and percentage (p = 0.030) of kick outs lost (unsuccessful).

5.3.3.8 Quarter summary – physical characteristics

In all games combined, there was a reduction in jogging (p = 0.006), high-speed running (p = 0.000), total distance (p = 0.006), LIA (p = 0.025), HIR (p = 0.004), VHIR (p = 0.000), and PlayerLoad™ (p = 0.002), in quarter 4 compared to quarter 1 (Table 5.27). In winning full games there were no significant differences in any physical performance indices between quarter 1 and quarter 4 (Table 5.28). In contrast, there was a decline in jogging (p = 0.024), high-speed running (p = 0.000), total distance (p = 0.022), HIR (p = 0.010), VHIR (p = 0.001) and PlayerLoad™ (p = 0.007) in the fourth quarter of games lost.

Table 5.15 Match characteristics and game statistics for the reference team across quarters for all games, n=20

Characteristic	Period				
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Difference Q1 - Q4**
Playing time (min:s)	18:25 ± 0:28	18:25 ± 0:28	18:35 ± 0:34	18:35 ± 0:34	-0:10 ± 0:38
Ball in play time (min:s)	9:25 ± 1:13	9:36 ± 1:20	9:11 ± 1:07	8:51 ± 1:14	0:34 ± 1:32
Stoppage time (min:s)	8:59 ± 1:23	8:48 ± 1:32	9:23 ± 1:21	9:43 ± 1:31	-0:44 ± 1:49
Statistic					
Substitution (n)	0.2 ± 0.5[a]	0.5 ± 0.8	1.9 ± 1.0	2.8 ± 1.3	-2.6 ± 1.5
Yellow card (n)	0.3 ± 0.6	0.3 ± 0.4	0.4 ± 0.6	0.5 ± 0.8	-0.2 ± 1.0
Black card (n)	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.3	0.3 ± 0.6	-0.3 ± 0.6
Red card/BCNR (n)	0.0 ± 0.0	0.1 ± 0.2	0.1 ± 0.3	0.1 ± 0.3	-0.1 ± 0.3

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]); BCNR = Black card not replaced; Q1 = quarter 1, Q4 = quarter 4.

Table 5.16 Match characteristics and game statistics for the reference team across quarters and by match outcome (win: n=8; lose: n=12)

	Group					
	Win			Lose		
Characteristic	**Quarter 1**	**Quarter 4**	**Difference Q1 - Q4**	**Quarter 1**	**Quarter 4**	**Difference Q1 - Q4**
Playing time (min:s)	18:32 ± 0:32	18:22 ± 0:34	0:10 ± 0:40	18:20 ± 0:24[a]	18:43 ± 0:33	-0:23 ± 0:32
Ball in play time (min:s)	9:04 ± 1:17	8:45 ± 1:10	0:20 ± 1:51	9:40 ± 1:09	8:55 ± 1:19	0:44 ± 1:21
Stoppage time (min:s)	9:28 ± 1:31	9:37 ± 1:18	-0:10 ± 2:06	8:40 ± 1:14[a]	9:47 ± 1:42	-1:07 ± 1:35
Statistic						
Substitution (n)	0.3 ± 0.7[a]	3.4 ± 1.4	-3.1 ± 1.8	0.2 ± 0.4[b]	2.4 ± 1.1	-2.3 ± 1.2
Yellow card (n)	0.3 ± 0.5	1.0 ± 1.1	-0.8 ± 1.0	0.3 ± 0.6	0.1 ± 0.3	0.2 ± 0.7
Black card (n)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	0.5 ± 0.7	-0.4 ± 0.8
Red card/BCNR (n)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.4	-0.2 ± 0.4

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]); BCNR = Black card not replaced.

Table 5.17 Possession for the reference team across quarters for all games

Performance indicator	Period Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Team possession					
Total number (n)	19.7 ± 2.3[a]	18.6 ± 3.2	18.6 ± 3.3	17.5 ± 2.7	2.2 ± 3.2
Proportion (%)	53.1 ± 9.5	55.2 ± 8.7	52.1 ± 7.8	50.5 ± 10.4	2.6 ± 17.1
Total time (s)	256.7 ± 63.9	273.1 ± 64.6	244.4 ± 42.8	231.7 ± 62.6	24.9 ± 102.6
Time/possession (s)	13.2 ± 3.7	15.6 ± 6.3	13.5 ± 3.2	13.6 ± 4.6	-0.4 ± 6.9
Origin defence (n)	11.6 ± 2.5	11.1 ± 2.4	11.1 ± 2.4	10.2 ± 3.0	1.4 ± 3.7
Origin midfield (n)	5.9 ± 2.6	5.3 ± 2.1	6.1 ± 2.6	5.3 ± 2.3	0.6 ± 3.3
Origin attack (n)	2.2 ± 1.3	2.2 ± 1.2	1.4 ± 0.9	2.1 ± 1.5	0.2 ± 2.0

Table 5.17 Possession for quarters continued

Performance indicator	**Period**				**Difference**
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Q1 - Q4**
Player possession					
Total number (n)	83.4 ± 18.0	83.3 ± 13.4	76.3 ± 13.7	72.7 ± 17.1	10.7 ± 26.6
Total time in possession (s)	165.8 ± 50.6	182.1 ± 50.3	164.4 ± 31.4	144.4 ± 40.6	21.3 ± 69.9
Time/possession (s)	2.0 ± 0.3	2.2 ± 0.4	2.2 ± 0.3	2.0 ± 0.3	0.0 ± 0.4
Origin defence (n)	24.2 ± 6.7	23.1 ± 6.5	24.2 ± 9.3	21.0 ± 7.7	3.3 ± 9.2
Origin midfield (n)	41.2 ± 16.7	43.8 ± 13.2	35.2 ± 9.3	35.4 ± 10.1	5.8 ± 18.6
Origin attack (n)	18.1 ± 7.6	16.5 ± 5.2	16.9 ± 7.4	16.4 ± 7.6	1.7 ± 10.5

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 5.18 Possession for the reference team across quarters and by match outcome

	Group									
	Win					Lose				
Performance indicator	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Team possession										
Total number (n)	20.6 ± 2.3[a]	20.0 ± 2.0	19.1 ± 4.1	17.8 ± 2.2	2.9 ± 3.0	19.0 ± 2.0	17.6 ± 3.5	18.2 ± 2.9	17.3 ± 3.0	1.7 ± 3.3
Proportion (%)	54.5 ± 7.3	55.2 ± 8.7	54.5 ± 8.9	54.2 ± 10.5	0.3 ± 16.4	52.1 ± 10.9	55.2 ± 9.1	50.5 ± 6.8	48.0 ± 9.9	4.1 ± 18.1
Total time (s)	248.1 ± 41.5	254.1 ± 45.0	254.6 ± 57.2	248.1 ± 71.3	-0.1 ± 85.7	262.4 ± 76.6	285.7 ± 74.1	237.6 ± 30.9	220.8 ± 56.6	41.6 ± 112.9
Time/possession (s)	12.1 ± 1.8	12.7 ± 2.0	13.9 ± 4.4	14.4 ± 5.4	-2.3 ± 6.1	14.0 ± 4.5	17.4 ± 7.6	13.3 ± 2.2	13.2 ± 4.2	0.9 ± 7.3
Origin defence (n)	10.4 ± 2.2	10.8 ± 2.3	11.9 ± 2.5	10.9 ± 2.2	-0.5 ± 2.8	12.3 ± 2.5[a]	11.3 ± 2.6	10.6 ± 2.2	9.7 ± 3.4	2.7 ± 3.8
Origin midfield (n)	7.6 ± 2.4[a]	6.8 ± 1.3	5.8 ± 2.9	4.6 ± 2.1	3.0 ± 1.9	4.8 ± 2.1	4.3 ± 2.0	6.3 ± 2.4	5.8 ± 2.5	-1.0 ± 3.2
Origin attack (n)	2.6 ± 1.7	2.5 ± 1.2	1.5 ± 0.9	2.3 ± 1.3	0.4 ± 2.4	1.9 ± 0.9	2.0 ± 1.2	1.3 ± 1.0	1.9 ± 1.7	0.0 ± 1.8

Table 5.18 Possession across quarters and by match outcome continued

Performance indicator	Win: Quarter 1	Win: Quarter 2	Win: Quarter 3	Win: Quarter 4	Win: Q1 - Q4	Lose: Quarter 1	Lose: Quarter 2	Lose: Quarter 3	Lose: Quarter 4	Lose: Q1 - Q4
Player possession										
Total number (n)	81.6 ± 13.0	78.8 ± 10.6	75.6 ± 19.4	75.4 ± 21.1	6.3 ± 24.4	84.6 ± 21.2	86.3 ± 14.5	76.7 ± 9.3	70.9 ± 14.6	13.7 ± 28.6
Total time in possession (s)	156.6 ± 30.7	173.3 ± 36.6	168.8 ± 36.8	156.3 ± 42.1	0.2 ± 50.0	171.9 ± 61.0	188 ± 58.5	161.4 ± 28.5	136.5 ± 39.4	35.3 ± 79.4
Time/possession (s)	1.9 ± 0.2	2.2 ± 0.3	2.3 ± 0.4	2.1 ± 0.4	-0.2 ± 0.3	2.0 ± 0.4	2.1 ± 0.4	2.1 ± 0.3	1.9 ± 0.2	0.1 ± 0.4
Origin defence (n)	23.1 ± 7.4	21.9 ± 6.3	24.9 ± 5.8	23.0 ± 7.5	0.1 ± 10.0	24.9 ± 6.4	23.8 ± 6.8	23.7 ± 11.3	19.6 ± 7.8	5.3 ± 8.4
Origin midfield (n)	36.6 ± 8.6	38.8 ± 9.3	34.6 ± 12.7	36.1 ± 14.3	0.5 ± 14.6	44.2 ± 20.2	47.2 ± 14.6	35.6 ± 6.9	34.8 ± 6.9	9.3 ± 20.6
Origin attack (n)	21.9 ± 6.4	18.1 ± 5.2	16.1 ± 8.0	16.3 ± 5.9	5.6 ± 10.7	15.5 ± 7.4	15.3 ± 5.0	17.4 ± 7.2	16.5 ± 8.8	-1.0 ± 10.0

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 5.19 Offensive play for the reference team across quarters

Performance indicator	Period: Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Attack					
Total number (n)	9.9 ± 2.3	9.3 ± 2.1	9.9 ± 1.8	8.2 ± 1.8	1.7 ± 3.2
Origin defence (n)	5.2 ± 1.9	4.9 ± 1.9	5.0 ± 2.0	4.4 ± 2.0	0.8 ± 2.3
Origin midfield (n)	4.4 ± 2.2	4.0 ± 1.8	4.7 ± 1.8	3.6 ± 1.8	0.8 ± 3.0
Origin attack (n)	0.4 ± 0.7	0.5 ± 0.5	0.2 ± 0.4	0.3 ± 0.4	0.1 ± 0.8
Efficiency (%)	67.9 ± 15.4	72.1 ± 17.0	72.2 ± 16.6	79.6 ± 21.3	-11.8 ± 27.6
Shot					
Total number (n)	6.6 ± 1.9	6.8 ± 2.2	7.2 ± 2.2	6.5 ± 2.2	0.1 ± 3.2
From play (n)	4.7 ± 1.8	5.0 ± 2.1	5.7 ± 2.3	4.7 ± 2.2	0.0 ± 3.3
From play (%)	69.6 ± 14.4	73.0 ± 15.5	77.8 ± 13.7	71.7 ± 18.8	-2.2 ± 27.7
From dead ball (n)	1.9 ± 0.9	1.8 ± 1.1	1.5 ± 0.8	1.8 ± 1.3	0.1 ± 1.7
From dead ball (%)	30.4 ± 14.4	27.0 ± 15.5	22.2 ± 13.7	28.3 ± 18.8	2.2 ± 27.7
Efficiency (%)	53.5 ± 20.5	45.9 ± 13.6	50.4 ± 21.2	51.5 ± 23.3	2.0 ± 31.5

Table 5.19 Offensive play across quarters continued

Performance indicator	Period				Difference
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Q1 - Q4**
Score					
Total combined	4.1 ± 2.1	3.5 ± 1.8	4.1 ± 2.7	3.7 ± 2.5	0.4 ± 2.9
Total number (n)	3.6 ± 1.5	3.1 ± 1.2	3.6 ± 2.0	3.2 ± 1.5	0.4 ± 1.9
Average attack/score (n)	3.0 ± 1.6	3.5 ± 1.6	3.0 ± 1.1	3.3 ± 2.3	-0.3 ± 2.6
Productivity	2.1 ± 1.1	1.9 ± 1.0	2.2 ± 1.3	2.2 ± 1.6	-0.1 ± 1.8
Point (n)	3.3 ± 1.5	2.9 ± 1.1	3.4 ± 1.8	3.0 ± 1.2	0.4 ± 1.9
Point from play (n)	2.0 ± 1.2	1.7 ± 1.2	2.3 ± 1.7	1.9 ± 1.1	0.1 ± 1.7
Point from dead ball (n)	1.4 ± 0.8	1.2 ± 0.7	1.1 ± 0.9	1.1 ± 0.9	0.3 ± 1.3
Goal (n)	0.3 ± 0.6	0.2 ± 0.5	0.3 ± 0.4	0.3 ± 0.6	0.0 ± 0.9

Values are mean ± SD.

Table 5.20 Offensive play for the reference team across quarters and by match outcome

Performance indicator	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Attack										
Total number (n)	11.0 ± 2.1[b]	10.3 ± 2.1	10.6 ± 1.8	7.8 ± 1.4	3.3 ± 2.3	9.1 ± 2.2	8.7 ± 1.8	9.3 ± 1.8	8.5 ± 2.0	0.6 ± 3.3
Origin defence (n)	4.6 ± 1.3	4.3 ± 1.3	6.4 ± 1.4	4.3 ± 2.2	0.4 ± 2.0	5.5 ± 2.2	5.3 ± 2.1	4.1 ± 1.8	4.5 ± 1.9	1.0 ± 2.5
Origin midfield (n)	5.8 ± 1.5[a]	5.5 ± 1.4	4.1 ± 1.7	3.1 ± 1.7	2.6 ± 1.3	3.4 ± 2.1	2.9 ± 1.3	5.0 ± 1.9	3.8 ± 1.8	-0.4 ± 3.2
Origin attack (n)	0.6 ± 0.9	0.5 ± 0.5	0.1 ± 0.4	0.4 ± 0.5	0.3 ± 1.0	0.2 ± 0.4	0.4 ± 0.5	0.3 ± 0.5	0.2 ± 0.4	0.0 ± 0.6
Efficiency (%)	73.1 ± 15.1	84.6 ± 16.3	70.0 ± 23.7	82.3 ± 26.8	-9.2 ± 34.3	64.4 ± 15.2	63.7 ± 11.8	73.7 ± 10.8	77.9 ± 17.8	-13.5 ± 23.5
Shot										
Total number (n)	7.9 ± 1.6	8.6 ± 2.0	7.5 ± 2.9	6.3 ± 2.0	1.6 ± 3.0	5.8 ± 1.7	5.5 ± 1.4	6.9 ± 1.7	6.7 ± 2.4	-0.9 ± 3.0
From play (n)	5.6 ± 1.7	6.6 ± 1.5	6.1 ± 3.3	4.4 ± 1.6	1.3 ± 2.7	4.1 ± 1.7	3.9 ± 1.8	5.4 ± 1.6	4.9 ± 2.6	-0.8 ± 3.5
From play (%)	71.3 ± 14.8	77.5 ± 8.8	77.3 ± 17.2	69.5 ± 16.4	1.9 ± 26.0	68.4 ± 14.7	69.9 ± 18.5	78.1 ± 11.6	73.3 ± 20.8	-4.9 ± 29.5
From dead ball (n)	2.3 ± 1.2	2.0 ± 1.1	1.4 ± 0.9	1.9 ± 1.0	0.4 ± 1.8	1.7 ± 0.5	1.6 ± 1.1	1.5 ± 0.8	1.8 ± 1.5	-0.1 ± 1.6
From dead ball (%)	28.7 ± 14.8	22.5 ± 8.8	22.7 ± 17.2	30.6 ± 16.4	-1.9 ± 26.0	31.6 ± 14.7	30.1 ± 18.5	21.9 ± 11.6	26.7 ± 20.8	4.9 ± 29.5
Efficiency (%)	59.8 ± 9.9	46.9 ± 17.6	56.9 ± 16.7	66.6 ± 22.0	-6.8 ± 24.8	49.3 ± 24.7	45.2 ± 10.9	46.1 ± 23.3	41.4 ± 18.8	7.9 ± 35.0

Table 5.20 Offensive play across quarters and by match outcome continued

Performance indicator	Win Quarter 1	Win Quarter 2	Win Quarter 3	Win Quarter 4	Win Q1 - Q4	Lose Quarter 1	Lose Quarter 2	Lose Quarter 3	Lose Quarter 4	Lose Q1 - Q4
Score										
Total combined	5.6 ± 1.9	4.4 ± 1.9	5.0 ± 2.8	4.5 ± 2.5	1.1 ± 3.1	3.0 ± 1.4	2.8 ± 1.5	3.5 ± 2.5	3.2 ± 2.4	-0.2 ± 2.7
Total number (n)	4.6 ± 0.7	3.9 ± 1.2	4.3 ± 2.2	4.0 ± 1.4	0.6 ± 1.5	2.8 ± 1.5	2.5 ± 0.8	3.2 ± 1.9	2.7 ± 1.4	0.2 ± 2.1
Average attack/ score (n)	2.4 ± 0.6	2.9 ± 0.9	3.1 ± 1.4	2.2 ± 0.9	0.2 ± 0.5	3.5 ± 1.9	3.9 ± 1.8	3.0 ± 0.9	4.1 ± 2.6	-0.8 ± 3.4
Productivity	2.8 ± 1.0	2.2 ± 1.0	2.6 ± 1.2	2.7 ± 1.7	0.1 ± 2.0	1.6 ± 0.9	1.7 ± 0.9	2.0 ± 1.4	1.9 ± 1.6	-0.3 ± 1.8
Point (n)	4.1 ± 0.8	3.6 ± 1.1	3.9 ± 2.0	3.8 ± 1.2	0.4 ± 1.6	2.8 ± 1.7	2.3 ± 0.9	3.0 ± 1.7	2.4 ± 1.0	0.3 ± 2.1
Point from play (n)	2.5 ± 0.8	2.4 ± 1.1	2.9 ± 2.0	2.4 ± 1.1	0.1 ± 1.1	1.6 ± 1.3	1.3 ± 1.1	1.9 ± 1.5	1.6 ± 1.0	0.0 ± 2.1
Point from dead ball (n)	1.6 ± 0.7	1.3 ± 0.5	1.0 ± 0.9	1.4 ± 0.7	0.3 ± 1.3	1.2 ± 0.8	1.1 ± 0.8	1.1 ± 1.0	0.8 ± 1.0	0.3 ± 1.3
Goal (n)	0.5 ± 0.8	0.3 ± 0.5	0.4 ± 0.5	0.3 ± 0.7	0.3 ± 1.2	0.1 ± 0.3	0.2 ± 0.6	0.2 ± 0.4	0.3 ± 0.6	-0.2 ± 0.7

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using either a one-sample t-test ([a]) or Wilcoxon signed-rank test ([b]).

Table 5.21 Defensive play for the reference team across quarters

Performance indicator	Period: Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Turnovers					
Total number (n)	7.6 ± 2.1	7.9 ± 2.6	7.2 ± 3.2	6.4 ± 2.2	1.2 ± 3.0
Origin defence (n)	4.8 ± 1.8	4.9 ± 1.7	4.4 ± 2.4	3.6 ± 1.7	1.3 ± 2.7
Origin midfield (n)	2.5 ± 1.4	2.6 ± 1.8	2.6 ± 1.8	2.6 ± 1.9	-0.2 ± 2.3
Origin attack (n)	0.4 ± 0.7	0.4 ± 0.5	0.2 ± 0.4	0.3 ± 0.6	0.1 ± 0.9
Tackles					
Total number (n)	21.9 ± 6.5	19.4 ± 8.1	19.5 ± 6.4	19.9 ± 5.3	2.0 ± 8.8
Successful (n)	2.6 ± 1.7	2.8 ± 1.8	1.8 ± 1.4	1.9 ± 0.8	0.8 ± 1.7
Successful (%)	11.5 ± 5.8	14.2 ± 8.5	8.7 ± 7.0	9.8 ± 4.8	1.6 ± 6.8
Unsuccessful (n)	19.3 ± 5.5	16.6 ± 7.3	17.7 ± 5.7	18.1 ± 5.3	1.2 ± 8.0
Unsuccessful (%)	88.5 ± 5.8	85.8 ± 8.5	91.3 ± 7.0	90.2 ± 4.8	-1.6 ± 6.8
Origin defence (n)	10.1 ± 4.5	9.6 ± 5.7	9.3 ± 3.9	9.8 ± 4.4	0.3 ± 7.2
Origin midfield (n)	9.8 ± 4.3	7.2 ± 3.1	8.1 ± 4.3	7.2 ± 3.5	2.6 ± 6.0
Origin attack (n)	2.1 ± 2.1	2.6 ± 1.8	2.1 ± 2.2	3.0 ± 2.5	-1.0 ± 3.2

Table 5.21 Defensive play across quarters continued

Performance indicator	Period: Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Free kick won					
Total number (n)	5.4 ± 2.7	5.6 ± 2.7	5.6 ± 2.2	5.1 ± 2.6	0.3 ± 2.4
Origin defence (n)	1.1 ± 1.0	1.3 ± 1.1	1.5 ± 1.2	1.1 ± 1.1	-0.1 ± 1.1
Origin midfield (n)	2.9 ± 1.8	3.0 ± 1.9	3.1 ± 1.9	2.7 ± 1.9	0.2 ± 2.0
Origin attack (n)	1.5 ± 1.0	1.4 ± 1.0	1.1 ± 1.0	1.3 ± 1.0	0.2 ± 1.3
Defensive actions					
Total number (n)	33.3 ± 7.1	31.0 ± 9.7	31.3 ± 8.3	31.3 ± 6.3	2.1 ± 9.1
Origin defence (n)	16.6 ± 5.4	15.4 ± 6.7	15.0 ± 5.0	15.2 ± 5.5	1.4 ± 8.1
Origin midfield (n)	13.8 ± 4.8	11.7 ± 4.7	12.6 ± 6.0	11.9 ± 5.0	1.9 ± 6.6
Origin attack (n)	2.9 ± 2.2	4.0 ± 2.2	3.7 ± 3.4	4.2 ± 3.4	-1.3 ± 3.9
Defensive efficiency (%)	32.1 ± 14.8	38.7 ± 12.4	34.4 ± 13.1	25.9 ± 23.3	6.1 ± 26.9

Values are mean ± SD.

Table 5.22 Defensive play for the reference team across quarters and by match outcome

Performance indicator	Group									
	Win					Lose				
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Q1 - Q4**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Q1 - Q4**
Turnovers										
Total number (n)	8.4 ± 2.3	8.9 ± 2.3	8 ± 4.5	6.9 ± 2.1	1.5 ± 3.1	7.1 ± 1.9	7.2 ± 2.7	6.7 ± 2.1	6.1 ± 2.4	1.0 ± 3.1
Origin defence (n)	4.5 ± 1.4	4.8 ± 1.8	5.3 ± 2.7	4.5 ± 1.6	0.0 ± 2.6	5.0 ± 2.0[a]	5.0 ± 1.8	3.8 ± 2.0	2.9 ± 1.5	2.1 ± 2.5
Origin midfield (n)	3.3 ± 1.4	3.8 ± 1.5	2.5 ± 1.9	2.1 ± 1.7	1.1 ± 1.6	1.9 ± 1.2	1.8 ± 1.5	2.7 ± 1.8	2.9 ± 2.0	-1.0 ± 2.3
Origin attack (n)	0.6 ± 0.9	0.4 ± 0.5	0.3 ± 0.5	0.3 ± 0.5	0.4 ± 0.9	0.2 ± 0.4	0.4 ± 0.5	0.2 ± 0.4	0.3 ± 0.6	-0.1 ± 0.8
Tackles										
Total number (n)	20.3 ± 7.7	18.8 ± 7.7	16.1 ± 6.4	18.9 ± 6.3	1.4 ± 10.3	22.9 ± 5.7	19.8 ± 8.7	21.7 ± 5.5	20.6 ± 4.7	2.3 ± 8.0
Successful (n)	2.6 ± 2.0	2.9 ± 1.8	1.4 ± 1.5	1.5 ± 0.8	1.1 ± 2.3	2.6 ± 1.6	2.7 ± 1.8	2.1 ± 1.3	2.1 ± 0.8	0.5 ± 1.3
Successful (%)	11.8 ± 6.2	14.6 ± 9.2	7.0 ± 7.2	8.8 ± 5.7	3.0 ± 9.7	11.3 ± 5.8	14.0 ± 8.5	9.8 ± 6.9	10.5 ± 4.2	0.8 ± 4.2
Unsuccessful (n)	17.6 ± 6.0	15.9 ± 6.6	14.8 ± 5.4	17.4 ± 6.4	0.3 ± 9.3	20.3 ± 5.1	17.1 ± 7.9	19.6 ± 5.2	18.5 ± 4.7	1.8 ± 7.3
Unsuccessful (%)	88.3 ± 6.2	85.4 ± 9.2	93.0 ± 7.2	91.2 ± 5.7	-2.9 ± 9.7	88.7 ± 5.8	86.0 ± 8.5	90.2 ± 6.9	89.5 ± 4.2	-0.8 ± 4.2
Origin defence (n)	9.4 ± 6.3	8.1 ± 4.0	8.4 ± 4.7	10.3 ± 4.9	-0.9 ± 9.0	10.5 ± 3.1	10.5 ± 6.7	9.9 ± 3.3	9.4 ± 4.3	1.1 ± 6.0
Origin midfield (n)	8.5 ± 3.2	7.6 ± 3.2	6.1 ± 2.4	7.0 ± 3.2	1.5 ± 5.1	10.6 ± 4.8	6.9 ± 3.1	9.4 ± 4.8	7.3 ± 3.9	3.3 ± 6.6
Origin attack (n)	2.4 ± 2.8	3.0 ± 2.3	1.6 ± 2.1	1.6 ± 1.8	0.8 ± 2.4	1.8 ± 1.6[a]	2.3 ± 1.4	2.3 ± 2.3	3.9 ± 2.6	-2.1 ± 3.2

Table 5.22 Defensive play across quarters and by match outcome continued

Performance indicator	Group									
	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Free kick won										
Total number (n)	6.5 ± 2.3	6.6 ± 3.1	5.5 ± 1.3	5.1 ± 1.4	1.4 ± 1.9	4.7 ± 2.7	4.9 ± 2.3	5.7 ± 2.7	5.1 ± 3.3	-0.4 ± 2.5
Origin defence (n)	0.9 ± 0.6	1.5 ± 1.4	1.6 ± 1.2	1.1 ± 1.0	-0.3 ± 1.3	1.2 ± 1.2	1.2 ± 0.9	1.3 ± 1.3	1.1 ± 1.2	0.1 ± 1.1
Origin midfield (n)	3.6 ± 1.2[a]	3.6 ± 1.8	2.6 ± 2.1	2.3 ± 1.2	1.4 ± 1.1	2.3 ± 1.9	2.5 ± 1.9	3.3 ± 1.7	3.0 ± 2.2	-0.7 ± 2.0
Origin attack (n)	2.0 ± 1.1	1.5 ± 1.2	1.3 ± 0.9	1.8 ± 0.9	0.3 ± 1.6	1.2 ± 0.8	1.3 ± 1.0	1.0 ± 1.0	1.0 ± 1.0	0.2 ± 1.1
Defensive actions										
Total number (n)	32.3 ± 8.7	31.3 ± 9.5	28.4 ± 9.2	30.9 ± 8.6	1.4 ± 11.7	34.0 ± 6.2	30.8 ± 0.3	33.3 ± 7.4	31.5 ± 4.6	2.5 ± 7.4
Origin defence (n)	15.5 ± 6.3	14.3 ± 5.1	15.4 ± 6.3	16.9 ± 6.7	-1.4 ± 10.1	17.3 ± 4.9	16.1 ± 7.6	14.8 ± 4.4	14.1 ± 4.4	3.3 ± 6.4
Origin midfield (n)	13.4 ± 4.2	13.0 ± 4.6	10.4 ± 4.4	11.1 ± 5.1	2.3 ± 6.5	14.1 ± 5.4	10.8 ± 4.7	14.1 ± 6.6	12.4 ± 5.1	1.7 ± 6.9
Origin attack (n)	3.4 ± 2.8	4.0 ± 2.7	2.6 ± 2.7	2.9 ± 2.8	0.5 ± 2.3	2.6 ± 1.9	3.9 ± 1.9	4.4 ± 3.8	5.0 ± 3.6	-2.4 ± 4.4
Defensive efficiency (%)	33.7 ± 6.4	40.3 ± 9.6	39.0 ± 6.3	20.7 ± 2.9	13.0 ± 25.4	31.0 ± 4.3	37.6 ± 4.2	31.4 ± 0.1	29.4 ± 8.2	1.6 ± 28.0

