Methodological advances for assessing individual and team performances in elite rugby union.

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Methodological Advances for Assessing Individual and Team Performance in Elite Rugby Union

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ABSTRACT

Appropriate methodologies were devised for constructing and assessing individual and team performance in rugby union with an emphasis on providing practical solutions for the coach or performance analyst. The Noldus 'Observer Video-Pro' analysis system (Noldus Information Technology, 1995) was used for all data collection with appropriate tests for reliability and validity conducted. Parsons and Hughes (2001) indicated varying skill demands of different rugby playing positions but within position differences were not investigated. The first study consequently created performance profiles for all playing positions, via the use of individual performance indicators (PIs), using all players used in 22 matches of the domestic season of a professional male rugby union team. A novel transformation to account for the time a player spent on the field was devised. Furthermore it was suggested that the appropriate descriptive statistics for presenting non-parametric summary information was via the median and confidence limits for a population median. Significant differences were observed between individuals of the same position for the most frequently performed PIs (passing, carrying and tackling for forward positions and passing, carrying, tackling and kicking for the backs) of all the playing positions tested. The findings suggested that while general positional performance profiles appear to exist, intra-positional differences may occur due to variations in an individual's style of play and physical attributes.

Hunter and O'Donoghue (2001) suggested specific indicators that differentiated successful and unsuccessful rugby union teams, although between team differences may have contributed to this. Twenty further matches of the same team used for study 1 were analysed using additional PIs designed to analyse team performance. Some of the

existing individual PIs were also modified, with off the ball behaviours added to enhance individual profiles. Only two of the team PIs (lineout success on the opposition throw and tries scored) revealed statistical differences between winning and losing performances although a general trend of superior performance was found when the team was winning. The individuality within positional roles that was found in study 1 was further tested and revealed that only one of 13 players' ball-in-hand behaviours differed significantly between two different seasons despite a considerable change in the remainder of the playing personnel.

Bracewell (2003a) used control charts to create individual performance scores although no attempt was made to encapsulate team performance. Thus, objective methods of scoring team performance were presented using a single score measure of performance through the use of PI weightings (study 3a), and secondly via the combination of comparative scores for a match (study 3b) using the same 20 matches as study 2. Study 3a calculated a single score using PI weightings based on correlation coefficients between 31 PIs and two elite coaches' assessment of overall match performance. These coefficients squared were multiplied with the performance value of each PI in a given match and combined to form the single score. Of the models tested, the one containing all PIs was found to have the smallest mean bias for scores out of 100 for both wet (4.18) and dry (1.14) conditions, a high correlation (r= 0.77 wet, 0.85 dry) and no significant difference (p= 0.35 wet, 0.88 dry) with the coach scores. This suggested that the model predicted coach scores and thus match performance well, although some variance remained. Further work is needed to assess the applicability of this approach, preferably using coach evaluations for validation purposes only.

Study 3b used 18 PIs from the 20th match of the same sample, standardised relative to the previous 5 and 19 matches producing distributions of median 50 and interquartile range 15. The standardised values were plotted on a 'form chart' to provide a visual assessment of each PI on one scale. This, coupled with non-standardised descriptive statistics, provided comprehensive and simple to understand feedback on performance relative to previously accomplished standards that can easily be used within a practical setting for any multi-faceted sport.

This thesis has investigated individual and team PIs and found that rugby union performance is best characterised by a number of comparative PIs. Future research needs to utilise this methodology to assess comparative strengths and weaknesses between different teams.

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed.. ....(Candidate)

Date... 24/02/2006 .....

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references.

Signed.. ....(Candidate)

Date.. 24/02/2006 .....

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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James, N., Jones, N.M.P. and Mellalieu, S.D. (2004). A comparison of individuals' decision making performance profiles in rugby union between two seasons. *Proceedings of the World Congress of Performance Analysis of Sport VI.* Belfast, Northern Ireland, p. 31.

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CHAPTER 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

In August 1995, the International Rugby Board (IRB) declared that the game of rugby union would become a professional sport. The game has consequently undergone dramatic changes both on and off the field since this announcement. Lucrative contracts are now attainable for elite players, coaches and management staff. Domestic clubs and governing bodies have been compelled to amend both their playing and business strategies in order to compete with performance standards at the highest level. The last decade has therefore been a period of enormous change, as the sport has adapted to its new professional structure (Howe, 1999).

As a direct consequence of professionalism and the monetary rewards available, increasing pressures and responsibilities have been placed on coaching and management staff (Jones, 2001). The transition from amateur to professional status (which has also shaped the majority of modern, competitive sports) has placed an emphasis on maximising the capture and use of match data. This has led to the comprehensive analysis of sports performance and tactical formation, known as performance or notational analysis (Lyons, 1997).

Despite this relatively recent progression within rugby union, the use of performance analysis in sport is not a new concept (Croucher, 1997). Indeed, published academic accounts of notational analysis appearing in *Research Quarterly*, date back to 1931 (Lyons, 1997). Nevertheless, it has been the incorporation of information technology that has enabled the analyst to process enormous volumes of information at the touch of a button (Croucher, 1997). According to Hughes (1996, p. 346), this extreme speed of data processing is "very important to coaches and athletes for immediacy of feedback of performance." These technological advances have led to an increased interest and

efficiency within performance analysis, especially in professional competitive sports such as soccer (Grehaigne *et al.*, 1997; Wilson and Barnes, 1998).

Further to its practical application, performance analysis has grown into a discipline of its own within sports science research. The field now embodies peer reviewed journals supported by a number of books covering research, application and education in the analysis of sporting performance. The use of performance analysis support is now widely acknowledged and accepted amongst most professional sports and governing bodies around the world.

Empirical performance analysis research within rugby union has generally been limited to the exploration of specific aspects of the game such as the tactical play of teams, or physical demands of individual players (e.g. Hughes and Williams, 1988; Hughes and White, 1997; Deutsch *et al.*, 2002). Recently however, researchers have emphasised the need to focus towards the development and utilisation of indicators of key performance areas within a sport, commonly known as performance indicators (PIs) (Hughes and Bartlett, 2002). By collecting data regarding PIs, subsequent performance profiles can be generated. These are suggested to be a description of a pattern of performance from a team or individual, typically created from combinations of PI frequencies that offer some prediction of future performance (Hughes *et al.*, 2001). The analysis of performance profiles yields detailed information concerning team or individual performance from which players and coaches can benefit within a practical setting. This use of feedback through analysis has long been recognised as an essential part of the coaching process (Franks, 2004; Hughes, 2004). Indeed, individual effort has been found to increase when players feel that their specific contribution to the team has been observed (Carron, 1988). However, despite the appealing practical nature of this

concept, there is a paucity of research in the existing literature on both individual and team PIs and their resultant profiles. Furthermore, previous performance analysis research has often suffered from methodological issues including a lack of reliability and inappropriate data analysis procedures (Atkinson and Nevill, 1998; Hughes *et al.*, 2002; Nevill *et al.*, 2002). In addition, the number of performances sampled before a representation of typical performance is generated has seldom been examined (Hughes *et al.*, 2001). Subsequently, the principal aim of this thesis is to investigate methodologies for constructing and assessing individual and team performance profiles within rugby union using appropriate reliability, data analysis and data sampling measures.

The investigation of individual performance profiles in rugby union has to date been restricted, possibly due to the complexity of the sport (Bracewell, 2003a), to a small selection of positions (e.g. Vivian *et al.*, 2001), or to common on or off the ball skill demands of different playing positions (e.g. Parsons and Hughes, 2001). However, in rugby union, each playing position has role responsibilities that are both unique and common to other positions in the team (Greenwood, 1997). Whilst a clear picture of skill demands for certain individual playing positions has been provided, specific performance profiles of all rugby union positions have not been investigated. Furthermore, there has been no research that has investigated individuality within positions. Acknowledgement of both common and position-specific PIs is therefore needed to present a more accurate representation of players' contributions to performance. Consequently, the first objective of this thesis (study 1) is to identify common and position-specific PIs and their subsequent profiles. From these profiles, comparisons between, and also within positions (individuality) will be made across an entire team.

Further to research investigating individual PIs and profiles, there have been a number of studies concerning team performance in rugby union (e.g. Hughes and White, 1997; Stanhope and Hughes, 1997; Hunter and O'Donoghue, 2001; McCorry *et al.*, 2001). However, the findings have provided restricted information on specific technical and tactical areas of rugby union due to the use of a limited number of team PIs, such as rucks, mauls, and methods of gaining possession. Furthermore, prior research has compared the aggregate performance data of two or more different teams (the winning and losing sides) rather than analysing one team's success and failure. Comparing winning and losing sides may result in a potential loss of any meaningful information due to each team possessing different styles of play and consequently, diverse performance profiles (Taylor *et al.*, 2004). A second objective of this thesis (study 2) therefore, is to develop a methodology to construct team performance profiles and examine the predictors of success in a single team through the comparison of winning and losing performances.

An additional area that has received little attention within analysis of rugby union is the assessment of overall team performance (e.g. via a match score). This may be a consequence of the complexity of the sport or as a result of other confounding variables which it may be necessary to account for when assessing performance, e.g. match venue, weather, and the opposition (James *et al.*, 2002). Whilst previous research has successfully constructed individual performance scores (Bracewell, 2003a), there are no published studies that provide a methodology for the objective scoring of team performance. An objective match score or combination of scores would provide a practical measure for coaches and analysts to assess the performance of their team, irrespective of match outcome. Consequently, the final intention of this thesis (study 3)

is to provide an objective method for scoring team performance in rugby union that can be used within a practical setting.

The structure of the thesis will employ the following procedure. First, a review of the relevant literature will examine the existing research pertaining to performance analysis. This will include the performance profiling of rugby union teams and individuals and the methodological issues associated with measurement and analysis procedures within this field. Second, there will be three research studies that will examine methodologies of performance profiling within rugby union. These studies will investigate individual and team PIs, assess these indicators as a function of success, and examine the creation of an objective measure of rugby union performance. Study 1 will propose and develop a framework of individual PIs within a reliable data collection system, examine when, and whether position specific data stabilises so that a profile can be created, and assess whether these data are independent of individual style.

Having attempted to construct individual profiles over a season, study 2 will comprise the identification and analysis of team PIs as a function of winning and losing, whilst further investigating individual profiles through the comparison of profiles between two seasons. The exploration of team indicators and profiles will endeavour to assess the importance of certain behaviours to success whilst providing preliminary data concerning the objective scoring of rugby union performance. The comparison of individual profiles across two differing seasons will attempt to highlight any effects of individuality on positional roles.

The third and final study will subsequently investigate the feasibility and applicability of scoring team performance in rugby union through the examination of two methodologies. The first will endeavour to create a single score for team performance

through the utilisation of a model based upon PI weightings (i.e. the importance of each PI to performance), while the second will provide a number of comparable, standardised scores for specific performance areas within the sport.

Although the three studies contained in this thesis possess diverse objectives that are specific to each study, they all share the principal aim of developing methodologies for the assessment of performance in rugby union. It is important to focus upon this aim when considering the respective results and discussions. However, a delimitation of all three studies is that they utilise a case study design and therefore, any results or profiles generated may not necessarily be applicable to other teams or individuals. Further research could therefore attempt to adapt and apply these methodologies to different teams, thereby investigating inter-team variance which is beyond the scope of this thesis. A further delimitation of the studies is that despite the use of representative samples, various external variables such as the weather, match venue and the opposition may all affect the results and profiles of the analysed team and individuals.

In conclusion, the final chapter of the thesis will discuss the findings of the three research studies, whilst providing a consideration of the practical and theoretical contributions to the area of enquiry. Practical recommendations for coaching and management staff will be proposed in order to facilitate the measurement of individual and team performance in rugby union. Finally, an assessment of the strengths and limitations of the methodologies employed will be discussed, together with recommendations for future research within the analysis of rugby union performance.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2: REVIEW OF LITERATURE

2.1 INTRODUCTION

The recognition of performance analysis as a vital component of the coaching process has led to a significant amount of research being devoted to developing objective systems for gathering information (Hughes, 1996). The principal aim of this chapter is to provide an introduction to performance analysis and to review and critique performance analysis studies that are relevant to this thesis. Attention will be directed towards research within the sport of rugby union that concerns itself with the analysis of patterns of play, the use of performance indicators (PIs) and profiles, and the issue of analysis system reliability. In order to substantiate and justify the various discussions, studies from the past five decades will be utilised (1960-2005).

2.2 CONCEPTUAL DEFINITIONS

Existing literature within performance analysis has often caused confusion for the reader in relation to interchangeable terms and definitions that they provide. For example, the term "match analysis" has been used in certain studies (e.g. Vivian *et al.*, 2001), whilst the term "notational analysis" has been used in others (e.g. Croucher, 1997). Match analysis refers to the analysis of sport that is played in the format of a match (e.g. a rugby or soccer match), whilst notational analysis refers to the notating of events for the purpose of collecting statistical details of performance (Reilly and Gilbourne, 2003). Furthermore, the term "performance analysis" refers to the collection of data that enable an accurate statistical interpretation of performance parameters (Hughes, 1988). Therefore, a number of terms and variables that will be used within this thesis are defined in Table 2.1 to provide verification and consistency throughout this body of work.

Table 2.1: Conceptual definitions of performance analysis terms and variables.

TERM	DEFINITION
Performance	"The perception of how well an individual played in a single match" (Bracewell, 2003a, p. 611). Performance in this thesis is solely concerned with observable behaviour.
Performance Analysis	"A means of objectively recording data during sports performances, enabling an accurate statistical delineation of performance parameters" (Hughes, 1988).
Notational Analysis	"The recording of events for purposes of collating statistical details of performance" (Reilly and Gilbourne, 2003, p.697).
Match Analysis	The analysis of sport that is played in the format of a match (e.g. a rugby or soccer match).
Performance Indicator (PI)	"A selection, or combination, of action variables that aims to define some or all aspects of a performance" (Hughes and Bartlett, 2002, p. 739). Can also be referred to as a behaviour.
Performance Profile	A profile of an individual or team's performance constructed using a collection of PIs (Hughes *et al.*, 2001).
Ability	The long term accumulation of performances also known as form. To understand ability, a series of matches must be considered as opposed to a performance in one match (Bracewell, 2003a).
Skill	The ability to perform an appropriate action in the correct situation in an efficient, effective and consistent manner (Williams *et al.*, 2003).
Stabilise (also known as normalise)	Collected data are sufficiently representative of typical performance to be interpretable.
Stabilised Performance Profile	An individual or team profile which is representative of all aspects of performance to be interpretable.
Strategy	"A plan devised to achieve an overall aim or specific objective" (Robertson, 1999, p. 4).
Tactics	Specific decisions and actions that need to be addressed in order to achieve a strategic goal (Robertson, 1999).
Analysis of Patterns of Play	An exploration into the way in which a team plays and performs. Essentially an investigation into the presence, advantages, and disadvantages of a team's tactics and strategies.

2.3 The Coaching Process and Performance Analysis

The primary objective of performance analysis in sport has been to inform the coaching process of an athlete's performance, and subsequently aid in the modification of athletic behaviour (Brackenridge and Alderson, 1985; Franks *et al.*, 2001). Although modern day sport has introduced a number of new activities to the role of the coach (e.g. the recruitment of individuals), instructing athletes on their performance remains a priority for most sports (Franks *et al.*, 2001). Indeed, the need for feedback through analysis has long been recognised as a vital part of the coaching and performance improvement processes (Franks, 2004; Hughes, 2004). Furthermore, it has been suggested that feedback is not only critical to the learning and performance of a physical activity, but also to the development of perceived competence and intrinsic motivation, which can in turn also enhance performance (Deci and Ryan, 1985; Larder, 1988; Shephard, 1990).

The use of performance analysis as a tool for providing feedback helps to eliminate subjectivity whilst objectifying the coaching process (Franks, 2004). However, it is important to note that performance analysis only provides raw data, it does not necessarily give answers (Robertson, 1999). These data should then be analysed by coaches, statistically or otherwise, to gain information on the subjects or teams.

2.4 The Use of Performance Analysis

Analysis of performance in sport is not a new academic activity (Lyons, 1997). The hand notation methods of Lloyd Lowell Messersmith in the 1930s and 1940s have long been seen as the first attempt to develop systems specifically for sporting analysis (see Hughes, 1996). However, since then more and more sports have now engaged in performance analysis to gain any, and every advantage possible (Peacock, 2001). This increase has arisen as a result of two factors; firstly, coaches' limited power of

observational recall, and secondly the major advances that have taken place within sports science (Vivian *et al.*, 2001). The widespread introduction of computers within the field has resolved many of the complications associated with hand notation whilst allowing for immediate data analysis (Kawai, 1997). Technology is becoming highly advanced and the use of computers and video playback in both analysis and presentation is proving to be the key for the future within the science of performance analysis (Franks, 1988; see Hughes and Franks, 2004a, for a full review of computerised and hand notation systems).

2.5 The Development of a Sport-Specific Notational System

The development of an accurate and relevant notational system is a vital area in performance analysis (Lames and Hansen, 2001). According to Franks and McGarry (1996, p. 370), "the structure of the particular sport would suggest the most suitable modeling procedure." The subsequent development of a flowchart which uses sequential events or states is the key to a successful system (Franks and McGarry, 1996).

Computerised notation systems have the ability to process vast amounts of data immediately, and are employable for the majority of analysis cases. This allows the investigation and analysis of sports using hierarchical flowcharts and sequential events. An example of a notational system which uses a series of sequential events (a flowchart for squash) is illustrated in Figure 2.1.