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 5.23 Passing for the reference team across quarters

Performance indicator	Period: Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Combined hand and kick pass					
Total number (n)	70.9 ± 16.3	70.3 ± 13.9	63.3 ± 12.7	60.1 ± 16.8	10.9 ± 25.5
Successful (n)	64.2 ± 17.9	65.0 ± 14.7	57.9 ± 13.5	55.1 ± 17.2	9.1 ± 27.3
Successful (%)	89.8 ± 5.6	92.1 ± 3.9	90.8 ± 5.6	91.1 ± 5	-1.3 ± 7.3
Unsuccessful (n)	6.7 ± 2.9[a]	5.3 ± 2.2	5.4 ± 2.4	5.0 ± 2.5	1.8 ± 3.3
Unsuccessful (%)	10.3 ± 5.6	7.9 ± 3.9	9.2 ± 5.6	8.9 ± 5	1.3 ± 7.3
Hand pass					
Total number (n)	50.2 ± 16.6	50.2 ± 13.7	43.8 ± 13.9	41.2 ± 15	9.0 ± 23.0
Successful (n)	48.9 ± 16.3	49.2 ± 13.7	42.9 ± 13.7	40.1 ± 14.8	8.8 ± 23
Successful (%)	97.4 ± 1.9	98.0 ± 2.5	97.7 ± 2.6	97.3 ± 3	0.2 ± 3.1
Unsuccessful (n)	1.3 ± 0.9	1.0 ± 1.1	0.9 ± 0.9	1.1 ± 1.0	0.3 ± 1.0
Unsuccessful (%)	2.6 ± 1.9	2.0 ± 2.5	2.3 ± 2.6	2.7 ± 3.0	-0.2 ± 3.1

Table 5.23 Passing across quarters continued

Performance indicator	Period Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Kick pass					
Total number (n)	20.8 ± 4.0	20.1 ± 4.4	19.5 ± 4	18.9 ± 4.5	1.9 ± 5.7
Successful (n)	15.4 ± 3.9	15.8 ± 4.2	15.0 ± 3.1	15.0 ± 4.0	0.4 ± 6.3
Successful (%)	74.1 ± 13.6	78.2 ± 8.7	77.3 ± 8.3	79.5 ± 10.4	-5.4 ± 17.1
Unsuccessful (n)	5.4 ± 3.0[a]	4.3 ± 1.9	4.5 ± 2.1	3.9 ± 2.2	1.5 ± 3.0
Unsuccessful (%)	25.9 ± 13.6	21.8 ± 8.7	22.7 ± 8.3	20.5 ± 10.4	5.4 ± 17.1

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 5.24 Passing for the reference team across quarters and by match outcome

Performance indicator	Group									
	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Combined hand and kick pass										
Total number (n)	68.0 ± 11.9	63.3 ± 8.6	62.8 ± 17.6	62.4 ± 21.0	5.6 ± 23.5	72.8 ± 18.9	74.9 ± 15.0	63.6 ± 9.0	58.5 ± 14.1	14.3 ± 27.2
Successful (n)	61.5 ± 12.4	58.4 ± 8.8	56.8 ± 19.5	56.9 ± 21.6	4.6 ± 24.2	66.0 ± 21.2	69.4 ± 16.4	58.6 ± 8.5	53.9 ± 14.6	12.1 ± 29.7
Successful (%)	90.2 ± 4.4	92.1 ± 3.4	88.9 ± 8.3	90.1 ± 5.2	0.1 ± 6.2	89.5 ± 6.5	92.0 ± 4.4	92.1 ± 2.3	91.7 ± 5.0	-2.3 ± 8.1
Unsuccessful (n)	6.5 ± 2.7	4.9 ± 2.0	6.0 ± 3.3	5.5 ± 1.9	1.0 ± 3.0	6.8 ± 3.2	5.5 ± 2.4	5.0 ± 1.6	4.6 ± 2.8	2.3 ± 3.6
Unsuccessful (%)	9.8 ± 4.4	7.9 ± 3.4	11.1 ± 8.3	9.9 ± 5.2	-0.1 ± 6.2	10.6 ± 6.5	8.0 ± 4.4	7.9 ± 2.3	8.3 ± 5.0	2.3 ± 8.1
Hand pass										
Total number (n)	45.9 ± 11.8	44.1 ± 8.4	42.6 ± 19.8	42.4 ± 18.9	3.5 ± 21.6	53.0 ± 19.1	54.2 ± 15.2	44.6 ± 9.0	40.3 ± 12.7	12.7 ± 24.1
Successful (n)	44.6 ± 11.3	43.8 ± 8.2	41.8 ± 19.7	41.1 ± 18.5	3.5 ± 21.5	51.7 ± 18.8	52.8 ± 15.7	43.7 ± 8.7	39.4 ± 12.6	12.3 ± 24.2
Successful (%)	97.4 ± 2.3	99.2 ± 1.1	97.4 ± 3.5	96.8 ± 3.6	0.6 ± 3.8	97.5 ± 1.6	97.2 ± 2.8	98.0 ± 2.0	97.6 ± 2.6	-0.1 ± 2.7
Unsuccessful (n)	1.3 ± 1.0	0.4 ± 0.5	0.9 ± 0.8	1.3 ± 1.2	0.0 ± 1.1	1.3 ± 0.9	1.3 ± 1.2	0.9 ± 1.0	0.9 ± 0.9	0.4 ± 0.9
Unsuccessful (%)	2.6 ± 2.3	0.8 ± 1.1	2.6 ± 3.5	3.2 ± 3.6	-0.6 ± 3.8	2.5 ± 1.6	2.8 ± 2.8	2.0 ± 2.0	2.4 ± 2.6	0.1 ± 2.7

Table 5.24 Passing across quarters and by match outcome continued

Performance indicator	Group									
	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Kick pass										
Total number (n)	22.1 ± 4.3	19.1 ± 5.2	20.1 ± 4.1	20.0 ± 3.5	2.1 ± 6.0	19.8 ± 3.7	20.8 ± 3.9	19.0 ± 4.2	18.2 ± 5.0	1.7 ± 5.8
Successful (n)	16.9 ± 2.7	14.6 ± 4.1	15.0 ± 1.9	15.8 ± 4.3	1.1 ± 5.1	14.3 ± 4.4	16.6 ± 4.2	14.9 ± 3.8	14.5 ± 3.8	-0.2 ± 7.1
Successful (%)	77.0 ± 7.6	76.8 ± 8.0	76.1 ± 11.1	77.6 ± 9.2	-0.6 ± 8.8	72.1 ± 16.5	79.2 ± 9.3	78.1 ± 6.3	80.7 ± 11.3	-8.6 ± 20.7
Unsuccessful (n)	5.3 ± 2.4	4.5 ± 2.1	5.1 ± 3.1	4.3 ± 1.3	1.0 ± 2.4	5.5 ± 3.4	4.2 ± 1.7	4.1 ± 1.2	3.7 ± 2.6	1.8 ± 3.5
Unsuccessful (%)	23.0 ± 7.6	23.2 ± 8.0	23.9 ± 11.1	22.4 ± 9.2	0.6 ± 8.8	27.9 ± 16.5	20.8 ± 9.3	21.9 ± 6.3	19.3 ± 11.3	8.6 ± 20.7

Values are mean ± SD.

Table 5.25 Dead ball distribution for the reference team across quarters

Performance indicator	Period				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Dead ball					
Total number (n)	12.7 ± 2.2	12.0 ± 3.0	12.2 ± 2.1	12.0 ± 2.5	0.7 ± 2.4
^Dead ball kick pass					
Successful (n)	7.8 ± 3.0	7.9 ± 2.6	8.1 ± 2.4	7.9 ± 2.6	-0.1 ± 3.1
Successful (%)	71.4 ± 19.6	78.3 ± 14.9	75.5 ± 12.7	77.7 ± 16.6	-6.4 ± 25.8
Unsuccessful (n)	3.0 ± 1.9	2.3 ± 1.8	2.7 ± 1.5	2.3 ± 1.6	0.7 ± 2.5
Unsuccessful (%)	28.6 ± 19.6	21.7 ± 14.9	24.5 ± 12.7	22.3 ± 16.6	6.4 ± 25.8
Dead ball FK pass					
Total number (n)	3.8 ± 2.4	4.4 ± 2.3	4.4 ± 2.4	3.8 ± 2.3	0.0 ± 2.2
Successful (n)	3.5 ± 2.4	4.1 ± 2.1	4.2 ± 2.2	3.4 ± 2.1	0.1 ± 2.0
Successful (%)	92.3 ± 14.6	95.9 ± 9.2	97.7 ± 5.9	91.6 ± 14.7	-0.3 ± 22.4
Unsuccessful (n)	0.3 ± 0.4	0.3 ± 0.6	0.2 ± 0.4	0.4 ± 0.6	-0.1 ± 0.8
Unsuccessful (%)	7.7 ± 14.6	4.1 ± 9.2	2.3 ± 5.9	8.4 ± 14.7	0.3 ± 22.4

Table 5.25 Dead ball distribution across quarters continued

Performance indicator	Period				Difference Q1 - Q4
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Dead ball kick out					
Total number (n)	6.2 ± 2.0	5.4 ± 1.8	5.9 ± 1.5	5.8 ± 2.4	0.5 ± 2.6
Successful (n)	3.6 ± 1.2	3.3 ± 1.1	3.6 ± 1.7	4.0 ± 2.2	-0.4 ± 2.2
Successful (%)	61.9 ± 22.2	66.3 ± 23.2	59.9 ± 21.9	71.9 ± 24.9	-10.0 ± 31.5
Unsuccessful (n)	2.6 ± 1.9	2.1 ± 1.5	2.4 ± 1.5	1.8 ± 1.6	0.9 ± 2.2
Unsuccessful (%)	38.1 ± 22.2	33.7 ± 23.2	40.1 ± 21.9	28.1 ± 24.9	10 ± 31.5

Values are mean ± SD; ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs; FK = Free kick.

Table 5.26 Dead ball distribution for the reference team across quarters and by match outcome

Performance indicator	Group									
	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Dead ball										
Total number (n)	13.1 ± 1.6	12.3 ± 2.4	11.9 ± 2.4	11.9 ± 1.5	1.3 ± 1.9	12.3 ± 2.6	11.8 ± 3.4	12.4 ± 2.0	12.0 ± 3.1	0.3 ± 2.6
^Dead ball kick pass										
Successful (n)	8.1 ± 2.0	8.3 ± 2.8	7.9 ± 2.8	7.3 ± 2.5	0.9 ± 2.6	7.5 ± 3.6	7.7 ± 2.5	8.3 ± 2.2	8.3 ± 2.7	-0.8 ± 3.4
Successful (%)	75.0 ± 15.7	80.3 ± 13.5	74.4 ± 10.1	70.9 ± 17.1	4.1 ± 12.1	68.9 ± 22.2	76.9 ± 16.1	76.3 ± 14.5	82.2 ± 15.3	-13.3 ± 0.4
Unsuccessful (n)	2.8 ± 1.7	2.0 ± 1.6	2.6 ± 1.2	2.8 ± 1.4	0.0 ± 1.1	3.2 ± 2.1	2.5 ± 2.0	2.7 ± 1.7	2.0 ± 1.7	1.2 ± 3.0
Unsuccessful (%)	25.0 ± 15.7	19.7 ± 13.6	25.6 ± 10.1	29.1 ± 17.1	-4.1 ± 12.1	31.1 ± 22.2	23.1 ± 16.2	23.8 ± 14.5	17.8 ± 15.3	13.3 ± 30.4
Dead ball FK pass										
Total number (n)	4.4 ± 1.5[a]	5.3 ± 2.5	4.3 ± 2.1	3.4 ± 1.2	1.0 ± 1.2	3.3 ± 2.8	3.8 ± 2.0	4.4 ± 2.6	4.0 ± 2.9	-0.7 ± 2.5
Successful (n)	4.0 ± 1.3	4.9 ± 2.4	4.0 ± 1.9	3.3 ± 1.4	0.8 ± 1.3	3.2 ± 2.9	3.6 ± 1.9	4.3 ± 2.4	3.5 ± 2.5	-0.3 ± 2.4
Successful (%)	92.0 ± 12.4	93.9 ± 8.7	95.4 ± 8.5	93.8 ± 17.7	-1.8 ± 24.1	92.5 ± 16.9	97.2 ± 9.6	99.2 ± 2.6	90.1 ± 12.8	1.0 ± 22.3
Unsuccessful (n)	0.4 ± 0.5	0.4 ± 0.5	0.3 ± 0.5	0.1 ± 0.4	0.3 ± 0.7	0.2 ± 0.4	0.2 ± 0.6	0.1 ± 0.3	0.5 ± 0.7	-0.3 ± 0.8
Unsuccessful (%)	8.0 ± 12.4	6.2 ± 8.7	4.6 ± 8.5	6.3 ± 17.7	1.8 ± 24.1	7.5 ± 16.9	2.8 ± 9.6	0.8 ± 2.6	9.9 ± 12.8	-1.0 ± 22.3

Table 5.26 Dead ball distribution across quarters and by match outcome continued

Performance indicator	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Dead ball kick out										
Total number (n)	5.4 ± 2.1	4.9 ± 1.2	5.6 ± 1.7	5.9 ± 0.8	-0.5 ± 1.8	6.8 ± 1.8	5.7 ± 2.1	6.1 ± 1.4	5.7 ± 3.1	1.1 ± 3.0
Successful (n)	3.3 ± 1.3	3.3 ± 1.2	3.6 ± 2.1	3.3 ± 1.4	0.0 ± 1.9	3.8 ± 1.2	3.3 ± 1.1	3.5 ± 1.4	4.5 ± 2.5	-0.7 ± 2.4
Successful (%)	63.9 ± 20.6	69.6 ± 26.5	61.8 ± 19.1	55.6 ± 23.5	8.3 ± 23.4	60.5 ± 23.9[a]	64.1 ± 21.6	58.7 ± 24.3	82.7 ± 19.9	-22.2 ± 31.0
Unsuccessful (n)	2.1 ± 1.6	1.6 ± 1.4	2.0 ± 1.1	2.6 ± 1.5	-0.5 ± 1.1	2.9 ± 2.1[a]	2.3 ± 1.6	2.6 ± 1.7	1.2 ± 1.4	1.8 ± 2.3
Unsuccessful (%)	36.1 ± 20.6	30.5 ± 26.5	38.2 ± 19.1	44.4 ± 23.5	-8.3 ± 23.4	39.5 ± 23.9[a]	35.9 ± 21.6	41.3 ± 24.3	17.3 ± 19.9	22.2 ± 31.0

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]); ^Dead ball kick pass includes: free kicks, sideline kicks and kicks outs; FK = Free kick.

Table 5.27 Physical characteristics for the reference team across quarters

Performance indicator	Period				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Difference Q1 - Q4
Stand (m)	157 ± 77	143 ± 36	155 ± 40	148 ± 28	8 ± 70
Walk (m)	9706 ± 1398	9799 ± 1471	9737 ± 1418	9781 ± 1397	-75 ± 531
Jog (m)	10098 ± 859[a]	9364 ± 675	9911 ± 953	9208 ± 836	890 ± 1280
Run (m)	5413 ± 718	5165 ± 510	5249 ± 478	5085 ± 541	328 ± 716
High-speed run (m)	2551 ± 404[a]	2316 ± 402	2441 ± 380	2159 ± 349	392 ± 383
Maximum-speed run (m)	591 ± 156	508 ± 182	589 ± 171	536 ± 187	55 ± 171
Total distance (m)	28603 ± 2623[a]	27377 ± 2144	28177 ± 2265	27003 ± 2085	1600 ± 2309
Low-intensity activity (m)	19961 ± 1791[a]	19306 ± 1719	19803 ± 1881	19138 ± 1506	823 ± 1508
High-intensity running (m)	8555 ± 1141[a]	7989 ± 884	8279 ± 767	7779 ± 923	775 ± 1040
Very high-intensity running (m)	3142 ± 500[a]	2824 ± 517	3030 ± 485	2694 ± 486	447 ± 464
PlayerLoad™ (AU)	2741 ± 176[a]	2587 ± 161	2656 ± 177	2558 ± 185	184 ± 224

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

Table 5.28 Physical characteristics for the reference team across quarters and by match outcome

Performance indicator	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Stand (m)	189 ± 117	156 ± 49	151 ± 46	147 ± 25	42 ± 100	135 ± 19	134 ± 23	158 ± 38	149 ± 32	-14 ± 29
Walk (m)	9266 ± 1493	9336 ± 1547	9021 ± 1369	9217 ± 1559	49 ± 299	9999 ± 1312	10108 ± 1397	10214 ± 1287	10157 ± 1201	-158 ± 642
Jog (m)	9868 ± 1086	9172 ± 613	9747 ± 855	8931 ± 782	938 ± 1548	10251 ± 677[a]	9492 ± 710	10020 ± 1035	9393 ± 851	858 ± 1140
Run (m)	5183 ± 642	4962 ± 591	5061 ± 399	4753 ± 494	430 ± 849	5566 ± 751	5301 ± 420	5375 ± 500	5307 ± 466	260 ± 643
High-speed run (m)	2419 ± 322	2182 ± 316	2337 ± 410	2122 ± 311	297 ± 486	2639 ± 441[a]	2405 ± 440	2510 ± 360	2183 ± 384	456 ± 304
Maximum-speed run (m)	639 ± 184	526 ± 143	632 ± 161	525 ± 119	114 ± 173	558 ± 133	496 ± 209	560 ± 178	543 ± 226	16 ± 164

Table 5.28 Physical characteristics for the reference team across quarters and by match outcome continued

Performance indicator	Group									
	Win					Lose				
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Q1 - Q4
Total distance (m)	27565 ± 2504	26333 ± 2121	26948 ± 1650	25700 ± 2234	1866 ± 2991	29295 ± 2566[a]	28073 ± 1939	28996 ± 2303	27872 ± 1508	1423 ± 1852
Low-intensity activity (m)	19324 ± 1746	18664 ± 1865	18919 ± 1502	18295 ± 1705	1029 ± 1749	20385 ± 1763	19734 ± 1547	20392 ± 1930	19700 ± 1098	686 ± 1390
High-intensity running (m)	8241 ± 953	7670 ± 833	8030 ± 695	7400 ± 803	841 ± 1371	8763 ± 1246[a]	8202 ± 886	8445 ± 796	8032 ± 942	731 ± 817
Very high-intensity running (m)	3058 ± 445	2707 ± 390	2969 ± 457	2647 ± 363	411 ± 625	3197 ± 545[a]	2901 ± 590	3070 ± 518	2726 ± 568	472 ± 348
PlayerLoad™ (AU)	2675 ± 157	2534 ± 123	2604 ± 114	2496 ± 202	179 ± 276	2786 ± 180[a]	2623 ± 179	2691 ± 206	2599 ± 169	187 ± 197

Values are mean ± SD; $p \leq 0.05$ vs. fourth quarter using a one-sample t-test ([a]).

5.3.4 Results summary: winning games, halves and quarters

This is the first investigation in Gaelic football to combine physical, technical and tactical analysis from an integrated team perspective. The results, summarised in Tables 5.29 to 5.31, illustrate the PIs which differentiated between winning and losing, across full games, halves and quarters in the RT examined. There were differences in 2 game statistics and 11 PIs in winning full games, as summarised in Table 5.29. Specifically, the RT received more yellow and less black cards, attacked more frequently from midfield, obtained more free kicks in attack, executed more shots and demonstrated a superior shot efficiency and productivity rating. This resulted in more scores and a higher frequency of scores, including both overall points scored and points from play obtained. However, the total distance covered and volume of running performed was lower.

The total distance covered was also lower in winning halves, partly due to reductions in LIA and walking. Including these 3 physical metrics, a total of 21 differences were evident in winning halves, as summarised in Table 5.30. The RT had a higher percentage team possession, although they reported fewer restarts from overall dead balls and kick outs. This resulted in fewer successful dead ball kick passes and kick outs. Nonetheless, the increase in possession translated into a higher frequency of attacks, shots and shots from play, resulting in both a superior shot and attacking efficiency. The differences highlighted in attacking play in halves were also evident in winning quarters. Similarly, in winning both halves and quarters, the RT was more effective with their possession, demonstrating a higher productivity rating and lower average attack per score. This resulted in a higher frequency of scores encompassing more points, including both points from play and from dead balls and goals.

Differences were evident in 43 PIs in winning quarters, as summarised in Table 5.31. The percentage, total time and average time per team possession was higher, whereas possessions originating from defence was lower. The frequency and total time in player possession was also higher, as was the number of player possessions originating from both midfield and attack. Defensive efficiency and attacks originating from defence were higher along with overall turnovers, and turnovers obtained in midfield. Combined passes were higher and the frequency and percentage of successful combined passes was also higher, consequently the frequency and percentage of unsuccessful combined passes was lower. The frequency and success rate of hand passes and percentage of successful kick passes was higher, whereas the frequency and percentage of unsuccessful kick passes was lower.

Similar to halves, the RT had fewer restarts from overall dead balls and kick outs in winning quarters. The percentage success of dead ball kick passes increased and the frequency and percentage of unsuccessful dead ball kick passes decreased. There was also a decrease in the frequency of both successful and unsuccessful kick outs. Walking distance was also lower in quarters won. Interestingly, there was no significant differences between winning and losing in HIR, VHIR, or indeed in PlayerLoad™, across full games, halves and quarters. In summary, differences in PIs were more apparent in winning quarters (n=43), compared to halves (n=21) and full games (n=11).

Table 5.29 Summary of differences demonstrated by the RT in winning full games, n=8 compared to losing, n=12

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
	Attack ↑ no. from MF				**Activity profile** ↓ running
	Shot ↑ no., & efficiency	**Free kick won** ↑ no. in AT			**Match measures** ↓ total distance
	Score ↑ total, no., points, points from play & productivity				

↑ = higher, ↓ = lower, No. = number, MF = midfield, AT = attack.

Table 5.30 Summary of differences demonstrated by the RT in winning vs. losing halves, n=19

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↑ %	**Attack** ↑ no. & efficiency **Shot** ↑ no., no. from play & efficiency **Score** ↑ total, no., points, points from play & from dead ball, goals & productivity & ↓ average AT/score			**Dead ball** ↓ no. **Dead ball kick pass** ↓ no. successful **Kick out** ↓ no. & no. successful	**Activity profile** ↓ walking **Match measures** ↓ total distance & low-intensity activity

↑ = higher, ↓ = lower, No. = number, AT = attack.

-Table 5.31 Summary of differences demonstrated by the RT in winning vs. losing quarters, n=34

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↑ %, time, time/possession & no. from DF **Player** ↑ no., time & no. in MF & AT	**Attack** ↑ no., no. from DF & efficiency **Shot** ↑ no., no. from play & efficiency **Score** ↑ total, no., points, points from play & from dead ball, goals & productivity & ↓ average AT/score	**Turnovers** ↑ no. & no. in MF **Efficiency** ↑	**Combined** ↑ no. & no. & % successful & ↓ no. & % unsuccessful **Hand pass** ↑ no. & no. successful **Kick pass** ↑ % successful & ↓ no. & % unsuccessful	**Dead ball** ↓ no. **Dead ball kick pass** ↑ % successful & ↓ no. & % unsuccessful **Kick out** ↓ no., no. successful & no. unsuccessful	**Activity profile** ↓ walking

↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield, AT = attack.

5.3.5 Results summary: temporal changes across halves and quarters

This is also the first study to combine team physical, technical and tactical analysis in the evaluation of temporal changes between the first and second halves and from the first to the fourth quarter. The results, summarised in Tables 5.32 to 5.37, illustrate temporal differences in PIs across all games and in both winning and losing contexts. When both winning and losing games were combined, there were 5 differences evident across the technical, tactical and physical PIs examined between the first and second halves, as summarised in Tables 5.32 to 5.34. Specifically, there was a reduction in the number of player possessions originating from midfield, frequency of combined hand and kick passes, and frequency and percentage of successful tackles. Consequently, there was an increase in the percentage of unsuccessful tackles. In games won, 7 differences were found including reductions in team possessions, attacks and free kicks originating in midfield, total free kicks and percentage successful tackles. There was also an increase in the percentage of unsuccessful tackles and in attacks originating from defence. In games that were lost, there were 11 differences in technical, tactical and physical PIs between the first and second halves. These included a reduction in team possessions and turnovers originating in defence, player possessions originating in midfield, frequency of combined passes and frequency of hand passes and high-speed running. In addition to more distance covered in the standing speed zone, there was also an increase in team possessions and attacks originating in midfield, shots from play and overall attacking efficiency.

There were 10 differences in performance characteristics between quarter 1 and quarter 4 when all games were examined, as summarised in Tables 5.35 to 5.37. Specifically, there were reductions in team possessions, unsuccessful combined passes and unsuccessful kick passes, jogging and high-speed running, total distance, LIA, HIR, VHIR and PlayerLoad™. There was an increase in the number of tackles originating in attack. In games that were won, differences were found in 6 PIs. Specifically, there was a reduction in team possessions, attacks and dead ball free kick passes, and possessions, attacks and free kicks originating in midfield. In games that were lost, there was a reduction in 10 PIs including team possessions and turnovers originating in defence, frequency and percentage of unsuccessful kick outs, jogging and high-speed running, total distance, HIR, VHIR and PlayerLoad™. There was however, an increase in both the tackles originating in attack and the percentage of successful kick outs.

Table 5.32 Summary of differences demonstrated by the RT in the second half compared to the first half across all games, n=20

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Player ↓ no. in MF		**Tackles** ↓ no. & % successful & ↑ % unsuccessful	**Combined** ↓ no.		

↑ = higher, ↓ = lower, No. = number, MF = midfield.

Table 5.33 Summary of differences demonstrated by the RT in the second half compared to the first half in games won, n=8

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↓ no. in MF	**Attack** ↓ no. from MF & ↑ no. from DF	**Tackles** ↓ % successful & ↑ % unsuccessful **Free kick won** ↓ no. & no. in MF			

↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield.

Table 5.34 Summary of differences demonstrated by the RT in the second half compared to the first half in games lost, n=12

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↓ no. in DF &↑ no. in MF **Player** ↓ no. in MF	**Attack** ↑ no. from MF & efficiency **Shot** ↑ no. from play	**Turnovers** ↓ no. in DF	**Combined** ↓ no. **Hand pass** ↓ no.		**Activity profile** ↑ Standing ↓ high-speed running

↑ = higher, ↓ = lower, No. = number, DF = defence, MF = midfield.

Table 5.35 Summary of differences demonstrated by the RT in the fourth quarter compared to the first quarter across all games, n=20

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↓ no.			**Combined** ↓ no. unsuccessful **Kick pass** ↓ no. unsuccessful		**Activity profile** ↓ jogging & high-speed running **Match measures** ↓ total distance, low-intensity activity, high-intensity running, very high-intensity running & PlayerLoad™

↓ = lower, No. = number.

Table 5.36 Summary of differences demonstrated by the RT in the fourth quarter compared to the first quarter in games won, n=8

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↓ no. & no in MF	**Attack** ↓ no. & no. from MF	**Free kick won** ↓ no. in MF		**Dead ball free kick pass** ↓ no.	

↓ = lower, No. = number, MF = midfield.

Table 5.37 Summary of differences demonstrated by the RT in the fourth quarter compared to the first quarter in games lost, n=12

Aspect of play					
Possession	**Offence**	**Defence**	**Passing**	**Dead ball distribution**	**Physical performance**
Team ↓ no. in DF		**Turnovers** ↓ no. in DF **Tackles** ↑ no. in AT		**Kick out** ↓ no. & % unsuccessful & ↑ % successful	**Activity profile** ↓ jogging & high-speed running **Match measures** ↓ total distance, high-intensity running, very high-intensity running & PlayerLoad™

↑ = higher, ↓ = lower, No. = number, DF = defence, AT = Attack.

5.3.6 Study 3 summary

The third study has further explored the comprehensive range of technical and tactical PIs examined in studies 1 and 2 and extended previous findings through the incorporation and evaluation of additional physical metrics. This combined approach has facilitated an integrated analysis of the performance of an elite Gaelic football team and revealed a range of physical, technical and tactical PIs that distinguished between winning and losing full games, halves and quarters. In addition, temporal changes in PIs between the first and second halves and from the first to the fourth quarter were outlined for all games combined and for both winning and losing contexts. Overall, the results provided specific insights regarding the team PIs that contributed to winning for this particular RT.

CHAPTER 6

DISCUSSION

6.1 Introduction

The main findings from the three studies conducted are considered and interpreted within the ensuing discussion. In this chapter, key themes from the research studies are contextualised within existing scientific and performance knowledge. In part 1, the discussion initially explores the technical and tactical PIs examined in Study 1, which differentiate between winning and losing games from three perspectives: 1a) analysis of all teams combined, 1b) sub-group comparisons and 1c) temporal changes between the first and second halves and from the first to the fourth quarter. In Part 2, the technical and tactical PIs associated with winning halves and quarters from Study 2 are contemplated. Finally, in Part 3, the technical, tactical and physical performance characteristics of the RT examined from Study 3 are initially considered (3a), prior to a discussion of the differentiating PIs in relation to the outcome of full games, halves and quarters (3b) and lastly in relation to temporal changes between halves and quarters (3c).

The discussion addresses specific findings associated with match characteristics and game statistics, possession, offence, defence, passing and dead ball distribution and where appropriate, multiple aspects of performance are combined, to provide an integrated interpretation of performance. Knowledge gleaned from each study is used to progress and evolve the discussion. Consequently, insights gained from the initial comprehensive technical and tactical evaluation of all teams was used to inform the holistic interpretation of the technical, tactical and physical performance of the RT.

6.2 Part 1: Winning full games; technical and tactical PIs (Study 1)

This first part of the discussion of Study 1 considers the main findings from the analysis of all games combined and explores the technical and tactical team PIs that differentiate winners from losers in relation to the outcome of full games. The importance and contribution of both traditional and novel PIs to winning games are highlighted. The next section explores the PIs that contributed to winning (and losing) within the RT, OTs and also for those teams competing in the AICSFF. When the match sample is examined by team context (i.e., RT, OTs or AICSFF), insights into the tactical strategies and technical profiles that distinguish winners from losers can be derived and performance benchmarks established. In the concluding section of the discussion for study 1, the implications of the temporal differences in PIs, demonstrated by winners and losers of full games, are examined in relation to specific aspects of play, following consideration of variations in games statistics.

6.2.1 Part 1a: Winning games; winners vs. losers

Gaining and using possession effectively to create and convert scoring opportunities is considered fundamental to successful match outcome and therefore winning games. In the multivariate analysis, both dteam possession origin midfield and dplayer possession origin attack were incorporated into the midfield-counterattacking component that explained the highest amount of variance (33%) between winners and losers in the PCA model. In addition, dplayer possession time (total) was highly loaded onto the possession component, and to a lesser extent incorporated into the defensive-counterattacking component, which explained 12% and 16% of the total variance, respectively. However, there were no differences reported in any possession characteristics between winners and losers in the univariate comparisons. This is in contrast to results recently reported from a comprehensive analysis of all possessions examined from the 2016 AIC (21). This study found differences between winners and losers in the frequency and overall percentage of possession even though the difference in possession between winners and losers was similar in both studies (W: ~51% vs. L: ~ 49%).

The midfield- and defensive-counterattacking PIs identified highlight the importance of instigating counterattacks from turnovers to create scoring opportunities from play. Interestingly, although midfield-counterattacking explained nearly double the total variance described by defensive-counterattacking, only the latter PI was found to differentiate between winning and losing teams. Indeed, the classification accuracy of 87.5% revealed for this novel component, was superior to the 71% reported previously using DA (20) in Gaelic football and comparable to the 88% reported using LogR in Australian football (17). Perhaps, the evaluation of the relative difference between winners and losers and use of a more extensive PI range in the present study, can explain the enhanced accuracy found compared to the previous Gaelic football study.

It is likely that successful Gaelic football teams regain possession through turnovers, generated via tackling, interceptions and/or unforced technical errors. In the present study, winners had more turnovers than losers confirming previous results (21,40). Both winners and losers generated 55% of their turnovers in defence, 40% in midfield and 5% in attack. A similar trend was reported from the analysis of turnovers during the 2016 AIC (21). In this study 70% of turnovers occurred in defence, whereas only 24% occurred in midfield (21). Turnovers are often produced from organised tackling strategies, although presently only 11% of tackles performed by winners and losers were deemed successful. This may be due to poor technical execution and/or a focus of tackling the player instead of the ball. The highest numbers of tackles in both winners and losers were recorded in midfield, reflecting the congested nature of this highly contested zone. In accordance with previous foul distribution results (46), both winners and losers committed approximately 50% of fouls in midfield, suggesting that teams may have employed a defensive press in this zone.

A common practice among inter-county teams when not in possession, is to withdraw all or some of their attacking players to establish a defensive screen, within which defensive actions are concerted. The defensive screen can range from 45 or 65 m from their goal line. This concentrated defensive tactic can result in turnovers if attacking teams do not have a tactical strategy to penetrate the defensive screen or the technical skill to shoot for scores from long range. Although these defensive formations are often viewed negatively within the media, it is likely that this tactic contributed to the higher number of turnovers acquired by both winners and losers in defence and midfield. The higher incidence of tackling in midfield, may indicate a greater utilisation of defensive screens in the middle third. In contrast, the higher number of turnovers generated in defence in 2016 (21), suggested more regular deployment of screens closer to the scoring zone. It is also likely, that the emergence and utilisation of congested defences (i.e., and screens) has propagated the evolution of defensive-counterattacking strategies.

Overall, winners performed more combined defensive actions (i.e., turnovers, tackles and fouls committed) in midfield, whereas losers committed slightly more in defence, supporting previous results (46). Between the 1980s and 2014-16, the percentage of passes completed in midfield increased from 51% to 56% (41). Similar to tactics adopted in other codes (e.g., soccer and Australian football) modern Gaelic football teams maintain control of the game by retaining possession (69). Using this strategy, teams patiently try to engineer offensive plays through probing organised formations or by having the opposition continually move their defensive lines in response to attacking players running to create and exploit space in their defensive positions (69). However, adoption of a high-press strategy (i.e., by the defensive team) may produce more turnovers in midfield and attack enabling counterattacks to be instigated in closer proximity to the opposition's goal, and may even occur before the opposing team have had time to organise their defensive system. Although the high-press strategy is associated with greater risk, the potential benefits of this approach were highlighted in recent findings, which revealed that from a scoring perspective, turnovers in attack or possession gained from a short opposition kick out, were very effective (21).

The ratio of turnovers to scores was recently reported to be 1:3 and 1:4 in defence and midfield, respectively (21). Not surprisingly, winners were more effective at ultimately executing shots from turnover possessions gained in these zones (21). While the outcome of turnovers originating in defence or midfield were not examined in the present study, the importance of defensive-counterattacking in differentiating between winners and losers was clearly evident and supports previous findings (21,38). Although defensive turnovers require the ball to be transferred, often through a large number of players towards the opposition's goal, they can however, result in successful counterattacks particularly when opposition players have committed to attack. Even though successful teams are cognisant of this risk and retain a degree of defensive structure, counterattacks incorporating intelligent deployment of offensive players and successful execution of technical skills enable purposeful penetration of both organised and disorganised defensive systems.

The attacking strategy of winning inter-county teams was associated with a more favourable average attack to score and productivity rating compared to losers. Similar findings have been reported for elite county teams (21) and successful club teams (125). The number of team possessions in both winners and losers (~72) was similar to those reported previously (46) with 4 out of every 10 possessions resulting in a scoring attempt. A lower average count of team possessions (~48) was reported by researchers who excluded the goalkeeper kick out from the overall possession count, although nearly a third of these possessions were converted to scores (21).

Three quarters of the shots were taken from open play. The importance of this PI was reflected in its inclusion in both the defensive- and midfield-counterattacking components generated by the PCA. In this study of NFL and AIC games, shot efficiency differentiated winners (53%) from losers (46%), replicating findings involving AIC games

(20,21,40), and suggests enhanced technical performance or decision making ability of winners (47). Congested defences result in players having reduced space and time to attempt shots. It is likely that players are being coached to be more clinical in their shot execution to negate defences (21).

The 97% success rate for hand passes was identical to that recently reported in inter-county games (41,46) and reinforces the importance placed on this mode of ball transfer. The high hand pass retention rate is likely to have contributed to the successful attack outcomes previously highlighted. In a recent study it was found that in comparison with passing sequences of 4 or fewer, longer chains of 5 or more passes were superior in regards to both shot conversion and score return (21).

The importance of dead balls in influencing match outcome is evident by the fact that approximately 60% and 65% of team possessions for winners and losers, respectively are instigated from a restart. In winners, kick outs accounted for 48% of dead balls, in comparison to the 51% for losers. The average kick out success of 66.5% across full games for both winners and losers was higher than the results reported previously for top (61%) and bottom (56%) ranked teams (40). The higher success may be attributed to a number of factors including improved coaching, enhanced technical ability, opposition tactics (i.e., employing a high press or deep defensive shield) and contemporary strategies directed towards ball retention (i.e., short kick outs). In 2016, 47% of all kick outs from the AIC were characterised as being short (21), which was much higher than the 30% reported from a sample of NFL and AIC games spanning from 2014-16 (46). Both kick outs and defensive free kicks provide a platform for teams to execute their offensive strategies.

Not surprisingly, almost 95% of all passes from free kicks were retained by both winners and losers, emphasising the primary importance being placed on dead ball restarts for ball retention to facilitate developing an attack.

6.2.2 Part 1b: Winning games; RT vs. OTs, OTs vs. RT and AICSFF

In winning, the RT spent greater time in both team and player possession than OTs. During both winning and losing, the RT had more team possessions than the OTs. These findings combined, indicate that the RT favoured passing strategies that prioritised retention of the ball, primarily using hand passing as opposed to the more direct kicking tactic. This contention is supported by the higher number of hand passes and total passes in the RT when losing to OTs. A similar, but non-significant finding, was also found when the RT won. In contrast, in both winning and losing contexts, the number of kick passes performed by the RT and OTs were very similar. The importance of hand passing for teams involved in the final stages of the championship is evident from the fact that winners from the AICSFF performed a higher percentage of successful passes and lower percentage of unsuccessful passes compared to losers.

In winning, the OTs had less team possessions in defence compared to the RT in losing. The lower possession count in defence for the OTs may be explained by the lower frequency of attacks and total scores obtained by the RT. This was probably related to the subsequent reduced volume of possession restarts (i.e., kick outs) executed by OT goalkeepers, as the number of turnovers in defence was similar between both teams in this context. The OT had less player possessions overall and player possessions originating in midfield when winning, indicating a more efficient transition of the ball from defence to attack. In addition, the OTs were more effective at converting this possession into scores as evinced by lower average attack per score and higher productivity (i.e., scores per 10 possessions) results. Although there were no differences in both winning and losing contexts, the OTs tended to obtain more team and player possessions originating in attack. This may be due to the use of a high-press tactic as the OTs had more defensive actions originating in attack than the RT, when losing. The OTs also had more defensive actions in midfield in both winning and losing contexts and this contributed to their higher overall defensive actions.

These findings suggest that the OTs prioritised pressing the RT in attack and midfield in an attempt to regain possession, whereas the RT did not employ this same strategy as regularly. The RT tended to concede kick outs to the opposition by withdrawing players back into defensive formations. The same principle applied if the RT lost possession during play via a turnover. When winning, the OTs gained more turnovers, particularly in midfield by thwarting the RT as they prepared to attack. In contrast, the RT gained more turnovers in defence when winning, perhaps facilitated by the defensive shield and organisation employed and increased player density (i.e., number of players congested around the ball) (68) experienced by the OTs in that zone of the pitch.

Differences in strategies implemented to contest possession of the ball were also evident. In comparison to the RT, the OTs performed more tackles in both winning and losing contexts, particularly in midfield. Although, the OTs had more unsuccessful tackles, the pressure applied to the ball carrier by players from OTs may have delayed the momentum of the RT and/or resulted in a subsequent turnover later in the phase of play. The OTs performed more tackles in attack compared to the RT when losing and interestingly this value was higher compared to when the OTs won games. Perhaps this was associated with concerted attempts to regain possession in the scoring zone, where there was a greater probability of converting a turnover to a scoring opportunity or score (21).

The RT won more free kicks in both winning and losing contexts. The difference only reached significance in losing games. In winning games, the RT obtained more free kicks originating in defence. This may have been due to their defensive organisation. When winning, the OTs conceded more free kicks in midfield compared to the RT. This perhaps could be related to the midfield press already mentioned and/or use of tactical fouling to disrupt the momentum (46) and attacking play of the RT. Interestingly, when winning the RT obtained more yellow cards and fewer black cards compared to when losing. The yellow cards may have been linked to tactical fouling by the RT during play to maintain their winning status, whereas not having to re-adjust personnel due to unplanned player replacement in response to a black card, was also obviously advantageous.

When winning the OTs distributed fewer dead balls overall compared to the RT. This was evident by their lower number of free kick passes and kick outs. The OTs also performed fewer successful dead ball kick passes, replicating the finding reported from winners from the AICSFF. These results are not necessarily negative and may be related to the offensive and/or defensive abilities of the RT as previously outlined. When compared to the OTs, the RT had a higher frequency of free kick passes and retained a higher number of these passes in winning and losing contexts. Retention of possession through proficient technical execution of free kicks is important to enable penetration into the opposition's defensive zone and to subsequently create scoring opportunities. The direction of passes were not examined. It is likely that some passes may have been in a lateral or backwards direction and therefore the influence of this PI on overall performance is unclear.

As expected, winners from the AICSFF had a higher total score and superior productivity compared to losers. In winning games, the OTs had a higher frequency of attacks and attacks originating in defence compared to the RT. When the analysis of all teams and games was combined, defensive-counterattacking was the only novel PI out of the four components identified from the PCA, able to differentiate winners from losers. Therefore, the ability to instigate successful attacks resulting in scores from defence is important. These findings indicate that the OTs were more effective at transitioning the ball from defence to offence and may explain the greater number of games won than lost by OTs. In addition to having a superior total score in winning games, both the RT and OTs had superior shot efficiency, number of points and points from play and a lower average attack per score. The OTs also had a higher productivity rating and goal frequency. It is apparent that these attacking qualities, which represent a culmination of various technical skills and are influenced by the tactics employed by the coach, are essential components of successful performance (i.e., winning). The underperformance of the RT in the games lost may be partly explained by results obtained in attacking PIs.

6.2.3 Part 1c: Winning games; temporal changes across halves and quarters

There was no difference in average playing time between the first and second halves or between the first and fourth quarters. The increase in stoppage time in both the second half and fourth quarter resulted in a decrease in ball in play time during these periods. Unfortunately, the frequency, cause and duration of each stoppage was not recorded, making it impossible to determine the percentage of stoppage time due to injuries and/or substitutions. There was no difference in the number of free kicks conceded or dead ball restarts executed across match periods. It is therefore likely that the additional stoppage time is related in part to the increase in the number of substitutions and the additional time related to the relative increase in black (i.e., for winners and losers) and yellow (i.e., for winners) cards issued in the second half of games.

A similar reduction in ball in play time and increase in stoppage time was reported across halves in a retrospective analysis of FIFA World Cup final games between 1966–2010 (68). The increase in stoppage time was due to an increase in the average duration and not frequency of stop events. The interaction between ball in play and stop periods can impact work to rest ratios and influence the intensity of subsequent play periods (68). The ensuing trend towards shorter more intense periods of play (68) and increased high-intensity running distance and actions (148), has the potential to impair physical performance as fatigue has been suggested to increase towards the end of games (80). Fatigue has been shown to impair activity profiles in Australian football through reductions in physical performance across halves and quarters (57,78). In the present study, it is unclear whether the increase in total stoppage time resulted in shorter, more intense periods of play in the second half. Nonetheless, the potential impact of physical decrements related to high-intensity activities and fatigue on decision making and technical competence towards the latter stages of games cannot be discounted.

Among winners, there was no difference in possession characteristics between the first half and the second half of play. In contrast there was a decline in the total time for both team and player possessions in losers suggesting that the technical and tactical superiority of winners translated into more effective retention of possession. The decrease in the frequency of team possessions, gained in both defence and midfield in the second half by losers contributed to the reduction in successful transitions from defence to attack in this period. The ability to counterattack, particularly from defence, but also from midfield, is dependent on a team gaining and maintaining possession, and the importance of defensive-counterattacking in distinguishing winners from losers has already been established. Similarly, a recent Gaelic football study reported that winners were more efficient at translating possession gained in defence and midfield into scoring opportunities compared to losers (21), highlighting the importance of effective counterattacking.

The frequency of team possessions was reduced in winners and losers in the fourth quarter. Among winners, this contributed to the decline in attacking frequency and in the number of player possessions in attack. Perhaps as a consequence, losers experienced less player possessions in defence but also in midfield. Additionally, psychological factors that may impact a player's performance need to be considered. It is likely that player motivation may decline if the outcome of a match is known in the second half due to superior opposition or a perceived unsurmountable lead. This may manifest as a decrease in physical performance and reduced effort attempting to regain possession (149,150).

It is plausible that the reduction in possession characteristics among losing teams was related to their passing profiles. In contrast to winners, losers had a reduction in the frequency and success rate of hand passes and in the number of kick passes executed across both halves and quarters. These findings indicate that winners throughout the duration of a game, have a superior level of technical execution and competence in passing compared to losers. Interestingly, the number of unsuccessful kick passes performed by losers decreased in the fourth quarter. This small improvement in kick passing competence by losing teams in the latter stages of games may be related to the fact that less pressure is applied to either the (kick) passer or intended receiver due to a reduction in the number of players congested around the ball (68). A reduction in player density provides players with more time and space (68). The probability of scoring in soccer has been shown to increase when there is more than 1 m of free space around the player taking a shot (151). Variations in player density may result from changes in tactical strategy during situations when either the contest is still in dispute or the outcome of the game is likely known. It is also plausible that more space will be available to pass or receive the ball in the latter part of games (23,50) due to decrements in performance resulting from the onset of fatigue (68).

Winners had a higher percentage of free kick passes retained in the second half. Losers in contrast, retained a higher percentage of their own kick outs in the fourth than the first quarter of play. These differences may be related to better technical execution of the dead ball pass. The influence of changes in the tactical deployment of players causing a lower player density for kick passer and/or receiver may also explain the superior retention rate of short as opposed to long kick outs reported previously (21,39,46). Teams often withdraw attacking players into defensive roles to increase the player density and defensive pressure on the ball carrier (68) within the defensive zone. This tactic allows the opposition to retain possession of short kick outs because the defending team does not apply the same level of tackling pressure outside of their established containment zone. Therefore, teams that adopt a deep defensive screen often concede the defence of kick outs or free kicks to the opposition, to enable their own players to retreat into organised protective formations.

The hypothesised lower player density may also be attributed to a reduction in the overall defensive intensity of winners in the latter stages of games. There was a reduction in midfield turnovers in the second half by winners, perhaps related to a reduction in their overall tackling success rate. Winners also had less turnovers and performed fewer tackles in attack in the fourth quarter. They also had a reduced number of attacks in both the second half and last quarter. These findings support the contention that winners may have withdrawn some of their attacking players into defensive roles and as a result, may not have committed the same number of players to attack or to press the opposition in their own defensive zone. Interestingly, the tactic of withdrawing players into defensive roles to try and protect a lead, may not have been as effective as planned or anticipated as winners had a decline in defensive efficiency in both the second half and fourth quarter. The decline in defensive efficiency coincided with an increase in the attacking efficiency of losers who executed a higher number of shots in the second half. This may have been influenced by the ability of losers to retain their own kick outs and translate the possession into scoring opportunities (21,39).

Conversely, there was a decline in the defensive performance of losers. Turnovers in defence were lower in both the second half and last quarter, and overall defensive actions and defensive actions in defence were lower in the fourth quarter. The frequency of defensive actions in defence in losers may have been lower due in part to the opposition not committing as many players to attack. Conversely, losers could have released players from their defensive roles and committed them to attack to obtain scores. As a consequence, in the second half losers performed more defensive actions in attack. A combination of losing teams releasing players from their defensive roles and encouraging them to attack, and winning teams withdrawing some of their players into defensive roles, resulted in attackers of winning teams experiencing a lower player density in the opposition's defensive area. The creation of space and time for decision making and technical execution, particularly for scoring attempts is obviously advantageous and preferable when attacking (68). The hypothesised lower player density in the latter stages of games combined with the reduction in defensive performance reported in the second half in both winners and losers, may partly explain the higher total scores often obtained by teams in the second halves of games.

6.3 Part 2: Winning halves and quarters; technical and tactical PIs (Study 2)

This part of the discussion considers the main findings from the analysis of all games combined and explores the technical and tactical team PIs that differentiate winners from losers in relation to the outcome of halves and quarters. The importance and contribution of the novel PIs to winning halves and/or quarters are highlighted.

Scoring opportunities are created from successful attacks, initiated from either a restart or turnover in possession, resulting in a counterattack. Previously, it was found that midfield-counterattacking explained the majority of the variance in the PCA conducted on full games in Study 1(a). In the same study, defensive-counterattacking was also found to differentiate winners from losers. In the present study, attacks originating from midfield during quarters and from defence during both halves and quarters were found to be important in distinguishing winners from losers. Furthermore, midfield-counterattacking was again found to explain the majority of the variance in the analysis of halves (25%) and quarters (20%) and also distinguished between winners and losers in the subsequent GEE analysis of these periods. In contrast to the results of full games, a defensive-counterattacking PI was not derived from the analysis of both halves or quarters due to dattack origin defence being excluded from the PCA models because its KMO score within the AIC matrix was less than 0.5. Although defensive-counterattacking goals scored was derived from the PCA for quarters, this variable explained the lowest proportion of the variance (8.3%) and was not found to be significant in the GEE model.

Successful counterattacking relies on a team's ability to transfer the ball from their own defence or midfield into their attacking zone, further emphasising the importance of the possession component. Although, the number of attacks was not significantly different between teams during halves, the higher attacking efficiency demonstrated by winners in both halves and quarters illustrates their ability to translate possession and attacking entries into scoring opportunities. This was evident in the higher volume of shots and shots from play executed by winners. The greater overall shot efficiency (i.e., reflecting offensive dead ball efficiency) in winning teams may indicate a superior technical competence and/or decision making ability (47). It is also likely that players from winning teams have benefitted from quality coaching and become more clinical in their shot execution (21). The proficiency of winning teams was also evident in their lower average attack per score and higher productivity (i.e., scores per 10 possessions), potentially providing an indication of the team's possession effectiveness (125). These PIs combined with the higher total points and goals scored, demonstrated that winning teams had more effective attacking strategies compared to losing teams across both halves and quarters. These results support the findings from full games reported in Study 1(a) and from previous studies (21,125).

There were no differences in the number of tackles, free kicks won or defensive actions between winners and losers. However, the higher defensive efficiency of winners in both halves and quarters indicated that winners defended their goal in a more organised and effective manner. When not in possession, contemporary Gaelic football teams have adopted strategies that require some or all attacking and midfield players to track back and establish defensive screens in front of their goal. This tactic, evinced by the low-press efficiency component, contributes to congesting the defensive and midfield zones, increases player density (68) and reduces the relative space for opposition attacking players to exploit. This tactical approach enables defending players in close proximity to tackle in groups to increase the probability of regaining possession of the ball. Although this strategy requires midfield and attacking players to possess high levels of physical fitness, it has proven effective at generating counterattacks. Many conservative coaches adopt this approach over a high press alternative, which can expose individual defenders and is therefore, deemed a higher risk option.

Importantly, the fact that high-press efficiency is included as a component demonstrates that winning teams can employ this tactic successfully. The findings also suggest that employing a high press in quarter 1 is more effective at contributing to winning than employing the same tactic in quarter 4. It is possible that towards the latter stages of games, winning teams may tactically withdraw some of their attacking and/or midfield players into defensive positions. This tactic is used to either protect a lead or facilitate their defensive-counterattacking strategy. This may also explain why midfield-counterattacking contributed more to winning in quarter 2 compared to quarter 4.

Throughout halves and quarters, only 11% of tackles were successful and nearly three times more tackles were performed in defence and midfield than attack. Each individual tackle was noted during the tagging process. During situations where players from one team tackled an opponent in groups, only one of the tackles made by the players trying to dispossess an opponent was deemed successful. The component tackle pressure was derived from a combination of tackles originating in defence and tackles categorised as unsuccessful (i.e., not directly resulting in turnover of possession). Many of the initial unsuccessful tackles may have contributed to a subsequent successful tackle outcome if possession was regained following the second or third tackle in a particular series. The proposed withdrawal of players into defensive formations in the latter stages of games, already highlighted, may also partly explain the greater importance of tackle pressure to winning in the second half. In soccer, recovery of the ball in the attacking zone, has been shown to translate into a greater percentage of scoring opportunities being created and a higher percentage of goals being scored compared to any other zone (152,153). Importantly, turnovers from tackling resulted in the highest percentage of scoring opportunities and goals scored (152). Similarly, findings from a recent Gaelic football study revealed that possession was more likely to result in a shot if originating in the attacking zone and gaining possession from an opposition kick out was also a significant predictor of possession leading to a shot (21). These findings combined provide a rationale for Gaelic football teams to consider a high press and highlight the potential benefits of coaching players to tackle more effectively and target turnovers in the offensive zone (153).

The higher number of turnovers gained by winners compared to losers in defence during halves and in defence and midfield during quarters again highlights the importance of defensive- and midfield-counterattacking as outlined in Study 1(a) and supports findings published previously from full games (21). In addition, winning teams are more successful in converting possession obtained from their defensive zone into shots (21).

Successful (i.e., top 4) soccer teams competing in the UEFA Champions League created more scoring opportunities following turnovers, from both their defensive and defensive midfield zones compared to less successful (i.e., ranked 5-16) teams (153). Other researchers have found that successful teams who recovered the ball in their defensive zone, were more effective at using penetrative passes to increase their number of shots and goals (8) and that a shot resulting from a counterattack had a positive effect on the probability of winning (154).

Winning teams had a higher percentage (53% vs. 47%) of overall possession than losers in both halves and quarters, even though the number of possessions were very similar. Likewise, in Australian football, a higher total time and percentage of time in possession of the ball was associated with winning quarters of games (155). With respect to full games, winning teams have higher percentages of ball possession in both Gaelic football (21) and soccer (6,7,10). Time in possession has been shown to be superior in higher ranked teams and in teams competing against lower opposition, whereas time in possession decreased by 3% when playing away from home (156). In the present study, the higher total time, average duration of team possessions and increased number and duration of individual player possessions, may indicate a technical and tactical superiority in the ability of winning teams to effectively retain possession of the ball, which is fundamental to creating scoring opportunities. The higher number of player possessions in midfield by winning teams, suggests that successful teams perhaps employed passing strategies in midfield to invite their opponents to abandon their defensive positions in an attempt to regain possession. This could have potentially occurred more in the second half, when losing teams were behind on scores, which enabled subsequent gaps to be exploited by the winning team.

The increase in possession demonstrated by winning teams translated into a higher number of total (i.e., hand and foot) passes and a higher percentage combined pass retention rate compared to losers throughout both halves and quarters. This finding was influenced by the higher number and success rate of hand passes performed by winners. During open play, the ball is predominantly transferred using a hand pass. This technique has previously been shown to be the primary method used to initiate counterattacks (38). However, the potential benefits of initiating a counterattack with a long kick pass from the defensive zone should also be considered. Investigators in soccer have suggested that this strategy increases the prospect of scoring and reduces the chance of conceding scores from opposition turnovers (153). Similarly, a long kick out (i.e., pass), for example following a restart, can also be used effectively to initiate an attack by being directed into the opposition's defensive zone. This has the advantage of bypassing a large number of opposition players, and if a turnover is obtained by the opposition, there is less risk of conceding a score directly as the ball has to be transferred into their attacking zone. Although the number of kick passes was very similar between winners and losers across match periods, the percentage of kick passes retained in quarters was higher in winners. This indicates that losers were unable to retain possession as effectively when they opted to kick pass and may not possess the technical ability or tactical organisation to adopt a more direct style of attack.