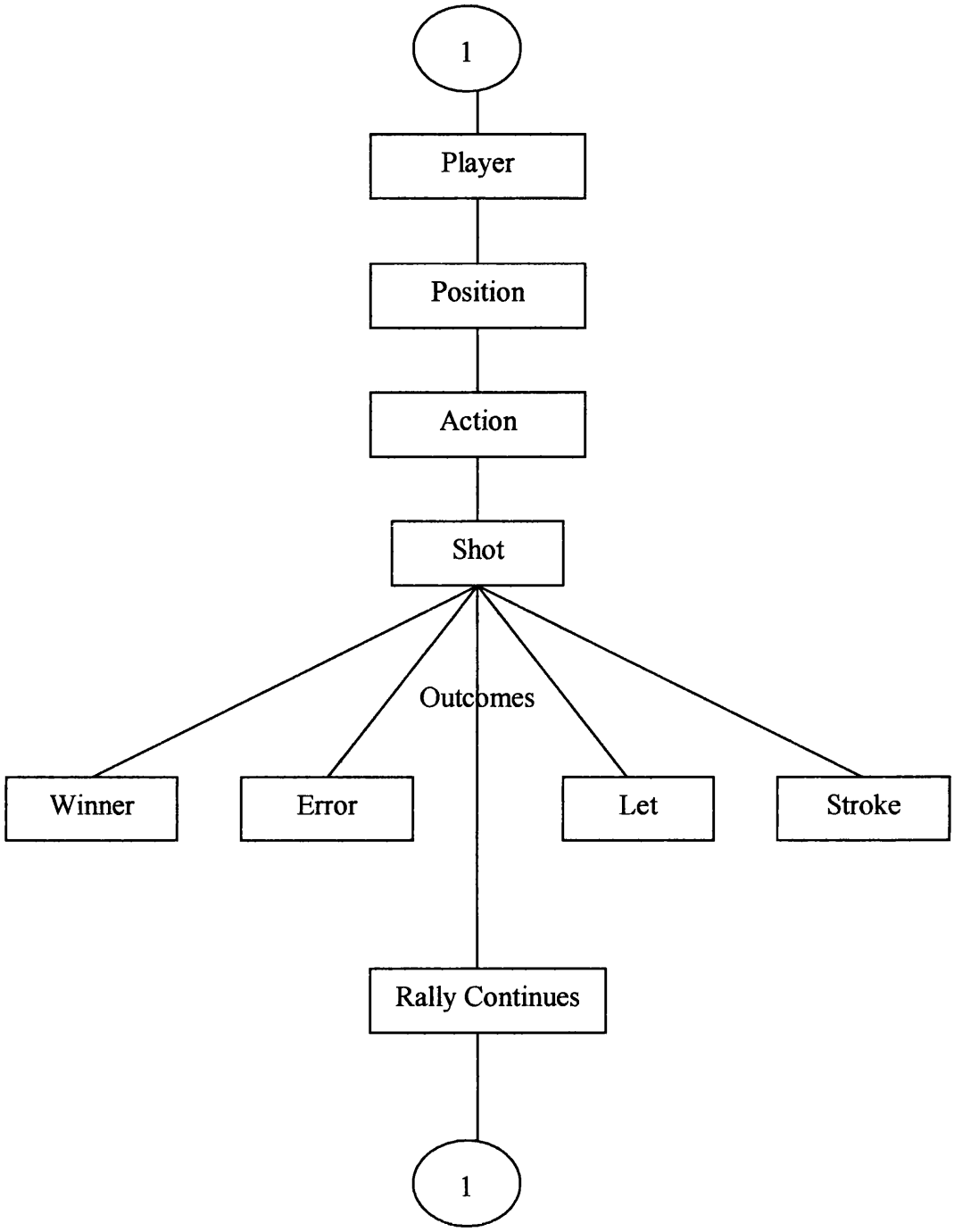

Figure 2.1: Simple flowchart for squash (Hughes and Franks, 2004b; p. 112).

The simplicity (or complexity) of a notational system is dependant upon what the objectives of the analysis are. For example, using the flowchart for squash (Figure 2.1) would provide the analyst and coaches with data on all aspects of the sport such as the relative success rates of each behaviour performed (e.g. volleys). However, if there was interest in just one of the players, or if the only behaviour being analysed was straight drives, the flowchart could be simplified by disregarding certain behaviours to provide only the relevant data. The depth of analysis can obviously be altered in line with the coach's requirements for different matches, or even stages of matches. When adopting a performance analysis strategy, it is important to work closely with all members of the coaching and management team as well as the performers, to ensure that any proposed system is designed to create the most in depth, relevant, and accurate results possible (Croucher, 1997). However, it is only recently that sports research has become aware that the aspect of 'purpose' has not been paid enough attention to (Lames and Hansen, 2001). Furthermore, there are a wide variety of purposes within observational systems in sport, e.g. measuring individual performance, physical loads, tactical solutions and decision making. Indeed, as Figure 2.2 illustrates, the purpose of the observational system must be identified before the model or flow chart can be finalised.

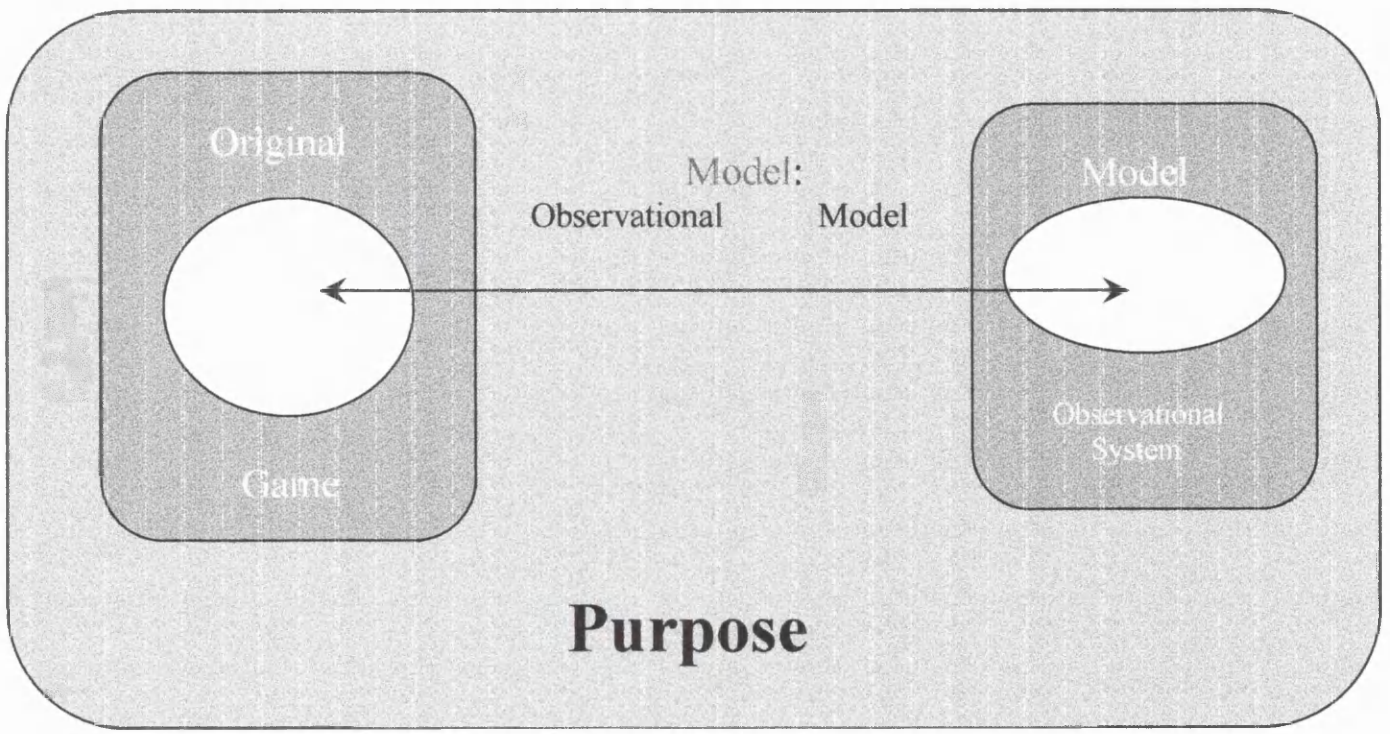

Figure 2.2: An observational system as a result of a model building process. The model relation is considered as being embedded in its purpose (Lames and Hansen, 2001, p. 84).

2.6 The Development of Performance Analysis for Invasion Games

Live computerised performance analysis is now prevalent in almost all invasion games (games where the teams attempt to enter each other's territory in order to score). The early development of notational systems in certain invasion games has led to the adaptation of systems to incorporate further sports. For example, systems developed to study established professional invasion games such as American football and soccer have led to an increase in the number of studies conducted in sports such as rugby union.

According to Purdy (1977, cited in Hughes and Franks, 2004a, p.61), notational systems were commercially used in sports such as American football as early as 1966. The complexity of American football and its tactical game play provide a necessity for computerised performance analysis. However, it is interesting to note that the rules of American football dictate a ban on the use of computerised notation systems in the stadium (Hughes and Franks, 2004a). To bypass this technicality, American football clubs use a simple hand notation system, which is then transferred to computer after the match. Clubs then competitively exchange notated data with other clubs, just as they would when exchanging videos on opponents (Hughes and Franks, 2004a). Published research into American football (although limited in nature), has provided information on aspects of the sport such as positions, actions and results of play (e.g. Hughes and Charlish, 1988). Despite the lack of attainable research, the analysis of American football is extensive within the USA's collegiate and professional environments.

According to Hill and Hughes (2001), existing performance analysis research conducted within soccer has extensively covered the areas of movement analysis and the analysis of patterns of play. However, as time has passed, developments have occurred within

soccer analysis. For example, early research concentrated on the simple analysis of event outcomes, such as the number of passes leading to goals or the ratio of shots to goals (e.g. Reep and Benjamin, 1968; Hughes, 1973), and either movement or work rates (e.g. Reilly and Thomas, 1976; Wither *et al.*, 1982). As the sophistication of notation systems has increased, so has the depth of analyses, so much so that the analysis of playing patterns and tactics have become possible (e.g. Partridge and Franks, 1989a, 1989b; Yamanaka *et al.*, 1993; Luhtanen *et al.*, 2001; Jones, James *et al.*, 2004).

In 1968, Reep and Benjamin produced one of the first and most comprehensive studies into patterns of play in soccer. Between 1953 and 1968, they collected data using a sample of 3213 matches involving 9175 goals, together with the passes leading to these goals, how possession was gained and the positions of these behaviours. Subsequent analysis found that 50% of all goals emanated from possession gained in the final attacking quarter, and that 80% of goals resulted from a sequence of three passes or less. The significance of this pioneering study lay in its influence in inspiring further work to be undertaken regarding patterns of attacking play.

The analysis of attacking play has indeed become one of the most researched areas within performance analysis of soccer. According to Hook and Hughes (2001, p. 295-296) this is because;

> *"to achieve victory in football, goals must be scored. By examining how goal scoring opportunities are created, a better understanding and knowledge of how to regularly produce these opportunities will be beneficial to players and coaches who strive for success."*

In addition to the analysis of patterns of soccer play there have been many studies which have analysed the work rate of specific players on the field (e.g. Reilly and Thomas, 1976; O'Donoghue and Parker, 2001). These studies found that the use of performance

analysis in analysing work rates could provide coaches and players with specific data concerning the varying forms of high intensity activity performed by different positions.

The last ten years has seen a great increase in the volume of match-analysis of soccer (Grehaigne *et al.*, 2001). However, it is only during the past few years that numerical data has been complemented by systems using many dynamically interacting elements of play as opposed to considering each component separately (Grehaigne *et al.*, 2001). A development such as this, coupled with an ever increasing level of professionalism within the sport, lends itself to the further development of not only soccer analysis but also less analysed sports such as rugby union.

2.7 Performance Analysis and Rugby Union

According to Jackson and Hughes (2001), the analysis of rugby union has taken place for many years utilising both computerised and hand notation systems. Nevertheless, it is a sport which presents unique problems for analysis due to its set-pieces, and the ensuing behaviour after a tackle; either a ruck or a maul (Hughes and Franks, 2004a). This may be one of the reasons why before 1997, there was still a reluctance amongst coaches and managers to adopt a notational strategy within their coaching methods (Hughes and White, 1997). However, the advent of specialised performance analysis equipment such as 'The Observer Video-Pro' (Noldus Information Technology, 1995), has increased awareness of performance analysis in rugby union. For example, in 2001 the Scottish Rugby Union (SRU) invested in twenty-four 'Video-Pro' licenses, together with laptops and MPEG encoders which are used throughout the National men's and women's squads, as well as in the top Scottish club teams (Noldus, 2001).

Furthermore, according to Eaves and Hughes (2003), performance analysis has now been integrated into the professional era of rugby union to provide objective feedback

on teams and individuals. As a result there have been many detailed notational studies into rugby union, its performers and officials. Studies have covered aspects such as the analysis of patterns of play, work-rates of players, performances of officials, laws of the game, comparisons between the male and female game, and performance profiling. Table 2.2 provides a summary of this existing research as a background to this section before the studies that are most relevant are discussed in more detail. The main findings and conclusions of the research are displayed, in addition to issues such as the number of matches analysed, the level of analysed play, and whether or not appropriate statistical and reliability procedures were used (these methodological issues are discussed in detail in sections 2.8.1 and 2.8.3 of this review). Although not included in Table 2.2, validation is another important methodological issue associated with performance analysis (discussed in detail in section 2.8.2 of this review). The reason for its exclusion within this summary is that despite many researchers having substantial experience and formal coaching qualifications, they do not always report this in their studies.

Table 2.2: A summary of performance analysis studies within rugby union.

AUTHOR (S) AND YEAR	NO. OF MATCHES	LEVEL OF PLAY	EVIDENCE OF RELIABILITY AND STATISTICAL PROCEDURES	MAIN FINDINGS AND CONCLUSIONS
Hughes and Williams (1988)	5	International (Five Nations 1986-87)	▪ Reliability: Not reported. ▪ Statistics: Un-named significance tests.	▪ No significant differences between patterns of play of successful and unsuccessful teams, although there were differences between the patterns of play of England and Wales compared with France, Scotland and Ireland.
Hughes and Clarke (1994)	18	9 International (World Cup 1991) 9 International after law changes (1992-93)	▪ Reliability: Not reported. ▪ Statistics: Un-named significance tests.	▪ New laws concerning mauls resulted in a significant rise in the number of passes per possession, and a significant fall in the number of possessions per match, whilst players and coaches were still struggling to understand the full implications of the new laws.
Bouthier *et al.* (1997)	Not reported	Not reported	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ Insufficient knowledge of decision making learning and relations between plans and regulations. ▪ A limited cognitive representation of players' possible actions and tactical intelligence.
Carter (1997)	Not reported	Elite club level	▪ Reliability: Inter-Observer. ▪ Statistics: Not reported.	▪ Methodologies used for heart rate monitoring, time-motion analysis were successful and can be used to enhance future research.
Herbert and Tong (1997)	Not reported	Elite club level	▪ Reliability: Not reported. ▪ Statistics: Un-named significance tests.	▪ Number eights work at significantly higher percentages of their maximum heart rate than wingers, as well as spending more time in higher intensity activities. ▪ Coaching techniques should adhere to these positional results.
Hughes and Hill (1997)	22	International (World Cup 1991)	▪ Reliability: Not reported. ▪ Statistics: Ratios.	▪ The scrummage was the area best area controlled by the referees, whilst rucks were not controlled well by both southern and northern hemisphere officials. ▪ Further research required to apply statistical processes etc.

Table 2.2 (continued)

Hughes *et al.* (1997)	5 female matches, not reported for male matches	International (female), International (male, World Cup 1991)	▪ Reliability: Not reported. ▪ Statistics: Chi-square, t-tests.	▪ Significant differences between men's and women's rugby in almost all areas. ▪ Coaches should therefore apply different methods of coaching for the women's game.
Hughes and White (1997)	32	International (World Cup 1991)	▪ Reliability: Inter and intra-observer. ▪ Statistics: Chi-square, t-tests.	▪ Forwards of successful teams able to dominate the lineouts by using more options. ▪ Successful teams technically superior in the scrummages and more dominant in rucks and mauls.
Potter (1997)	12	International (Five Nations 1992-1994)	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ Descriptive statistics on game content for the English team over three seasons. ▪ England's success was based on a tight game away from home whilst playing more open at home and with fewer errors.
Stanhope and Hughes (1997)	32	International (World Cup 1991)	▪ Reliability: Yes. ▪ Statistics: Un-named significance tests.	▪ Successful and unsuccessful teams played similar games, however successful teams were far better at rucking and kicked better. ▪ This resulted in more penalties being gained and the exploitation of unsuccessful teams' poor defending in danger areas of the pitch.
Carter and Potter (2001a)	32	International (World Cup 1995)	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ Descriptive statistics for each team and their management of game time (e.g. lineout, kicking preparation).
Carter and Potter (2001b)	32	International (World Cup 1995)	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ Descriptive statistical breakdown of how, from where, the relevant times recorded etc. of the tries scored in the 1995 World Cup.
Hunter and O'Donoghue (2001)	22	International (World Cup 1999)	▪ Reliability: Not reported. ▪ Statistics: Wilcoxon signed-rank test.	▪ Significant indicators between winning and losing teams: number of occasions that a team were in the opposition's third, and the number of occasions that an attack went around the opposition ▪ Further work required to develop a performance model for performance predictions to be made.

Table 2.2 (continued)

Jackson and Hughes (2001)	8	International (Women's 6 Nations and Canada Cup 1999-200)	▪ Reliability: Inter and intra-observer. ▪ Statistics: Anderson-Darling test and non-parametric tests.	▪ Successful teams had a higher pass per possession rate, tackle count, and a greater number of players in each ruck and maul situation.
Marshall and Hughes (2001)	8 plus 5 from Kitchen's (1994) study	International (England Women's 1990, 1991, 1993 and 2000)	▪ Reliability: Inter and intra-observer. ▪ Statistics: Chi-square.	▪ Elite women's rugby union is no longer basic. ▪ Quality and quantity of events far exceeded the levels recorded by Kitchen (1994).
Martin *et al.* (2001)	Not reported	Elite club and International	▪ Reliability: Inter and intra-observer. ▪ Statistics: T-tests.	▪ Descriptive statistics illustrating the possibilities of analysis conducted by the IRB centre for rugby union analysis ▪ The centre helps provide valuable information about the development of the sport and its players.
McCorry *et al.* (2001)	8	International (Knock-out stages of World Cup 1995)	▪ Reliability: Not reported. ▪ Staticstics: Not reported.	▪ Descriptive statistics concerning frequencies of behaviours such as positive and negative actions carried out in the oppositions final third, within the knock-out stages of the 1995 World Cup.
Parsons and Hughes (2001)	Not reported	Elite European club level (1999/2000) and International (Six Nations and World Cup 1999)	▪ Reliability: Intra-observer. ▪ Statistics: Mann-Whitney *U* test.	▪ The 'with ball' and 'without ball' activities of the different playing positions are displayed as being dramatically different, with certain roles being evident for specific positions. ▪ Profiles provide a clear picture of the skill demands of different playing positions which forms a basis for coaching support with elite players.
Potter and Carter (2001a)	32	Internationl (World Cup 1995)	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ Descriptive breakdown of behaviours from all matches. ▪ During knock-out stages, losing sides passed the ball more than the winners.
Potter and Carter (2001b)	64	International (World Cups 1991 and 1995)	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ 'Actual playing time' increased by 8% between the World Cups of 1991 and 1995. ▪ In 1995 the lineout had become a major source of possession, whilst there was a greater emphasis on ball retention and the recycling of possession.