The number of free kicks was similar in winners and losers. Therefore, the lower volume of dead balls distributed by winners in both halves and quarters was mostly influenced by fewer restarts executed from kick outs compared to losers. This likely reflected the superior defensive efficiency of winning teams, which limited the number of shots and scores obtained by the opposition, ultimately resulting in fewer kick outs. Conversely, winning teams employed more effective attacking strategies that facilitated an increased number of shots and subsequent scores. This resulted in a greater number of kick outs by the opposition goalkeeper. This reflects previous findings which found that losing teams had 20% more kick outs than winning teams (21). Even though winners had fewer successful dead ball kick passes, their percentage retention rate was higher in quarters but not halves, perhaps supporting the contention that winning players were more technically proficient at kick passing than losing players.

During halves, dead balls were the primary mode of initiating a team possession and accounted for 59% and 65% of total team possessions obtained for both winners and losers, respectively. This highlights the importance of developing dead ball strategies that facilitate retention of possession, result in penetration into the opposition attacking zone and conclude with a score. In addition, successful teams likely develop tactics to negate the dead ball restart (i.e., kick out) strategy of the opposition as the percentage of opposition kick outs won has previously been shown to differentiate top from bottom teams (40) and distinguish between winners and losers in games where the difference was ≥ 6 points (20).

6.4 Part 3: Winning and losing for RT; physical, technical and tactical PIs (Study 3)

In this section, the combined technical and tactical characteristics and physical performance metrics of an elite Gaelic football team (RT) are initially examined and key PIs that differentiate between winning and losing are then identified in relation to full games, halves and quarters. The influence of PIs on match/period outcome are explored through direct comparison with previous results from winners and losers (i.e., from studies 1 and 2). Next, temporal changes in physical, technical and tactical PIs across halves and quarters are considered overall and in relation to winning and losing contexts. When interpreting these findings, it should be noted that the temporal changes were influenced by a variety of contextual factors, highlighted within the discussion.

Through combining performance data analysis, interpretations can be contextualised in a manner that is not possible when both technical and tactical (e.g., Studies 1 and 2) or physical results are examined in isolation. In addition, evaluation of halves and quarters can provide insights and enhance understanding of specific factors that contribute to period and overall match outcome (i.e., win or lose) as presented in Studies 1 and 2. Furthermore, exploration of match characteristics and game statistics assists with contextualising the performance data. The implications of the main findings in relation to both physical conditioning and technical practice are considered in the ensuing discussion.

6.4.1 Part 3a: Physical, technical and tactical performance characteristics; RT

In interpreting the physical, technical and tactical performance profiles obtained in this study, it is important to examine the anthropometric and fitness capacities of the RT players and the tactical approaches employed by the coaching team. In comparison to data presented in Table 2.1 for modern players (i.e., from studies ≥2015), the RT had a slightly younger profile (age; 24.5 vs. 25.9 y) but were similar in (height; 181.9 vs. 182.1 cm) and body mass (83.5 vs. 84.2 kg). Although, there were no aerobic capacity results reported for modern players, the mean estimated $\dot{V}O_{2max}$ of 56.5 ± 3.3 $ml \cdot kg^{-1} \cdot min^{-1}$ achieved by the RT was comparable to the 57.0 ± 3.9 $ml \cdot kg^{-1} \cdot min^{-1}$ reported previously for Gaelic footballers (76). Overall, the anthropometric and aerobic fitness profiles demonstrated by the RT were comparable to benchmarks previously established in the literature.

In terms of tactical deployment, to enhance the team's defensive organisation, some attacking players were often assigned roles characterised as either an additional (i.e., third) midfielder or as defensive sweepers (Figure 2.2). Outfield players were regularly tasked with alternating between high- and low-defensive presses when not in possession. During offensive play, the team utilised a combination of long direct kicks, multiple short hand passes and/or carried the ball into the attacking zone, with the latter two strategies requiring players to perform repeated support runs, to pass or receive the ball. These tactical roles and strategies directly influenced the activity and technical profiles obtained from the players. Nevertheless, the primary aim of this RT was to gain and maintain possession, transfer the ball into the attacking zone to create scoring opportunities and convert as many of these chances as possible into scores.

6.4.2 Part 3b: Winning full games, halves and quarters; RT

The physical and technical performance profile obtained during match play is likely influenced by: the player's; prior experience, training age, fitness level and fatigue status, context; home or away, competition status (i.e., league or championship) and importance, stage of season (i.e., early, mid, late), level of opposition (i.e., Tier 1-4), pacing and tactical strategy (43,57,157–160). Many of these factors are considered in the development of the tactical strategies communicated by the coach, rehearsed in training and implemented during specific competitive games. Although tactical strategies will vary in the defensive and offensive formations employed and roles in which players are deployed, the fundamental aim of most strategies, excluding those premised on rigid congested defences and damage limitation, is to convert possession into scoring opportunities and scores.

The tactical and technical execution of a game plan requires players to possess high levels of physical conditioning to maintain sufficient performance levels throughout the duration of a game. Importantly, if performance levels are perceived to decline, coaches can also use their substitution options to positively impact the dynamic or momentum of play, by introducing new players to enhance the physical profile, creativity and/or organisation of their teams. Not surprisingly, there were no significant differences between winning and losing match periods in the frequency of substitutions made as coaches generally availed of the opportunity to rotate players. Unfortunately, the analysis conducted in this study did not specifically examine the technical or physical impact of these substitution players in isolation and it is therefore difficult to interpret whether the substitution strategies employed by the RT contributed to match outcome.

The importance of possession was highlighted in Study 1(a) with the principal component possession found to explain ~12% of the variance between winners and losers during full games. These results were supported by a recent study, which found that winners had a higher frequency and overall percentage of possession than losers in the 2016 AIC. In games lost by the RT throughout two competitive seasons, there was a small but non-significant decline (-3%) in the percentage of overall possession. Similarly, possession was found to be lower in soccer when playing against stronger opposition and interestingly, was greater when losing games than when winning (161–163). Players also covered a greater total distance when their team was losing (164). They also covered a greater distance walking and jogging when playing against stronger teams (7). Players from less successful teams (i.e., those competing at the bottom of the table) also covered more total distance than teams ranked in the top five (165).

The RT covered significantly more total distance and performed more running in full games lost, supporting the findings highlighted from soccer. In Australian football, the percentage time running at >14 $km \cdot h^{-1}$ (~equivalent to HIR) and >19 $km \cdot h^{-1}$ (~equivalent to VHIR) without possession was significantly greater in quarter wins than losses (155), indicating the contribution of this component to match period wins. Physical performance with- and without-possession was not evaluated in the present study. It is plausible that the significant increase in total distance and running in full games lost, reflected a greater requirement of the RT players when not in possession to move into specific field positions and defensive formations (e.g., Figures 2.2 and 2.3) to deny space, thwart offensive manoeuvres and chase and pressurise the opposition to regain possession (166). In support of this view, stronger positive correlations were found between the total distance ran by some playing positions and opposition time in possession compared to the relation between distance ran and time in possession demonstrated by a RT (46). It is reasonable to postulate that when losing, the players may have stretched their physical capacity in an attempt to draw or win the match (164). Furthermore, total distance, walking and LIA, was lower in halves won compared to halves lost and walking was lower in quarters won compared to quarters lost. It is unclear whether these findings were due to: fatigue, situational or psychological factors, or indeed a combination of these and/or other factors.

Possession explained ~20% of the variance in winning both halves and quarters and was also found to contribute significantly to winning these periods (Study 2). In contrast to full games, the percentage of overall possession by the RT was higher in winning both halves (7.5%) and quarters (6.1%). This highlights the importance of possession in determining the outcome of specific periods and potentially the match. In winning quarters, 8 of the 13 PIs associated with team and player possession were significantly different compared to losing, whereas only 1 variable was significant in winning halves. The discrepancy in these findings may be related to the greater sample used in the comparison of winning and losing quarters (n=36, win:lose), compared to halves (n=19, win:lose) and full games (n=8 win vs. n=12 lose).

In winning quarters, the RT was more effective at retaining possession. This was demonstrated by the higher total time and average duration of team possessions. It was also reflected in a higher frequency and total time of individual player possessions. Similarly, in winning quarters in Australian football, time spent in possession was higher than without possession, whereas there was no difference in time spent with or without possession reported between winning and losing full games (155). It was speculated that this discrepancy may have been due to the influence of the cumulative effect of the four quarters on reducing the sensitivity of possession on match outcome (155).

The differences found in possession in winning quarters in the present study was reflected in a higher frequency and success rate of both combined (i.e., hand and kick) passes and also hand passes in addition to a higher percentage of successful kick passes. At the same time the frequency and percentage of unsuccessful combined passes and kick passes was lower. This would seem to indicate more effective technical execution of passing by the RT players, when winning compared to losing quarters. It is also possible that less pressure may have been applied to either the passer or receiver by the opposition players. Moreover, the percentage of successful dead ball kick passes was higher in winning compared to losing, whereas the percentage of unsuccessful kick passes and kick outs was lower. These findings support the contention that the technical execution of the RT players was better when winning. An alternative explanation may be that the opposition players withdrew into defensive positions and conceded the possession restart(s).

The decrease in total kick outs executed in winning quarters contributed to the reduction in team possessions originating from defence in winning compared to losing. Even though the frequency of possessions was lower in defence during quarters won, attacks originating from defence were found to be higher. This is important because, defensive-counterattacking goals explained ~8% of the variance in quarters (Study 2), whereas defensive-counterattacking explained 16% of the variance and was found to significantly contribute to winning full games (Study 1a). Counterattacking generally results from turnovers and the increase in overall turnovers and turnovers originating in midfield during quarters, may have reduced the relative penetration of the OTs into the attacking zone in these periods. The superior defensive efficiency of the RT when winning compared to losing quarters reduced the number of shots resulting from opposition attacks. The RT's ability to regain possession in midfield and translate this into attacks was important because midfield-counterattacking explained ~33%, 25% and 20% of the variance in winning full games (Study 1a), halves and quarters (Study 2), respectively and, also contributed significantly to winning halves and quarters as demonstrated in Study 2.

Turnovers in attack resulting from the adoption of a defensive system in the attacking zone, similar to the high-press efficiency component previously identified (Study 2), explained ~10% of the variance between winners and losers in both halves and quarters. However, this component was only found to differentiate winners during quarters. In winning full games, the RT had more free kicks originating in attack. It is possible that the increase in free kicks originating in attack was due to the adoption of a high press, highlighting the potential benefit of employing this tactical strategy.

Furthermore, translating dead ball opportunities into scores is desirable as the component offensive dead ball efficiency explained ~13% of the variance in halves and quarters and this component was also found to significantly contribute to winning quarters.

In relation to the attacking PIs (n=19) examined in the RT, there were differences between winning and losing in full games (n=8), halves (n=13) and quarters (n=14). Compared to losing, attacking efficiency was higher in winning halves (7.4%) and quarters (11.0%), although the difference in full games (6.7%) was not significant. The superior attacking efficiency of the RT was reflected in a higher number of shots and an improved shot efficiency in all periods. Shots from play were higher in halves and quarters won resulting in a lower average attack per score being recorded in these periods. Possession was also used more effectively in all match periods by the RT when winning, evinced by the higher productivity (i.e., scores per 10 possessions) ratings achieved.

From the match period sample analysed, it is clear that attacking PIs differentiated the performance of the RT in winning compared to losing. Additional factors also contributed to explaining the period outcome, with differences found more frequently in halves and quarters. An increase in the sample of full games may provide additional insights and replicate the differences found in the performance characteristics highlighted in halves and quarters.

6.4.3 Part 3c: Temporal changes across halves and quarters; RT

A decrease in ball in play time and increase in stoppage time and frequency of substitutions was previously reported between the first and second halves and from the first to the fourth quarter (Study 1c). In losing match contexts in the present study, the increase in stoppage time in both the second half and last quarter, may have been related to the opposition tactics of disrupting any positive momentum of the RT by regularly stopping play. In addition, to the increase in the number of substitutions compared to the first half and quarter 1, delays due to the ball going out of play, fouls or injuries could have been manipulated (i.e., time wasting). The decrease in ball in play time, in the second half was similar to findings reported from analysis of soccer World Cups from 1966–2010 (68), although no change in ball in play time was noted in another soccer study (81). A positive correlation between ball in play time and total distance and high-speed distance run by Gaelic football players was previously reported (46). It is plausible that the decline in ball in play time in both the second half and last quarter in games lost impacted negatively on the running performance of the Gaelic football RT examined in this study.

In comparing the first to the second half, the only significant team physical performance decline was a reduction in high-speed running in games lost. Similar reductions in high-speed running were previously reported in inter-county hurling (142) and Australian soccer (54), whereas no difference was found in the pilot study (Appendix F) conducted as part of this research project or in English soccer (79). Various contextual factors may help to explain the discrepancies in studies, as inconsistent results have also been reported in respect of HIR and VHIR. Some studies have failed to find a significant reduction in HIR during the second half (167), whereas others have reported declines in HIR (81,165) and VHIR (53,165). Conflicting results were also reported in Australian football, with one study showing a decrease in HIR in the second half (57), although this trend was not replicated in a more recent investigation (78). Unfortunately, none of these studies examined team performance or considered the data in relation to winning or losing. Nonetheless, the data from the RT indicate that most physical PIs did not decline significantly across halves, potentially influenced by the tactics, pacing and substitution strategy employed by the coaching team.

In contrast, declines in physical PIs were more pronounced when comparing quarter 1 to quarter 4. The decrements in physical performance observed across all games combined replicate findings in the pilot study (Appendix F) and from other previous research (50). In the pilot study, there was a decline in PlayerLoad™, HIR and HR responses during the last 15 min of games, supporting similar findings of decrements in total distance covered and high-speed running (≥4.7 $m \cdot s^{-1}$) distance in quarter 4 (50). Decrements observed in HIR (56,57,78) and in total distance (57) from quarter 1 to quarter 4 have been reported during Australian football. The decline in exercise intensity may be due to high levels of fatigue, although the influence of tactics and opponent performance may be contributing factors (57). Reductions in HIR (≥4.0 $m \cdot s^{-1}$) through comparisons of the first and last 15 min periods (79) have also be reported in soccer, reinforcing the contention that fatigue occurs towards the end of games (80).

The postulated reduction in exercise (i.e., match) intensity and observed physical performance declines in LIA, HIR and VHIR may help to explain the decline in PlayerLoad™, as this metric is influenced by accelerations, decelerations, locomotor activities and physical impacts. The decrements in physical performance that occur towards the latter stages of games (23) may coincide with a decrease in player density (68) and manifest in a reduction in the intensity of man-to-man marking or incidence of physical contests. Interestingly, declines in physical performance in quarter 4 were observed in games that were lost but not in games that were won. It is unclear whether these decrements were due to situational, fatigue or psychological factors and/or contributed to the overall outcome. For example, a perception that the game was unwinnable, may negatively impact a player's motivation and subsequent performance (149,150) and result in a reduced effort to gain or regain possession.

With the exception of high-speed running, there were no other notable differences in physical performance between halves. From a coaching perspective, it is important to know whether the decline in physical performance, observed in the last quarter of all games and particularly in games lost, manifested in reduced technical performance. Unfortunately, there are limited studies documenting actual team performance and the available literature generally represents a collation of player profiles (81,165,168). Previous analysis of skill related performance in soccer players reported declines from the first to the second half in involvements with the ball, short passes and successful short passes (165). In addition, reductions in total possession and ball distributions (i.e., passes) were reported between halves and from the first to the last 15 min of the game (168). In contrast, no significant differences in possession or passing characteristics between match halves or indeed the first and last 15 min of games were reported in another study (81). Unfortunately, differences were not examined in relation to winning or losing in these studies.

In the present study, possession frequency and time did not differ between the first and second halves across match contexts when examined at either a team or individual player level. Previously, it was found that winners did not experience the same reduction in time in possession (i.e., team and player) and frequency of possessions (i.e., player) as losers (Study 1c). In this same sample of games, team possession frequency decreased in quarter 4 in both winners and losers, whereas only player possession frequency decreased in losers. In the present study, team possession frequency declined during quarter 4 in all games, and also in winning but not losing. Maintenance of possession frequency in quarter 4 in games lost, may partly be explained by the increase in playing time reported in both the second half and quarter 4 in these games. The higher baseline frequency of team possession in quarter 1 in winning compared to losing and the subsequent greater difference observed when compared to quarter 4, potentially explains why the decline was only significant in winning and not losing. Nevertheless, the decrease in the frequency of team possessions overall in quarter 4 may indicate a decline in match intensity (57).

The importance of gaining possession in defence or midfield to instigate direct (i.e., from a restart) attacks or counterattacks has been highlighted previously (Studies 1a and 2). In games lost in this study, team possessions originating in defence declined in the second half and last quarter. This decline was associated with similar reductions in turnovers in the defensive zone in these periods. These findings replicated the trend observed for losers in Study 1(a). A reduced ability to regain possession in defence, limits the potential for defensive-counterattacking. The importance of this component has previously been identified (Study 1a). In games won, team possessions originating in midfield declined in the second half, which coincided with an increase in attacks originating in defence and a reduction in free kicks won in midfield. The ability of the RT to retain possession and transfer from defence to attack combined with the inability or reluctance of the OTs to concede free kicks (i.e., foul) potentially contributed to this reduction. Conversely, in the second half of games lost, team possessions for the RT increased in midfield, mirroring the finding of losers from Study 1(c). This increase in team possessions in midfield coincided with a non-significant increase in free kicks obtained by the RT in this zone. This may have been due to tactical fouling by the OTs to disrupt momentum and thwart attacks. Consequently, there was an increase in attacks originating from midfield in games lost for the RT, whereas there was a decline in games won.

Although, player possessions originating in midfield were maintained in the second half in games won, they declined across all games and in games lost, mirroring temporal results from Study 1(c). This suggests an inability to either carry or pass the ball through this zone in these contexts, perhaps due to physical, technical or tactical limitations, or potentially being subjected to a higher defensive press by the opposition. Although, not directly examined, this decline may reflect fewer defensive players making support runs into midfield when their team was attacking and similarly, fewer offensive players coming into midfield to create space in the attacking third. Forwards may also have performed less defensive tracking of OT players.

Player possessions declined in midfield during quarter 4 of games won. This suggests that as the match entered the latter stages, the RT adopted a more direct attacking and/or counterattacking style involving fewer passes and/or committed less players forward, evinced by the reduction in tackles originating in attack in this period. In Study 1(c), it was reported that in quarter 4, there were less player possessions in attack in winning and less in defence and midfield in losing. The decrease in player possessions originating in defence in games lost by the RT, may also suggest a more direct kick out strategy in an attempt to maintain possession and gain territory more rapidly. In support of this strategy there was an increase in the success of dead ball kick outs, which potentially also indicates less pressure on the ball receiver due to the opposition withdrawing attacking players towards the defensive area. The RT may also have attempted to limit player possessions in defence, to prevent OT turnovers being converted into scoring opportunities and scores in this zone. Recent research found that possession obtained in the attacking zone from an opposition kick out was a predictor of resulting in a shot (21).

Interestingly, in the second half, the percentage of successful tackles declined across all games and in games won, but not lost, again replicating findings from winners in Study 1(c). This suggests that the RT were more effective at tackling when there was additional pressure to regain possession and address the match score differential (i.e., when losing). This also supports the association between the greater emphasis on regaining possession and increase in total distance covered by teams when losing, alluded to previously (164,166).

In the present study, there was a reduction in the total number of combined (i.e., hand and kick) passes in the second half in all games and in games lost. The decline was attributed primarily to a reduction in hand passes. The reduction in passing experienced by the RT replicated findings from soccer, where declines in total passes (168) and short passes (165) were found in the second half of games, although match outcome was not considered. The reduction in passing by the RT coincided with a non-significant decrease in the total time in team possession in all games from 530 to 476 s and in games lost from 548 to 458 s, respectively. This trend approached the significance level reported in losers in the second half in Study 1(c).

Although non-significant, the percentage of team possession decreased from 54.3% to 51.2% in all games and from 53.9% to 49.1% in games lost, between the first and second halves, respectively. In Study 1(c), a similar trend was reported for losers, whereas winners increased their percentage possession in the second half. Although, these findings did not reach statistical significance, they indicate a greater reduction in the duration and overall percentage of possession in losing compared to all games combined. Consequently, the OTs had more possession in games where the RT lost. The reduction in passing may also be related to changes in player movement profiles (i.e., players running to be in a position to give or receive a pass) or may reflect the enhanced effectiveness of the opposition in gaining turnovers. In quarter 4, there were fewer unsuccessful combined passes and kick passes across all games, perhaps due to less pressure on both the kick passer and/or receiver as highlighted previously (Studies 1c and 2), although there was no difference between winning and losing.

An improvement in attacking efficiency was observed in the second half of games lost, albeit the score of 64.2% obtained in the first half was considerably lower than the 69.8% and 78.2% reported for the first halves of all games and games won, respectively. This replicated the lower shot efficiency findings in losers in Study 1(c). Reasons for this inefficiency in the first half of games lost was potentially addressed at half time through coaching and rotation of players, although the improvement in the second half was obviously not sufficient to alter the eventual match outcome. Nonetheless, the enhanced attacking efficiency in the second half resulted in more shots from play, similar to Study 1(c). Unfortunately, the shot efficiency in the games lost by the RT was the lowest recorded and perhaps reflected poor decision making and/or technical execution, which could have been related to fatigue and/or greater player density and therefore, defensive actions in the opposition's defence.

CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The main findings from the three studies that identified the team PIs that distinguish between winning and losing in elite Gaelic football are summarised below. Furthermore, specific recommendations for advancing current practice are incorporated within each study summary. In addition, the contribution of this research to extending the existing scientific knowledge base is outlined. A number of study limitations are presented and consideration of these has assisted in the development of a rationale for various future research directions. Throughout the research project, a number of issues emerged that demonstrated significant gaps in the performance evaluation of elite Gaelic football in comparison to other professional football codes. Therefore, to address this deficit and to facilitate the overall development of elite Gaelic football, general recommendations for consideration by the GAA, are also outlined.

7.2 Main findings and recommendations for advancing current practice

7.2.1 Study 1: Winning full games; technical and tactical PIs

In Study 1, a comprehensive range of technical and tactical PIs were explored across five aspects of play: possession, offence, defence, passing and dead ball distribution, and significant differences were demonstrated between winners and losers in a combined sample of NFL and AIC games (n=24), as summarised in Table 3.43. Specifically, winners were distinguished from losers by their superior offensive characteristics; they executed 29.5 ± 5.7 shots and achieved a shot efficiency of 53.2 ± 11.5%. Winners also demonstrated a superior ability to generate more turnovers (~32.5 ± 7.5 per game) and used the hand pass effectively to retain possession with a success rate of 97.6 ± 1.2%.

Moreover, the benefit of using PCA to combine a large number of existing PIs into new aggregated PIs was illustrated. Four novel component PIs explained ~82% of the variance in the outcome of full games (Figure 3.3 and Table 3.16). These were midfield-counterattacking (33%), defensive free kick efficiency (20%), defensive-counterattacking (16%) and possession (12%). Defensive-counterattacking was the only component PI found to significantly differentiate winners from losers. To determine the effectiveness of defensive-counterattacking to predict match outcome, a LOOC was used in conjunction with both DA and LogR and the two models demonstrated a classification accuracy of 87.5%. The results from the PCA analyses and subsequent LOOC classification for both the full games (Study 1a) and halves and quarters (Study 2) are summarised in Table 7.1.

The defensive-counterattacking PI identified confirmed the importance of designing and practicing tactical strategies that promote the generation of turnovers in the defensive area to be converted into effective counterattacks. Therefore, coaches need to incorporate game based scenarios that target and facilitate the development of effective transitioning from offence to defence and from defence to offence into their field practice sessions. In addition to refining and optimising the performance of their own team, coaches should consider tailoring these plans on an ongoing basis to address and exploit strengths and weaknesses in the opposition.

In the sub-sample analysis conducted within Study 1(b), differences in the technical and tactical PIs that differentiated winning from losing: in the RT compared to the OTs (n=8), in the OTs compared to the RT (n=12) and in winners from the AICSFF (n=4) compared to losers, were presented and summarised in Tables 3.44 and 3.45. With the exception of shot efficiency and other offensive characteristics, the RT and OTs demonstrated different performance profiles when winning compared to losing, which reflected the diverse tactical strategies employed and experienced by these opposing teams. However, the superior ability of the OTs to attack from defence compared to the RT, partly explained their increased frequency of winning games (i.e., 12 vs. 8) and reinforced the importance of the novel defensive-counterattacking PI previously identified.

Overall, successful teams were more effective at instigating attacks (or counterattacks) from their own defensive zone and employed strategies that promoted the efficient transition of the ball from defence to offence. For example, as well as demonstrating very high hand pass retention rates (97.5 ± 1.4%) winning teams from the AICSFF also achieved 2.4 ± 0.8 scores for every 10 possessions, demonstrating their efficient translation of possession into scores (i.e., productivity). In addition to effective counterattacking, winning games therefore requires teams to possess attacking qualities, which result in superior shot efficiency and overall productivity ratings. There is a need for coaches to develop and enhance the shooting competency of their players. This facet of performance can be improved through targeted drills that challenge and promote effective movement (i.e., decoy and support runs) and decision making under pressure (i.e., decide to carry, pass or shoot), whilst honing and embracing the creative individual flair of players during attacks.

In the final analyses of Study 1(c), temporal changes between the first and second half and from the first to the fourth quarter were examined across all games (n=24). Differences that contributed to the performance of winners and losers and influenced match outcome were revealed, as summarised in Tables 3.46 and 3.47. Across halves and quarters, losers experienced greater declines in possession characteristics and passing profiles compared to winners. As winners did not exhibit the same reduction in these technical PIs, it is clear that winners were more effective at retaining possession. Notably, winners demonstrated reduced defensive efficiency in the second half, however, losers were unable to translate an improved attacking efficiency, resulting in more shots in the second half, into a higher number of scores. This may be due to winners employing defensive systems that resulted in losers attempting shots from outside the traditional scoring zone, and/or because losers demonstrated inferior technical shooting competence, perhaps influenced by the manifestation of fatigue.

Consideration should therefore be given to the development of strategies and practice drills that emphasise acquiring possession, for example: contesting restarts, tackling effectively, gaining interceptions and generating turnovers. Additionally, the ability of players to retain possession can be practiced and enhanced using progressively challenging passing drills and competitive scenarios that simulate the intensity of match play and require players to demonstrate tactical awareness and technical proficiency in increasingly fatigued states (i.e., replicating the last quarter of games). This can help to ensure that players (and teams) have the necessary conditioning and technical competence to maintain sufficient performance levels and attenuate the decrements often observed in the latter stages of games. Similarly, to exploit the scoring opportunities that may arise from defensive gaps in the second half and/or last quarter, it is equally important for players to practice shooting competence under fatigued conditions.

7.2.2 Study 2: Winning halves and quarters; technical and tactical PIs

The findings from Study 1 were extended in Study 2 through the examination of all halves (i.e., first and second; n=49) and quarters (i.e., 1,2,3 and 4; n=85) combined. The univariate analysis demonstrated the technical and tactical PIs that differentiated winners from losers in halves and quarters, across the five aspects of play evaluated, as summarised in Tables 4.11 and 4.12, respectively. In winning both halves and quarters, in addition to demonstrating superior possession and passing characteristics, winners achieved more turnovers in defence and also attacked more frequently from defence, which supported and confirmed the importance of defensive-counterattacking. Furthermore, winners also achieved more turnovers and also attacked more frequently from midfield in winning quarters, which highlighted and reinforced the contribution of midfield-counterattacking.

In study 2, the analysis of PIs was progressed using a PCA, followed by a GEE, to initially identify the contribution of novel components to winning either halves or quarters and then to determine if particular components contributed more to wining specific halves or quarters, which extended the previous temporal analysis conducted in study 1. Six components explained ~84% of the total variance in the outcome of halves (Figure 4.1 and Table 4.9). These were midfield-counterattacking (25%), possession (19%), offensive dead ball efficiency (13%), high- (11%) and low- (10%) press efficiency and tackle pressure (6%). Four of these components: midfield-counterattacking, possession, low-press efficiency and tackle pressure, all contributed significantly to winning halves, with possession and tackle pressure contributing more to winning in the second than the first half. Using the four components contributing to the outcome of halves, the associated LOOC demonstrated a mean accuracy of 77.5% for predicting match outcome (Table 7.1).

Similarly, six components explained ~81% of the total variance in the outcome of quarters: midfield-counterattacking (20%), possession (20%), offensive dead ball efficiency (13%), high- (9%) and low- (9%) press efficiency and defensive-counterattacking goals (8%) (Figure 4.2 and Table 4.10). The components: midfield-counterattacking, possession, offensive dead ball efficiency and high-press efficiency, contributed significantly to winning quarters, with high-press efficiency and midfield-counterattacking contributing more to winning in quarters 1 and 2, respectively, in comparison to quarter 4. Using the four components contributing to the outcome of quarters, the associated LOOC demonstrated a mean accuracy of 76.5% for predicting match outcome (Table 7.1).

Winning halves and quarters highlight specific aspects of play, for example: counterattacking, possession, passing (i.e., including dead ball distribution), shooting (i.e., including shots from dead balls) and tackling (i.e., utilising a combination of low- and high-press strategies), that should be practiced regularly. Effective development of these technical and tactical PIs can contribute to optimising overall performance and improve period (i.e., half and quarter) and match outcome (i.e., winning).

7.2.3 Study 3: Winning and losing for RT; physical, technical and tactical PIs

In Study 3, differences across full games (win; n=8 and lose; n=12), halves (win and lose; n=19) and quarters (win and lose; n=34) in the technical, tactical and physical performance of the RT were examined in relation to winning and losing. In the sample of matches obtained from two complete competitive seasons, differences in PIs were more apparent in winning quarters (n=43; Table 5.31), compared to halves (n=21; Table 5.30) and full games (n=11; Table 5.29).

Likewise, temporal changes in PIs were more pronounced when examined by quarter (n=10; Table 5.35) compared to half (n=5; Table 5.32) across all games combined. Significant alterations were also more evident in games lost (H: n=11; Table 5.34 and Q: n=12; Table 5.37) compared to games won (H: n=7; Table 5.33 and Q: n=6; Table 5.36). Physical performance levels in the RT were generally maintained across halves and quarters in games that were won, compared to changes in performance observed in games lost (H: n=2; Table 5.34 and Q: n=6; Table 5.37). In contrast, the number of technical and tactical performance differences were similar between games won (H: n=7; Table 5.33 and Q: n=6; Table 5.36) and lost (H: n=9; Table 5.34 and Q: n=6; Table 5.37), suggesting that performance outcome was determined by small but important variations in these PIs.

To attenuate the declines in physical performance observed, particularly towards the latter stages of games and in games lost, coaches and support staff can use these results to inform the design and prescription of specific interval running conditioning drills and game based scenarios. These activities should address the acquisition, retention and effective use of possession (i.e., to contribute to scoring) alongside the development of both extensive and intensive endurance capacities.

Table 7.1 Summary of the novel performance indicators derived from the principal component analyses of match periods and the associated classification accuracy in predicting match outcome

Analysis	Full games	Halves	Quarters
Principal component analysis, performance indicators and explained variance (%)	Midfield-counterattacking (33) Defensive free kick efficiency (20) Defensive-counterattacking (16) Possession (12)	Midfield-counterattacking (25) Possession (19) Offensive dead ball efficiency 13) High-press efficiency (11) Low-press efficiency (10) Tackle pressure (6)	Midfield-counterattacking (21) Possession (20) Offensive dead ball efficiency (13) High-press efficiency (9) Low-press efficiency (9) Defensive-counterattacking goals (8)
Total explained variance (%)	**81.9**	**83.5**	**81.0**
Discriminating performance indicators	Defensive-counterattacking	Midfield-counterattacking Possession* Low-press efficiency Tackle pressure*	Midfield-counterattacking# Possession Offensive dead ball efficiency High-press efficiency#
Match outcome predictive accuracy (%)	**87.5**	**77.6**	**76.5**

*Performance indicator contributed more to winning in SH vs. FH, # Performance indicator contributed more to winning in Q1 & Q2 vs. Q4.

7.2.4 Thesis summary and conclusions

This research project has used comprehensive video analysis and innovative player tracking technology to explore technical, tactical and physical aspects of elite Gaelic football performance in a sample of games from the NFL and AIC. The benefit of using PCA to facilitate data (i.e., variable) reduction was demonstrated through the incorporation of an extensive range of technical and tactical PIs into new aggregated variables. Using progressive analyses, winners were distinguished from losers, across full games, halves and quarters, using a combination of traditional and novel PIs. In addition, temporal differences between the first and second halves and from the first to the fourth quarter were highlighted for winners and losers when all teams were combined and also between winning and losing contexts for the RT.

The emergence and utilisation of defensive screens and congested defences has likely facilitated the generation of turnovers during play and propagated the evolution of contemporary counterattacking strategies. Regardless of whether possession originates in defence or midfield (or indeed attack), the results from the investigations outlined demonstrate that successful teams are more effective at counterattacking and transitioning from defence to offence. Winners are more efficient at generating turnovers and translating possession through effective passing into scoring opportunities and scores, evinced by superior shot efficiency and productivity ratings. Therefore, to obtain a competitive advantage, elite teams should incorporate these key aspects of performance into their preparation programmes. Rehearsing and refining technical skills and tactical approaches and developing necessary physical capacities through progressive practice scenarios, will enable teams to execute their strategies effectively during games.

7.3 Research contributions

At the elite level, Gaelic football is evolving and subject to influences from other sports. Coaches, support staff and players are constantly striving to obtain a competitive edge by evaluating and employing strategies and interventions that promote marginal gains in performance. This research has illustrated how innovative technologies and novel analysis approaches can be used to address knowledge gaps and specific research questions in relation to our understanding of performance and what it takes to win. The combined use of univariate and multiple multivariate analyses techniques and integration of technical, tactical and physical PIs, support and extend findings from previous studies conducted in Gaelic football. Moreover, the differences and temporal alterations in technical, tactical and physical PIs demonstrated provide important insights that enhance understanding of how specific periods and overall matches were won and lost.

Through the publication of articles in peer reviewed journals and conference presentations, these studies have contributed to enhancing the limited scientific literature pertaining to the performance evaluation of elite Gaelic football teams. The PIs and winning profiles presented in this thesis have expanded the current knowledge base and improved contemporary understanding of key factors that should be considered by coaches and support teams in developing preparation and performance strategies for elite players. For example, the results, categorised into five general aspects of play:

possession, offence, defence, passing and dead ball distribution, can be used as a comprehensive reference for coaches and practitioners in establishing team benchmarks and targets for specific match periods. In addition, the novel component PIs identified can be used to inform the development of physical, technical and tactical practice. The information provided can also be used by coaches and practitioners to: develop, plan and implement their tactical strategies and assist with optimising match performance.

In summary, the three studies designed and conducted within this project addressed the initial research questions and identified the PIs which discriminated between winning and losing teams and also showed temporal differences between winners and losers. The results obtained from the methodology employed and subsequent interpretation, have contributed significantly to expanding the existing knowledge base. Moreover, the recommendations for advancing current practice presented within this thesis and highlighted in the published papers, can contribute to ensuring that the theoretical findings identified, positively impact preparation and performance and attenuate the ‘theory-practice gap’ (33) previously discussed. In conclusion, the information contained within this research thesis regarding the team PIs that discriminate between winning and losing can be used as a reference to enhance knowledge of what it takes to win, inform advancements in current practice by improving coaching and team preparation and inspire possible future studies.

7.4 Limitations

The main limitations associated with this research are outlined below and are considered in relation to the match sample, PI range and analyses conducted.

7.4.1 Match sample

The relatively small sample of games (n=26) precluded a comparison of NFL (n=16) and AIC (n=10) games. Although semi-finals and finals from both the NFL and AIC were included, the overall performance profiles presented may have been influenced and slightly underestimated by results obtained from early stages of the NFL. Unfortunately, physical performance data was evaluated from one RT only.

7.4.2 Performance indicators

Although a diverse range of technical, tactical and physical performance metrics were included, it is possible that other PIs not examined in this research, contributed to match outcome. The direction (i.e., forwards, lateral or backwards) and length (i.e., short or long) of passes and kicks outs was not examined. The derived PI global defensive actions was combined from fouls, turnovers and tackles, but the original fouls PI also included non-intentional (i.e., technical) fouls, which should not be classified as a defensive action.

7.4.3 Analyses

In the sub-group analysis, there was a difference in the comparisons relating to the number of games won by the RT (n=8), OTs (n=12) and teams competing in the AICSFF (n=4). In the analysis of halves and quarters, the performance profiles used complete match data and were therefore based on halves that had slightly different (although non-significant) durations, which also influenced the calculation of subsequent quarters. Team data was examined and no between or within player analyses were performed. An evaluation of the impact of substitution players was not included. Although not directly assessed, it is likely that the results obtained were influenced by various contextual and/or psychological factors that were not considered.

7.5 Future research

The majority of the performance research conducted to date in elite Gaelic football has been descriptive or observational in nature and essentially employed isolated measures. To progress understanding of performance, there is a need to examine specific constructs in a multifactorial manner and integrate physical, technical and tactical data with psychological perspectives from players and coaches, i.e., how does in-game or real-time feedback or instruction influence activity profiles, technical execution or tactical deployment? How does positive and negative momentum influence performance and/or how do players respond to challenging scenarios (i.e., when winning by a narrow margin, or when drawing or loosing)? Are game based practice scenarios the most effective methods to develop and optimise defensive organisation and counterattacking strategies? What is the best way to prepare substitution players to maximise their impact on the game? Addressing and answering these questions may assist with expanding current knowledge and enhance the holistic development and preparation of players. In addition, in relation to the limitations highlighted previously regarding the match sample, PI range and analyses conducted, some other considerations for future research are presented below.

7.5.1 Match sample

To extend these findings, performance profiles incorporating a range of physical, technical and tactical PIs, should be obtained from a large sample of teams competing across different competitions and seasons and analysed in relation to match score i.e., when winning, drawing or losing.

7.5.2 Performance indicators

Future studies should include PIs relating to: counterattacking (i.e., from defence, midfield or attack) and the direction and length of both passes and kick outs. In addition, important PIs emerging from other football codes should be examined and considered to determine their contribution (if any) to winning in elite Gaelic football.

7.5.3 Analyses

To enhance knowledge regarding the PIs which differentiate between winners and losers, future studies should also consider evaluating the effect of final score line difference, i.e., ± 3, 6, 9, and 12 points on PIs to determine the effect of winning and losing on performance. PIs expressed relative to actual playing or ball in play times, could be examined in conjunction with physical performance data. Replicating the analysis methods employed in this study could be used to validate the use of the novel component PIs identified and assist with establishing these as KPIs. In addition, it is worth evaluating contextual factors such as the influence of: home advantage, level of opposition and stage of season, on overall team performance and match outcome. Examining physical performance with- and without-possession may provide further insight into the relationship between running performance and possession with other technical and tactical components and psychological factors associated with match/period outcome. Finally, the team PIs could be complimented by examining the performance profiles of successful players, enabling position specific player benchmarks to be developed.

7.6 General recommendations for consideration by the: GAA, county officials, coaches, support practitioners, players and researchers

1. The relatively small sample of games from 2014-15 utilised in this project precluded appropriate consideration and analyses of contextual factors such as: comparisons between stage of season (i.e., early, middle or late), competitions (i.e., NFL vs. AIC), venue (i.e., home, away or neutral) and level of opposition (i.e., Tier 1-4). A central server/repository containing video footage and applicable contextual information should be established by the GAA to collate relevant information from all NFL and AIC games. This would facilitate prospective and retrospective performance analyses to be conducted using dedicated computer algorithms and/or machine learning and enable for example, the evolution of game play to be determined in addition to the impact of changes in playing rules to be comprehensively examined, in larger and statistically more powerful samples.

2. The GAA should consider and progress the commissioning of a performance science/applied research division, similar to departments already established and active in professional football codes, to coordinate and align practice and research activities across the Gaelic games community/network. This division could assume responsibility for: agreeing core PIs and operational definitions; examining current developments in other football codes; evaluating and approving the use of specific training interventions (e.g., return to sport), nutritional practices (e.g., supplements) or technologies (e.g., player tracking devices); interpreting findings

from research studies and distilling key take home messages and implications for improving practice to coaches, support teams, officials and players. This unit could also facilitate or promote the development of a dedicated journal focusing on applied practice and research in Gaelic games.

3. The GAA should consider the implementation of non-invasive video technologies to facilitate player tracking within Croke Park and the other nominated provincial and/or county stadiums.

4. With the evolution of player tracking technologies, computer software and analysis programmes, media broadcasting and audience interactions, there is merit in the GAA contemplating and developing or accessing a performance database similar to that provided by Champion Data for the AFL. This platform uses 'cutting edge, agile technology' to provide 'data driven insights with speed and precision' in a 'dynamic visual package' (169). A dedicated collaboration such as this could address the need for a centralised approach to capturing, storing, processing and visualisation of performance data (e.g., technical, tactical and physical) patterns and trends and align practices within counties, thereby eliminating/reducing existing inefficiencies and/or expenditures. This would also enable practitioners and researchers to access, analyse and interrogate a significant range of PIs across multiple levels (e.g., team or individual) and periods.

5. There is limited information pertaining to how training practices and loads impact competition performance in Gaelic football. Given the significant expenditure currently invested in the preparation of elite inter-county teams, findings from applied research and relevant case studies should be used to inform and develop best practice guidelines for training programme design and prescription and competition scheduling.

7.7 Derry team photographs from 2014-15

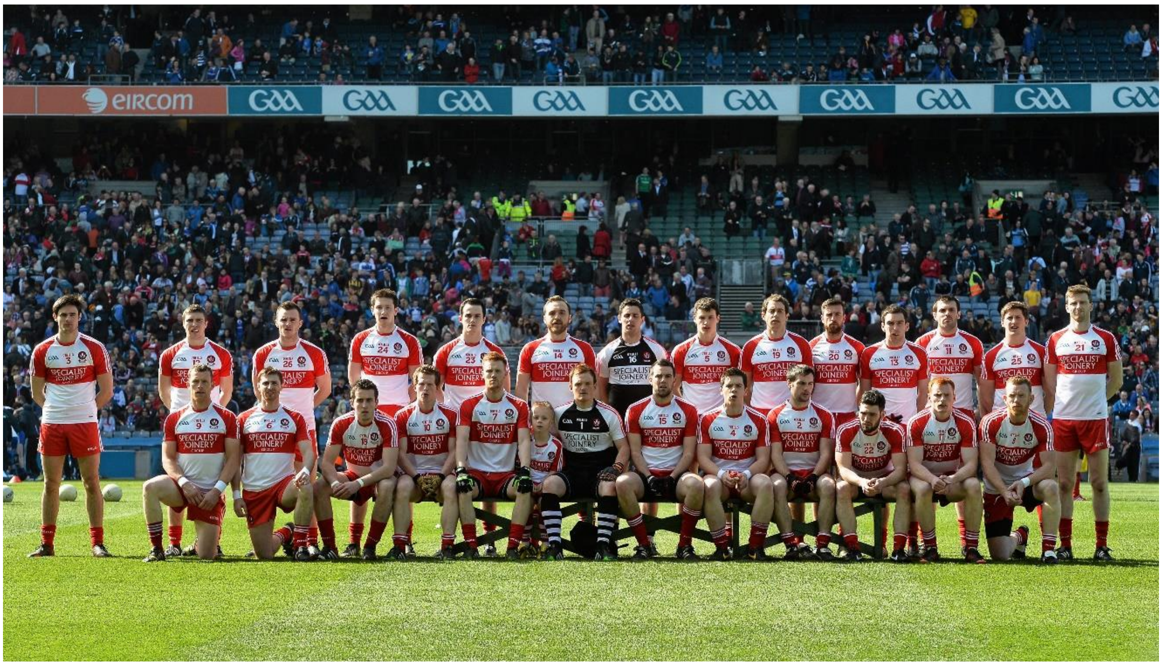


Figure 7.1 Allianz Football League Division 1 Final, Dublin v Derry, Croke Park (27/04/2014). Picture: David Maher / SPORTSFILE

Figure 7.2 Ulster Championship Semi-Final, Derry v Donegal. St Tiernach's Park (27/06/2015). Picture: Oliver McVeigh / SPORTSFILE

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APPENDICES

Appendix A DCU Ethical approval application

Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

DCU

Mr Declan Gamble
School of Health and Human Performance

13th December 2013

REC Reference: **DCUREC/2013/226**

Proposal Title: **Quantification of the physical and physiological demands of Gaelic football**

Applicants: **Declan Gamble, Prof. Niall Moyna**

Dear Declan,

Further to review, the DCU Research Ethics Committee approves this research proposal. Materials used to recruit participants should note that ethical approval for this project has been obtained from the Dublin City University Research Ethics Committee. Should substantial modifications to the research protocol be required at a later stage, a further submission should be made to the REC.

Yours sincerely,

DCU Research & Innovation

Dónal O'Mathúna

Dr. Donal O'Mathuna
Chairperson
DCU Research Ethics Committee

Taighde & Nuálaíocht Tacaíocht
Ollscoil Chathair Bhaile Átha Cliath,
Baile Átha Cliath, Éire

Research & Innovation Support
Dublin City University,
Dublin 9, Ireland

T +353 1 700 8000
F +353 1 700 8002
E research@dcu.ie
www.dcu.ie

Dublin City University

RESEARCH ETHICS COMMITTEE

APPLICATION FOR APPROVAL OF A PROJECT INVOLVING **HUMAN PARTICIPANTS**

Application No. *(office use only)* DCUREC/2013/

This application form is to be used by researchers seeking ethics approval for individual projects and studies. Your application must be e-mailed to the DCU Research Ethics Committee at rec@dcu.ie –no hardcopy required**. Student applicants must cc their supervisor on that e-mail** – this applies to undergraduate, masters and postgraduate students.

NB - The application should consist of one electronic file only, with an electronic signature from the PI. The completed application must incorporate all supplementary documentation, especially that being given to the proposed participants. It must be proofread and spellchecked before submission to the REC.

All sections of the application form must be answered – please consult the Guidelines to Applicants on page 2 where directed. Applications which do not adhere to these requirements will not be accepted for review and will be returned directly to the applicant.

Applications must be completed on the form; answers in the form of attachments will not be accepted, except where indicated. No hardcopy applications will be accepted. **Research must not commence until written approval has been received from the Research Ethics Committee.**

Note: If your research requires approval from the Biosafety Committee, this approval should be in place prior to REC submission. Please attach the approval from the BSC to this submission.

PROJECT TITLE	Quantification of the physical and physiological demands of Gaelic football
PRINCIPAL INVESTIGATOR(S)	Declan Gamble and Prof. Niall Moyna
START AND END DATE	1/1/14 – 1/6/14

Please confirm that all supplementary information is included in your application (in electronic copy). If questionnaire or interview questions are submitted in draft form, please indicate this by

putting (draft) after YES. A copy of the final documentation must be submitted for final approval when available.

	INCLUDED (mark as YES)	**NOT APPLICABLE**
Bibliography	**Yes**	
Recruitment advertisement	**Yes**	
Plain language statement/Information Statement	**Yes**	
Informed Consent form	**Yes**	
Evidence of external approvals related to the research	**Yes**	
Questionnaire/Survey		**N/A**
Interview/Focus Group Questions		**N/A**
Debriefing material		**N/A**
Other (INSERT TYPE)		**N/A**

Please note:

1. Any amendments to the original approved proposal must receive prior REC approval.
2. As a condition of approval investigators are required to document and report immediately to the Secretary of the Research Ethics Committee any adverse events, any issues which might negatively impact on the conduct of the research and/or any complaint from a participant relating to their participation in the study

Please submit the electronic copy of your completed application to rec@dcu.ie

Guidelines to Applicants

1.1 PRINCIPAL INVESTIGATOR(S): *The named Principal Investigator is the person with primary responsibility for the research project. Doctoral researchers and Research Masters or their supervisors may be listed as Principal Investigators, depending on the conventions of the discipline and on the individual case. It should be made clear, in subsequent sections of this application, who is carrying out the research procedures. In the case of Taught Masters and undergraduate student projects the supervisors are Principal Investigators.*

2.0 PROJECT OUTLINE: *Provide a brief outline of the project, aims, methods, duration, funding, profile of participants and proposed interaction with them. This description must be in everyday language that is free from jargon. Please explain any technical terms or discipline-specific phrases.*

2.1 LAY DESCRIPTION: *Provide a brief outline of the project, including what participants will be required to do. This description must be in everyday language which is free from jargon. Please explain any technical terms or discipline-specific phrases. (No more than 300 words).*

2.2 AIMS OF AND JUSTIFICATION FOR THE RESEARCH: *State the aims and significance of the project (approx. 400 words). Where relevant, state the specific hypothesis to be tested. Also please provide a brief description of background research, a justification as to why this research project should proceed in that context and an explanation of any expected benefits to the community.* ***NB – all references cited should be listed in an attached bibliography.***

2.3 PROPOSED METHOD: *Provide an outline of the proposed method, including details of data collection techniques, tasks participants will be asked to do, the estimated time commitment involved, and how data will be analysed. If the project includes any procedure which is beyond already established and accepted techniques please include a description of it. There should be enough detail provided to facilitate ethical review, but applicants are encouraged to keep it as succinct as possible.*

2.4 PARTICIPANT PROFILE: *Provide number, age range and source of participants. Please provide a justification of your proposed sample size. Please provide a justification for selecting a specific gender.*

2.5 MEANS BY WHICH PARTICIPANTS ARE TO BE RECRUITED: *Please provide specific details as to how you will be recruiting participants. How will people be told you are doing this research? How will they be approached and asked if they are willing to participate? If you are mailing to or phoning people, please explain how you have obtained their names and contact details. This information will need to be included in the plain language statement. If a recruitment advertisement is to be used, please ensure you attach a copy to this application.*

3.3 POTENTIAL RISKS TO PARTICIPANTS AND RISK MANAGEMENT PROCEDURES*: Identify, as far as possible, all potential risks to participants (physical, psychological, social, legal or economic etc.), associated with the proposed research. Please explain what risk management procedures will be put in place.*

3.6 ADVERSE/UNEXPECTED OUTCOMES: *Please describe what measures you have in place in the event that there are any unexpected outcomes or adverse effects to participants arising from involvement in the project.*

3.7 MONITORING: *Please explain how you propose to monitor the conduct of the project (especially where several people are involved in recruiting or interviewing, administering procedures) to ensure that it conforms with the procedures set out in this application. In the case of student projects please give details of how the supervisor(s) will monitor the conduct of the project.*

3.8 SUPPORT FOR PARTICIPANTS: *Depending on risks to participants you may need to consider having additional support for participants during/after the study. Consider whether your project would require additional support, e.g., external counselling available to participants. Please advise what support will be available.*

4.0 INVESTIGATORS' QUALIFICATIONS, EXPERIENCE AND SKILLS: *List the academic qualifications and outline the experience and skills relevant to this project that the PI, other researchers and any supporting staff have in carrying out the research and in dealing with any emergencies, unexpected outcomes, or contingencies that may arise.*

5.2 HOW WILL THE ANONYMITY OF THE PARTICIPANTS BE RESPECTED? *Please bear in mind that where the sample size is very small, it may be impossible to guarantee anonymity/confidentiality of participant identity. Participants involved in such projects need to be advised of this limitation in the Plain Language Statement/Information Sheet.*

5.3 LEGAL LIMITATIONS TO DATA CONFIDENTIALITY: *Participants need to be aware that confidentiality of information provided can only be protected within the limitations of the law - i.e., it is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions. Depending on the research proposal you may need to specifically state these limitations.*

6.0 DATA/SAMPLE STORAGE, SECURITY AND DISPOSAL: *For the purpose of this section, "Data" includes that in a raw or processed state (e.g., interview audiotape, transcript or analysis). "Samples" include body fluids or tissue samples.*

8.0 PLAIN LANGUAGE STATEMENT: *This is written information in plain language that you will be providing to participants, outlining the phases and nature of their involvement in the project and inviting their participation. Please note that the language used must reflect the participant age group and corresponding comprehension level. See link to sample template below.*

9.0 INFORMED CONSENT FORM: *This is a very important document that should be addressed by participants to researchers, requiring participants to indicate their consent to specific statements, and give their signature. See link to sample template below.*

FOR FURTHER INFORMATION AND NOTES ON THE DEVELOPMENT OF PLAIN LANGUAGE STATEMENTS AND INFORMED CONSENT FORMS, PLEASE CONSULT THE DCU REC WEBSITE*:*

HTTP://WWW4.DCU.IE/RESEARCH/RESEARCH_ETHICS/REC_FORMS.SHTML

1. ADMINISTRATIVE DETAILS

PROJECT TYPE: *(mark Y to as many as apply)*	Research Project	Y	Funded Consultancy	…
	Practical Class	…	Clinical Trial	…
	Student Research Project *(please state level, e.g., PhD/MSc Research/MSc Taught)*	Y PhD	Other - *Please Describe:*	…

1.1 INVESTIGATOR CONTACT DETAILS *(see pg. 2 Guidelines)*

PRINCIPAL INVESTIGATOR(S):

NAME	*SCHOOL/UNIT*	*EMAIL*
Declan Gamble	School of Health and Human Performance	declangamble@sini.co.uk
Professor Niall Moyna	School of Health and Human Performance	Niall.Moyna@dcu.ie

(NB – if the applicant is from the School of Nursing and Human Sciences, please note all students including PhD's must attach the letter from the NHS Ethics Advisory Committee to this application)

OTHER INVESTIGATORS:

NAME	*SCHOOL/UNIT*	*EMAIL*
Dr Richard McCann	Sports Institute Northern Ireland	richardmccann@sini.co.uk
Dr Gerard McMahon	Sports Institute Northern Ireland	gerardmcmahon@sini.co.uk
Damian Martin	Sports Institute Northern Ireland	damianmartin@sini.co.uk
Jonathan Bradley	Sports Institute Northern Ireland	jonathanbradley@sini.co.uk
Laura Ostler	Sports Institute Northern Ireland	lauraostler@sini.co.uk

1.2 WILL THE RESEARCH BE UNDERTAKEN ON-SITE AT DUBLIN CITY UNIVERSITY? N

The match analysis research will be conducted at Gaelic football Stadiums around the country, which are hosting Division One NFL games. The training analysis will be conducted at Owenbeg, which is the training centre of excellence used by the County Derry Senior Gaelic football team. The fitness profiling will be conducted at both Owenbeg and the Sports Institute Northern Ireland, located at the University of Ulster in Jordanstown.

1.3 IS THIS PROTOCOL BEING SUBMITTED TO ANOTHER ETHICS COMMITTEE, OR HAS IT BEEN PREVIOUSLY SUBMITTED TO AN ETHICS COMMITTEE? N

DECLARATION BY PRINCIPAL INVESTIGATOR(S)

The information contained herein is, to the best of my knowledge and belief, accurate. I have read the University's current research ethics guidelines, and accept responsibility for the conduct of the procedures set out in the attached application in accordance with the form guidelines, the REC guidelines (https://www4.dcu.ie/researchsupport/research_ethics/guidelines.shtml), *the University's policy on Conflict of Interest, Code of Good Research Practice and any other condition laid down by the Dublin City University Research Ethics Committee or its Sub-Committees. I have attempted to identify all risks related to the research that may arise in conducting this research and acknowledge my obligations and the rights of the participants.*

If there any affiliation or financial interest for researcher(s) in this research or its outcomes or any other circumstances which might represent a perceived, potential or actual conflict of interest this should be declared in accordance with Dublin City University policy on Conflicts of Interest.

I and my co-investigators or supporting staff have the appropriate qualifications, experience and facilities to conduct the research set out in the attached application and to deal with any emergencies and contingencies related to the research that may arise.

Electronic Signature(s): *Principal investigator(s):* D. Gamble

Print Name(s) here:_____Declan Gamble_______________Date: __29/11/13

2. PROJECT OUTLINE

2.1 LAY DESCRIPTION *(No more than 300 words - see pg. 2 Guidelines)*

Inter-county Gaelic football teams have used player-tracking technology (GPS devices) in recent years to assist with quantifying the physical demands of games. Variables such as; distance covered walking, jogging, running and sprinting, number of jumps, change of direction left or right, number of impacts and repeated high intensity efforts, can be evaluated. This information, combined with heart rate observations, can illustrate physical exertion in relation to positional play. Furthermore, a microchip has been developed to facilitate ball tracking; enabling quantification of ball possession, pass chains between teammates and work-rate during possession and without possession of the ball.

The management of the county Derry Senior Gaelic football team have agreed to facilitate the study. The players will wear portable GPS tracking devices and heart rate monitors during designated training sessions and games. A pilot project will be conducted during 3-5 games of the McKenna Cup in January 2014, depending on progress from the group stages to the final of the competition. The main study will be conducted during the 7 rounds of the National football League (NFL) and during the semi-final and final if the team progress to that stage. During each round the opposition team will also be invited to participate in the study to facilitate competing player analyses (i.e., corner forward vs corner back).