Table 2.2 (continued)

Smyth *et al.* (2001)	11	Elite European club level (1996/1997)	▪ Reliability: Intra-observer. ▪ Statistics: Un-named significance tests.	▪ Most contact situations take place in the middle third of the field. ▪ Most successful position for a ball carrier to take to retain possession is low and to turn towards supporting players. ▪ Forwards carry the ball significantly more than backs at both set plays and in the loose.
Vivian *et al.* (2001)	Not reported	Elite European club level (1999/200) and International (Six Nations and World Cup 1999)	▪ Reliability: Intra-observer. ▪ Statistics: Kruskal-Wallis *H* test.	▪ Despite a lack of significant differences, there were general observed increases in frequencies of positional behaviours as the level of play rose. ▪ Data said to have stabilised after five matches. ▪ Conclusion made that the study gave a clear picture of the skill demands of each playing position, and should therefore form a basis for detailed coaching support for elite players.
Deutsch *et al.* (2002)	Not reported	Elite club level (Super 12)	▪ Reliability: Not reported. ▪ Statistics: One-way ANOVA.	▪ Forwards perform 2.5 times more high intensity work than backs. In addition 90% of this high intensity work performed by forwards was in a horizontal position (rucking, mauling, scrummaging and tackling). ▪ The study therefore identified a potential flaw in the vertical strength conditioning methods currently used within rugby union (for example power lifting).
Sasaki *et al.* (2002)	9	International (Japan's World Cup 1999 qualifiers)	▪ Reliability: Not reported. ▪ Statistics: Correlation co-efficients and un-named significance tests.	▪ Contributing factors to successful attacks were the frequencies of 'individual gain', 'passing', 'making ground' and the distances of 'individual running gain' and 'kicking gain'.
Eaves and Hughes (2003)	16	International (5 Nations: 4 games from 1988-92 period, 4 from 1993-95, 4 from 1996-99 and 4 from 6 Nations 2002-03)	▪ Reliability: Intra-observer ▪ Statistics: Stability (modified Bland and Altman Plots), Normality (Shapiro-Wilk), Sphericity (Mauchley), and mixed model repeated measures ANOVA.	▪ A significant increase in play time, ruck and activity frequency was found to have occurred when pre and post professional playing times were analysed. ▪ The results suggest that there were more physical demands on the professional rugby player as the game was faster and more intense than in the the pre-professional era.

Table 2.2 (continued)

Silberberg and Wlodarczyk (2003)	114	International (New Zealand versus Australia between 1903 and 2000)	▪ Reliability: Official Test Scores were used. ▪ Statistics: Confidence Intervals.	▪ A comparison was made between the results and the points margins of New Zealand versus Australia matches since 1903. A conclusion was made that the data showed New Zealand to have been the better rugby union Nation over time.
Thomas (2003)	30 women's matches, not reported for men's.	International (Women's World Cup 2002, 6-Nations 2002, Tri-Nations 2002	▪ Reliability: Inter and intra-observer. ▪ Statistics: Chi-square, Kruskal-Wallis, percentage differences.	▪ A lack of strength within the women's game needs to be compensated for by higher skill levels. ▪ Therefore, differences between the two games have implications on the nature of coaching.
Boddington and Lambert (2004)	5	International World Cup 2003	▪ Reliability: Not reported. ▪ Statistics: Chi-square, t-test.	▪ South Africa tended to start scoring movements from the right side of the field between halfway and attacking 22m. ▪ They predominantly moved the ball more from right to left and needed more time in possession to secure points in the first half.
James *et al.* (2004)	15	International 2003 World Cup	▪ Reliability: Yes. ▪ Statistics: Kruskal Wallis *H*	▪ Losing teams had more 1 phase possessions than the winner. ▪ A balance was apparent between forward and back plays which was then dependant on the weather. ▪ There was unpredictability of possession strategies in international matches and particularly the World Cup final.
Jones, Peters *et al.* (2004)	185	International World Cup 1987, 1991, 1995, 1999, 2003	▪ Reliabilty: Not reported. ▪ Statistics: ANOVA, Kruskal-Wallis	▪ The use of bonus point scoring systems was found to be ineffective for enhancing the weaker teams, their scoring profiles and their progression to the knock-out stages of the World Cup 2003.
Long and Hughes (2004)	30	International 5/6 Nations 15 pre 1995 15 post 1995	▪ Reliability: Inter and intra-observer. ▪ Statistics: Mann-Whitney *U*.	▪ Styles of play of back-row forwards have changed since professionalism in 1995. ▪ More rucks are now formed and the professional back-rows make fewer tackles in order to compete at the breakdown.

Table 2.2 (continued)

Laird and Lorimer (2004)	32	International (2003)	▪ Reliability: Not reported (used IRB statistics). ▪ Statistics: Pearson Correlation.	▪ 75% of tries examined came from possession gained within the opponents half. ▪ 39% of tries came from possession gained within the opposition's 22m area. ▪ The paper highlights the potential for use of comparative data collected from other team sports (e.g. soccer).
Murakami *et al.* (2004)	12	9 Elite Club Level (Super 12) 3 International	▪ Reliability: Not reported. ▪ Statistics: Not reported.	▪ The time consumed for a lineout, scrum or ruck in super 12 competition was shorter than in Japanese Internationals.
Hughes and Jones (2005)	16	International Seven-a-side (2001 IRB World Sevens Series)	▪ Reliability: Intra-observer. ▪ Statistics: Percentage error variation, Wilcoxon signed-rank test.	▪ With exception of tackling by successful teams all profiles stabilised by the 8th analysed match. ▪ Successful sevens teams play a less direct approach, play with more width and are more dominant in both defence and attack than un-successful teams.
Sasaki *et al.* (2005)	10	International Under 21 World Cup 2002	▪ Reliability: Not reported. ▪ Statistics: Multiple regression analysis.	▪ 'Upper teams' turned the ball over on more occasions, got more gains and also more points from turnovers. ▪ Teams should create systematic turnover play to get points.
Williams *et al.* (2005)	21	International Six-Nations and Tr-Nations (1999-2002)	▪ Reliability: Inter and intra-observer. ▪ Statistics: Kruskal-Wallis, Mann-Whitney *U* tests.	▪ The 'use it or lose it' law reduced the number of clean scrums, but it had less of an effect on the game as the new law became established.

2.7.1 General Notational Analysis Research within Rugby Union

This section discusses the empirical notational analysis research within rugby union which has led to more specific studies concerning performance profiling of teams and individuals (section 2.7.2). One of the first studies using computerised notation in rugby union was conducted by Treadwell (1987), who analysed the sport from the perspective of work rate using a time-motion analysis method. He developed initial and specific computer software that utilised the concept keyboard (a touch sensitive digitisation pad). Hughes and Williams (1988) developed further software using a similar hardware system to that of Treadwell (1987) to notate five matches involving the five 'Home Nations' over the seasons of 1985-86, and 1986-87. Hughes and Williams (1988) found that while there were no significant differences between the patterns of play of successful and unsuccessful teams, there were differences between the patterns of play (with respect to the frequency of passes, kicks, runs and number of rucks and mauls set up and won) of three of the Nations when compared with the other two. This early computerised system provided accurate, objective information for rugby union (Hughes and Williams, 1988). However, there was no evidence of any reliability testing within the study which presents a potential discrepancy with this statement.

A further study (Potter, 1997) which investigated patterns of play in rugby union was the analysis of England's performances in the Five Nations during the period of 1992-1994. However, this study, along with a number of others (e.g. Carter and Potter, 2001a; Carter and Potter, 2001b; Potter and Carter, 2001a) were aimed at simply reporting data rather than investigating direct hypotheses. Despite this, these studies can be used to gain important information on game structure and patterns of play within rugby union for the respective periods of time when analysis took place.

Notational analysis in rugby union has also been found to provide detailed results that relate to specific areas of matches and training (e.g. Carter, 1997; Herbert and Tong, 1997; Deutsch *et al.*, 2002). An intermittent, high intensity sport such as rugby union, involves a complex combination of factors that contribute to performance and ultimately fatigue which can be investigated through notational analysis (Deutsch *et al.*, 2002). Deutsch *et al.* (2002) notated movement through video analysis to investigate the work rates and physical conditioning of elite club and 'super 12' (the southern hemisphere's elite club competition) rugby union players. It was found that forwards perform 2.5 times more high intensity work than backs during a game. In addition, 90% of this high intensity work performed by forwards was in rucking, mauling, scrummaging and tackling. In their conclusions, Deutsch *et al.* (2002) stated that the analysis system employed identified a potential flaw in the strength conditioning methods that were used within rugby union (for example power lifting). The relative merits of the strength development techniques warranted questioning, as the majority of high intensity elements within a forward's game involved the production of power and force in a horizontal direction rather than in a vertical one (Deutsch *et al.*, 2002).

Another aspect of rugby union that has been investigated through notational analysis is the effects of the law changes made in 1992 by the International Rugby Board (IRB). Hughes and Clarke (1994) investigated the effects of these changes which were made in an attempt to make the game more aesthetically pleasing for the spectator. It was found that a new law concerning 'maul time' encouraged players to release the ball, thus increasing the number of passes per possession. However, it was also found that players and coaches were still struggling to understand the full implications of the new laws, therefore highlighting a need for the IRB to provide further literature and coaching on the changes (Hughes and Clarke, 1994).

A further study which analysed rugby union before and after the major law changes of 1992 was conducted by Potter and Carter (2001b). The study compared matches during the 1991 and 1995 rugby union World Cups. One of the major differences between the play of the two World Cups was that of 'actual playing time'. According to Potter and Carter (2001b), the 'actual playing time' increased by 8% (nearly two minutes per match) between 1991 and 1995. The two most probable reasons for this were said to be the environmental factors (in 1991 the tournament was held in the United Kingdom and in 1995 the tournament was held in South Africa), and the major law changes made between the two World Cups involving the lineout, ruck and maul (Potter and Carter, 2001b). The study concluded that there had been a change in the way that rugby union was played between 1991 and 1995. The lineout had become a major source of possession, whilst there was a greater emphasis on ball retention and the recycling of possession in 1995 (Potter and Carter, 2001b). It is however important to note that there was no evidence of reliability tests within both Potter and Carter's (2001b) study and in Hughes and Clarke's (1994). In addition, although changes were said to have occurred between the two World Cups (Potter and Carter, 2001b), this was not scientifically supported through the use of any statistical analysis. These two issues should therefore be taken into consideration when the results of these studies are utilised in future research.

In addition to the comparison of the playing periods before and after major law changes, a study by Eaves and Hughes (2003) investigated the differences between patterns of play within International rugby union before and after the introduction of professionalism to the sport in 1995. The study was tested for internal reliability and used a number of statistical tests, including a repeated measure ANOVA to identify significant differences between the two playing periods. It was found that there was an

increase in playing time and ruck and activity frequency which Eaves and Hughes (2003) suggested was indicative of the heightened physical demands on the modern International rugby union player.

Although the vast majority of notational analysis research has concentrated on the analysis of performers, rugby union was one of the first sports used for the analysis of officials. In a study of referees from the 1991 rugby World Cup, Hughes and Hill (1997) illustrated the difficulties that rugby union has with its complex laws and set-pieces. It was found that there was inconsistency between referees from the southern hemisphere and northern hemisphere, as well as certain areas of the game such as 'the ruck', which posed problems for both sets of officials. Nevertheless, this study, and the research into the effects of imposed law changes (Hughes and Clarke, 1994; Potter and Carter, 2001b) have been effective in indicating the need for assessment and feedback to enable referees to improve their performance, and to improve continuity in rugby union.

The aforementioned research into patterns of play, laws and officials, and positional work rates has provided an initial body of literature from which performance analysis within rugby union has developed. More recently it has been suggested that researchers should focus upon the development and utilisation of PIs, therefore enabling accurate performance profiles to be developed (Hughes and Bartlett, 2002). This recommendation is based upon the fact that PIs, when expressed as non-dimensional ratios, can be independent of any other variables used (Hughes and Bartlett, 2002).

2.7.2 Performance Indicators and Performance Profiles

PIs are pre-selected variables which are aimed at defining specific aspects of an individual or team's performance (Hughes and Bartlett, 2002). Essentially each PI or behaviour is a core trait of performance, which summarises a player's single task variables for each match (Bracewell, 2002). A related area of investigation is the establishment of averages of behaviours and goals, known as performance profiles. Performance profiles are suggested to be a description of a pattern of performance from an analysed team or individual, and potentially offer some prediction of future performance, typically being created from collected frequencies of a combination of PIs (Hughes *et al.*, 2001).

The use of a multivariate approach using measured variables (PIs) to assess performance ensures a clearer and more accurate interpretation of data (Hughes and Bartlett, 2002). This is especially true of rugby union due to its open structure and large variances in opposition teams and individual players. PIs have also become increasingly popular within media coverage of rugby, with statistics such as possession, tackling, and passing being reported regularly (Bracewell, 2001; Hughes and Bartlett, 2002). Although performance profiles have often been limited to certain individual sports such as squash (e.g. Lynch *et al.*, 2001), there have been a number of studies which have addressed both individual and team performance profiles within rugby union.

2.7.2.1 Individual Performance Profiles

Despite the problems that performance analysis and rugby union face due to the complexity of the game (i.e. set-pieces), the sport lends itself well to the prediction of certain variables through the creation of averages and goals known as game models

(Treadwell, 1992). Furthermore, it has been suggested that game models are attainable within rugby union regardless of confounding variables such as team selection, referees, coaching style, or even the weather (Treadwell, 1992).

Parsons and Hughes' (2001) study into the patterns of play of elite rugby union players analysed the 'with ball' skills of individuals. The study used a sample of International Six Nations and World Cup matches, as well as a selection of European club matches (between 1999 and 2001). The skill demands of each player were analysed with particular reference to their 'with ball' and supporting activities. The findings suggested that the playing positions of prop and hooker were involved in supporting roles to a greater extent than ball carrying. The results of the study provided an indication of the varying skill demands of different playing positions (Parsons and Hughes, 2001). The 'with ball' and 'without ball' activities of the different playing positions were displayed as being dramatically different, with certain roles being evident for specific positions. For example, Parsons and Hughes (2001) described the main role of the scrum-half as being a distributor of the ball to other players due to the high percentage of passing movements within their 'with ball' activities (254 passes out of 310 'with ball' behaviours). The authors concluded that the study was successful in creating profiles that could be utilised by coaches due to the detailing of the roles of different playing positions.

As with Parsons and Hughes, Vivian *et al.* (2001) also attempted to develop individual performance profiles. The principal concerns of the study were to investigate individual profiles at league, European cup and International level (between the seasons 1999/2000/2001). The study used a notational system tested for internal reliability to construct performance profiles involving attacking and defending behaviours, for the

playing positions of flanker, number eight and scrum-half. Table 2.3 displays a selection of the profiles generated by Vivian *et al.* (2001) (values approximated from charts) for league, European cup and International matches.

As Table 2.3 suggests, the differences between the highest levels within the sport of rugby union were detectable through analysis. For example, the pivotal position within rugby union (the scrum-half), displayed steady increases in all behaviours as the level of playing standard increased (Vivian *et al.*, 2001). However, with the exception of the behaviour 'running with the ball' for the position of number eight, there were no significant differences found between playing levels for any of the positions. This could indicate that from elite club level upwards, the structure of the game and the way in which players performed did not necessarily change accordingly. Vivian *et al.* (2001) concluded that the profiles generated gave a clear picture of the skill demands of each playing position, and therefore formed a basis for detailed coaching support of elite players.

Table 2.3: Performance profiles of elite rugby union players (values approximated from charts).

	Mean Totals (per match)								
	Scrum-Halves			Flankers			Number Eights		
	League	Europe	International	League	Europe	International	League	Europe	International
Defensive Behaviours	3	4	5	13	15	15	6	5	6
Attacking Behaviours	25	31	44	18	20	21	11	12	21
Tackles	2	3	4	10	12	9	4	2	4

Adapted from Vivian *et al.* (2001)

Vivian *et al.* (2001) suggested that the individual skill profiles began to "normalise" after about five matches. Normalise in this context was taken to mean that the data collected for each position was sufficiently representative of typical performance to be interpretable. However, normalise has an obvious, and unfortunate, association with the term normal, used in statistics to refer to the inverted bell shaped distribution. Typically, performance data exist in a positively skewed distribution and consequently it is suggested that this is not the most appropriate term to use. The issue of the amount of data required before a representative profile can be created is a valid one however, and the alternative term 'stabilise' which has been used in some papers is advocated in this thesis (e.g. Hughes *et al.*, 2001).

In another recent study, Sasaki *et al.* (2002) examined the Japanese National rugby union team of 1998 as a function of successful attacks and the resulting gains made by each player (in metres). Sasaki *et al.* (2002) defined a successful attack as one which contained more than one 'maul' or 'ruck' when there was a gain of five metres or more. The study involved a highly detailed analysis of the types of attack used to gain ground. Specific directions of running and kicking were analysed so that the results would clarify who was contributing to successive attacks and by what type of play. The authors suggested that the results of their study could be applied as an index for assessing player performance and that there was potential for them to be used for player selection. Table 2.4 illustrates a selection of the details of play contributing to successful attacks during one of the matches analysed in the study.

Table 2.4: A selection of the details of plays contributing to successful attacks in a specific match.

		Frequency of Individual Gain	Run (m)	Kick (m)	Pass (no. of times)
1	Prop	1	5		3
2	Hooker	1	5		7
3	Prop				
4	Lock				
5	Lock	2	20		2
6	Flanker	6	40		2
7	Flanker	7	45		4
8	No. 8	5	35		8
9	Scrum-Half	5	10	65	34
10	Outside-Half	13	20	235	12
11	Wing	5	45		2
12	Centre	9	45	85	7
13	Centre	4	25	40	3
14	Wing	2	60		2
15	Full-Back	4	70		3

(Adapted from Sasaki *et al.*, 2002, p. 168)

Sasaki *et al.* (2002) concluded that contributing factors to successful attacks were the frequencies of 'individual gain', 'passing', 'making ground' and the distances of 'individual running gain' and 'kicking gain'. However, the method of data collection used in the study is problematic as Table 2.4 is simply the data gained for an individual match. For a true performance profile to be gained, as discussed previously, the Japanese Rugby Union would have needed to carry out a full analysis of a larger sample (until the data stabilised). Another potential limitation is the lack of evidence of reliability testing procedures for the analysis system. It may therefore be unwise to draw comparisons with this study as the data and therefore the conclusions may be unreliable (section 2.8.1 discusses reliability concerns in further detail).

The introduction of professionalism and various law changes within rugby union has (as previously discussed in section 2.7.1) had a profound effect on the way in which the sport is played. Indeed, Long and Hughes (2004) found that professionalism had transformed the performance profiles of International back row players within the Five/Six Nations Championship. It was found that the profiles had altered significantly with back row forwards being required to perform fewer initial tackles in order to compete at breakdown situations since the conception of professionalism.

Whilst some studies have simply provided information concerning specific rugby union positions and profiles, the development of the Eagle Rating by Eagle Sports (Bracewell, 2001, 2002, 2003a, 2003b) has incorporated all of the various positions (through positional clusters) within rugby union in an attempt to provide a practical approach to performance profiling. This has been used by the New Zealand Rugby Football Union and Sky Television to provide players with an overall match score (between 0 and 100) where credit is given for positive behaviours such as turnovers and successful tackles,

and conversely negative credit is assigned for behaviours such as missed tackles and handling errors (Bracewell, 2003a). Players' scores were then utilised to construct a mean individual Eagle Rating which could be used to assess specific match performances and current form. In order to do this, Shewhart control charts were used (control charts where the control limits are set at 2 SD from the mean), whilst upper and lower control limits acted as alarm triggers if performance fell or rose dramatically (Bracewell, 2003a). In addition, the rating could also be used to compare scores from other individuals of the same position for selection purposes. Ranking and selection are natural functions of a measurement of performance which can be utilised by coaches, selectors and the media (Bracewell, 2003a). Consequently, the Eagle Rating could become more widely used and popular as professionalism and performance analysis within rugby union intensifies.