The players will be asked to wear the GPS devices during county training and to record other training/sporting activities in a diary to facilitate quantification of their internal training load. Blood profiling will be conducted throughout the preparation and competition phases to determine how players are tolerating the physical load. Fitness levels would be profiled prior to the McKenna Cup, and then following the NFL. This would provide a baseline profile and enable training related progressions in fitness to be demonstrated.

2.2 AIMS OF AND JUSTIFICATION FOR THE RESEARCH *(Approx. 400 words - see pg. 2 Guidelines)*

Aims

The primary aim of this research is to provide a comprehensive analysis of Gaelic football, through evaluation of the physical and physiological demands imposed on players at inter-county level. Analysis of these games will enable the variation in workload from game to game to be illustrated and positional profiles to be established for defenders, attackers and midfielders. Secondary objectives involve; 1) quantification of the training load of players during the preparation phases for the McKenna Cup and NFL, and 2) determination of how the training and competition load is being tolerated.

Justification

It was previously highlighted that among the football codes, Gaelic football was the sport most depended on generic literature (Douge, 1988). This deficiency in the scientific investigation of Gaelic football prompted Reilly and Doran (2001) to conduct a review which examined the extant research relating to; the characteristics of players (Reilly, 1990; Watson, 1995; Reilly and Doran, 1999), work-rates during matches (Keane et al., 1993), physiological responses to match-play (Florida-James and Reilly, 1995; Reilly and Keane, 2002), task and skill analysis (Doggart et al., 1993) and predisposition to injury (Watson, 1997; 1999). The authors acknowledged that the majority of the published literature comprised of anthropometric evaluations, fitness assessments and physiological investigations. Moreover, there was limited match analysis, compelling applied practitioners to draw heavily from the general body of research knowledge (Reilly and Doran, 2001). It was anticipated that many of the research questions arising from this initial review would be addressed subsequently due to the integration of sport science support programmes within senior county squads and renewed interest from researchers in academic institutions within Ireland. However, in a recent update on Science and Gaelic sports, it was evident that only a few studies have complimented the previous research base and the need for systematic investigations in physiology and performance analysis was again emphasised (Reilly and Collins, 2008). My colleagues and I have previously used GPS tracking devices to quantify the demands imposed on Gaelic football players (unpublished observations) and referees (Gamble et al., 2007). Moreover, GPS devices have been used successfully to quantify the physical and physiological demands imposed on players in Australian Rules football (Jennings et al., 2012), Rugby Union (Cunniffe et al., 2009), Rugby League (Gabbett et al., 2012) and Soccer (Casamichana et al., 2013). This research study will provide information to facilitate the strategic objectives of the GAA, which include; 1) promoting coaching and games development, and 2) enhancing medical and player welfare, and subsequently enhance the knowledge of coaches, support staff and players.

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6. Gabbett, T. Jenkins, D & Abernathy, B. (2012) Physical demands of professional rugby league training and competition using microtechnology. *Journal of Science and Medicine in Sport,* **15**(1)**,** 80-86.
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13. Reilly, T. & Doran, D. (2001) Science and Gaelic football: A review. *Journal of Sport Science*, **19**, 181-193.
14. Reilly, T., & Keane, S. (2002). Estimation of physiological strain on Gaelic football players during match play. In W. Spinks, T. Reilly, & A. Murphy (Eds.), Science and football IV (pp. 157-159). London: Routledge.
15. Reilly, T. & Collins, K. (2008) Science and the Gaelic Sports: Gaelic football and Hurling. *European Journal of Sports Science*, **8**(5), 231-240.
16. Watson, A.W.S. (1995). Physical and fitness characteristics of successful Gaelic footballers. *British Journal of Sports Medicine***, 29**,229-231.
17. Watson, A.W.S. (1997). Injuries in schoolboy players of basketball, field-hockey, hurling, Gaelic football, rugby and soccer. *New Zealand Journal of Sports Medicine*, **25**, 22-24.
18. Watson, A.W.S. (1999). Ankle sprains in players of the field- games Gaelic football and hurling. *Journal of Sports Medicine and Physical Fitness*, **39**, 66-70.

2.3 PROPOSED METHOD *(see pg. 2 Guidelines)*

Study Overview

The match and training analysis will take place during the Dr McKenna Cup Competition (January 2014) and during the NFL (February-April 2014). The study will require all players to wear portable GPS tracking devices (OptimEye S5, Catapult Sports, Australia) and heart rate monitors (Polar T31, Finland), in an undergarment worn under their jersey. The players would have an opportunity to wear the devices and familiarise themselves with the technology during designated training sessions. Players would have their fitness levels profiled at two stages during the study, prior to the start of the McKenna Cup, and then following the NFL. This would provide a baseline profile and enable training related progressions in fitness to be demonstrated.

Player Monitoring Devices

The GPS device has a streamlined design, facilitating placement between the shoulder blades, overlying the upper thoracic spine of the player. The sampling rate of 10Hz enables positional, velocity and acceleration data to be obtained. In addition, the units also include a 3 axis; configurable 100Hz 2-12g accelerometer to measure linear motion, impact forces, acceleration and deceleration, configurable 200-2000 degrees per second gyroscope to measure angular motion and rotation, allowing accurate classification of specific movement patterns and a 100Hz magnetometer to measure direction and orientation. The players would wear the tracking devices during all of their games and training sessions to enable the physical and physiological load to be objectively quantified.

Training Diary

In addition to measuring the external training load, the players will also be asked to complete a training diary to quantify their subjective internal training load. This will enable quantification of both indoor and outdoor training sessions and enable evaluation of the total training load experienced by players. The training load will be calculated by using the subjective ratings of perceived exertion (RPE). This method, proposed by Foster et al. (2001) involves multiplication of the whole session RPE using the category ratio scale (CR10-scale) outlined by Borg et al. (1996) by the session duration. The resulting number represents the internal training load in arbitrary units (Impellizzeri et al., 2004).

Match and Training load Tolerance and Recovery Status

Creatine kinase (CK) has been used previously in team sports to provide an indirect assessment of muscle damage and recovery status (Gill et al., 2006; Takata, 2003; McLellan et al., 2011). The time points for evaluation of the CK levels will depend on the match and training schedule prepared by the team management. It is planned to evaluate CK before each game, and prior to the start of designated training sessions. A 30 μL quantity of blood will be obtained from a finger prick. An Accu-chek Safe-T-Pro lancet (Roche, UK) will be used to stimulate blood flow into a capillary tube. The blood will then be transferred using a pipette onto a CK reagent strip, which will subsequently be inserted into the Reflotron plus analyser (Roche, UK) for determination of CK levels.

Physical Characteristics and Fitness Assessment

Physical characteristics including height and body mass will be obtained from each player. In addition a number of field fitness tests will be conducted to assess; upper and lower body power, speed, agility, repeated sprint ability, and aerobic endurance.

Upper Body power: From a seated position the player will use two hands to throw a medicine ball (4 kg) for maximum horizontal distance. The best score of three attempts will be recorded.

Lower Body Power: From a standing position the player will perform a jump for maximal horizontal distance. The best score of three attempts will be recorded.

Speed: Players will sprint maximally for 20m. Electronic timing gates will be positioned at 5m intervals. The best score of three attempts will be recorded.

Agility: Players will complete a predetermined course in the fastest time possible. The total time will be measured using electronic timing gates. The best score of three attempts will be recorded.

Repeated Sprint Ability: Players are required to perform 6 sprints of 30m. The stop watch starts with the first sprint and the player then performs a subsequent sprint every 20s until the 6 sprints are completed i.e at 0, 20 sec, 40 sec, 1 min, 1min 20 sec and 1min 40 sec after the start of the first sprint. The total time for the 6 sprints is recorded using the timing gates and a fatigue index is also obtained by comparing the best and worst sprint times.

Aerobic Endurance and Maximum Heart Rate Assessment: Two versions of the Yo-Yo intermittent test will be used. The endurance version will be used to obtain an accurate maximum heart rate value for each player and the recovery version will be used to correlate the results with high-intensity running during games. The endurance test has a short active break of 5 seconds after each 40m (2 x 20 m runs) of increasing speed, compared to 10 seconds in the intermittent recovery test. In both cases the test is terminated when a player withdraws voluntarily, or has failed to reach the target line on two consecutive occasions.

Statistical Analysis:

The statistical software, SPSS for Windows, will be used to perform the analysis. Differences in the physical demands (i.e., distance covered at various movement speeds, changes of direction, accelerations, decelerations, impacts, jumps and repeated high-intensity effort activities) among playing positions will be compared using a one-way analysis of variance (ANOVA). Comparisons between the overall match demands of all playing positions and those recorded during traditional conditioning, repeated high-intensity effort exercise, game-based training, and skill training activities will also be compared using a one way ANOVA. If any significant differences are evident between groups, post hoc tests will be used to determine the source of the significance. The relationships between session-RPE and the GPS/HR-based exercise load will be analysed using Pearson' s product moment correlation. Average weekly session-RPE will be analysed using a one-way ANOVA, followed by specific post hoc tests. Significance will be accepted at the $P < 0.05$ level of confidence and all data will be reported as means and 95% confidence intervals.

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4. Foster, C., Florhaug, J. A. Franklin, J. et al. (2001) A new approach to monitoring exercise training. *J. Strength Cond. Res.* **15**:109–115.
5. Gill, N.D. Beaven, C.M. & Cook, C. (2006) Effectiveness of post-match recovery strategies in rugby players. *Br J Sports Med*; **40**:260-263.
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7. McLellan, C. P., Lovell, D.; & Gass, G. (2011) Markers of Post match Fatigue in Professional Rugby League Players. *Journal of Strength & Conditioning Research.* 25(4):1030-1039.
8. Takarada. Y (2003) Evaluation of muscle damage after a rugby match with special reference to tackle plays. *Br J Sports Med,* **37**:416–419.

2.4 PARTICIPANT PROFILE *(see pg. 2 Guidelines)*

Inclusion criteria: Apparently healthy males, currently playing at inter-county and/or intervarsity level, between the age of
18-42 years. 30-40 players will participate from the Derry squad, depending on the availability of players during the study. A maximum of 30 players from each opposition team will be given the opportunity to familiarise themselves with the technology during a designated training session. Potentially 20-25 of these players could participate in the match analysis, when playing against Derry during the McKenna Cup and/or NFL competitions.

Exclusion criteria: Players will be excluded from the exercise tests and training and match analysis if they have any medical conditions or injuries that contraindicate exercise participation.

2.5 MEANS BY WHICH PARTICIPANTS ARE TO BE RECRUITED *(see pg. 2 Guidelines)*

An invitation to participate in the study was communicated via a letter, which was emailed to the secretaries of Co. Derry and Co. Tyrone, as both Ulster teams were participating in Division One of the NFL in 2014. Tyrone declined to participate and Derry accepted. Two further letters were sent to the secretaries of the counties competing against Derry in the group stages of the McKenna Cup and Division One of the NFL inviting them to participate. To date one opposition team have confirmed their participation, and another team has declined due to a previous player monitoring arrangement they had in place. The aim and rationale for the study, the practical implications and logistics involved and potential benefits have been explained in the letter. This information will be reinforced during face-to-face meetings and/or interactions with players and management teams. Both coaches and players will be provided with an opportunity to ask questions. If they agree to participate in the study, the players will be asked to provide written informed consent.

2.6 PLEASE EXPLAIN WHEN, HOW, WHERE, AND TO WHOM RESULTS WILL BE DISSEMINATED, INCLUDING WHETHER PARTICIPANTS WILL BE PROVIDED WITH ANY INFORMATION AS TO THE FINDINGS OR OUTCOMES OF THE PROJECT?

The study findings will be presented at scientific meetings and published in peer-reviewed journals. All players and management teams will be provided with a copy of their individual and team summary reports.

2.7 ARE OTHER APPROVALS REQUIRED TO GAIN ACCESS TO ANOTHER LOCATION, ORGANISATION ETC.? Y

Both the Ulster and Central Councils of the GAA are supporting the research. This was required to initiate communication with individual counties and to facilitate access to stadiums. Approvals from both councils are attached at the end of this document.

2.8 HAS A SIMILAR PROPOSAL BEEN PREVIOUSLY APPROVED BY THE REC? N

(If YES, please state both the REC Application Number and Project Title)

3. RISK AND RISK MANAGEMENT

3.1 ARE THE RISKS TO SUBJECTS AND/OR RESEARCHERS ASSOCIATED WITH YOUR PROJECT GREATER THAN THOSE ENCOUNTERED IN EVERYDAY LIFE? Y

The players will be required to wear a small portable GPS device, worn in an undergarment under their jersey. The device is located between the shoulder blades overlying the upper thoracic spine. A forceful impact/collision in that region could potentially result in an injury to a player. However, this technology is commonly used in elite field team sports such as American football, Australian rules, and Rugby League and Rugby Union. Although these sports have a high incidence of impacts and collisions, to my knowledge there has been no reported injury to any players related to wearing a portable GPS device.

During the fitness assessments the players will be required to exert themselves maximally i.e., to the point of exhaustion.

3.2 DOES THE RESEARCH INVOLVE:

	YES or NO
• use of a questionnaire? (attach copy)?	No
• interviews (attach interview questions)?	No
• observation of participants without their knowledge?	No
• participant observation (provide details in section 2)?	No
• audio- or video-taping interviewees or events?	No
• access to personal and/or confidential data (including student, patient or client data) without the participant's specific consent?	No
• administration of any stimuli, tasks, investigations or procedures which may be experienced by participants as physically or mentally painful, stressful or unpleasant during or after the research process?	Yes
• performance of any acts which might diminish the self-esteem of participants or cause them to experience embarrassment, regret or depression?	No
• investigation of participants involved in illegal activities?	No
• procedures that involve deception of participants?	No
• administration of any substance or agent?	No
• use of non-treatment of placebo control conditions?	No
• collection of body tissues or fluid samples?	Yes
• collection and/or testing of DNA samples?	No
• participation in a clinical trial?	No
• administration of ionising radiation to participants?	No

3.3 POTENTIAL RISKS TO PARTICIPANTS AND RISK MANAGEMENT PROCEDURES *(see pg. 2 - Guidelines)*

The nature and risks involved in the study will be explained prior to starting the study and a contact number will be provided.

Players may experience a slight discomfort during the fingerpick blood test. Players may also experience some muscle soreness in their legs or nausea, following the repeated sprint test or maximal exercise tests. Exercise testing is associated with a very small risk of abnormal heart rhythms, heart attack or death in less than one in 30,000 patients. The pre-test likelihood of these risks in asymptomatic men < 55 years of age is very low. A thorough standardized warm-up will be performed prior to the exercise test(s) to reduce the possibility of injury.

3.4 ARE THERE LIKELY TO BE ANY BENEFITS (DIRECT OR INDIRECT) TO PARTICIPANTS FROM THIS RESEARCH? *Y*

The results from the study will provide an objective assessment of each player's match performance and training load. This information can be used to optimise the preparation programmes of players and to tailor their individual recovery requirements.

3.5 ARE THERE ANY SPECIFIC RISKS TO RESEARCHERS? *(e.g., where research is undertaken at an off-campus location)* ***Y***

There is a small risk of needle stick injury or cross-infection from blood samples. Standard safety procedures will be strictly adhered to.

3.6 DEALING WITH ADVERSE/UNEXPECTED OUTCOMES *(see pg. 2 - Guidelines)*

The researcher and colleagues who may assist with the match and training interventions are all trained in basic first aid. In addition, in the event of an injury or medical issue, the team doctor or physiotherapist will be onsite to provide assistance.

3.7 HOW WILL THE CONDUCT OF THE PROJECT BE MONITORED? *(see pg. 2 - Guidelines)*

A monthly progress report will be sent to Prof. Niall Moyna to facilitate discussion and feedback and to monitor progress. Follow-up face-to-face meetings will also be organised to facilitate communication.

3.8 SUPPORT FOR PARTICIPANTS *(see pg. 2 - Guidelines)*

It is anticipated that no additional support will be required.

3.9 DO YOU PROPOSE TO OFFER PAYMENTS OR INCENTIVES TO PARTICIPANTS? *N*

3.10 DO ANY OF THE RESEARCHERS ON THIS PROJECT HAVE A PERSONAL, FINANCIAL OR COMMERCIAL INTEREST IN ITS OUTCOME THAT MIGHT INFLUENCE THE INTEGRITY OF THE RESEARCH, OR BIAS THE CONDUCT OR RESULTS OF THE RESEARCH, OR UNDULY DELAY OR OTHERWISE AFFECT THEIR PUBLICATION? *N*

4. INVESTIGATORS' QUALIFICATIONS, EXPERIENCE AND SKILLS *(Approx. **200 words** – see pg. 2 - Guidelines)*

The principle investigator (Declan Gamble) is a PhD student. Previous academic qualifications include; a BSc in Sport, Exercise and Leisure (First Class Honours) – University of Ulster, Jordanstown and an MSc in Sport Physiology (Commendation) – Liverpool John Moores University.

Applied experience includes a professional placement for one year at the Western Australian Insitute of Sport (2000). More than 10 years (since 2002) experience working as a sport physiologist at the Sports Institute Northern Ireland and currently managing a performance science team of eight practitioners from the fields of physiology, nutrition and performance analysis. This has involved extensive experience providing support to a wide range of individual athletes and sports teams.

Drs Richard McCann and Gerard McMahon and Damian Martin (MSc) all have at least three years experience of providing physiological support to athletes and teams.

Jonathan Bradley (MSc) and Laura Ostler (MSc) have significant experience of providing performance analysis support.

Prof. Niall Moyna has extensive experience conducting applied physiological research.

5. CONFIDENTIALITY/ANONYMITY

5.1 WILL THE IDENTITY OF THE PARTICIPANTS BE PROTECTED? ***Y***

IF YOU ANSWERED YES TO 5.1, PLEASE ANSWER THE FOLLOWING QUESTIONS:

5.2 HOW WILL THE ANONYMITY OF THE PARTICIPANTS BE RESPECTED? *(see pg. 2 - Guidelines)*

Confidentiality will be maintained throughout the study. Player's identities, or other personal information, will not be revealed or published. Players will be assigned an ID number and all personal information will be stored in a secure file and saved in a password-protected file on the SINI server. The investigators alone will have access to the data.

5.3 LEGAL LIMITATIONS TO DATA CONFIDENTIALITY: HAVE YOU INCLUDED APPROPRIATE INFORMATION IN THE PLAIN LANGUAGE STATEMENT AND CONSENT FORM? *(see pg. 2 - Guidelines)* ***Y***

6 DATA/SAMPLE STORAGE, SECURITY AND DISPOSAL *(see Guidelines)*

6.1 HOW AND WHERE WILL THE DATA/SAMPLES BE STORED?

Hard copies of files and information will be stored in a locked cabinet in the SINI office.

6.2 WHO WILL HAVE ACCESS TO DATA/SAMPLES?

Colleagues from within the SINI performance science team, and who are listed as additional investigators on this application form, may assist in profiling the players, and/or collecting the match and training GPS data, training diary information and blood samples. The principle investigator (DG) will collate all of the results.

6.3 IF DATA/SAMPLES ARE TO BE DISPOSED OF, PLEASE EXPLAIN <u>HOW</u>, <u>WHEN</u> AND <u>BY WHOM</u> THIS WILL BE DONE?

Blood samples will be disposed of in accordance with standard procedures e.g., blood consumables and waste will be placed in clinical waste bags and sent for incineration. The principle investigator will be responsible for the security of the collected data. The data will be kept in a locked cabinet in the SINI office. Access to the data will only be attainable by the main researcher and colleagues who are assisting with the research. Data will be kept for a minimum of five years from the date of publication of the research. The data will be shredded by the principle investigator (DG), five years after the research has been published.

7. FUNDING

7.1 HOW IS THIS WORK BEING FUNDED?

The Sports Institute Northern Ireland is paying the tuition fees and providing resources (staff, equipment and consumables) to facilitate the match and training study and fitness profiling.

7.2 PROJECT GRANT NUMBER (If relevant and/or known – otherwise mark as N/A) N/A

7.3 DOES THE PROJECT REQUIRE APPROVAL BEFORE CONSIDERATION FOR FUNDING BY A GRANTING BODY? ***N***

7.4 HOW WILL PARTICIPANTS BE INFORMED OF THE SOURCE OF THE FUNDING?

The source of the funding is outlined in the plain language statement.

7.5 DO THE FUNDERS OF THIS PROJECT HAVE A PERSONAL, FINANCIAL OR COMMERCIAL INTEREST IN ITS OUTCOME THAT MIGHT COMPROMISE THE INDEPENDENCE AND INTEGRITY OF THE RESEARCH, OR BIAS THE CONDUCT OR RESULTS OF THE RESEARCH, OR UNDULY DELAY OR OTHERWISE AFFECT THEIR PUBLICATION? *N*

8. PLAIN LANGUAGE STATEMENT *(Attach as appendix to this document. Approx. 400 words – see pg. 2 - Guidelines)*

PLEASE CONFIRM WHETHER THE FOLLOWING ISSUES HAVE BEEN ADDRESSED IN YOUR PLAIN LANGUAGE STATEMENT/ INFORMATION SHEET FOR PARTICIPANTS:

	YES/NO
Introductory Statement (PI and researcher names, school, title of the research)	**Yes**
What is this research about?	**Yes**
Why is this research being conducted?	**Yes**
How will the data be used and subsequently disposed of?	**Yes**
What will happen if the person decides to participate in the research study?	**Yes**
How will their privacy be protected?	**Yes**
What are the legal limitations to data confidentiality?	**Yes**
What are the benefits of taking part in the research study?	**Yes**
What are the risks of taking part in the research study?	**Yes**
Can participants change their mind at any stage and withdraw from the study?	**Yes**
How will participants find out what happens with the project?	**Yes**
Contact details for further information (including REC contact details)	**Yes**

If any of these issues are marked NO, please justify their exclusion:

9. INFORMED CONSENT FORM *(Attach as appendix to this document. Approx. 300 words – see pg. 2 - Guidelines)*

NB – IF AN INFORMED CONSENT FORM IS NOT BEING USED, THE REASON FOR THIS MUST BE JUSTIFIED HERE

DUBLIN CITY UNIVERSITY

Plain Language Statement

Introduction to the Research Study

Study Title: Quantification of the physical and physiological demands of Gaelic football

The research study is being funded by the **Sports Institute Northern Ireland (SINI)** and is supported by the **Gaelic Athletic Association (GAA)**

Principle Investigators: Declan Gamble: (+44) 07748861286 / declangamble@sini.co.uk
Prof. Niall Moyna (School of Health and Human Performance, DCU)

Other Investigators: Dr Richard McCann, Dr Gerard McMahon, Damian Martin, Jonathan Bradley and Laura Ostler (members of the SINI Performance Science team)

Purpose

The primary aim of this research is to provide a comprehensive analysis of Gaelic football, through evaluation of the physical and physiological demands imposed on players at inter-county level. Analysis of competitive games will enable the variation in workload from game to game to be illustrated and positional profiles to be established for defenders, attackers and midfielders. Secondary objectives involve; 1) quantification of the training load of players during the preparation phases for the McKenna Cup and NFL, and 2) determination of how the training and competition load is being tolerated.

Participation in the Research Study

You will have the purpose of the study, each of the stages involved and the risks of participating in the study explained to you. You will have the opportunity to ask questions and if you are satisfied with the answers you will provide written informed consent for participation in the research project. You will then complete a medical history form, which will ask questions about your general health, personal and family health history, smoking, exercise and dietary habits. If you agree to participate in the study you will have your fitness profiled during two occasions, prior to the McKenna Cup and then following the completion of the NFL. *The fitness profiling applies to players within the Derry squad only*.

During the fitness evaluation, you will be asked to complete tests that assess upper and lower body muscular power, speed, agility, repeated sprint ability and aerobic endurance. These tests will involve maximal exertion and you may experience some muscle fatigue and soreness as a result of participation. The aerobic endurance tests involve repeated pairs of 20m runs at progressively increasing speeds until you fatigue.

During the training and match analysis you will be required to wear a portable GPS tracking device and heart rate monitor, which will be located in an undergarment worn under your jersey. You will have a chance to familiarise yourself with this technology during training. Players within the Derry squad will be required to complete a training diary each week, detailing all of your physical training. You will provide a subjective rating of how demanding you felt each session or match was. Players within the Derry squad will also provide a small blood sample prior to designated matches and training sessions to enable your physical status and recovery to be determined.

Potential Risks

Exercise testing is associated with a very small risk of exercise induced asthma, abnormal heart rhythms, heart attack, or death in less than one in 30,000 patients. The risk of sudden death during exercise for healthy men is 1:15000-18000. Because you will be asked to give maximal effort, you may experience some muscle soreness in your arms and legs or nausea following the maximal exercise test(s) (*Derry players only*).

The GPS device is located between the shoulder blades overlying the upper thoracic spine. A forceful impact/collision in that region could potentially result in an injury. However, this technology is commonly used in elite field team sports such as Australian rules and Rugby League and Rugby Union. Although these sports have a high incidence of impacts and collisions, there have been no reported injuries to any players related to wearing a portable GPS device.

Benefits of Participation in the Research Study

The study results will provide an objective assessment of your match performance and training load (*Derry players only*). Your management team, based on this information, can then optimise subsequent training programmes and recovery strategies. You will get a copy of your own results.

Confidentiality

Your identity and other personal information will not be revealed, published or used in further studies. You will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file on a SINI server. The principle investigator(s) and members of the research team, listed on the ethics application will have access to the data. The results of the study will be presented at scientific meetings and published in peer-reviewed journals. You need to be aware that confidentiality of information provided can only be protected within the confinements of the law. It is possible for data to be subject to subpoena, freedom of information requests or mandated reporting by some professions. The original documentation will be stored for a maximum of 5 years after publication of the research. Thereafter it will be shredded.

Involvement in the Research Study is Voluntary

Your participation in this research project is voluntary and you may withdraw from the *research study* at any point. If participants have concerns about this study and wish to contact an independent person, please contact: **The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000.**

DUBLIN CITY UNIVERSITY

Informed Consent Form

Study Title: Quantification of the physical and physiological demands of Gaelic football

Principle Investigators: Declan Gamble and Prof. Niall Moyna (School of Health and Human Performance, DCU)

Other Investigators: Dr Richard McCann, Dr Gerard McMahon, Damian Martin, Jonathan Bradley and Laura Ostler (members of the SINI Performance Science team)

Purpose: The primary aim of this research is to provide a comprehensive analysis of Gaelic football, through evaluation of the physical and physiological demands imposed on players at inter-county level, during training and competitive games.

Participant Requirements
If I agree to participate in the study I will have my fitness profiled during two occasions, prior to the McKenna Cup and then following the completion of the NFL (*Derry players only*).

During the training and match analysis I will be required to wear a portable GPS tracking device and heart rate monitor, which will be located in an undergarment worn under my jersey. I will have a chance to familiarise myself with this technology during training.

I will be required to complete a training diary each week, detailing all of my physical training. I will provide a subjective rating of how demanding I felt each session or match was (*Derry players only*).

I will provide a small blood sample prior to designated matches and training sessions to enable my physical status and recovery to be determined (*Derry players only*).

Potential Side Effects and Risks from Performing Exercise Tests
I am aware that I may experience some discomfort during the exercise testing and there are small risks associated with exercise tests that require me to run to volitional exhaustion (*Derry players only*).

<u>Participant – please complete the following (Circle Yes or No for each question)</u>	
I have read the Plain Language Statement (or had it read to me)	*Yes/No*
I understand the information provided	*Yes/No*
I have had an opportunity to ask questions and discuss this study	*Yes/No*
I have received satisfactory answers to all my questions	*Yes/No*

Involvement in the Research Study is Voluntary
I am aware that I may withdraw from the research study at any point.

Confidentiality
My identity or personal information will not be revealed or published. The researchers will protect all the information about me within the limitations of the law. The study findings may be presented at scientific meetings and published in a scientific journal and/or as part of a postgraduate thesis, but my identity will not be divulged and only presented as part of a group.

I have read and understood the information in this form. The researchers have answered my questions and concerns, and I have a copy of this consent form. Therefore, I consent to take part in this research project

Participant's Signature: ______________________________

Name in Block Capitals: ______________________________

Witness: ______________________________

Date: ______________________________

Standard template for ethical justification for blood sampling associated with human studies conducted within DCU.

Version 1 September 2006

Completion instructions:

This document is intended to prompt responses to a number of standard questions which generally need to be answered to justify the sampling of blood associated with human studies.

The document is not meant to be an exhaustive exploration of the justification for such sampling and in specific situations, additional information may be required/ requested.

Answers are expected to be brief but should also be informative. See a sample completed form at the end.

Queries should be directed to the Secretary of the Research Ethics Committee in the OVPR office.