This is also true of the Centre for Analysis of Rugby Union which was formed in 1997 by the International Rugby Board (IRB) (Martin *et al.*, 2001). The centre was established so that every International or elite club match being played in the world could be archived using video and computerised data gathering systems (Martin *et al.*, 2001). The main aims of this large database were to monitor and profile the sport, to enable the IRB to answer questions concerning the structure of the game and to anticipate the effects of any suggested rule changes (Martin *et al.*, 2001). Martin *et al.* (2001) analysed the role of the centre by presenting statistical and graphical examples of archived matches. It was concluded that the Centre provided the IRB with objective assessments of patterns of play, and that the 'mapping' of the game by the Centre provided a means for the IRB to keep its "finger on the pulse of the sport" (Martin *et al.*, 2001, p. 110). Indeed, the examples demonstrated by Martin *et al.* (2001) show how as

rugby union players developed through physical and technical improvements, individual and team profiles within the sport altered markedly.

In order to further assist the coaching process in rugby union and subsequent player performance, the establishment and monitoring of individual profiles is a key area that needs to be addressed fully. To date, however, there has been little guidance in prior literature on how to develop a performance profile. There has also been a distinct lack of statistical basis to quantify the number of matches that need to be analysed in order to achieve a true performance profile (Hughes *et al.*, 2001). Indeed, the underlying factor when attempting to form a performance profile is to determine when and how the data stabilises (Hughes *et al.*, 2001; Hughes *et al.*, 2002). Hughes *et al.* (2001) investigated the issue of how many matches were required for the creation of a performance profile in rugby union. As Table 2.5 illustrates, it was found that between three and seven matches were needed to create true averages of the main behaviours in the sport.

Table 2.5: The minimum number of rugby union matches required to be analysed in order to achieve a true average that represents the population.

	Number of Matches	Averages per Team, per Half
Tackles	5	25-26
Passes	5	48-49
Kicks	4	11-12
Rucks	5	21-22
Mauls	7	5-6
Scrums	3	6-7

(Hughes *et al.*, 2001, p. 16)

Although Table 2.5 may provide a guide to the stabilisation of rugby union data, intuitively the greater the database, the more accurate the performance profile is upon

which to compare future performances (Potter and Hughes, 2001). The authors (Potter and Hughes, 2001, p. 58) stated that "an established model provides for the opportunity to compare single performance against it." However, as Hughes *et al.* (2001) pointed out, as a database increases in size it becomes more insensitive to changes in playing patterns. Indeed, one would expect fluctuations in performance as a consequence of the opposition, changing players and a whole host of other factors. Despite this, significant differences have been found after multiple observations when they were not present from the first piece of datum (Wells *et al.*, 2004). This is because within-group variance tends to decrease as more matches are used to analyse a subject or team (Wells *et al.*, 2004). In the case of rugby union it is important to note that variances in analysed behaviours are inevitable due to the sport's open nature. In a study involving squash players, McGarry and Franks (1994) suggested that consistency of play was more evident when players were faced with the same opponent. However, in an invasion game such as rugby union, not only is there a difference in weekly opposition to take into consideration, but also that successful and unsuccessful PIs can be dependant upon previous performances or behaviours of the team or individual (Hughes and Bartlett, 2002). It is therefore important that this issue is acknowledged when conducting performance analysis research within rugby union.

Despite the results shown in Table 2.5 a larger sample of matches may be necessary to gain more accurate averages for all rugby union behaviours. Indeed, Hughes and Jones (2005) found that certain variables in rugby union did not stabilise until the eighth match, whilst some did not stabilise at all. However, this study was concerned with the seven-a-side format of rugby union which may not necessarily be comparable with the fifteen-a-side game due to its openness and lack of structure (i.e. fewer set pieces and pre-planned moves). Nevertheless, as with the majority of invasion games there are a

number of existing potential confounding variables that may affect the frequencies of a rugby union player's PIs and also the number of matches needed for the data to stabilise (James *et al.*, 2002). Factors such as the weather, home ground-away ground effect, the type of match played (e.g. large win, narrow loss), tactics, whether a player performed well or badly, and the section of the match that the individual played in, i.e. if he was a substitute or was substituted (e.g. defending or attacking during the section) can all effect performance or specific PIs during a match (Bracewell, 2002). Furthermore, according to Rue and Salvesen (2000, p. 399), there are certain factors which the outcome of a soccer match actually depends upon; "home ground-away ground effect, the effect of injured players and various psychological effects". Indeed, an underlying assumption with sports statistics is that they provide an insight into performance and ability (how well an individual or team played in one match) (Bracewell, 2003a). However, ability, or a performance profile cannot be established from just one match (or performance), as performances vary from match to match due to sampling variability and situational constraints (Bracewell, 2003a). Despite this, within a practical setting a player displaying outstanding skills within one match could be judged to possess outstanding ability and be selected for future matches based on this assumption. Take for example Ryan Jones' performance against Otago on the 2005 British and Irish Lions tour. After a 'man-of-the-match' display in his 'Lions' debut, Jones (a late call up to the squad) was selected on the bench for the first test against New Zealand. However, it is important to note that whilst the performance against Otago may have been largely responsible for his test selection, his form over the season for Region and Country would also have been taken into consideration. In accounting for the variability within an individual's performance and situational constraints, a larger sample size (for example a season's data) could therefore minimise the effects of

confounding factors when constructing a performance profile. Indeed, conclusions drawn from investigations should be related to the size of the sample. Too small a sample may provide an inaccurate depiction of a profile, whilst too large a sample may be insensitive to changes in performance.

2.7.2.2 Team Performance Profiles

Further to the use of individual PIs and the formation of individual profiles, there have been a number of studies which have attempted to provide indicators and profiles of team performance. Hughes and White (1997) investigated the differences between the patterns of play of the forwards of successful and unsuccessful teams during 32 matches from the 1991 rugby union World Cup.[1] The principal findings of this study were that the forwards of the successful teams were more dominant in the lineout through the use of more options, more dominant in driving areas of the game (rucking and mauling), as well as being technically superior at scrummaging. Although the study concluded that the computerised system was reliable through the use of *r* values, it has been suggested that correlation techniques alone are insufficient for confirming reliability (Bland and Altman, 1986, 1999).

Stanhope and Hughes (1997) also looked at team performances from the 1991 rugby World Cup by examining the tactical significance to successful teams of the different methods of scoring points[1]. Successful teams were found to be far better at rucking and kicking although they played a similar game to the unsuccessful teams. A more effective rucking and kicking game resulted in more penalties being gained by the successful teams and the exploitation of the unsuccessful teams' poor defending in danger areas of the pitch.

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[1] In this instance, the term successful teams denotes those sides who progressed to the knock-out stages of the tournament whilst unsuccessful teams defines those who did not progress.

A further study by McCorry *et al.* (2001) used a manual match analysis system which addressed positive and negative attacking and defensive play, possession changes and methods of gaining territory in the 1995 rugby World Cup. The indicator of possession gain to loss (also known as turnovers won or lost) was found to reflect the tournament ranking of the four semi-finalists, whereas the positive (good play, e.g. a try scored) to negative (poor play, e.g. a penalty conceded) ratios for offensive and defensive play did not. However, the authors recommended further research within the area as the study only provided simple frequencies and ranking strategies as opposed to any statistical significance tests.

The analysis techniques used by McCorry *et al.* (2001) were also implemented by Hunter and O'Donoghue (2001) to analyse the 1999 men's rugby World Cup. The study found that there were a number of significant indicators which distinguished between winning and losing teams. These included the number of occasions that a team were in the opposition's last third (opposition's defensive third of the field), and the number of occasions that an attack went around the opposition (Hunter and O'Donoghue, 2001). The study used 22 matches and utilised the pool matches of the tournament as well as the knockout stages. This provided further distinction between winning and losing sides. However, the authors suggested that the indicators which significantly distinguished between winning and losing sides required further investigation to develop a model so that performance predictions could be made.

Another study which attempted to examine indicators of successful and unsuccessful teams was conducted by Jackson and Hughes (2001). The study analysed eight International women's matches from 1999 and 2000 and looked at aspects of the games from both the winning and losing team's performances. It was found that successful

teams had a higher pass per possession rate, tackle count, and a greater number of players in each ruck and maul situation than the unsuccessful teams. The computerised analysis system that was used was also rigorously tested for intra and inter-observer reliability. However, it is important to note that the study used data collected from women's rugby union which has been found in prior research to possess significant differences compared with the men's game for PIs such as kicking, running and passing (see Hughes *et al.*, 1997).

Whilst the aforementioned studies have provided detailed information concerning indicators of successful teams within rugby union, the opportunity to analyse the differences between PIs for a single team when winning and losing has not been recognised. Furthermore, although methodologies for scoring individual performance have been successfully constructed (Bracewell, 2003a), there has been no published research that has assessed team performance through the creation of match scores. Objective scores for team performance would provide coaches with a valuable tool to monitor performance and progression within a practical setting.

2.8 Methodological Issues in Performance Analysis

2.8.1 Reliability

A methodological issue that is an integral part of any research is the reliability of the measures adopted (Thomas and Nelson, 2001). Reliability pertains to the consistency, or repeatability of a measure (Thomas and Nelson, 2001). According to Wilson and Barnes (1998, p. 265) "one potential limitation with any performance analysis system concerns the reliability of data input." Errors within testing, due to system or participant errors can render gathered data completely useless. Indeed, inconsistent interpretation of performer behaviours or movement patterns can be a threat to overall

system reliability (Wilson and Barnes, 1998). Factors such as motivation, mood, fluctuations in memory, specific knowledge and the consistency of the test or system can all affect the reliability of data, and the validity of subsequent analysis (Thomas and Nelson, 2001). Furthermore, it has also been suggested that the recorder of the data should have a high level of knowledge and feeling for the game being played as the specific event details may well be subjective and open to dispute (Croucher, 1997).

According to Hughes *et al.* (2002), the majority of systems used within performance analysis are specifically designed for individual experiments. Despite this, there is little evidence shown by researchers that their systems are reliable (More, 2002; Nevill *et al.*, 2002). Table 2.2 illustrates the lack of reliability procedures carried out within performance analysis research into rugby union. Indeed, in a survey of papers presented at world conferences for studies using performance analysis systems within a variety of sports, 70% of the 67 papers produced did not present any evidence of reliability studies (Hughes *et al.*, 2002). A further 15% of the papers only used correlations to provide evidence of consistency and repeatability of data (Hughes *et al.*, 2002). According to Bland and Altman (1986, 1999), correlations as a sole statistical procedure are not a complete process for confirming reliability. In addition, in their review of the papers, Hughes *et al.* (2002) found that some of the studies that did show evidence of reliability tests, used parametric techniques when their data were non-parametric. The issue of the quantity of data used to test for reliability has also been highlighted by researchers within the field. Atkinson and Nevill (2001) suggest that at least 50 occurrences of each variable are needed to adequately assess reliability. However, previous research, for example James *et al.* (2002) used only 15 minutes of a match which is unlikely to have provided high frequencies of all analysed behaviours.

Reliability testing within performance analysis should therefore be addressed to the same high levels as it is with any other form of research. However, there are additional factors that should be taken into account when conducting reliability tests. Certain observations can be more problematical to judge than others. For example, in rugby union, complex areas such as the ruck and maul can be difficult to distinguish between when conducting an observation. For this reason, certain authors (e.g. Wilson and Barnes, 1998) have argued that there should be different levels of acceptability for accuracy, depending on the nature of the data that are being measured. Furthermore, the results of reliability tests should be represented in the precision used to present associated data. For example, if the intra-observer reliability of an analysis system was shown to be 95% accurate, reporting data to two decimal places would disregard the level of inconsistency implied by the reliability test results. It is essential therefore, that once the level of required accuracy has been determined, the reliability of a data collection system is demonstrated clearly and in a manner that is compatible with the intended analyses (Hughes *et al.*, 2002).

2.8.2 Validity

Validity is another key aspect of performance analysis that needs to be taken into consideration when conducting rigorous research. Validity refers to the ability of a test to measure what it is supposed to investigate (Atkinson and Nevill, 1998). The majority of performance analysis research possesses a high level of ecological validity as data are often collected from live, competitive recordings. Consequently, the data do not suffer from the limitations associated with laboratory style investigations. However, it is important that any analysis system is developed using expert knowledge of the sport in question, so that collected data are relevant, whilst problematic areas (e.g. the ruck in rugby union) are identified and operational definitions outlined. Needless expenditure

of time and effort can be avoided through the selection and measurement of specific variables that are of interest and direct relevance to the research question.

As stated previously, the content validation of analysis systems has rarely been reported within prior studies. This is despite large numbers of researchers possessing expert coaching and playing knowledge either through their own personal experience or through consultations with experts within the sport. One simple way of ensuring a system is valid is through content validity procedures with an expert of the sport in question. Future performance analysis research should therefore report this procedure within a methodology so as to inform the reader of its presence.

2.8.3 Statistical Analysis

Data and statistics are natural by-products of competitive sport, as in many instances (e.g. runs, goals, points, time) this information is used to determine match results (Bracewell, 2002). Biddle *et al.* (2001) stated that sport and exercise psychologists had become increasingly interested in the consideration of research methods and measurement techniques. However, recent research within performance analysis has unearthed concerns regarding the use of appropriate statistical techniques within this field (Hughes *et al.*, 2002). Indeed, whilst the majority of the discrete data that are collected through performance analysis does not follow the normal distribution, researchers have still used parametric statistical tests within their analysis (Hughes *et al.*, 2002; Nevill *et al.*, 2002). Furthermore, the use of means and standard deviations as methods of presenting data are also associated with the normal distribution and should therefore not be used when discussing non-parametric data. In these cases, medians and associated confidence limits should be utilised as they minimise the effects of potential outliers that are associated with non-parametric data (Zar, 1999).

In addition, many papers do not present any statistics at all to compare data sets, whilst others simply display probability values with no indication of the particular test used (Hughes *et al.*, 2002). It is important, therefore, to present the reader with evidence of statistical procedures so as to inform them of the exact processes that the data were exposed to. The exclusion of, or inappropriate use of statistical techniques can often put data and conclusions at risk (Hughes *et al.*, 2002). Table 2.6 illustrates the range of, or lack of statistical processes (both parametric and non-parametric) reported by researchers in 72 randomly selected performance analysis papers (Hughes *et al.*, 2002, p. 3).

Table 2.6: Statistical processes used in performance analysis research papers.

Statistical Processes for Data Analysis	**Number of Papers**	**Percentage**
Chi-Square	21	29
None	19	26
Not Specific	12	17
T-Test	8	11
ANOVA	5	7
Factor Analysis	2	3
ANCOVA	1	1
Mann Whitney	1	1
Hotelling T^2 Test	1	1
Wilcoxon	1	1
Bivariate Analysis	1	1
Total	**72**	**100**

(Hughes *et al.*, 2002, p. 3)

2.8.4 Data Presentation: Frequencies or Percentages?

Rugby union, along with the majority of modern invasion sports, generates a vast amount of data concerning PIs. However, the question arises as to how these PIs should be presented. If displayed in isolation, a PI can give a distorted impression of team or individual performance (Hughes and Bartlett, 2002). For example, if the number of tackles missed by a team during a rugby union match is presented as a sole frequency, little information can be drawn from the statistic. However, coupled with the number of tackles made by the opposition or by the analysed team in their previous match, more relevant data can be obtained.

A further issue to consider when presenting data is that for any performance variable you have positive and negative outcomes. These can be treated as two separate frequencies or combined as a proportionate value or ratio (Hopkins *et al.*, 1999; Hughes and Bartlett, 2002). For example, the number of tackles missed by a team during a match could be presented as a percentage of the total tackles attempted during that match. The advantage of combining PIs to a proportionate value in this case is that some rate of success is evident. However on some occasions this may not be necessary. For example, in tries scored in rugby union, it does not make a difference whether three tries were scored in a match as a result of 100 or 200 carries of the ball, the positive attribute of tries scored remains identical. Indeed, there is a need to be cautious to avoid information being lost through "normalisation" (Hughes and Bartlett, 2002).

A specific point that should therefore be considered when presenting performance data is the purpose of the intended analyses. For example, when presenting a performance profile for a particular player in rugby union, an analyst may wish to provide information concerning exactly what that player does during a match. Whilst it may be

interesting to view the percentage success rate of tackles, the frequency of tackles made presented alongside the frequency of tackles missed would be more beneficial to the profile. If needed, these two frequencies could then be combined with other PIs to form an overall depiction of that player's role within the team and subsequently compared with other players of the same position. The principal advantage of frequency data is that the magnitude of PIs are displayed. However, as a consequence of this, twice the number of PIs are generated compared with typical proportionate values or ratios. In summary then, it is suggested that the analyst or researcher takes care to present PIs in a manner that is appropriate to the performance data, and provides a full representation of performance.

2.9 SUMMARY

The preceding review of literature has discussed and critiqued the existing performance analysis research within rugby union. More detailed consideration has been given to research concerned with the development of individual and team performance profiles through the utilisation of PIs. In doing so, it has become apparent that these areas are relatively young and require further investigation in order to provide an adequate understanding of individual and team PIs, and consequently the demands and roles of the various playing positions in rugby union. The review has also highlighted the lack of, or inappropriate use of validity, reliability, and statistical procedures surrounding the current measurement and analysis of performance in rugby union.

This review suggests therefore, that a more detailed, conceptual and methodological approach is required to the development and measurement of position-specific and team PIs and their resultant performance profiles. With appropriate methodologies in place,

the potential to create an objective measure of team performance in rugby union may then be realised.

CHAPTER 3

STUDY 1

THE DEVELOPMENT OF POSITION-SPECIFIC PERFORMANCE INDICATORS IN ELITE RUGBY UNION

CHAPTER 3: STUDY 1

3.1 INTRODUCTION

Despite the work of researchers such as Parsons and Hughes (2001) and Vivian *et al.* (2001), insufficient data currently exist regarding the valid and reliable measurement of performance indicators (PIs) in elite rugby union. In particular, there is a dearth of published research concerning position-specific PIs, their consequent profiles and any individuality that may exist within positions. Research has also yet to establish the confidence to which these performance profiles have 'stabilised' and are truly representative of an individual's performance. Finally, from an applied perspective, there is a need to develop a rigorous methodology for practitioners to use when conducting the analysis of performance behaviours in rugby union (Hughes and Williams, 1988; Potter and Hughes, 2001). The formation of individual performance profiles, through the utilisation of PIs using a reliable computerised analysis system, therefore represents an important area for investigation (Hughes and Bartlett, 2002).

Consequently, the principal aim of this first study is to investigate the construction and development of a valid and reliable methodology for the analysis of individual positional performance profiles within the sport of rugby union. Specifically, it is intended to propose and develop a framework of common and position-specific PIs for each playing position within a rugby union team. The PIs of different individuals from the same playing position will then be analysed to investigate any individuality within positions (intra-positional differences) that may have occurred within the team.

It is however, important to focus on the principal aim of this study which is to present an effective methodology for the construction and assessment of individual performance profiles within rugby union. Nevertheless, it must be noted that there are several

delimitations associated with the current study. Firstly, any profiles that are generated may not necessarily be transferable to other teams or individuals due to a case study design. Further research could therefore utilise and adapt the methodologies outlined here using data collected from other teams. A second delimitation is that any variability within the PIs is not investigated with reference to potential confounding variables. Future research could again utilise the current methodology to explore this issue through the categorisation of matches and therefore the construction of condition specific profiles (e.g. a winning profile or a wet weather profile).

3.2 METHODOLOGY

3.2.1 STUDY DESIGN

A computerised notation system was devised to analyse (post-event) a selection of an elite European rugby team's domestic league, cup and European cup matches that had been recorded using terrestrial television cameras. This development was conducted in two sections. Section one comprised of the designing and testing of the performance analysis system (including the identification of the proposed PIs), whilst section two involved the collection and processing of the match data in preparation for analysis. Subsequent analysis of the acquired data took place on a weekly basis once match recordings had been obtained.

3.2.2 PARTICIPANTS

Participants were elite, male rugby union players (n= 22) who were all members of a professional European rugby union club's squad during the season 2001/2002. Although the club used a total of 40 players throughout the season, only individuals who had participated in more than five whole matches were utilised (*cf.* Hughes *et al.*, 2001; Vivian *et al.*, 2001). Participants' ages ranged from 20 to 36 years old (mean ± s: 26.9 ± 4.3). Seventy percent of the squad had represented their country at international level with a sum of 295 appearances (mean ± s: 19.67 ± 7.34). Prior to the commencement of the study, ethical approval was granted by the University of Wales, Swansea Ethics Committee (Appendix A), with informed consent to use match recordings gained from the rugby club.

3.2.3 DATA

The data used were generated through the analysis of a selection (n= 22 from a seasons total of 29) of the rugby club's fixtures from the season 2001/2002. The rationale for fixture selection was based upon the availability of match recordings. The results of this sample are displayed in Appendix B and summarised in Table 3.1. Each match was analysed and its events coded using a specifically designed notational system (see section 3.2.4). The data were therefore, in essence, the behaviours of the players involved in these matches.

Table 3.1: Summarised results of the selected fixtures from the 2001/2002 season of the analysed professional team.

	All Matches	Home Matches	Away Matches
Total No.	22	12	10
No. Won	10	7	3
% Won	45.45	58.33	30
Points For	465	269	196
Points Against	439	207	232
Average Score (Analysed Team First)	21 – 20	22 – 17	20 – 23

3.2.4 PROCEDURE

In order to analyse matches, the data collection process comprised of three stages. Stage one consisted of recording matches onto writeable compact discs. VHS recordings of matches were obtained from terrestrial television companies via the rugby club. This was then converted using a video recorder (Panasonic NV-HS820B) and television (Panasonic TX-21JT1) from VHS to MPEG format via a Fast Multimedia Clipmaster MPEG converter (Fast Multimedia AG, 1999). A specially designed software package, Dazzle MovieStar Digital Video Creator (Fast Multimedia AG, 1999) was used to present and archive the recordings upon a Dell Latitude C600/500 PP01L

laptop computer. The matches were then written onto CD (one CD per half a match) using the Roxio Easy CD Creator 5 Platinum package (Roxio Inc., 1999) to free up hard drive space and ensure a robust form of data storage.

Stage two involved the analysis of the matches which was carried out using the laptop computer. To facilitate effective data collection, a computerised notational system was devised using the Noldus 'Observer Video-Pro' behavioural measurement package (Noldus Information Technology, 1995). A unique coding structure was constructed within the package so that single key presses translated to specific behaviours. The codes used were (where possible) the first letter of the behaviour being performed. In order to allow a detailed analysis, several codes were entered for certain behaviours e.g. if the playing position of outside-half kicked the ball, the individual's squad number would be entered followed by the codes for a kick, a descriptor for the type of kick and finally an indicator of the kick's outcome. Figure 3.1 illustrates the coding structure in detail. Collections of data were thereby carried out in accordance with the aforementioned coding structure. Prior to analysis, players, position numbers, the opposition and the dates of matches were recorded. This information was noted so that data collected throughout the season could be compared and contrasted in terms of positions played by individuals, opposition standard and whether matches were played at home or away.

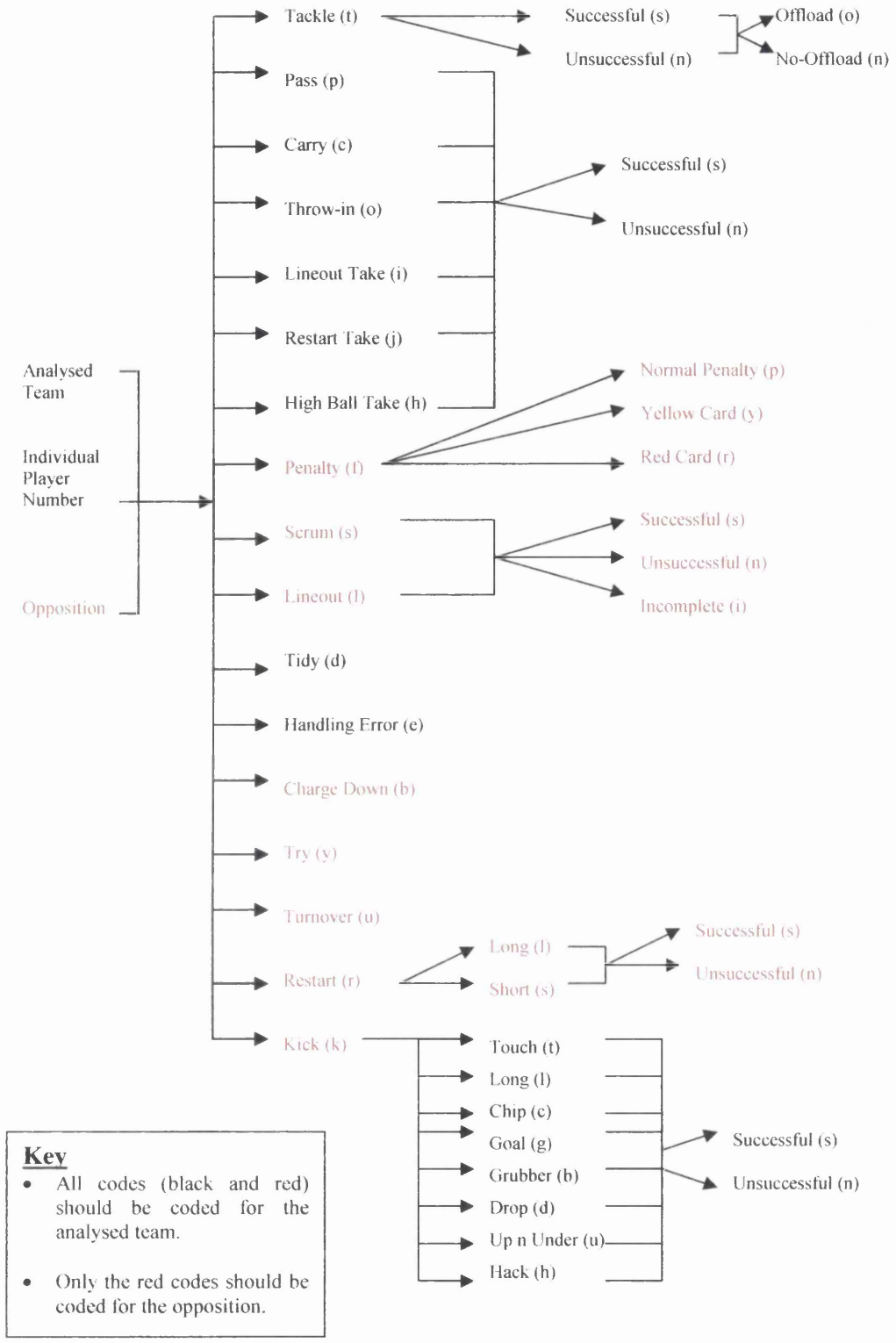


Figure 3.1: The coding structure of the notational system used during the season 2001/2002 (the letters in brackets represent the code entered when analysing a match).

Once the raw data had been collected, the third phase was to transport the information so that data analysis could take place. Firstly, the data were opened as text files in Microsoft Word 2002. These data were then converted from a textual format into a numeric code, thus providing a unique number for each type of behaviour that had been entered. A macro of this time consuming procedure was recorded to enable immediate conversion from 'text' to 'number' once further data had been collected. The numeric data were then tabulated and transferred into the SPSS 10.0 statistics package (SPSS Inc., 2000).

The statistics package was pre-prepared with value labels which were created so that data could once again be presented in a textual format for ease of use. Once the data from the 22 matches had been copied into the SPSS file, over 11,000 separate lines of data had been collected. The use of SPSS 10.0 (SPSS Inc., 2000) allowed a comprehensive analysis of data to take place, resulting in the figures and tables presented in the results section of this study.

3.2.5 Identification of Performance Indicators

When designing a notational system, it is essential to decide initially what information is required (Hughes and Franks, 2004b). Specific behavioural elements for each individual position (or cluster of positions as used by Bracewell (2003a), for example the positions of wing and full-back contain the same PIs), were developed as measures of performance in three stages. First, key behaviours and positional roles were listed by the three members of the research team (the thesis author and supervisors) with a combined experience of 30 years in performance analysis and 50 years in rugby union, and knowledge of the existing literature within the field (the positional roles are displayed in Appendix C). As some behaviours could occur in combinations (e.g.

passing and tackling), and sometimes related to specific positions (e.g. a hooker's throw-in to the lineout), both common and specific PIs were identified for each position. The intention was not to produce an exhaustive list of all behaviours but merely to identify the most important (or key) indicators that defined successful or unsuccessful performance for each position. For example, the playing position of hooker may kick the ball occasionally but the frequency of such an event is so small that to include it as a performance measure would be inappropriate. Furthermore, as previously discussed in section 2.8.4, PIs were expressed as frequencies as opposed to ratios to gain the magnitude of each PI, thereby creating an accurate depiction of each positional profile. Following development, the list of common and specific behaviours was presented to a panel of elite level coaches for content validation purposes. Here, the coaches (with a combination of 50 years playing and coaching experience at elite level) were asked to comment upon, clarify, or add to the list. Appropriate changes or alterations were subsequently made. A full list of the common and specific PIs is presented in Table 3.2.

Table 3.2: Individual performance indicators that were identified for specific rugby union positions during the season 2001/2002.

POSITION	PERFORMANCE INDICATORS
PROPS	1) Handling Errors
	2) Passes of Ball – Successful / Unsuccessful
	3) Carries – Successful / Unsuccessful
	4) Tackles – Made / Missed
	5) Conceded Penalties
	6) Tries Scored
HOOKER	1) Handling Errors
	2) Passes of Ball – Successful / Unsuccessful
	3) Carries – Successful / Unsuccessful
	4) Tackles – Made / Missed
	5) Conceded Penalties
	6) Tries Scored
	7) Throw-in – Successful / Unsuccessful
LOCKS	1) Handling Errors
	2) Passes of Ball – Successful / Unsuccessful
	3) Carries – Successful / Unsuccessful
	4) Tackles – Made / Missed
	5) Conceded Penalties
	6) Tries Scored
	7) Lineout Takes – Successful / Unsuccessful
	8) Restart Takes – Successful / Unsuccessful
NUMBER EIGHT AND FLANKERS	1) Handling Errors
	2) Passes of Ball – Successful / Unsuccessful
	3) Carries – Successful / Unsuccessful
	4) Tackles – Made / Missed
	5) Conceded Penalties
	6) Tries Scored
	7) Turnovers Won
HALF-BACKS AND CENTRES	1) Handling Errors
	2) Passes of Ball – Successful / Unsuccessful
	3) Carries – Successful / Unsuccessful
	4) Tackles – Made / Missed
	5) Conceded Penalties
	6) Tries Scored
	7) Kicks – Type of Kick – Successful / Unsuccessful
FULL-BACK AND WINGS	1) Handling Errors
	2) Passes of Ball – Successful / Unsuccessful
	3) Carries – Successful / Unsuccessful
	4) Tackles – Made / Missed
	5) Conceded Penalties
	6) Tries Scored
	7) Kicks – Type of Kick – Successful / Unsuccessful
	8) High Ball Takes – Successful / Unsuccessful

Finally, to ensure consistent coding of behaviours, operational definitions for each PI were formulated (Partridge and Franks, 1989). These definitions provided the analyst (and trained researchers for reliability purposes) with fixed parameters to reduce uncertainty or confusion about a code. Table 3.3 provides an example of the operational definitions that were used (the full list of operational definitions is displayed in Appendix D). As with the identification of the PIs, all definitions were subject to separate verification by the panel of elite coaches with changes made in response to specific feedback where appropriate.

Table 3.3: Examples of the operational definitions for a pass and a touch kick.

OPERATIONAL DEFINITIONS			
BEHAVIOUR		**OUTCOME**	
PASS	A throw of the ball from a player's hands to another player of the same team	**Successful**	• A pass that goes straight to the receiving player's hands (regardless of whether or not the ball is caught)
		Unsuccessful	• When the ball hits the floor before reaching the receiving player. • If the pass is intercepted. • When the ball is passed and the receiving player has to alter their running speed, or move their hands to above their shoulders or below their knees in order to catch the ball.
TOUCH KICK	A kick out of the hands of a player with the aim of putting the ball into touch.	**Successful**	• If the ball reaches touch.
		Unsuccessful	• If the ball fails to make touch (however, if a player clearly kicks long over the top of the opposition, it should be coded as a successful, long kick).

3.2.6 System Reliability

The effectiveness of the measurement tool and the implications of measurement error are important aspects of any type of research (*cf.* Atkinson and Nevill, 1998). The first step in the reliability testing of this study was the identification of any 'potential coding inaccuracies' (PCIs). Problems or dubious events (for example when there was confusion about what code to enter) were labelled as PCIs as they occurred during analysis. The system was then amended accordingly (either through changing the operational definitions, or by adding a new code). This method proved to be highly valuable as a large number of anomalies presented themselves during the first few analysed matches. After just two matches, the number of anomalies was reduced to around five, and no further anomalies were identified after the eighth analysed match.

To ensure acceptable reliability, both intra and inter-observer tests were calculated with percentage errors for each variable (Bland and Altman, 1986; Hughes *et al.*, 2002). For intra-observer procedures, the analyst (over 100 hours experience on the analysis system) viewed three randomly selected matches twice over a four week period under the same conditions. This resulted in low percentage errors for all variables when differences were re-examined in detail to identify reasons for discrepancies ($< 5\%$). For inter-observer procedures, two researchers with a combined rugby experience of 22 years and a basic knowledge of the system also analysed the same matches. Each output was then compared with that of the main analyst. Both observers demonstrated relatively high error levels for many variables ($\leq 16.67\%$ for observer 1, $\leq 25\%$ for observer 2). The purpose of this inter-observer test was to ensure that the main analyst did not make consistent biased errors which would not be exposed by an intra-observer test. To investigate the potential inaccuracies highlighted by the high error levels, the three analysts involved in the reliability tests examined all of the errors in detail to

identify reasons for discrepancies. This procedure showed that the errors in the inter-observer tests were due to a lack of familiarity with the operational definitions of the system (possibly due to guessing codes instead of looking at the definitions), rather than consistent biased errors being made by the main analyst. Since the study was reliant solely on the main analyst for data input, the reliability results confirm acceptable levels of error. The inter-observer test results could have been reported after the investigation into discrepancies had been completed (low levels of error), but the high levels of error serve to inform the reader of the pit-falls of using analysts who are not substantially trained on the analysis system (*cf.* James *et al.*, 2002). The full results of the intra and inter-observer reliability tests are displayed in Appendix E. These results are reflected in the precision used to present quantitative data throughout the study. Data which were collected using the analysis system are presented to an accuracy of one decimal place (see section 2.8.1 for discussion on reliability and data precision).

3.2.7 Data Transformation

While rugby matches last 80 minutes (plus extra time for stoppages), often individual players do not play the full match due to substitution or injury. If data were disregarded when players participated in less than 80, or even 30 minutes of a match, there would have been insufficient data for certain positions such as props and flankers (where substitutions and squad rotation are prevalent). Therefore, when constructing a performance profile for each position (using frequencies of behaviours performed) a decision had to be made to account for these individual contributions. For example, although an individual may make five tackles in one-half of a match, it is not certain whether this will equate to 10 tackles in a whole match. In order to overcome this limitation, the environment from which the data are collected needs to be considered. Specifically, each rugby match is subject to different environmental factors (e.g.

weather, playing surface, team composition), which may be considered as potential confounding variables (Hughes and Bartlett, 2002; James *et al.*, 2002). When data collected from different matches are assessed as part of a bigger data set (e.g. all home matches), the random error associated with each individual measurement needs to remain integral to that quantity and not subsumed within the cumulative data, i.e. if all data were simply added together. Consequently, an issue arises of how to treat data that are collected from an individual playing 40 or 20 minutes as opposed to the whole match. In the current study, the proposed solution was to transform the data to account for the number of minutes an individual player was on the pitch. To transform data, according to Howell (1992, p. 316), is appropriate as long as the "nature of the transformation is sensible."

In order to compensate for the potential inaccuracy in playing time, the raw frequency data were transformed into a proportionate rate related to time on the pitch. Specifically, the frequency of the behaviour was divided by the number of minutes on the pitch (expressed as a fraction) using the following formula:

$$Transformation1 = F\left(\frac{80}{n}\right)$$

where F is the frequency of the performance variable and n is the number of minutes played. Transformation 1 therefore successfully created rates that accounted for the time a player was on the pitch. Inspecting the transformation values (Figure 3.2) it can be seen that they are exponential in nature, increasing greatly for low playing times (i.e. less than half a match played). This seems appropriate considering that data collected from small playing times are less likely to be good predictors of full match performance than data from larger playing times. This can also be thought of as the "certainty" of the data and relates to the possibility of chance factors affecting the observed frequencies

within the playing time, including variables that are hypothesised to occur relatively randomly, e.g. a pool of water causing a player to slip, or an incorrect decision made by an official. This 'random' variation is therefore expected to have less of an effect on the data when an individual plays 80 minutes compared to only two minutes. While the transformation seems appropriate, a situation may arise where a player comes off the replacements bench in the latter stages of a match and plays only two minutes during which time the team is constantly defending. When converting the tackle rate (which would be expected to have been relatively high due to the team defending) for the period the individual was on the pitch to a full 80 minutes play, an unrealistically high rate would be created (as the frequency would be multiplied by 40). It is suggested therefore that while the values obtained by transformation 1 existed in the correct pattern (an exponential curve), and accurately reflected the nature of the certainty of the data, the weighting of the transformation for small periods of the match played by an individual was too high. The extent to which credit should be given to a player in this situation therefore also needs to be considered i.e., the magnitude of the transformation.