1) Briefly explain why blood sampling is required

Creatine kinase (CK) levels can only be measured via blood sampling.

2) Outline the analytes, components or general applications to be investigated in subject blood (now and any future studies)

Creatine kinase (CK)

3) Are any alternatives available to substitute the venous sampling of blood? **yes**/no.

A fingerprick blood sample can be obtained to failictate the analysis of CK.

4) Will sampling require cannulation or direct vein puncture? yes/**no**

5) Outline the minimum volume of original subject blood (i.e., not serum or plasma) required to measure the required components.

30 μL of blood is required for the determination of CK.

6) Are steps being taken in the protocol to minimise the volume of blood samples being taken? **yes**/no

The minimum amount of blood is being taken to facilitate determination of CK.

7) Are steps included to minimise the number of blood samples/vein puncture being taken? **yes**/no

The number and timing of the blood sampling points will depend on the training and match schedule. However, no more than three samples will be taken per week.

8) Anticipated sampling methodology

Volume of blood to be taken per sample	30 μL
Maximum number of samples to be taken per “sitting”	1-2
Maximum number of samples taken per day	1-2
Maximum number of samples to be taken over the course of the full study (if long duration study indicate the amount taken in an active 1 month period)	3/week, 12/month (16 wks = 4 months)
Maximum anticipate number of vein puncture episodes	0
Total volume of blood that will be taken from subject.	48*30 = 1440 μL / 1.44 mL

9) I certify that:-

- all persons sampling blood in this study are certified to do so through the school/unit where this work is being conducted
- that all those manipulating the resultant samples are fully trained in the safe practice of handling blood
- all persons handling this blood have received appropriate information according to current vaccination policy.

Signature of Study PI

D. Gamble

Declan Gamble Date **29/11/13**

An original signed copy must accompany electronic submissions. Alternatively, a PDF or other scanned version with a signature may be submitted

GAA
Páirc an Chrócaigh
Baile Átha Cliath 3
Guthán +353 1 8363222
Faics +353 1 8366420
www.gaa.ie

GAA
Croke Park
Dublin 3
Telephone +353 1 8363222
Fax +353 1 8366420
www.gaa.ie

1 Samhain 2013

Declan Gamble,

Head of Performance Science,

Sports Institute of Northern Ireland

<u>Catapult GPS Trial</u>

Dear Declan,

I wish to confirm that the Gaelic Athletic Association are happy to assist you with your proposed pilot study using the Catapult GPS devices during a game in the Allianz Football League Division One in 2014.

As per our telephone conversation, the level of cooperation with the study will be at the discretion of the individual Counties involved; however once agreement has been reached from County teams to participate, it would be our intention to facilitate the trial working with yourself and the relevant teams.

Kind Regards,

Feargal Mc Gill

Head of Games Administration/Player Welfare

Email from Dr Eugene Young

Declan

Just to confirm. Ulster GAA is happy to work with yourself and SINI to facilitate the studies and collaborate with SINI in the projection of the outcomes to senior counties.

As such we are happy that you go ahead and approach the county secretaries to see if you can get the senior teams to buy into the project.

We would hope that the outcomes will be available for wider distribution in due course and that Kevin McGuigan could be of assistance in helping to gather the data. Please provide dates when it suits to meet.

We wish you well with the project.

Regards,

Eugene

Dr. Eugene Young

Director of Coaching and Games Development

Ulster GAA, Ceannarás Uladh, 8-10 Market Street,
Armagh, BT617BX

Email: eugene.young.ulster@gaa.ie

mobile: 07736349749

Dr. Eoghan de Suin

CLG Uladh, Ceannarás Uladh, 8-10 Sráid an Mhargaidh, Ard Mhacha, BT61 7BX

Email: eugene.young.ulster@gaa.ie

mobile: 07736349749

T: 028 (048) 3752 1900 **F:** 028 (048) 3752 8092 **W:** www.ulster.gaa.ie

Recruitment of Team

Dear Secretary (Derry and Tyrone),

My name is Declan Gamble and I am conducting a series of studies relating to the *'Physical and Physiological Demands of Gaelic football'*. These research studies are part of a PhD, which is being supervised by Professor Niall Moyna at Dublin City University. Both the Sports Institute Northern Ireland (SINI) and the Ulster Council of the GAA support the research. I have been employed at SINI since 2002. During that time I have provided sports science support to elite athletes, coaches and squads; including numerous inter-county Gaelic football teams. I am writing to the senior county management teams of Derry and Tyrone, as both teams are competing in Division One of the National Football League in 2014, to invite them to participate in a match and potential training analysis study involving GPS player tracking devices. I am proposing to conduct this study throughout the duration of the McKenna Cup and NFL in 2014.

The study will involve the innovative Catapult Sports ball and player tracking technology. Inter-county Gaelic football teams have used player-tracking technology in recent years to assist with quantifying the physical demands of games. Individual player and team performance metrics can be evaluated to illustrate physical exertion in relation to positional and/or tactical play. Furthermore, a microchip has now been developed to facilitate ball tracking. This will enable quantification of ball possession, pass chains between teammates and work-rate during possession and without possession of the ball. To date this technology has been trialled successfully in American football, Australian Rules football, and Rugby football. I have been working with O'Neills to have these chips inserted into Gaelic footballs and the technology is now ready to trial.

Study Protocol

Priority Objective - the main objective is to evaluate the physical and physiological demands imposed on players during games throughout the entire NFL 2014 campaign. Analysis of these games will enable the variation in workload from game to game to be illustrated and positional profiles to be established for defenders, attackers and midfielders.

- The study would require all players to wear portable GPS tracking devices and heart rate monitors, in an undergarment worn under their jersey.
- Prior to the start of the match analysis study, all players would have an opportunity to wear the devices and familiarise themselves with the technology during designated training sessions.
- It is planned to initially pilot this during the McKenna Cup.
- During each round of the NFL the opposition team (i.e., Cork, Dublin, Kerry, Kildare, Mayo and Westmeath) will also be invited to participate in the study to facilitate competing player analyses (i.e., corner forward vs corner back).
- Data confidentially will be maintained throughout, and each team will only receive a report on their respective players.
- A summary of the average data will be provided at the end of the competition for those teams participating in the study.
- Players would have their fitness levels profiled at 2-3 stages during the study, e.g., prior to the McKenna Cup, and then prior to and following the NFL. This would provide a baseline profile and enable training related progressions in fitness to be demonstrated.

Secondary Objectives

1) There may be an opportunity to quantify the training load of each player within the squad during the preparation phases for the McKenna Cup and NFL. This would require the players to wear the GPS devices during county training and to record their club, higher education and other training/sporting activities in a training diary.

2) There is also the potential to conduct some blood profiling throughout the preparation and competition season to determine how individual players are tolerating the training and competition load.

Potential Benefits

Match Analysis

A comprehensive report can be provided to the management team to facilitate the review of each individual player and team performance during games. For example, physical performance metrics such as; total distance covered, distance covered walking, jogging, running and sprinting, number of accelerations, decelerations and jumps, change of direction left or right, number of impacts, player load, and number of repeated high intensity efforts, can be combined with heart rate observations to provide a detailed summary of each player. This objective information can be refined to demonstrate variables of importance identified by the coaching team. The information can also be relayed real-time during games to inform tactical changes or player substitutions. The contribution of new players to the overall team work-rate can be determined.

Knowledge of the specific demands of games can be used to; tailor the training requirements of the squad, enhance the design of each training session and optimise the end-stage rehabilitation programmes of injured players. For example, the peak work-rate periods or toughest 5 min stages during games can be identified and these worst-case scenarios can be recreated and performed in training. Individual player load can be monitored and recovery strategies can be tailored to prevent unnecessary overload or overuse injuries.

Training related improvements in fitness can be demonstrated through increased player work-rates during games. Team performance levels can be enhanced through demonstration of how improvements in work-rate can facilitate more efficient attacking and defending. Awareness of the fitness standards required to optimise performance can also assist with positively impacting on player application during training and games.

The ball-tracking component will for the first time enable coaching and conditioning staff to objectively analyse player movement patterns and link these to possession chains. This will help to bridge the gap between tactical, technical and physical components of performance and facilitate more informed decisions regarding preparation.

Training Analysis

Quantification and analysis of training can also help to increase the efficiency of training and optimise preparation of players. The training load (volume and intensity) can be correlated with performance(s) during games. Worst-case scenario and position specific training drills can be implemented and compared to game data. Knowledge of the physiological cost of training enables more intelligent decisions about training and recovery to be made thereby optimising preparation for games

Process

Can you please pass on this invitation to your senior management team for consideration? I am available to meet with the management team to discuss this proposal in more detail. I am hoping to have the participating team confirmed by the 1st of November to facilitate the pilot study during preparation for the McKenna Cup. If the management team is not in a position to participate at this stage can you respond before the 18th of October to enable me to issue an invitation to another team? If the management team is interested can you respond as soon as possible confirming this so that we can arrange a meeting.

Thank you for taking the time to read this proposal.

Regards,

Declan Gamble

Recruitment of Opposition Teams

Dear Secretary (Division One Teams),

My name is Declan Gamble and I am conducting a series of studies relating to the *'Physical and Physiological Demands of Gaelic football'*. These research studies are part of a PhD, which is being supervised by Professor Niall Moyna at Dublin City University. Both the GAA and the Sports Institute Northern Ireland (SINI) support the research. I have been employed at SINI since 2002. During that time I have provided sports science support to elite athletes, coaches and squads; including numerous inter-county Gaelic football teams. I am writing to the senior county management teams that are competing in Division One of the National Football League in 2014, to invite them to participate in a match analysis study involving GPS player tracking devices.

The study will involve the innovative Catapult Sports player tracking technology. Inter-county Gaelic football teams have used player-tracking technology in recent years to assist with quantifying the physical demands of games. Individual player and team performance metrics can be evaluated to illustrate physical exertion in relation to positional and/or tactical play. Furthermore, a microchip has now been developed to facilitate ball tracking. This will enable quantification of ball possession, pass chains between teammates and work-rate during possession and without possession of the ball. To date this technology has been trialled successfully in American football, Australian Rules football, and Rugby football. I have been working with O'Neills to have these chips inserted into Gaelic footballs and the technology is now ready to trial.

Because of geographical constraints I contacted Derry and Tyrone initially to enquire if either would be interested in wearing the GPS devices throughout the duration of the NFL in 2014. Derry agreed to participate. I am therefore writing to the other teams competing in Division One (i.e., Cork, Dublin, Kerry, Kildare, Mayo, Tyrone and Westmeath) to invite them to participate in the study to facilitate competing player analyses (i.e., corner forward vs corner back). Data confidentially will be maintained throughout, and each team will only receive a report on their respective players. The Derry team will not be given the data of the opposition team(s). A summary of the performance data will be provided at the end of the competition for those teams participating in the study.

Study Protocol

The main objective is to evaluate the physical and physiological demands imposed on players during games throughout the entire NFL 2014 campaign. Analysis of these games will enable the variation in workload from game to game to be illustrated and positional profiles to be established for defenders, attackers and midfielders.

- The study would require all players to wear portable GPS tracking devices and heart rate monitors, in an undergarment worn under their jersey.
- For those teams agreeing to participate in the study, prior to the match against Derry, players would have an opportunity to wear the devices and familiarise themselves with the technology during a designated training session.

Potential Benefits

A comprehensive report can be provided to the management team to facilitate the review of each individual player and the team performance during the game. For example, physical performance metrics such as; total distance covered, distance covered walking, jogging, running and sprinting, number of accelerations, decelerations and jumps, change of direction left or right, number of impacts, player load, and number of repeated high intensity efforts, can be combined with heart rate observations to provide a detailed summary of each player. This objective information can be refined to demonstrate variables of importance identified by the coaching team. The contribution of substitute players to the overall team work-rate can also be determined.

Knowledge of the specific demands of games can be used to; tailor the training requirements of the squad, enhance the design of each training session and optimise the end-stage rehabilitation programmes of injured players. For example, the peak work-rate periods or toughest 5 min stages during games can be identified and these worst-case scenarios can be recreated and performed in training. Team performance levels can be enhanced through demonstration of how improvements in work-rate can facilitate more efficient attacking and defending. Awareness of the fitness standards required to optimise performance can also assist with positively impacting on player application during training and games.

The ball-tracking component will for the first time enable coaching and conditioning staff to objectively analyse player movement patterns and link these to possession chains. This will help to bridge the gap between tactical, technical and physical components of performance and facilitate more informed decisions regarding preparation.

Process

Can you please pass on this invitation to your senior management team for consideration? I am available to discuss this proposal in more detail if required. I am hoping to have the participating teams confirmed by the 6th of December 2013 to facilitate the logistical planning. If the management team is interested can you respond as soon as possible confirming this so that we can arrange a meeting or teleconference to discuss? If the management team is not in a position to participate at this stage can you also respond to confirm this?

Thank you for taking the time to read this proposal.

Regards,

Declan Gamble

Appendix B Letter to County Secretaries of teams competing against Derry in McKenna Cup 2014

Dear Secretary,

My name is Declan Gamble and I am conducting a series of studies relating to the *'Physical and Physiological Demands of Gaelic football'*. These research studies are part of a PhD, which is being supervised by Professor Niall Moyna at Dublin City University. Both the GAA and the Sports Institute Northern Ireland (SINI) support the research. I have been employed at SINI since 2002. During that time I have provided sports science support to elite athletes, coaches and squads; including numerous inter-county Gaelic football teams.

The study will involve the innovative Catapult Sports player tracking technology. Inter-county Gaelic football teams have used player-tracking technology in recent years to assist with quantifying the physical demands of games. Individual player and team performance metrics can be evaluated to illustrate physical exertion in relation to positional and/or tactical play. Furthermore, a microchip has now been developed to facilitate ball tracking. This will enable quantification of ball possession, pass chains between teammates and work-rate during possession and without possession of the ball. To date this technology has been trialled successfully in American football, Australian Rules football, and Rugby football. I have been working with O'Neills to have these chips inserted into Gaelic footballs and the technology is now ready to trial.

Because of geographical constraints I contacted Derry and Tyrone initially to enquire if either would be interested in wearing the GPS devices throughout the duration of the NFL in 2014, as both teams were competing in Division One. Derry agreed to participate. I am also writing to the other teams competing in Division One (i.e., Cork, Dublin, Kerry, Kildare, Mayo, Tyrone and Westmeath) to invite them to participate in the study to facilitate competing player analyses (i.e., corner forward vs corner back).

I am planning to run a pilot study during the 2014 Dr McKenna Cup competition in preparation for the main study. I am therefore writing to the management teams that are competing in the same group as Derry in the McKenna Cup competition (Fermanagh, Monaghan and St Mary's University) to invite them to participate in this GPS match analysis study. Data confidentially will be maintained throughout, and each team will only receive a report on their respective players. The Derry team will not be given the data of the opposition team(s). A summary of the performance data will be provided at the end of the competition for those teams participating in the study.

Study Protocol

The main objective is to evaluate the physical and physiological demands imposed on players during games throughout the 2014 Dr McKenna Cup and NFL campaign. Analysis of these games will enable the variation in workload from game to game to be illustrated and positional profiles to be established for defenders, attackers and midfielders.

- The study would require all players to wear portable GPS tracking devices and heart rate monitors, in an undergarment worn under their jersey.
- For those teams agreeing to participate in the study, prior to the match against Derry, players would have an opportunity to wear the devices and familiarise themselves with the technology during a designated training session.

Potential Benefits

A comprehensive report can be provided to the management team to facilitate the review of each individual player and the team performance during the game. For example, physical performance metrics such as; total distance covered, distance covered walking, jogging, running and sprinting, number of accelerations, decelerations and jumps, change of direction left or right, number of impacts, player load, and number of repeated high intensity efforts, can be combined with heart rate observations to provide a detailed summary of each player. This objective information can be refined to demonstrate variables of importance identified by the coaching team. The contribution of substitute players to the overall team work-rate can also be determined.

Knowledge of the specific demands of games can be used to; tailor the training requirements of the squad, enhance the design of each training session and optimise the end-stage rehabilitation programmes of injured players. For example, the peak work-rate periods or toughest 5 min stages during games can be identified and these worst-case scenarios can be recreated and performed in training. Team performance levels can be enhanced through demonstration of how improvements in work-rate can facilitate more efficient attacking and defending. Awareness of the fitness standards required to optimise performance can also assist with positively impacting on player application during training and games.

The ball-tracking component will for the first time enable coaching and conditioning staff to objectively analyse player movement patterns and link these to possession chains. This will help to bridge the gap between tactical, technical and physical components of performance and facilitate more informed decisions regarding preparation.

Process

Can you please pass on this invitation to your senior management team for consideration? I am available to discuss this proposal in more detail if required. I am hoping to have the participating teams confirmed by the 6th of December 2013 to facilitate the logistical planning. If the management team is interested can you respond as soon as possible confirming this so that we can arrange a meeting or teleconference to discuss? If the management team is not in a position to participate at this stage can you also respond to confirm this?

Thank you for taking the time to read this proposal.

Regards,

Declan Gamble

Appendix C 2104 and 2015 NFL League Tables

Compete in Division 1 semi-finals
Automatic relegation to Division 2

Team	Pld	W	D	L	F	A	Diff	Pts
Cork	7	5	1	1	9-115	9-97	18	**11**
Derry	7	4	1	2	11-101	9-90	17	**9**
Mayo	7	4	1	2	14-106	14-91	15	**9**
Dublin	7	4	1	2	9-99	8-94	8	**9**
Tyrone	7	3	2	2	10-110	11-102	5	**8**
Kerry	7	3	0	4	10-93	6-94	11	**6**
Kildare	7	2	0	5	9-110	10-113	-6	**4**
Westmeath	7	0	0	7	5-72	10-125	-68	**0**

[1]Derry, Mayo and Dublin are ranked by points difference.

https://en.wikipedia.org/wiki/2014_National_Football_League_(Ireland)

Compete in Division 1 semi-finals
Automatic relegation to Division 2

Team	Pld	W	D	L	F	A	Diff	Pts
Cork	7	5	0	2	10-89	7-90	8	**10**
Dublin	7	4	1	2	7-93	2-78	30	**9**
Monaghan	7	4	0	3	4-86	7-84	-7	**8**
Donegal	7	3	1	3	6-75	5-70	8	**7**
Mayo	7	3	1	3	8-79	7-79	3	**7**
Kerry	7	3	1	3	6-88	9-90	-11	**7**
Tyrone	7	1	3	3	3-76	6-81	-14	**5**
Derry	7	1	1	5	4-75	5-89	-17	**3**

[1]Donegal, Mayo and Kerry are ranked by points difference.

https://en.wikipedia.org/wiki/2015_National_Football_League_(Ireland)

Appendix D Reliability evaluation; intraclass correlation coefficient for all match periods.

			Intraclass correlation coefficient (ICC)			Level of significance (*P* – value)		
Number	**Performance indicator**	**Measure**	**Full games (n=4)**	**Halves (n=8)**	**Quarters (n=16)**	**Full games**	**Halves**	**Quarters**
1	Team possession	n	1.000	1.000	0.996			0.000
2	Team possession	%	0.999	1.000	1.000	0.000	0.000	0.000
3	Team possession	m:s	1.000	1.000	1.000	0.000	0.000	0.000
4	Team possession average	s	1.000	1.000	0.995		0.000	0.000
5	Team possession origin - Defence	n	0.993	0.992	0.985	0.001	0.000	0.000
6	Team possession origin - Midfield	n	0.981	0.988	0.982	0.004	0.000	0.000
7	Team possession origin - Attack	n	1.000	1.000	1.000			
8	Team player possession total	n	0.999	1.000	0.999	0.000	0.000	0.000
9	Team player possession total	m:s	0.995	0.999	0.999	0.001	0.000	0.000
10	Player possession average	s	1.000	1.000	0.992			0.000
11	Player possession origin - Defence	n	0.999	0.999	0.997	0.000	0.000	0.000
12	Player possession origin - Midfield	n	0.992	0.997	0.997	0.000	0.000	0.000
13	Player possession origin - Attack	n	0.999	0.999	0.995	0.000	0.000	0.000
14	Pass total: hand pass + kick pass	n	0.997	0.999	0.999	0.000	0.000	0.000
15	Pass total successful	n	0.999	1.000	0.999	0.000	0.000	0.000
16	Pass total successful	%	0.975	0.985	0.970	0.009	0.000	0.000
17	Pass total unsuccessful	n	0.969	0.974	0.958	0.013	0.000	0.000
18	Pass total unsuccessful	%	0.975	0.985	0.970	0.009	0.000	0.000
19	Hand pass	n	0.999	0.999	0.998	0.000	0.000	0.000
20	Hand pass successful	n	0.999	0.999	0.999	0.000	0.000	0.000
21	Hand pass successful	%	0.950	0.977	0.931	0.025	0.000	0.000
22	Hand pass unsuccessful	n	0.930	0.976	0.953	0.040	0.000	0.000
23	Hand pass unsuccessful	%	0.950	0.977	0.931	0.025	0.000	0.000
24	Kick pass	n	0.997	0.997	0.996	0.000	0.000	0.000
25	Kick pass successful	n	0.997	0.997	0.995	0.000	0.000	0.000

26	Kick pass successful	%	0.991	0.988	0.982	0.002	0.000	0.000
27	Kick pass unsuccessful	n	0.993	0.987	0.984	0.002	0.000	0.000
28	Kick pass unsuccessful	%	0.991	0.988	0.982	0.002	0.000	0.000
29	Dead ball total	n	0.999	0.999	0.994	0.000	0.000	0.000
30	Dead ball kick pass successful	n	1.000	1.000	1.000			
31	Dead ball kick pass successful	%	0.971	0.993	0.946	0.005	0.000	0.000
32	Dead ball kick pass unsuccessful	n	0.989	0.990	0.975	0.001	0.000	0.000
33	Dead ball kick pass unsuccessful	%	0.971	0.993	0.946	0.005	0.000	0.000
34	Dead ball free kick total	n	0.993	0.996	0.995	0.002	0.000	0.000
35	Dead ball free kick successful	n	0.993	0.997	0.997	0.001	0.000	0.000
36	Dead ball free kick successful	%	0.952	0.956	0.978	0.015	0.000	0.000
37	Dead ball free kick unsuccessful	n	0.977	0.948	0.959	0.006	0.000	0.000
38	Dead ball free kick unsuccessful	%	0.952	0.956	0.978	0.015	0.000	0.000
39	Dead ball kick out total	n	1.000	1.000	0.990			0.000
40	Dead ball kick out successful	n	1.000	1.000	1.000			
41	Dead ball kick out successful	%	1.000	1.000	0.972			0.000
42	Dead ball kick out unsuccessful	n	1.000	1.000	0.980			0.000
43	Dead ball kick out unsuccessful	%	1.000	1.000	0.972			0.000
44	Turnover total (won)	n	0.997	0.996	0.996	0.000	0.000	0.000
45	Turnover origin - Defence	n	0.982	0.979	0.972	0.006	0.000	0.000
46	Turnover origin - Midfield	n	0.997	0.998	0.997	0.000	0.000	0.000
47	Turnover origin - Attack	n	1.000	1.000	1.000			
48	Tackle total	n	0.996	0.996	0.980	0.000	0.000	0.000
49	Tackle successful	n	0.982	0.963	0.954	0.005	0.000	0.000
50	Tackle successful	%	0.974	0.966	0.950	0.008	0.000	0.000
51	Tackle unsuccessful	n	0.968	0.993	0.982	0.006	0.000	0.000
52	Tackle unsuccessful	%	0.974	0.966	0.950	0.008	0.000	0.000
53	Tackle origin - Defence	n	0.938	0.950	0.915	0.011	0.000	0.000
54	Tackle origin - Midfield	n	0.992	0.973	0.963	0.001	0.000	0.000
55	Tackle origin - Attack	n	0.960	0.978	0.954	0.017	0.000	0.000
56	Free kick / foul total (won)	n	0.983	0.991	0.991	0.004	0.000	0.000

57	Free kick origin - Defence	n	0.986	0.988	0.984	0.001	0.000	0.000
58	Free kick origin - Midfield	n	0.976	0.976	0.967	0.004	0.000	0.000
59	Free kick origin - Attack	n	0.987	0.984	0.981	0.002	0.000	0.000
60	Defensive actions total	n	0.995	0.996	0.990	0.000	0.000	0.000
61	Defensive actions - Defence	n	0.974	0.970	0.944	0.001	0.000	0.000
62	Defensive actions - Midfield	n	0.996	0.981	0.976	0.001	0.000	0.000
63	Defensive actions - Attack	n	0.983	0.988	0.972	0.004	0.000	0.000
64	Defensive efficiency	%	0.951	0.974	0.942	0.021	0.000	0.000
65	Attack total	n	0.993	0.995	0.988	0.001	0.000	0.000
66	Attack origin - Defence	n	0.950	0.898	0.922	0.019	0.004	0.000
67	Attack origin - Midfield	n	0.982	0.945	0.941	0.005	0.001	0.000
68	Attack origin - Attack	n	0.957	0.905	0.889	0.003	0.001	0.000
69	Attack Efficiency	%	0.951	0.974	0.942	0.021	0.000	0.000
70	Shot total	n	0.994	0.992	0.989	0.001	0.000	0.000
71	Shot from play	n	0.993	0.989	0.984	0.001	0.000	0.000
72	Shot from play	%	0.967	0.946	0.951	0.002	0.000	0.000
73	Shot from dead ball	n	0.970	0.954	0.937	0.002	0.000	0.000
74	Shot from dead ball	%	0.967	0.946	0.951	0.002	0.000	0.000
75	Shot efficiency	%	0.989	0.997	0.998	0.003	0.000	0.000
76	Score total	PT + G	1.000	1.000	1.000			
77	Number of scores	n	1.000	1.000	1.000			
78	Attack per score average		0.998	0.999	0.997	0.000	0.000	0.000
79	Productivity		1.000	1.000	0.999			0.000
80	Point	n	1.000	1.000	1.000			
81	Point from play	n	0.978	0.990	0.987	0.005	0.000	0.000
82	Point from dead ball	n	0.993	0.985	0.981	0.001	0.000	0.000
83	Goal	n	1.000	1.000	1.000			
	Mean		**0.98**	**0.98**	**0.98**			
	Minimum		**0.93**	**0.90**	**0.89**			

Appendix E Performance indicators excluded and included in the principal component analysis for full games.

Number	Performance indicator	Measure	PIs excluded in preliminary analysis (n=48)	Exclusion criteria	PIs included in preliminary PCA analysis (n=35)	PIs removed due to high correlation >0.9 or low KMO (n=17)	PIs included in final PCA analysis (n=18)
1	dTeam possession	n	X	Combination			
2	dTeam possession	%	X	%			
3	dTeam possession	m:s			✓	X	
4	dTeam possession average	s			✓	X	
5	dTeam possession origin - Defence	n			✓		✓
6	dTeam possession origin - Midfield	n			✓		✓
7	dTeam possession origin - Attack	n			✓	X	
8	dTeam player possession total	n	X	Combination			
9	dTeam player possession total	m:s			✓		✓
10	dPlayer possession average	s			✓	X	
11	dPlayer possession origin - Defence	n			✓		✓
12	dPlayer possession origin - Midfield	n			✓	X	
13	dPlayer possession origin - Attack	n			✓		✓
14	dPass total: hand pass + kick pass	n	X	Combination			
15	dPass total successful	n	X	Combination			
16	dPass total successful	%	X	%			
17	dPass total unsuccessful	n	X	Combination			
18	dPass total unsuccessful	%	X	%			
19	dHand pass	n	X	Combination			
20	dHand pass successful	n			✓	X	
21	dHand pass successful	%	X	%			
22	dHand pass unsuccessful	n			✓	X	
23	dHand pass unsuccessful	%	X	%			
24	dKick pass	n	X	Combination			

25	dKick pass successful	n	X	Combination			
26	dKick pass successful	%	X	%			
27	dKick pass unsuccessful	n	X	Combination			
28	dKick pass unsuccessful	%	X	%			
29	dDead ball total	n	X	Combination			
30	dDead ball kick pass successful	n	X	Combination			
31	dDead ball kick pass successful	%	X	%			
32	dDead ball kick pass unsuccessful	n	X	Combination			
33	dDead ball kick pass unsuccessful	%	X	%			
34	dDead ball free kick total	n	X	Combination			
35	dDead ball free kick successful	n			✓		✓
36	dDead ball free kick successful	%	X	%			
37	dDead ball free kick unsuccessful	n			✓		✓
38	dDead ball free kick unsuccessful	%	X	%			
39	dDead ball kick out total	n	X	Combination			
40	dDead ball kick out successful	n			✓		✓
41	dDead ball kick out successful	%	X	%			
42	dDead ball kick out unsuccessful	n			✓	X	
43	dDead ball kick out unsuccessful	%	X	%			
44	dTurnover total (won)	n	X	Combination			
45	dTurnover origin - Defence	n			✓		✓
46	dTurnover origin - Midfield	n			✓		✓
47	dTurnover origin - Attack	n			✓	X	
48	dTackle total	n	X	Combination			
49	dTackle successful	n			✓	X	
50	dTackle successful	%	X	%			
51	dTackle unsuccessful	n			✓	X	
52	dTackle unsuccessful	%	X	%			
53	dTackle origin - Defence	n			✓		✓
54	dTackle origin - Midfield	n			✓		✓
55	dTackle origin - Attack	n			✓		✓

56	dFree kick / foul total (won)	n	X	Combination			
57	dFree kick origin - Defence	n			✓		✓
58	dFree kick origin - Midfield	n			✓	X	
59	dFree kick origin - Attack	n			✓	X	
60	dDefensive actions total	n	X	Combination			
61	dDefensive actions - Defence	n	X	Combination			
62	dDefensive actions - Midfield	n	X	Combination			
63	dDefensive actions - Attack	n	X	Combination			
64	dDefensive efficiency	%	X	%			
65	dAttack total	n	X	Combination			
66	dAttack origin - Defence	n			✓		✓
67	dAttack origin - Midfield	n			✓		✓
68	dAttack origin - Attack	n			✓	X	
69	dAttack Efficiency	%	X	%			
70	dShot total	n	X	Combination			
71	dShot from play	n			✓		✓
72	dShot from play	%	X	%			
73	dShot from dead ball	n			✓	X	
74	dShot from dead ball	%	X	%			
75	dShot efficiency	%	X	%			
76	dScore total	PT + G	X	Combination			
77	dNumber of scores	n	X	Combination			
78	dAttack per score average		X	Combination			
79	dProductivity		X	Combination			
80	dPoint	n	X	Combination			
81	dPoint from play	n			✓		✓
82	dPoint from dead ball	n			✓	X	
83	dGoal	n			✓	X	

PCA = Principal component analysis, KMO = Kaiser Meyer-Olkin.