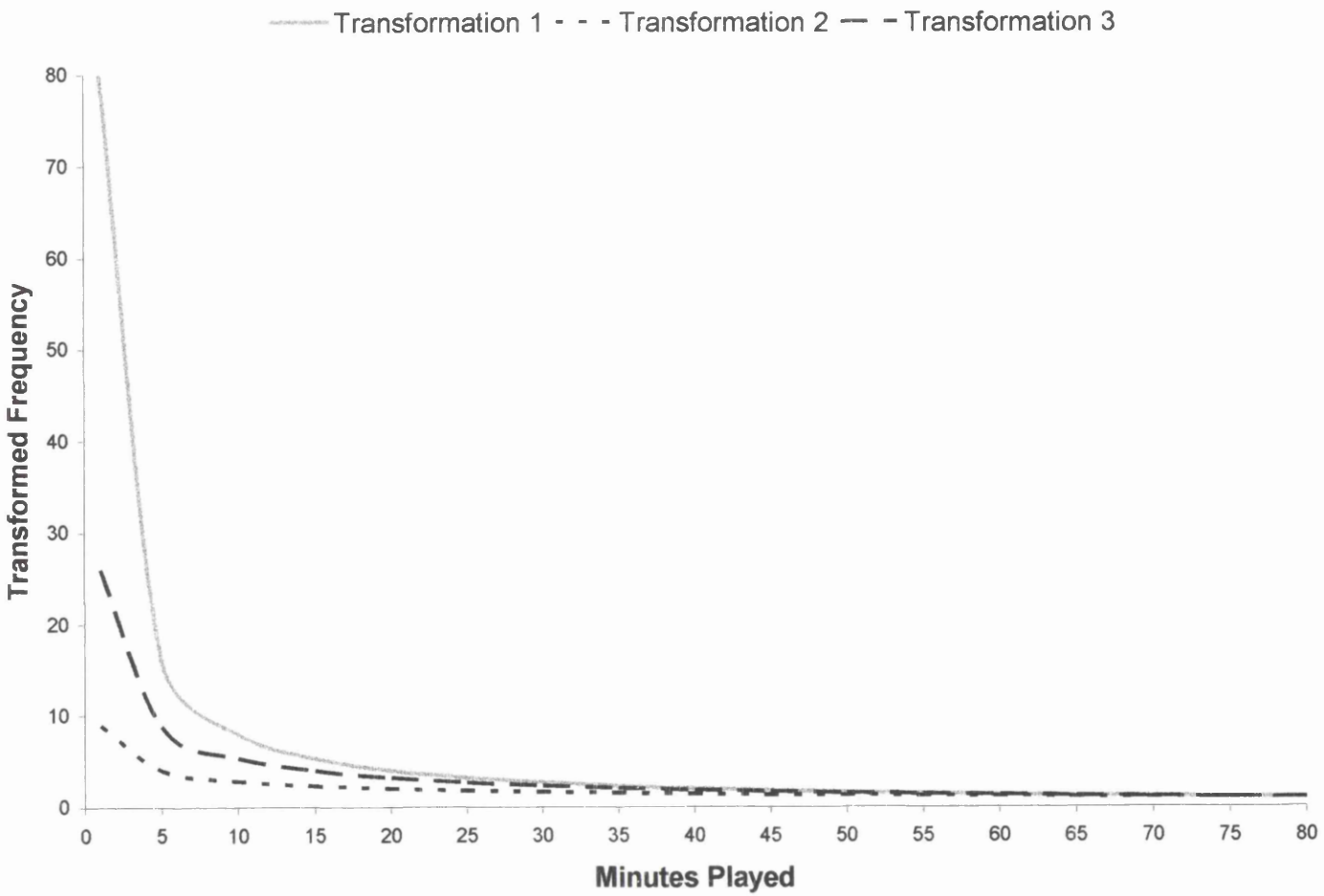


Figure 3.2: Multiplication values as a consequence of applying transformations to frequency data (F= 1) to account for time played (transformations 1, 2 and 3).

The formula adopted for this problem was the commonly used square root transformation (Howell, 1992) as this lowers the magnitude of the transformation for small playing periods while maintaining the integrity of the shape of the curve (Figure 3.2). The formula used was:

$$Transformation2 = F\left(\sqrt{\frac{80}{n}}\right)$$

where F is the frequency of the performance variable and n is the number of minutes played. This dramatically reduced the substantial outliers produced by transformation 1 for small playing times. However, while transformation 2 had the required properties, examination of real data revealed that the resultant value did not appropriately credit performances for small playing times. The ideal transformation was hypothesised (using a trial and error method combining two commonly used transformations), to exist somewhere between transformations 1 and 2 (Figure 3.2) calculated by the following equation:

$$Transformation3 = F\left(\sqrt{\frac{80}{n}}\right)\left(\left(\log_{10}\frac{80}{n}\right)+1\right)$$

where F is the frequency of the performance variable and n is the number of minutes played. This transformation provides a rate which lessens the multiplication factor for behaviours made within small periods (compared to transformation 1), but also does not under estimate a player's contribution (transformation 2). To illustrate the transformation, take an example that occurred during analysis of an individual player who made five successful tackles in four minutes of a match. Transformation 3 provides a value of 51.45 successful tackles per match. Although this rate is exceptionally high (compared to typical values) it is nearly half the size of the rate that transformation 1 gives (100) but retains the value's rightful outlier status.

It could also be argued that where a player only participates for a short period of time, during which the match is dominated by defence for example, then a small value for a particular behaviour may under represent typical performance. This occurs when a behaviour is absent from the performance and in this situation all transformations will underestimate. One solution is to use the median value previously calculated for a single behaviour. This can be problematical however, as previous data may be unavailable or unreliable due to an exceptional previous performance. It should also be noted that even in a full match, players may not undertake specific behaviours and so values of zero can be expected. Consequently, where behaviours were absent, no effort was made to increase them as no general rule could be formulated that accounted for all eventualities. Thus, the resultant predictability of the performance behaviours should be interpreted with respect to the possibility of small underestimations in certain, but rare instances. Coaches may therefore consider the possibility of making *ad hoc* adjustments for these situations.

3.2.8 Development of Performance Profiles

In order to assess whether data collected are representative of a performance profile, previous researchers (e.g. Hughes *et al.*, 2001) have suggested assessing the 'stability' of profiles by comparing sample data with sample means from similar distributions collected over larger periods. However, this procedure is impossible when collecting data for the first time and is limited in its applicability in many cases due to fluctuations in factors such as team changes, maturation and the fact that some performances never stabilise. An alternative approach is suggested whereby the specific estimates of population medians are calculated from the sample data through confidence limits (CLs). Medians were selected, as opposed to means, as the data distributions were found (through the assessment of skewness and kurtosis statistics) to be typically non-

normal (as are the majority of notational analysis data, Hughes *et al.*, 2002), suggesting a non-parametric approach (Zar, 1999; Hughes *et al.*, 2002). CLs represent upper and lower values between which the true (population) median is likely to fall based on the observed values collected. Confidence limits for the population median are obtained using the lower *n*th and the upper *n*th values of the rank order data based upon the size of the data sample (Zar, 1999). Calculated CLs naturally change as more data are collected, typically resulting in the confidence interval decreasing (confidence interval= upper CL - lower CL). Confidence intervals (CIs) are therefore suggested to be more appropriate as performance guides compared to using median values alone. Using a fixed value appears to be too constrained due to potential confounding variables that typically affect performance and the variability of the data.

From a theoretical perspective, the use of CLs can also add significance to the judgement of the predictive potential of a data set, i.e. whether the data collected allow a reasonable estimation of performance. For the current investigation, the size of the CI and relative stability of the PIs were explored. Initially 95% CLs were calculated for each PI as soon as enough match data had been collected (n= 2) and each time more data were added, the new CI was calculated. This meant that CIs could be constructed for each PI after 2, 3 and.... n matches respectively. Behavioural frequencies fell outside the 95% CLs more often for small data sets and less often as the data set increased. However, this was inevitable as any measure related to the median of a data set becomes progressively more resistant to change as the data set increases. In addition, it was found that certain individuals possessed larger CIs for certain PIs possibly indicating a greater variability or unpredictability within their style of play. The use of CLs thereby provided the opportunity to present the data of those individuals who had participated in relatively few matches and whose performances were variable.

3.2.9 INTRA-POSITION ANALYSIS

A final objective of the study was to analyse the PIs of different individuals from the same playing position to investigate intra-positional variations within the team. To allow comparisons, the 15 positions of a rugby union team were split into groups known as positional clusters (Bracewell, 2003a). The original nine clusters described by Bracewell (2003a) were amended to 10 after consideration of the positional profiles. These consisted of prop, hooker, lock, open-side flanker, blind-side flanker, number eight, scrum-half, outside-half, centre and outside-back (incorporating the two wings and full-back). Due to the uneven nature of the data (certain players had participated in all 22 matches, whilst others had participated in as little as eight of them), a chi-square test was used to examine any significant differences between the behaviours of individuals from the same positional cluster (Vincent, 1999; Nevill *et al.*, 2002). According to Vincent (1999) the chi-square test compares two or more sets of nominal data that have been arranged into categories by frequency counts. From this data the test then reveals the significance of the differences in the frequency counts. Alpha levels were set at the 95% level of statistical significance (Fleming and Nellis, 1994).

The formula for chi-square is as follows:

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

Where O = the observed frequency and E = the expected frequency.

When comparing individuals, only principal PIs were selected for analysis due to the low occurrence (frequency) of certain behaviours. Specifically, passing, carrying and tackling were selected for the forward positional clusters, while passing, carrying, tackling and kicking were selected for the backs.

3.3 RESULTS

3.3.1 POSITIONAL PROFILES

Median values for PIs (plus associated CLs) and the resultant performance profiles were calculated for each of the 10 identified positional clusters. Each positional profile utilised combined data from all available players, although in four instances only one player was available (Tables 3.4 – 3.6). As Tables 3.4 – 3.6 indicate, expected differences were observed between the positional clusters. For example, the prop positional cluster had a median of 3 successful tackles (+/- CLs= 4 and 2.9), compared to the open-side flanker who had a median of 10.6 (+/- CLs= 14 and 9). An example of these inter-positional differences (comparing the scrum-half and outside-half clusters) is illustrated in Figure 3.3.

Table 3.4: Median profiles and 95% confidence limits for the positional clusters of prop, hooker and lock from the 2001/2002 season of the analysed professional team.

Matches Played	Prop (3 players)*** 13, 22 and 15			Hooker (1 player) 13			Lock (4 players)** 20, 14, 14 and 11		
	Median	+CL	-CL	Median	+CL	-CL	Median	+CL	-CL
Successful Tackles	3	4	2.9	4	6.3	1.9	5	6	4
Unsuccessful Tackles	0	0	0	0	1.2	0	0	0	0
Successful Carries	3.5	5.5	2	2.5	5.8	1.2	2	2.7	1.1
Unsuccessful Carries	0	0	0	0	1.1	0	0	0	0
Successful Passes	1	2	0	0	2	0	0	1	0
Unsuccessful Passes	0	0	0	0	0	0	0	0	0
Handling Errors	0	0	0	0	0	0	0	1	0
Normal Penalties	0	1	0	0	1.1	0	0	1	0
Yellow Cards	0	0	0	0	0	0	0	0	0
Tries Scored	0	0	0	0	0	0	0	0	0
Successful Throw-ins	-	-	-	9	11.3	7	-	-	-
Unsuccessful Throw-ins	-	-	-	2.5	4	1.3	-	-	-
Successful Lineout Takes	-	-	-	-	-	-	4	5	3
Unsuccessful Lineout Takes	-	-	-	-	-	-	0	0	0
Successful Restart Takes	-	-	-	-	-	-	0	0	0
Unsuccessful Restart Takes	-	-	-	-	-	-	0	0	0

Key: Significant intra-positional differences from the chi-square test are indicated by: *= $p < .05$, **= $p < .01$, ***= $p < .001$

Table 3.5: Median profiles and 95% confidence limits for the positional clusters of back row (blind and open-side flanker and number eight) from the 2001/2002 season of the analysed professional team.

Matches Played	Blind-side (2 players)*** 13 and 9			Open-side (1 player) 22			Number Eight (1 player) 12		
	Median	+CL	-CL	Median	+CL	-CL	Median	+CL	-CL
Successful Tackles	9.5	13	7	10.6	14	9	7	9	4
Unsuccessful Tackles	1	1.1	0	1	2	0	1	2	0
Successful Carries	7.6	11	5	2.3	4	1	8.4	10	6.2
Unsuccessful Carries	0	0	0	0	0	0	0	1	0
Successful Passes	3.2	7.4	2	1.3	2	0	4.3	7	0
Unsuccessful Passes	0	0	0	0	0	0	0	2	0
Handling Errors	1	2	0	0	1	0	0.5	1.1	0
Normal Penalties	1	2	0	1	2	0	1	1.1	0
Yellow Cards	0	0	0	0	0	0	0	0	0
Tries Scored	0	0	0	0	0	0	0	0	0
Turnovers Won	0	2	0	0.5	1	0	0	0	0

Key: Significant intra-positional differences from the chi-square test are indicated by: *= $p < .05$, **= $p < .01$, ***= $p < .001$

Table 3.6: Median profiles and 95% confidence limits for the positional clusters of scrum-half, outside-half, centre and outside-back from the 2001/2002 season of the analysed professional team.

Matches Played	Scrum-Half (1 player) 16			Outside-Half (2 players)*** 14 and 11			Centre (2 players)* 21 and 11			Outside-Back (5 players)*** 11, 13, 11, 9 and 17		
	Median	+CL	-CL	Median	+CL	-CL	Median	+CL	-CL	Median	+CL	-CL
Successful Tackles	10.4	11.7	4	4.7	6	2	6	8	4.6	3.7	4	3
Unsuccessful Tackles	1.7	3.2	0	1	2	0	1	2	0	1	1	0
Successful Carries	9.9	11.8	8	4	5.4	2	8	10	6	5	6	5
Unsuccessful Carries	0	1.3	0	0	0	0	0	0	0	0	0	0
Successful Passes	45.1	53.2	37.7	17	20.9	14	5.9	9	5	2	3	1.1
Unsuccessful Passes	2.9	5.2	1	1	2	1	1	1.2	0	0	0	0
Handling Errors	1.2	2.5	1	0	1	0	1	1	0	0	1	0
Normal Penalties	0	1	0	0	0	0	0	0	0	0	0	0
Yellow Cards	0	0	0	0	0	0	0	0	0	0	0	0
Tries Scored	0	0	0	0	0	0	0	0	0	0	0	0
Successful Kicks	3.1	4.4	1	13.3	16	12	0	1	0	1	1	0
Unsuccessful Kicks	2	3	1	5.4	7	5	0	0	0	0	0	0
Successful High Ball	-	-	-	-	-	-	-	-	-	0	1	0
Unsuccessful High Ball	-	-	-	-	-	-	-	-	-	0	0	0

Key: Significant intra-positional differences from the chi-square test are indicated by: *= $p < .05$, **= $p < .01$, ***= $p < .001$

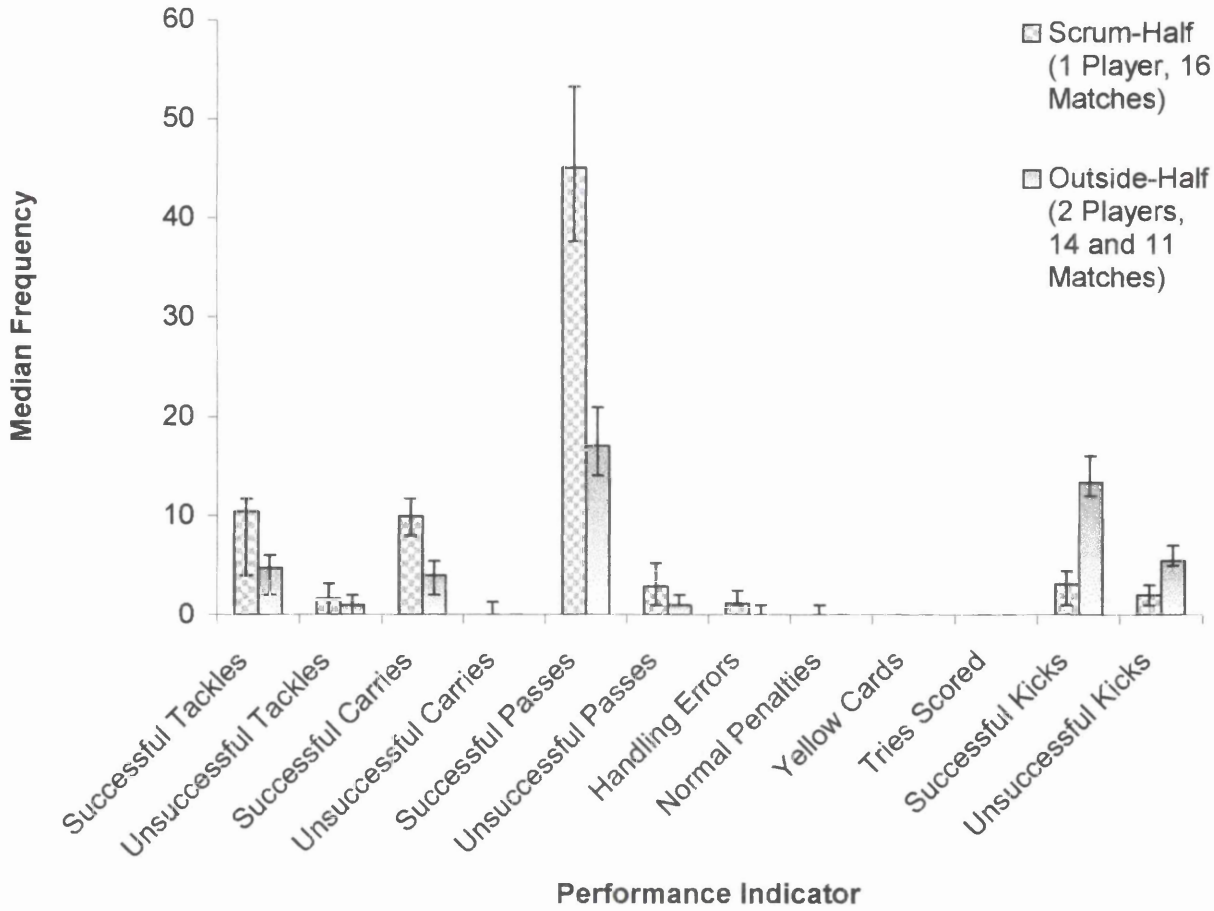


Figure 3.3: Inter-positional comparison of the positional clusters of scrum-half and outside-half, illustrating median frequencies and 95% confidence limits for the population median from the 2001/2002 season of the analysed professional team.

3.3.2 INTRA-POSITION ANALYSIS

Performance profiles of each positional cluster containing more than one individual were analysed (prop, lock, blind-side flanker, outside-half, centre and outside-back). Significant differences were found within all clusters when the principal indicators were analysed (see Tables 3.4 – 3.6). For example, for the positional cluster of prop forward, although players 1, 3 and 24 showed similar frequencies of successful tackles (player 1, *mdn*= 5, +/- CLs= 6.2 and 1, player 3, *mdn*= 3, +/- CLs= 6.7 and 2.8, player 24, *mdn*= 3, +/- CLs= 4 and 1), differences were observed between the individuals' successful carries, with player 1 possessing a median of more than three times larger than player 3 (player 1, *mdn*= 6.2, +/- CLs= 15.5 and 2.1, player 3, *mdn*= 2, +/- CLs= 4 and 1, player 24, *mdn*= 4, +/- CLs= 6 and 2). Comparison of the individuals in the outside-half position (Figure 3.4) revealed significant differences between the two players of this position. Player 21's performance was characterised by significantly greater successful carries (*mdn*= 6, +/- CLs= 13 and 3) and successful tackles (*mdn*= 7, +/- CLs= 11 and 0) at the expense of successful passes (*mdn*= 14, +/- CLs= 20.9 and 9) and successful kicks (*mdn*= 13, +/- CLs= 15 and 7.8). In contrast player 10's profile indicated significantly greater successful passes (*mdn*= 20, +/- CLs= 28 and 14.2) and successful kicks (*mdn*= 15.5, +/- CLs= 17 and 12) at the expense of successful tackles (*mdn*= 3, +/- CLs= 5 and 1) and successful carries (*mdn*= 2, +/- CLs= 5 and 1). In addition, the larger confidence intervals shown by player 21 for these four PIs (e.g. successful tackles, player 10 CI= 4, player 21 CI= 11) show this individual to possess a higher level of intra-player variance when compared with player 10. However, it is important to note that this increase in CI size may have been a result of player 21 having played fewer matches within the sample than player 10 (player 10= 14 matches, player 21= 11 matches). Individual median

performance profiles and 95% CLs for all 22 analysed players from the season 2001/2002 are displayed in Appendix F.

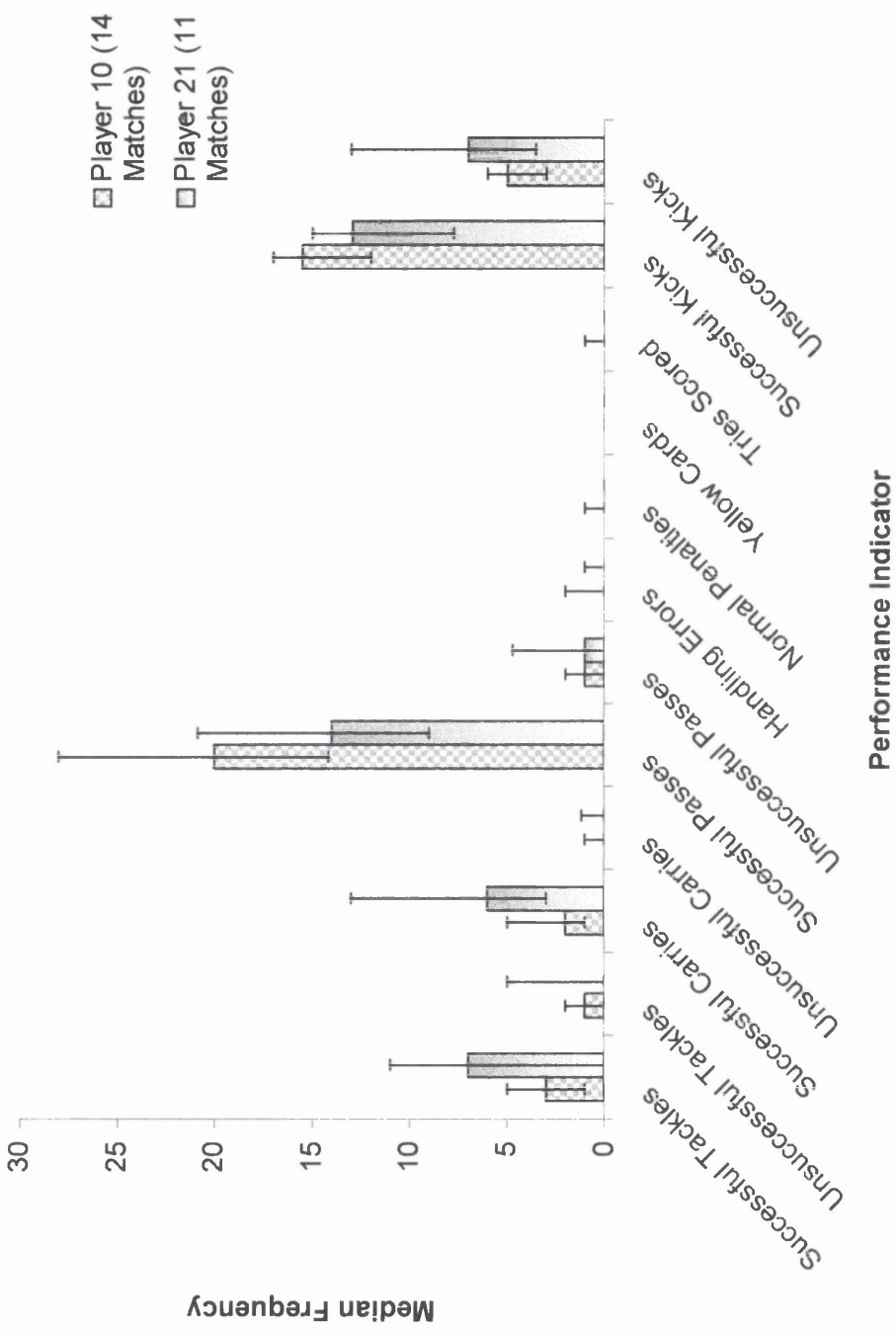


Figure 3.4: Intra-positional comparison of the players 10 and 21 within the positional cluster of outside-half, illustrating median frequencies and 95% confidence limits for the population median from the 2001/2002 season of the analysed professional team.

3.4 DISCUSSION

The aim of this study was to construct a valid and reliable methodology for the analysis of individual performances within a professional rugby union team. This was achieved through the development of PIs (Hughes and Bartlett, 2002) that had been validated by elite coaches, the adoption of appropriate reliability procedures (Hughes *et al.*, 2002) and the use of novel statistical techniques to determine individual player performance profiles and make intra-positional comparisons.

Despite the use of performance analysis in applied sports science for some time, little detail has been documented, particularly in rugby union, regarding the design and construction of systems and scientific procedures utilised to assess the reliability and validity of these systems (Hughes *et al.*, 2002; More, 2002; Nevill *et al.*, 2002). The first objective of the study was therefore to investigate the construction and development of a scientific methodology through the establishment of PIs that were defined and coded in a valid and reliable manner though the use of appropriate content validity and repeatability measures. The current system developed here presents a suitable applied methodology for conducting analysis of individual player performance profiles within a group framework that has been rigorously tested. Further, this study has presented an explicit process for identifying key performance behaviours, together with suitable descriptions of these behaviours, verified by individuals with a wealth of coaching and playing experience in the sport.

A further objective of this study was to utilise the performance profiles of players to compare intra-positional differences in PIs. The results showed that when compared, general positional profiles were evident, although significant between-player differences were found for all of the analysed positional clusters. This suggests that for some

positions a general profile may be created, which is probably specific to each team, and may indicate the strengths and weaknesses of the performances of players in that position. With regard to the differences of the principal behaviours for individuals of the same positions, the findings observed particular variation within the playing position of outside-half. Previous scientific and coaching literature discussing playing behaviours suggests that the outside-half is a key position within rugby union. Together with the position of scrum-half, the pair occupy positions of centrality within the team and are therefore required to be frequently involved in decision making behaviours (Greenwood, 1997; Parsons and Hughes, 2001; Deutsch *et al.*, 2002). The differences observed between the two outside-halves are therefore likely to represent individual differences in decision-making which translate into the different styles or patterns of play displayed. The magnitude of the confidence interval for a key behaviour, indicative of performance variability, may therefore also be an indicator of the decision-making demands for this position.

An important issue in the current notational analysis literature is the construction of performance profiles and the amount of data required for the analyst to be confident that the number of behaviours recorded, are truly representative of an individual's performance of that behaviour (Hughes *et al.*, 2001). Indeed, Hughes *et al.* (2001) suggested that without achieving a stable profile for a set of performance behaviours, any inferences regarding an individual or team performance can be taken as somewhat spurious. In this study, CLs for the population median (Zar, 1999) were introduced for performance behaviours, which was deemed sufficient to permit the creation of profiles (*cf.* Hughes *et al.*, 2001; Vivian *et al.*, 2001). The use of medians as opposed to the more commonly used mean (e.g. Hughes and White, 1997; Vivian *et al.*, 2001; Deutsch *et al.*, 2002; Boddington and Lambert, 2004) provided a measure of central tendency

that was appropriate to the non-parametric nature of the data. Additionally, it is advocated that the use of CLs is the most applicable methodology, particularly to the applied practitioner, in that performance profiles regarding individual and team behaviours can be established after the collection of relatively few data sets. However, it is important to consider the number of matches used to create an individual profile, especially when comparing one profile with another. Larger CIs may not necessarily indicate higher levels of intra-player variance (the variability or unpredictability of the individual), they may simply be a result of a smaller sample size. Nevertheless, it should also be noted that some performance profiles may consistently possess relatively wide CLs (a large CI) and may never 'stabilise' or become constant due to this intra-player variance (O'Donoghue, 2005). In this case the use of CLs provides an appropriate means for assessing such inconsistency in performance. An additional issue to consider when using CIs concerns the presence and effect of potential confounding variables (e.g. winning and losing or the weather). When PIs possess relatively small CIs it is likely that variability and therefore the influence of these variables upon individual PIs is low. A delimitation of this study is that although profiles were generated for all of the positional clusters within rugby union, any variability within PIs (shown by the size of their respective CIs) was not investigated with reference to potential confounding variables. Future research could utilise the current methodology to explore this issue through the categorisation of matches and therefore the construction of condition specific profiles (e.g. a winning profile or a wet weather profile).

While this study has introduced some new scientific techniques to facilitate the development of systems to analyse and collect behaviour, it is acknowledged that the findings are preliminary and there are several areas that require further investigation.

Firstly, although individual PIs were investigated, some further aspects of the game of rugby union which form additional components of certain playing positions' performances (i.e., 'cleaning' opposition players out of rucks, driving in mauls, 'bridging' at the breakdown and making breaks), were not incorporated due to analysis complications. Indeed, the performance profiles of certain positions such as prop and lock contained low frequencies for a large number of the PIs. This indicated that certain individuals contributed to a match in a way that was not included within the profiles outlined by the current study. This concurs with the findings of Parsons and Hughes (2001) who found that positions such as prop and hooker were involved in off-the-ball supporting roles to a greater extent than ball carrying. Future research should therefore attempt to include these additional behaviours in order to further the current line of research into rugby union and contribute to the development of a more comprehensive profile of an individual's performance.

Secondly, it must be noted that whilst the aim of the study was to create a methodology for the construction of individual performance profiles, a delimitation is that the profiles were generated using a case study design. Therefore, the results may not necessarily be applicable to all teams and all standards of play. However, future research could utilise the outlined methodologies to investigate any similarities or differences that exist between individual profiles from other teams. Furthermore, certain aspects of the study design (e.g. analysis techniques such as accounting for the time spent on the field of play by individuals) could also be utilised (with the necessary modifications) within other team sports such as soccer and hockey.

Finally, to further enhance the understanding of the performance of rugby union teams, there is a need to complement these individual performance profiles with the analysis of

patterns of play or team profiles. For example, Hunter and O'Donoghue's (2001) preliminary work investigating positive and negative aspects of attacking and defensive play in successful and unsuccessful rugby union teams, suggested distinct differences in terms of changes in possession and methods used by the teams to gain territory. Additional direction may also come from research into other sports such as soccer, where some relative success has been achieved in identifying patterns of play and team strategies (e.g. Luhtanen *et al.*, 2001; Jones, James *et al.*, 2004).

CHAPTER 4

STUDY 2

TEAM PERFORMANCE INDICATORS AS A FUNCTION OF WINNING AND LOSING IN ELITE RUGBY UNION

CHAPTER 4: STUDY 2

4.1 INTRODUCTION

Study 1 provided detailed information concerning the profiles of individuals within a professional rugby union team. However, to compliment this and gain a greater understanding of performance within a team sport such as rugby union, there is a need to analyse and construct team performance indicators (PIs) and profiles. Consequently, the principal objective of this study is to develop a methodology to create team performance profiles and examine the predictors of success in a single team through the comparison of winning and losing performances. Although there have been a number of studies which have investigated indicators of team performance (e.g. Hughes and White, 1997; Stanhope and Hughes, 1997; Jackson and Hughes, 2001; Hunter and O'Donoghue, 2001; McCorry *et al.*, 2001), results have provided partial information on specific areas of rugby union due to a limited number of team PIs, for example rucks, mauls, and frequencies of territorial advantage. In particular, prior research within the area has neglected the opportunity to analyse one team when winning and losing rather than comparing two or more different teams (the winning and losing sides). Subsequently, further work is required to develop observable team PIs which allow performance predictions to be made as a function of winning and losing.

Despite not investigating team performance, study 1 presented valuable data regarding the assessment of individual players and their respective positions. Specifically, both inter and intra-positional differences were found within the analysed team's playing squad. However, the low frequencies of behaviours observed for certain positions (e.g. prop and lock) suggest that the individual profiles could be further developed through the inclusion of certain off-the-ball behaviours identified as a limitation in study 1. Indeed, previous research has found that playing positions such as prop and hooker were

involved in supporting roles off-the-ball to a greater extent than ball carrying (Parsons and Hughes, 2001). Consequently, a second objective is to adapt the analysis system through the addition or rectification of codes, thus providing more accurate and detailed individual profiles.

A final objective of this study is to investigate consistency between the profiles of individuals across two different seasons. This will be achieved through a comparison of the individual profiles generated during study 1 and those created during this second study. In particular, attention will be focused towards the individuals' decision making with the ball-in-hand as these behaviours are least affected by the opposition and are more easily compared across two seasons. This will facilitate further investigation into the intra-positional differences identified during study 1, and will also allow the assessment of similarities and differences between the respective profiles of players who participated in both studies (two differing seasons).

Whilst this study aims to provide further knowledge concerning the construction and assessment of both individual and team performance profiles, there are a number of delimitations present within the study design. Firstly, it must be noted that the analysis of one team provides profiles of that single team when winning and losing, rather than a winning profile gained from the average of a number of teams. The winning profile of one team may not necessarily correspond with the winning profile of another (i.e. different strengths within teams). A second delimitation is that whilst the study aims to investigate the effect of winning and losing on team PIs, variables such as match venue and the weather may have an effect on the data. Despite the small sample size of a season's data, the best possible representative sample of these conditions will be utilised.

4.2 METHODOLOGY

4.2.1 STUDY DESIGN

The computerised notation system and methodology that were used during study 1 were again utilised. However, with reference to the limitations outlined in section 3.4 and the aims of this study (section 4.1), a number of methodological modifications were employed. Specifically, some individual PIs were amended and others, pertaining to team performance, added.

4.2.2 PARTICIPANTS

Participants were elite, male rugby union players (n= 26), who were all members of the same professional, European rugby club's squad during the season 2002/2003. The participant selection procedure was the same as with study 1, players were selected from the squad of 58 players utilised by the club during the season 2002/2003, if they had played more than five whole matches (*cf.* Hughes *et al.*, 2001; Vivian *et al.*, 2001). Participants' ages ranged from 20 to 33 years old (mean ± s: 27 ± 3.7). Fifty-four percent of the squad had represented their country at international level with a sum of 231 appearances (mean ± s: 8.88 ± 15.1). Thirteen of the 26 players utilised had also performed in five or more matches during study 1 (season 2001/2002). Prior to the commencement of analysis, ethical approval was granted by the University of Wales, Swansea Ethics Committee with informed consent to use match recordings gained from the rugby club.

4.2.3 DATA

The data were collected through the analysis of the rugby club's fixtures from the season 2002/2003 (n= 20) out of a total of 32 matches. The rationale for fixture selection was based solely upon the availability of match recordings. The results of this

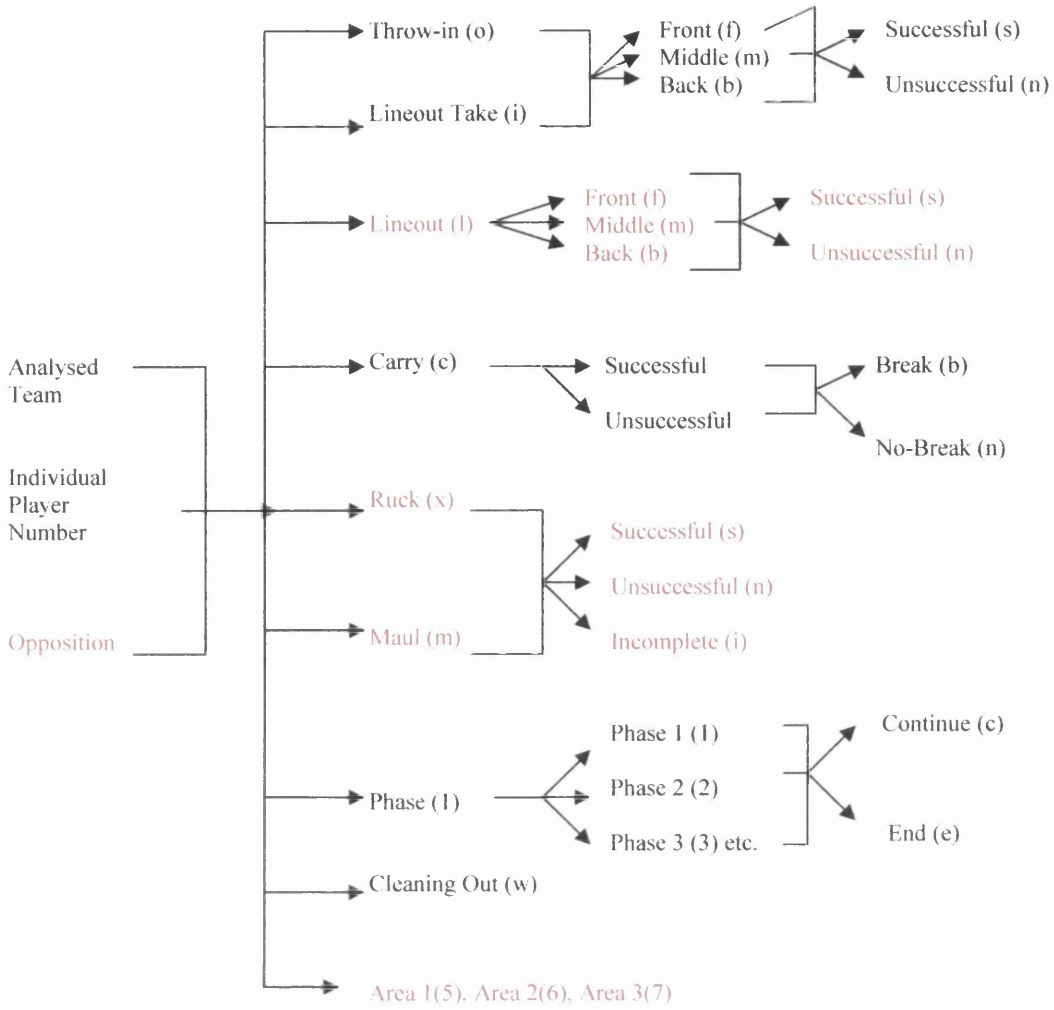
sample are displayed in Appendix G and summarised in Table 4.1. Each match was analysed and its events coded using the adapted version of the notational system that was used during study 1 (see section 4.2.4).

Table 4.1: Summarised results of the selected fixtures from the 2002/2003 season of the analysed professional team.