Appendix F Activity profile, PlayerLoad™ and heart rate response of Gaelic football players – a pilot study (results)

Table 1 Full game match activity measures between different positional groups.

Match measure	Full-back (n = 12)	Half-back (n = 12)	Midfield (n = 4)	Half-forward (n = 10)	Full-forward (n = 12)	Mean (n = 50)
Playing time (m:s)	74:12 ± 1:05	74:14 ± 1:00	74:02 ± 0:12	74:26 ± 1:21	74:41 ± 1:15	74:21 ± 1:06
Rel. distance ($m \cdot min^{-1}$)	67.0 ± 13.0	113.2 ± 16.0[a,e]	100.3 ± 13.2[a]	107.2 ± 10.9[a,e]	82.0 ± 18.3[a]	92.4 ± 23.3
Stand ($m \cdot min^{-1}$)	0.6 ± 0.1	0.4 ± 0.1 [a]	0.5 ± 0.2	0.4 ± 0.2[a]	0.4 ± 0.1[a]	0.5 ± 0.1
Walk ($m \cdot min^{-1}$)	27.0 ± 5.1	32.8 ± 2.4[a,e]	33.5 ± 6.5[a]	31.1 ± 5.9	27.4 ± 5.7	29.8 ± 5.5
Jog ($m \cdot min^{-1}$)	23.3 ± 6.1	42.5 ± 7.5[a,e]	37.9 ± 8.4[a]	43.6 ± 8.2[a,e]	31.4 ± 11.4[a]	35.1 ± 11.6
Run ($m \cdot min^{-1}$)	10.6 ± 3.8	26.7 ± 6.6[a,c,e]	20.6 ± 5.9[a]	22.9 ± 3.5[a,e]	15.2 ± 4.3[a]	18.8 ± 7.8
High SR ($m \cdot min^{-1}$)	5.1 ± 1.8	11.5 ± 3.2[a,e]	8.1 ± 1.6[a]	9.2 ± 2.5[a]	7.5 ± 2.8[a]	8.3 ± 3.4
Maximum SR ($m \cdot min^{-1}$)	1.6 ± 1.2	1.4 ± 0.9	1.4 ± 0.9	2.1 ± 1.9	2.1 ± 1.4	1.7 ± 1.3
HIR ($m \cdot min^{-1}$ ≥4.0 $m \cdot s^{-1}$)	17.3 ± 5.9	39.5 ± 8.8[a,e]	30.0 ± 3.7[a]	34.2 ± 3.3[a,e]	24.8 ± 6.5[a]	28.8 ± 10.4
VHIR ($m \cdot min^{-1}$ ≥5.5 $m \cdot s^{-1}$)	6.8 ± 2.5	12.9 ± 3.6 [a]	9.5 ± 2.4	11.2 ± 3.7 [a]	9.5 ± 3.8	10.0 ± 3.9
Peak speed ($m \cdot s^{-1}$)	8.0 ± 0.4	7.6 ± 0.3	7.8 ± 0.6	7.8 ± 0.5	8.0 ± 0.6	7.8 ± 0.5
Peak HR ($b \cdot min^{-1}$)	191 ± 6	192 ± 9	197 ± 7	192 ± 10	190 ± 11	192 ± 9
Average HR ($b \cdot min^{-1}$)	157 ± 12	165 ± 7	169 ± 6	167 ± 9	160 ± 11	162 ± 10
Rel. PlayerLoad ($PL \cdot min^{-1}$)	7.0 ± 1.4	10.2 ± 1.6[a,e]	9.8 ± 1.6[a]	10.2 ± 1.3[a,e]	8.6 ± 1.6[a]	9.0 ± 1.9

Values are mean ± SD; Symbols indicate significantly different ($p \leq 0.05$) from full-back (a); midfield (c); and full-forward (e); Rel. = relative, SR = speed run, HIR = high-intensity running, VHIR = very high-intensity running, HR = heart rate.

Table 2 **Match activity measures for each period and half (all players combined, n=50).**

Variable	P1 0–15 min	P2 20–35 min	P3 35-50 min	P4 55-70 min	First half	Second half
Playing time (m:s)	15:00 ± 0:00	15:00 ± 0:00	15:00 ± 0:00	15:00 ± 0:00	37:24 ± 1:09	36:57 ± 0:24
Rel. distance ($m \cdot min^{-1}$)	101.7 ± 29.1	92.0 ± 26.2$^{\alpha}$	92.7 ± 27.3$^{\alpha}$	89.8 ± 24.6$^{\alpha}$	93.5 ± 25.2	91.3 ± 23.4
Stand ($m \cdot min^{-1}$)	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.1	0.2 ± 0.1
Walk ($m \cdot min^{-1}$)	5.9 ± 1.2	6.2 ± 1.3	5.7 ± 1.2	6.2 ± 1.3	15.1 ± 3.0	14.7 ± 2.8
Jog ($m \cdot min^{-1}$)	8.2 ± 3.1	7.0 ± 2.7$^{\alpha}$	7.1 ± 2.8$^{\alpha}$	6.8 ± 2.7$^{\alpha}$	18.1 ± 6.3	17.0 ± 5.9
Run ($m \cdot min^{-1}$)	4.5 ± 2.1	3.7 ± 1.7$^{\alpha}$	4.0 ± 1.9	3.5 ± 1.7$^{\alpha}$	9.5 ± 4.2	9.3 ± 3.9
High SR ($m \cdot min^{-1}$)	1.9 ± 1.0	1.7 ± 0.9	1.7 ± 1.1	1.5 ± 0.7	4.2 ± 1.8	4.1 ± 1.8
Maximum SR ($m \cdot min^{-1}$)	0.3 ± 0.3	0.3 ± 0.3	0.4 ± 0.4	0.4 ± 0.3	0.8 ± 0.7	1.0 ± 0.8
HIR ($m \cdot min^{-1} \geq 4.0\ m \cdot s^{-1}$)	6.7 ± 2.7	5.7 ± 2.4$^{\alpha}$	6.2 ± 2.7	5.4 ± 2.2$^{\alpha}$	14.5 ± 5.6	14.3 ± 5.3
VHIR ($m \cdot min^{-1} \geq 5.5\ m \cdot s^{-1}$)	2.3 ± 1.1	2.0 ± 1.0	2.2 ± 1.2	1.8 ± 0.8	5.0 ± 2.2	5.1 ± 2.0
Peak speed ($m \cdot s^{-1}$)	7.2 ± 0.6	7.4 ± 0.6	7.4 ± 0.5	7.4 ± 0.7	7.6 ± 0.5	7.7 ± 0.5
Peak HR ($b \cdot min^{-1}$)	189 ± 9	187 ± 10	185 ± 9	185 ± 9	190 ± 9	187 ± 9
Average HR ($b \cdot min^{-1}$)	167 ± 12	165 ± 12	160 ± 9$^{\alpha}$	160 ± 11$^{\alpha}$	165 ± 11	160 ± 10*
Rel. PlayerLoad ($PL \cdot min^{-1}$)	9.9 ± 2.5	9.0 ± 2.2$^{\alpha}$	9.1 ± 2.3	8.7 ± 2.0$^{\alpha}$	9.1 ± 2.1	8.9 ± 2.0

Values are mean ± SD; Symbols indicate significantly different ($p \leq 0.05$) from P1 (α) and first half (*); P = period, Rel. = relative, SR = speed run, HIR = high-intensity running, VHIR = very high-intensity running, HR = heart rate.

Table 3 Positional differences in activity profiles between periods and halves.

Variable	P1 0–15 min	P2 20–35 min	P3 35-50 min	P4 55-70 min	First Half	Second half
Full-back *(n = 12)*						
Walk (m·min^{-1})	5.3 ± 1.2	5.5 ± 1.5	5.4 ± 1.1	5.6 ± 1.4	13.6 ± 3.1	13.4 ± 2.5
Jog (m·min^{-1})	5.1 ± 1.3	4.2 ± 1.4	5.0 ± 1.7	4.9 ± 1.8	11.4 ± 2.6	11.9 ± 4.0
Run (m·min^{-1})	2.2 ± 1.0	1.8 ± 0.8	2.6 ± 1.3	2.3 ± 1.2	4.8 ± 1.5	5.8 ± 2.7
High SR (m·min^{-1})	1.1 ± 0.5	0.9 ± 0.5	1.0 ± 0.8	1.2 ± 0.6	2.4 ± 0.8	2.7 ± 1.4
Max. SR (m·min^{-1})	0.3 ± 0.4	0.4 ± 0.3	0.4 ± 0.3	0.3 ± 0.3	0.8 ± 0.7	0.9 ± 0.6
Half-back *(n = 12)*						
Walk (m·min^{-1})	6.6 ± 0.7	6.8 ± 0.6	6.3 ± 0.5	6.8 ± 0.8	16.5 ± 1.5	16.2 ± 1.6
Jog (m·min^{-1})	10.1 ± 2.1	8.6 ± 2.4	9.0 ± 1.8	7.4 ± 2.3$^{\alpha}$	22.3 ± 4.5	20.2 ± 4.3
Run (m·min^{-1})	6.3 ± 1.5	5.3 ± 1.6	5.7 ± 1.7	4.8 ± 1.8$^{\alpha}$	13.7 ± 3.4	12.9 ± 3.5
High SR (m·min^{-1})	2.5 ± 0.8	2.5 ± 0.8	2.6 ± 1.1	1.8 ± 1.0$^{\alpha, \beta, \gamma}$	5.7 ± 1.5	5.8 ± 2.0
Max. SR (m·min^{-1})	0.3 ± 0.3	0.2 ± 0.2	0.2 ± 0.3	0.3 ± 0.3	0.7 ± 0.6	0.7 ± 0.5
Midfield *(n = 4)*						
Walk (m·min^{-1})	6.7 ± 1.4	6.6 ± 1.0	6.8 ± 1.6	7.2 ± 1.4	16.4 ± 2.8	17.1 ± 3.1
Jog (m·min^{-1})	10.1 ± 2.2	7.9 ± 2.0	7.1 ± 2.5$^{\alpha}$	6.9 ± 1.1$^{\alpha}$	21.2 ± 4.5	16.7 ± 4.9
Run (m·min^{-1})	5.0 ±1.9	3.9 ± 0.9	4.1 ± 1.7	3.6 ± 1.1	11.2 ± 2.4	9.3 ± 2.4
High SR (m·min^{-1})	2.1 ± 1.2	1.6 ± 0.6	1.9 ± 0.5	1.0 ± 0.2	4.3 ± 1.6	3.8 ± 1.2
Max. SR (m·min^{-1})	0.1 ± 0.1	0.2 ± 0.2	0.4 ± 0.3	0.5 ± 0.5$^{\beta}$	0.3 ± 0.8	1.0 ± 1.1
Half-forward *(n = 10)*						
Walk (m·min^{-1})	6.4 ± 0.9	6.5 ± 1.1	5.8 ± 1.4	6.2 ± 1.4	16.0 ± 2.9	15.1 ± 3.7
Jog (m·min^{-1})	10.8 ± 2.4	8.5 ± 1.9$^{\alpha}$	8.3 ± 1.7$^{\alpha}$	8.7 ± 2.8$^{\alpha}$	22.9 ± 5.4	20.8 ± 3.0
Run (m·min^{-1})	5.8 ± 1.2	4.4 ± 1.1$^{\alpha}$	5.0 ± 1.1	4.3 ± 1.3$^{\alpha}$	11.6 ± 3.1	11.4 ± 3.3
High SR (m·min^{-1})	2.2 ± 0.9	1.9 ± 0.7	1.8 ± 0.8	1.6 ± 0.5	4.8 ± 1.5	4.4 ± 0.1
Max. SR (m·min^{-1})	0.4 ± 0.4	0.3 ± 0.3	0.5 ± 0.6	0.3 ± 0.3	0.9 ± 0.3	1.1 ± 0.8
Full-forward *(n = 12)*						
Walk (m·min^{-1})	5.2 ± 1.2	5.9 ± 1.4	5.1 ± 1.2	5.8 ±1.3	13.9 ± 3.3	13.5 ± 2.6
Jog (m·min^{-1})	6.6 ± 2.5	6.6 ± 2.4	6.1 ± 3.5	6.6 ± 3.0	15.7 ± 5.1	15.7 ± 6.7
Run (m·min^{-1})	3.6 ± 1.6	3.1 ± 1.0	2.9 ± 1.5	2.8 ± 1.2	7.9 ± 2.5	7.3 ± 2.5
High SR (m·min^{-1})	1.9 ± 1.0	1.6 ± 0.8	1.4 ± 1.0	1.5 ± 0.5	3.9 ± 1.6	3.6 ± 1.4
Max. SR (m·min^{-1})	0.4 ± 0.4	0.4 ± 0.4	0.6 ± 0.5	0.5 ± 0.4	0.8 ± 0.7	1.2 ± 0.8

Values are mean ± SD; Symbols indicate significantly different ($p \leq 0.05$) from P1 (α); P2 (β); and P3 (γ); P = period, SR = speed run, Max. = maximum.

Table 4 Positional differences in relative distance, high-intensity running, peak speed and heart rate between periods and halves.

Variable	P1 0–15 min	P2 20–35 min	P3 35-50 min	P4 55-70 min	First Half	Second half
Full-back *(n = 12)*						
RD (m·min^{-1})	68.4 ± 13.4	62.4 ± 15.1	71.0 ± 19.0	70.5 ± 20.1	64.9 ± 11.1	69.1 ± 17.9
HIR (RD ≥ 4.0 m·s^{-1})	3.6 ± 1.5	3.1 ± 1.2	4.1 ± 1.9	3.9 ± 1.8	7.9 ± 2.5	9.4 ± 4.1
VHIR (RD ≥ 5.5 m·s^{-1})	1.4 ± 0.7	1.3 ± 0.6	1.4 ± 0.9	1.6 ± 0.7	3.2 ± 1.3	3.6 ± 1.6
Peak speed (m·s^{-1})	7.3 ± 0.5	7.7 ± 0. 6	7.6 ± 0. 4	7.4 ± 0.8	7.8 ± 0.6	7.8 ± 0.4
Peak HR (b·min^{-1})	187 ± 7	184 ± 8	184 ± 8	186 ± 11	188 ± 5	188 ± 9
Half-back *(n = 12)*						
RD (m·min^{-1})	125.6 ± 16.5	114.1 ± 22.0	116.5 ± 20.0	103.1 ± 22.2$^{\alpha}$	116.3 ± 18.9	110.2 ± 17.0
HIR (RD ≥ 4.0 m·s^{-1})	9.1 ± 1.8	8.0 ± 2.3	8.6 ± 2.4	6.9 ± 2.6$^{\alpha}$	20.2 ± 4.6	19.4 ± 4.7
VHIR (RD ≥ 5.5 m·s^{-1})	2.8 ± 0.8	2.7 ± 1. 0	2.8 ± 1.2	2.1 ± 1.1	6.4 ± 1.9	6.5 ± 2.1
Peak speed (m·s^{-1})	7.1 ± 0.5	7.3 ± 0.4	7.1 ± 0.3	7.2 ± 0.6	7.6 ± 0.4	7.4 ± 0.4
Peak HR (b·min^{-1})	189 ± 8	189 ± 8	184 ± 7	186 ± 7	190 ± 9	188 ± 6
Midfield *(n = 4)*						
RD (m·min^{-1})	117.6 ± 14.3	99.2 ± 11.7	98.9 ± 19.5	93.6 ± 14.2	105.2 ± 12.0	95.4 ± 12.2
HIR (RD ≥ 4.0 m·s^{-1})	7.3 ± 1.0	5.8 ± 1.2	6.4 ± 1.4	5.1 ± 1.0	15.9 ± 2.4	14.1 ± 2.4
VHIR (RD ≥ 5.5 m·s^{-1})	2.2 ± 1.3	1.8 ± 0.8	2.3 ± 0.6	1.4 ± 0.4	4.7 ± 2.2	4.8 ± 1.7
Peak speed (m·s^{-1})	7.0 ± 0.3	7.2 ± 0.6	7.5 ± 0.5	7.4 ± 1.0	7.3 ± 0.4	7.8 ± 0.5
Peak HR (b·min^{-1})	191 ± 8	190 ± 8	191 ± 6	190 ± 8	192 ± 10	195 ± 9
Half-forward *(n = 10)*						
RD (m·min^{-1})	124.8 ± 11.4	105.8 ± 12.9$^{\alpha}$	105.0 ± 8.9$^{\alpha}$	103.3 ± 21.0$^{\alpha}$	109.9 ± 12.0	104.4 ± 15.1
HIR (RD ≥ 4.0 m·s^{-1})	8.4 ± 1.5	6.7 ± 1.2$^{\alpha}$	7.4 ± 1.4	6.2 ± 1.6$^{\alpha}$	17.3 ± 1.5	16.9 ± 2.6
VHIR (RD ≥ 5.5 m·s^{-1})	2.6 ± 1.0	2.3 ± 0.8	2.3 ± 0.9	1.9 ± 0.6	5.7 ± 1.8	5.6 ± 0.9
Peak speed (m·s^{-1})	7.4 ± 0.6	7.4 ± 0.4	7.4 ± 0.6	7.2 ± 0.4	7.6 ± 0.6	7.7 ± 0.6
Peak HR (b·min^{-1})	192 ± 10	188 ± 11	186 ± 10	184 ± 10	192 ± 8	186 ± 7
Full-forward *(n = 12)*						
RD (m·min^{-1})	86.6 ± 22.2	85.4 ± 21.1	78.4 ± 29.8	83.5 ± 23.7	81.7 ± 16.7	82.3 ± 21.7
HIR (RD ≥ 4.0 m·s^{-1})	5.9 ± 2.4	5.1 ± 1.4	4.9 ± 2.5	4.7 ± 1.5	12.6 ± 3.6	12.1 ± 3.5
VHIR (RD ≥ 5.5 m·s^{-1})	2.3 ± 1.3	1.9 ± 1.0	2.0 ± 1.4	1.9 ± 0.8	4.8 ± 2.1	4.8 ± 1.9
Peak speed (m·s^{-1})	7.3 ± 0.6	7.3 ± 0.6	7.5 ± 0.7	7.6 ± 0.9	7.6 ± 0.5	8.0 ± 0.6
Peak HR (b·min^{-1})	186 ± 13	185 ± 14	183 ± 10	182 ± 10	189 ± 13	184 ± 10

Values are mean ± SD; Symbols indicate significantly different ($p \leq 0.05$) from P1 (α); P = period, RD = relative distance, HIR = high-intensity running, VHIR = very high-intensity running, HR = heart rate.

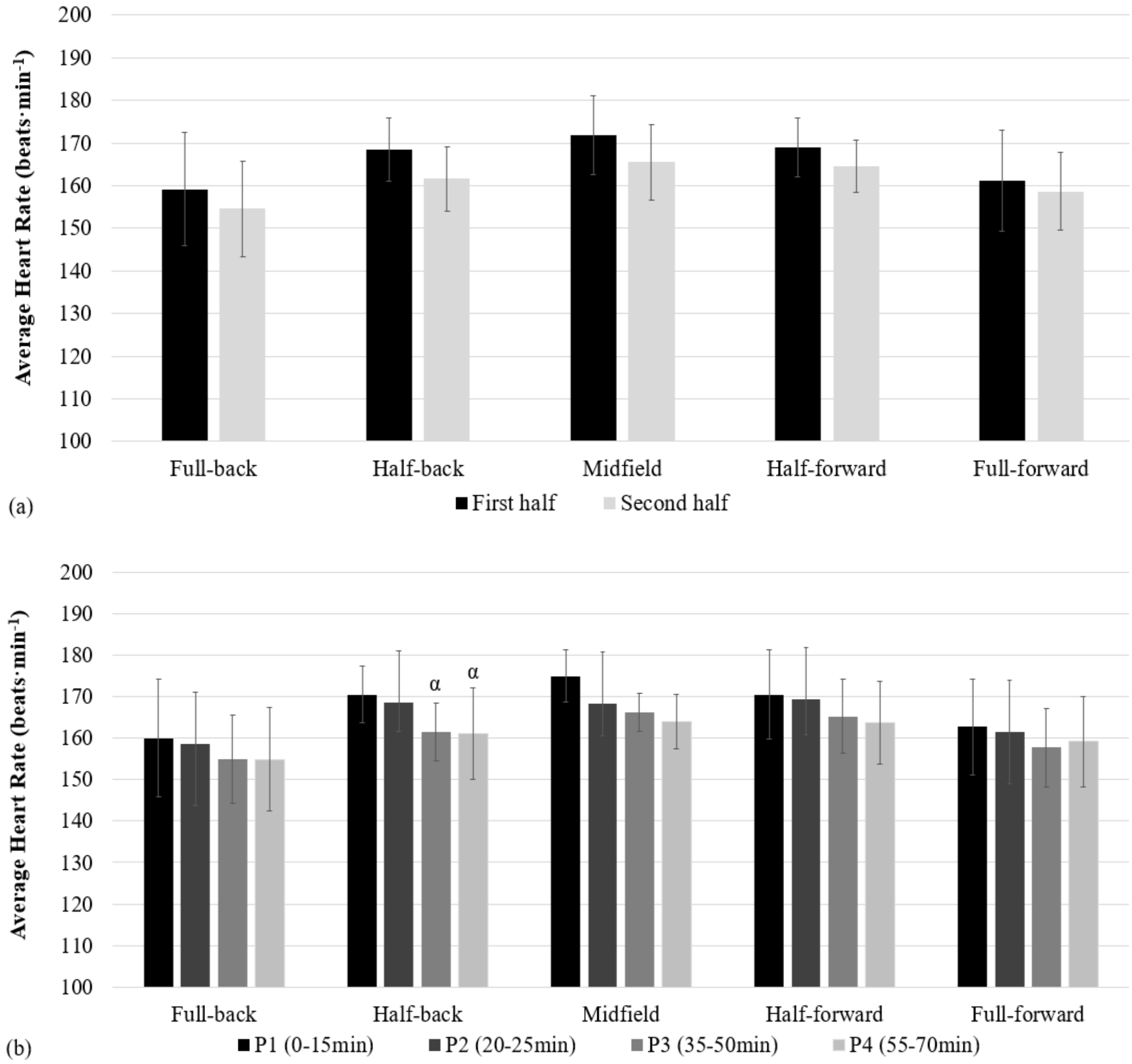

Figure 1. Differences in average heart rate during (a) first and second halves and (b) across four match periods, mean ± SD. Symbols indicate significantly different ($p \le 0.05$) from P1 (α).

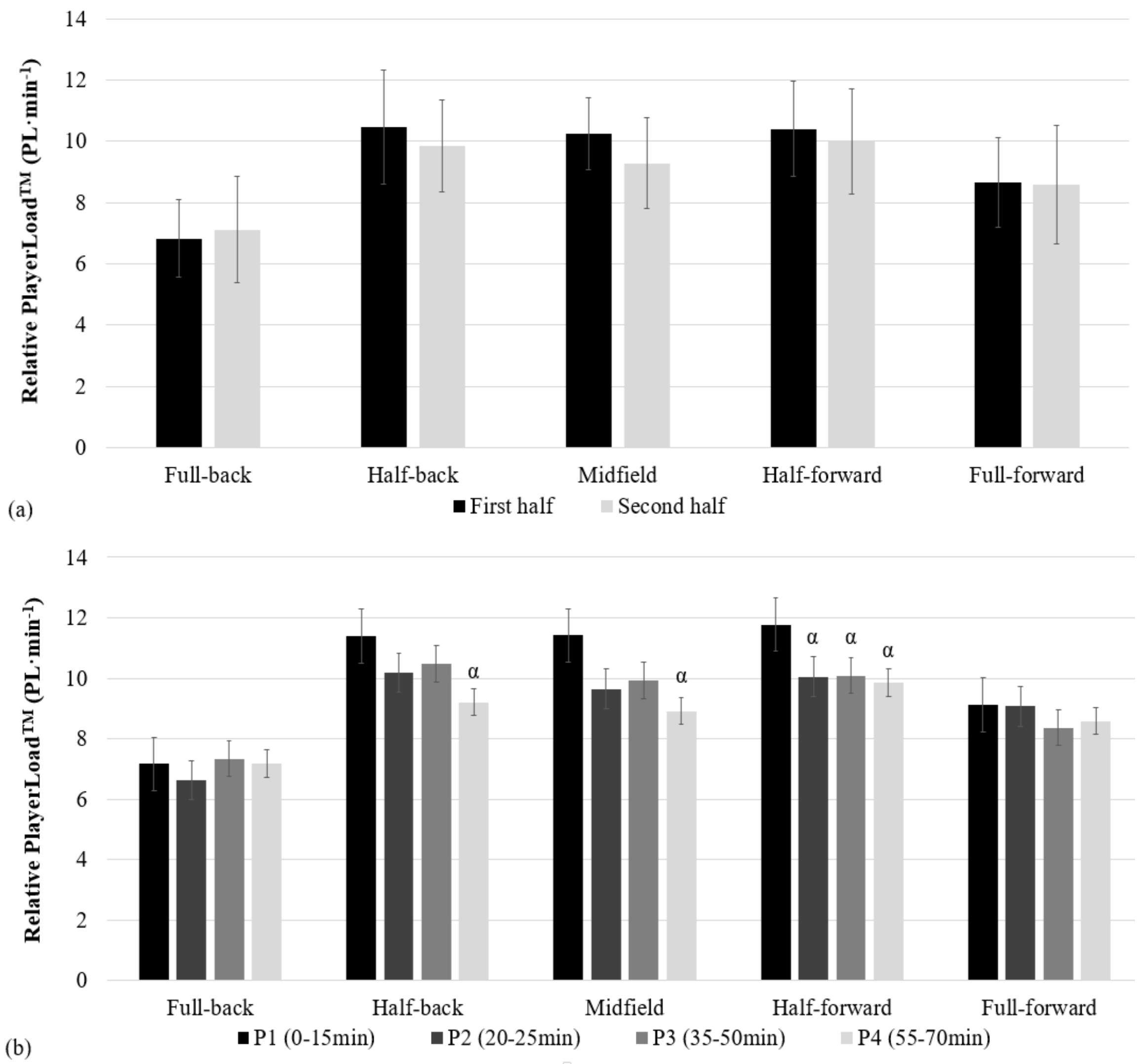

Figure 2. Differences in PL.min-1 during (a) first and second halves and (b) across four match periods, mean ± SD. Symbols indicate significantly different (p ≤ 0.05) from P1 (α).