	All Matches	Home Matches	Away Matches
Total No.	20	10	10
No. Won	8	6	2
% Won	40	60	20
Points For	491	254	237
Points Against	723	252	471
Average Score (Analysed Team First)	24 – 36	25 – 25	24 – 47

4.2.4 PROCEDURE

The three procedural stages of the data collection process that were employed in study 1 were again utilised. There were however, several variations with the second stage. Stage one (the recording of matches onto writeable compact discs) remained unchanged, whilst the coding structure constructed for stage two; analysis using the 'Observer Video-Pro' behavioural measurement package (Noldus Information Technology, 1995), was amended according to the changes made to the PIs (sections 4.2.5 and 4.2.6). The alterations to the coding structure are displayed in Figure 4.1. These codes are in addition to those used during study 1 (see Figure 3.1).



Key

- All codes (black and red) should be coded for the analysed team.
- Only the red codes should be coded for the opposition.

Figure 4.1: Study 2 modifications to the coding structure of the notational system (letters in brackets represent the code entered when analysing a match).

Operational definitions were again used for each behaviour to increase the consistency of operator coding (Partridge and Franks, 1989). The table of operational definitions is displayed in Appendix H.

The third stage of the data collection process (transportation of the raw data) remained the same as in study 1. Once coded, the match data were transferred into an SPSS v10.0 file (SPSS Inc., 2000) where the final data were compiled for analysis (>21,000 rows of data). This increase in the quantity of raw data was due to the additional codes and PIs.

4.2.5 Identification of Team Performance Indicators

The PIs that were used during study 1 were scrutinised and four additional codes (displayed in Figure 4.1, full operational definitions are presented in Appendix H) were employed in order to analyse team performance. This was completed using the knowledge and experience of the two elite level rugby union coaches that were used in study 1 (combined playing and coaching experience at elite level= 51 years).

The four new codes were; rucks (successful/unsuccessful), mauls (successful/ unsuccessful), area of the field (area 1/2/3, illustrated in Figure 4.2), and a code which labelled the number of phases of play the analysed team had completed in a particular movement. The additional codes were then combined with existing codes to form 22 team PIs. These indicators were developed using prior literature (e.g. Hughes and White, 1997; Stanhope and Hughes, 1997; Hunter and O'Donoghue, 2001; McCorry *et al.*, 2001) and the knowledge and experience of the two elite rugby union coaches.

Where possible, team indicators were expressed as percentages to provide a more accurate analysis of team performance (*cf.* Hopkins *et al.*, 1999; Hughes and Bartlett, 2002). Whilst it was important to analyse PI occurrences within the individual profiles in study 1, the purpose of the team PIs was to provide an indication of success through

winning and losing performances. The use of ratios therefore provided a more detailed depiction of the performance of each variable (PI) rather than a frequency of occurrences within a match (see section 2.8.4). The advantage of using percentages can be explained using the following example. If five missed tackles were made in two separate matches, they would appear the same if they were both expressed as frequencies. However, if 50 tackles were made in one match (5/50= 90% success) compared with 100 in another (5/100= 95% success), the percentages would reflect the subtle difference whereas the frequencies would not. The full list of team PIs is displayed in Table 4.2.

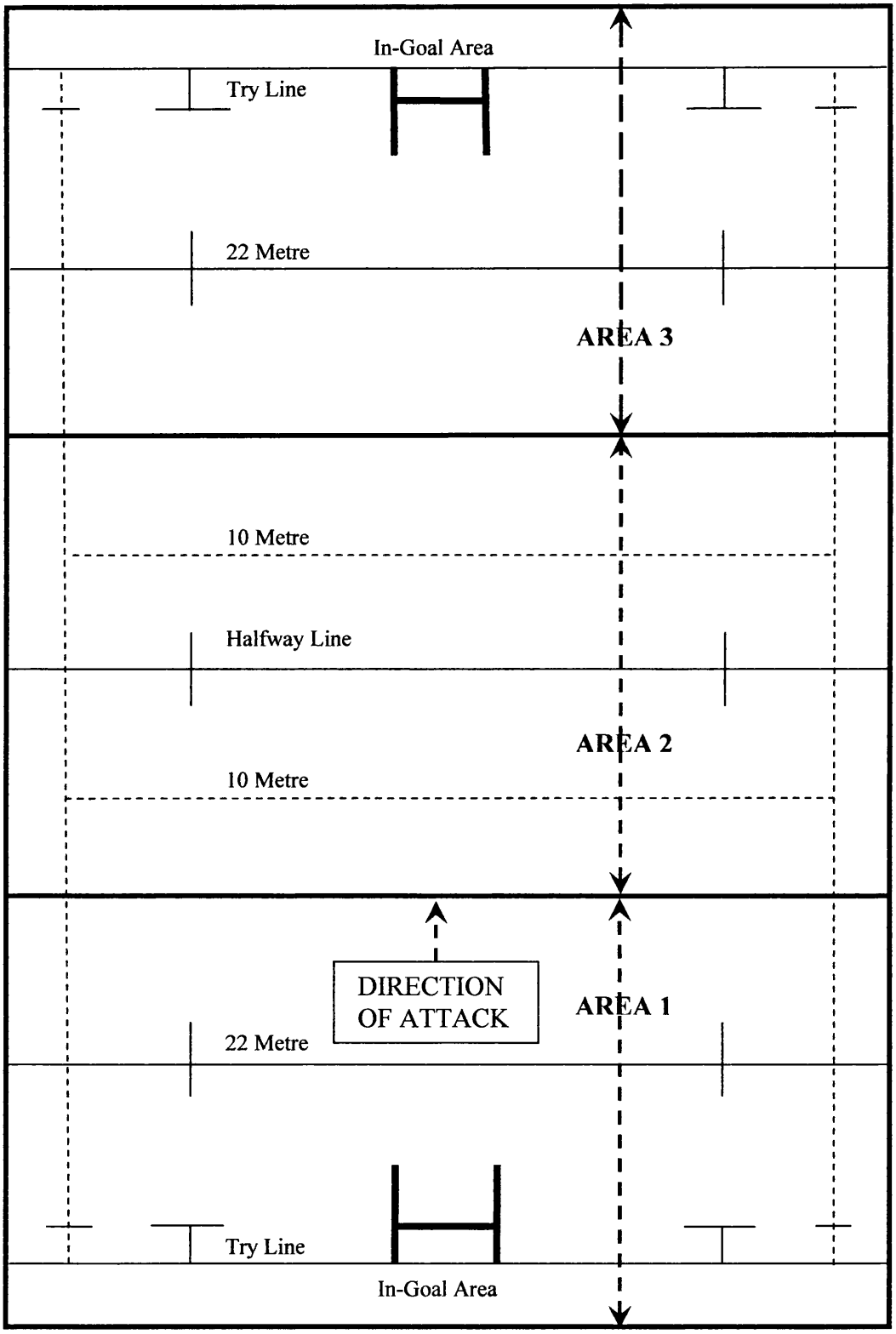


Figure 4.2: Diagram of a rugby union pitch illustrating the three territorial areas.

Table 4.2: Team performance indicators for rugby union that were identified for use during study 2.

	Team Performance Indicators
1	Scrum success (analysed team ball)
2	Scrum success (opposition ball)
3	Lineout success (analysed team ball)
4	Lineout success (opposition ball)
5	Ruck success (analysed team ball)
6	Ruck success (opposition ball)
7	Maul success (analysed team ball)
8	Maul success (opposition ball)
9	Successful tackles made as a % of the total number of analysed team tackles
10	Offloaded tackles made as a % of the total analysed team tackles
11	Offloaded passes made as a % of the total analysed team carries
12	Breaks made as a % of the total analysed team carries
13	Turnovers won as a % of the total turnovers made by both teams
14	Place kick success
15	Tries scored as a % of the total tries scored in a match
16	Penalties given away as a % of the total penalties awarded in a match
17	Errors made in area 1 (defending third) as a % of the total errors made by the analysed team
18	Errors made in area 2 (middle third) as a % of the total errors made by the analysed team
19	Errors made in area 3 (attacking third) as a % of the total errors made by the analysed team
20	Total frequency of errors made in a match
21	Frequency of intrusions in area 3 (attacking third)
22	Time in possession (minutes)

4.2.6 THE AMENDMENT OF THE INDIVIDUAL PERFORMANCE INDICATORS

The two elite coaches were again used to validate any amendments to the existing individual PIs (see Table 3.2). The first major alteration was the addition of an indicator of work rate; supporting the ball carrier during a ruck or maul. 'Cleaning out' opposition players and securing the ball at the breakdown is an important aspect of rugby union which was overlooked in study 1 due to concerns over analysis complications (Hughes and Franks, 2004a). However, as the analysis in study 1 illustrated, there is a particular emphasis upon the supporting roles for playing positions that do not carry the ball to the same extent as other positions (e.g. prop and lock). Therefore, the behaviour; 'cleaning out' was added to the existing PIs for every position (the operational definition is displayed in Appendix H). In addition, several PIs were adapted to highlight individual performance to a greater extent (Table 4.3).

Table 4.3: Study 2 modifications to the individual performance indicators that were identified during study 1.

AREA OF ANALYSIS	TYPE OF MODIFICATION
Carry	Modified to show whether a player broke the opposition's line of defence whilst carrying the ball.
Lineout	The lineout, lineout throw, and lineout take were divided into front, middle and back balls depending upon where the ball was aimed at in the lineout. This was for two reasons. Firstly, to split the lineout due to varying levels of difficulty, and secondly to investigate which area in the lineout had the highest success rate for the analysed team.
Touch Kick	Kicks to the touch line directly from a penalty were coded as penalty touch kicks rather than normal kicks so as to gain a better perspective of kicking from hand during open play.
Yellow Card	If a player received a yellow card during a match due to foul play, the appropriate time that the player was sent off for, was taken away from their total 'time on field'.
Goal Kicking	Opposition kicks at goal from penalty kicks, conversions and drop goal attempts were coded.

4.2.7 SYSTEM RELIABILITY

Essentially the design of the notational analysis system and the implementation of the data collection methods were the same as were utilised during study 1. It was therefore only deemed necessary to conduct an intra-observer reliability test on the five additional codes of the current study. The test (as with the intra-observer test in study 1) involved the trained observer (over 100 hours experience on the system), analysing a random sample of three matches twice, under the same conditions, with a four week period between each analysis (to prevent memory affecting the results). Percentage errors (Hughes *et al.*, 2002) were calculated once differences between the two data sets and a criterion data set had been examined. In addition, to ensure that the analyst had not made consistent biased errors during analysis, an independent observer examined the new codes and their respective operational definitions. The findings of this procedure and the results displayed in Table 4.4 suggest that the system was reliable for use by the trained observer as low percentage errors for each of the new variables (< 5%) were achieved.

Table 4.4: Summary of intra-observer reliability errors for the areas of analysis that were introduced during study 2.

	Intra-Observer Reliability		
Area of Error	Total no. of entries in area	Test 1 Errors	Test 2 Errors
Cleaning Out	448	21 **(4.68%)**	22 **(4.91%)**
Ruck	348	9 **(2.58%)**	11 **(3.16%)**
Maul	48	1 **(2.08%)**	1 **(2.08%)**
Area of Field	302	15 **(4.97%)**	14 **(4.64%)**
Phase Play	123	2 **(1.62%)**	1 **(0.81%)**
Totals	1269	48 **(3.78%)**	49 **(3.86%)**

One PI that has been referred to in previous research but was omitted from this particular study is that of metres gained (e.g. Bracewell, 2003a). The coding of this PI

using the 'Observer Video-Pro' behavioural measurement package (Noldus Information Technology, 1995) proved to be unacceptable in terms of reliability. An intra-observer reliability test was carried out, and a percentage error of 37.5% was calculated. It was therefore decided to simplify the territorial classification by using three segments (thirds) of the pitch. Intrusions into the opposition's defending third (Hunter and O'Donoghue, 2001) were then used as an approximate (and acceptable, < 5% error) measure of territorial gain.

4.2.8 Data Transformation

The raw data that was collected was transformed (as in study 1) to account for the length of time that a player was on the field for. Transformation 3 (shown below), was again employed to transform the individual data collected during study 2.

$$Transformation3 = F\left(\sqrt{\frac{80}{n}}\right)\left(\left(\log_{10}\frac{80}{n}\right)+1\right)$$

where F is the frequency of the performance variable and n is the number of minutes played. When team PIs were expressed, no transformation was utilised as the time spent on the field by a team is never a fraction of a match.

4.2.9 Analysis of Team Behaviours as Indicators of Success

The data distributions were assessed through skewness and kurtosis statistics and were found to be typically non-normal (as are the majority of notational analysis data, Hughes *et al.*, 2002), thereby suggesting a non-parametric approach (Zar, 1999; Hughes *et al.*, 2002). A Mann-Whitney *U* test was used to test for significant differences between the team PIs when winning and losing. According to Vincent (1999), the Mann-Whitney *U* test is used to determine the significance of the difference between two groups of subjects who have been scored on the same variable. It is one of the more powerful of the non-parametric tests and is the equivalent of an independent, two-

group *t* test (Thomas and Nelson, 2001). Alpha levels were set at the 95% level of statistical significance (Fleming and Nellis, 1994). The Mann-Whitney *U*, unlike equivalent parametric tests, assesses the data through rank order and thus lessens the effect of outliers. This was deemed sensible as data from rugby union typically contains outliers, mainly due to potential confounding variables such as opposition, weather, and individual performance (James *et al.*, 2002). Medians for the percentages and 95% confidence limits (CLs) were again used as an alternative to means and standard deviations to present the findings.

4.2.10 Analysis of Individuals Between Two Seasons

The performance data of those individuals (n= 13) who had participated in more than five whole matches in both seasons (season 2001/2002 and season 2002/2003) were analysed for differences between the two seasons using a chi-square test. Alpha levels were set at the 95% level of statistical significance (Fleming and Nellis, 1994). It was decided to only investigate behaviours concerning the player with the ball-in-hand (carrying, passing and kicking for backs, and carrying and passing for forwards). This provided accurate information concerning individuals' decision making which could be compared over two seasons. In addition, the frequencies of the individual behaviours (e.g. passes) were expressed as percentages of the total number of ball-in-hand behaviours. This allowed comparisons to be made irrespective of the varying possession frequencies between the two seasons. As with the analysis of the team PIs, medians and 95% CLs were used to present the data.

4.3 RESULTS

4.3.1 ANALYSIS OF TEAM BEHAVIOURS AS INDICATORS OF SUCCESS

Only two of the 22 team PIs were statistically different between wining and losing performances (Table 4.5). These were the percentage of lineouts won on the oppositions throw-in (*mdn*= 14.6, +/- CLs= 38.5 and 3.7 when winning, and *mdn*= 6.3, +/- CLs= 11.1 and 0 when losing) and the percentage of tries scored out of the total tries scored (*mdn*= 64.6, +/- CLs= 80 and 40 when winning, and *mdn*= 29.2, +/- CLs= 37.5 and 14.3 when losing).

Of the PIs concerning distinct phases of play, i.e. set-piece (scrum or lineout) and breakdown (ruck or maul), only successful scrums on the analysed team's ball resulted in a lower median percentage of success when the analysed team was winning (Figure 4.3 displays those PIs concerning the set-piece or breakdown). Furthermore, relatively large but non-significant differences were found in winning matches for turnovers (*p*= 0.1, *mdn*= 71.9, +/- CLs= 88.9 and 33.3 when winning, and *mdn*= 47.3, +/- CLs= 72.2 and 30 when losing) and errors made (*p*= 0.96, *mdn*= 93.5, +/- CLs= 111 and 69 when winning, and *mdn*= 98, +/- CLs= 107 and 92 when losing). Conversely, certain PIs were found to differ very little or even improve for losing performances, for example breaks made as a percentage of total carries (*p*= 0.79, *mdn*= 10.5, +/- CLs= 14.6 and 7.9 when winning, and *mdn*= 11.7, +/- CLs= 17.4 and 5.3 when losing). Figure 4.4 displays those PIs that were not concerned with the set-piece or breakdown. It is important to note that for certain PIs, a lower frequency or percentage refers to a better performance for the PI (e.g. frequency of errors made).

Table 4.5: Medians and 95% confidence limits for the professional team's performance indicators from the 2002/2003 season for winning (n=8), losing (n=12) and all matches (n= 20)[1].

		All Matches (n= 20)			Winning (n= 8)			Losing (n= 12)			Mann-Whitney P Values
	Team Performance Indicators	Median	+CL	-CL	Median	+CL	-CL	Median	+CL	-CL	
1	Scrum success (analysed team ball) (%)	**76.4**	86.7	66.7	**76.4**	100	50	**78**	91.7	63.6	0.79
2	Scrum success (opposition ball) (%)	**0**	0	0	**0**	12.5	0	**0**	6.7	0	0.84
3	Lineout success (analysed team ball) (%)	**68.5**	75	61.5	**71.7**	88.9	50	**63.4**	75	53.3	0.15
4	Lineout success (opposition ball) (%)	**8.1**	12.5	3.7	**14.6**	38.5	3.7	**6.3**	11.1	0	<0.05
5	Ruck success (analysed team ball) (%)	**90.8**	95.1	89.2	**92.8**	100	86.8	**90.5**	95.1	88.9	0.54
6	Ruck success (opposition ball) (%)	**3.9**	4.8	2	**3.9**	9.7	1.6	**3.8**	4.8	1.6	0.37
7	Maul success (analysed team ball) (%)	**100**	100	75	**100**	100	75	**100**	100	33.3	0.26
8	Maul success (opposition ball) (%)	**0**	0	0	**0**	33.3	0	**0**	11.1	0	0.92
9	Successful tackles (%)	**88.8**	92.6	87.7	**89.3**	95.4	87.7	**88.3**	93.4	85.8	0.22
10	Offloaded tackles made (%)	**9.9**	11	8.3	**8.4**	10.7	7	**10.7**	14.5	8.3	0.09
11	Offloaded passes made (%)	**6.5**	9.5	5.3	**6.3**	14.6	0	**6.7**	9.5	5.3	1
12	Breaks made (%)	**11.2**	14.4	8.8	**10.5**	14.6	7.9	**11.7**	17.4	5.3	0.79
13	Turnovers won (%)	**59.1**	75	41.2	**71.9**	88.9	33.3	**47.3**	72.2	30	0.1
14	Place kick success (%)	**66.7**	83.3	57.1	**69.1**	100	50	**66.7**	100	50	0.76
15	Tries scored (%)	**38.8**	50	25	**64.6**	80	40	**29.2**	37.5	14.3	<0.001
16	Penalties conceded (%)	**46.6**	55.6	39.1	**50**	75	27.3	**45.6**	55.6	38.1	0.59
17	Errors made in area 1 (%)	**26.4**	30.1	22	**28.2**	38.5	17.7	**24.5**	35.3	20.8	0.49
18	Errors made in area 2 (%)	**51.6**	56.4	48.2	**51.3**	66.7	44.9	**52.1**	60.4	48.2	0.76
19	Errors made in area 3 (%)	**19.6**	22.8	15.7	**18.5**	29	12.9	**20.2**	29	15.7	0.49
20	Total frequency of errors made	**96**	101	92	**93.5**	111	69	**98**	107	92	0.96
21	Frequency of intrusions in area 3	**24**	26	21	**24.5**	28	17	**23**	31	20	0.19
22	Time in possession (minutes)	**8.6**	9.9	7.6	**8.4**	11.6	5.2	**8.6**	10.4	7.4	0.54

[1] The team performance indicators are abbreviated. Full descriptions are displayed in Table 4.2.

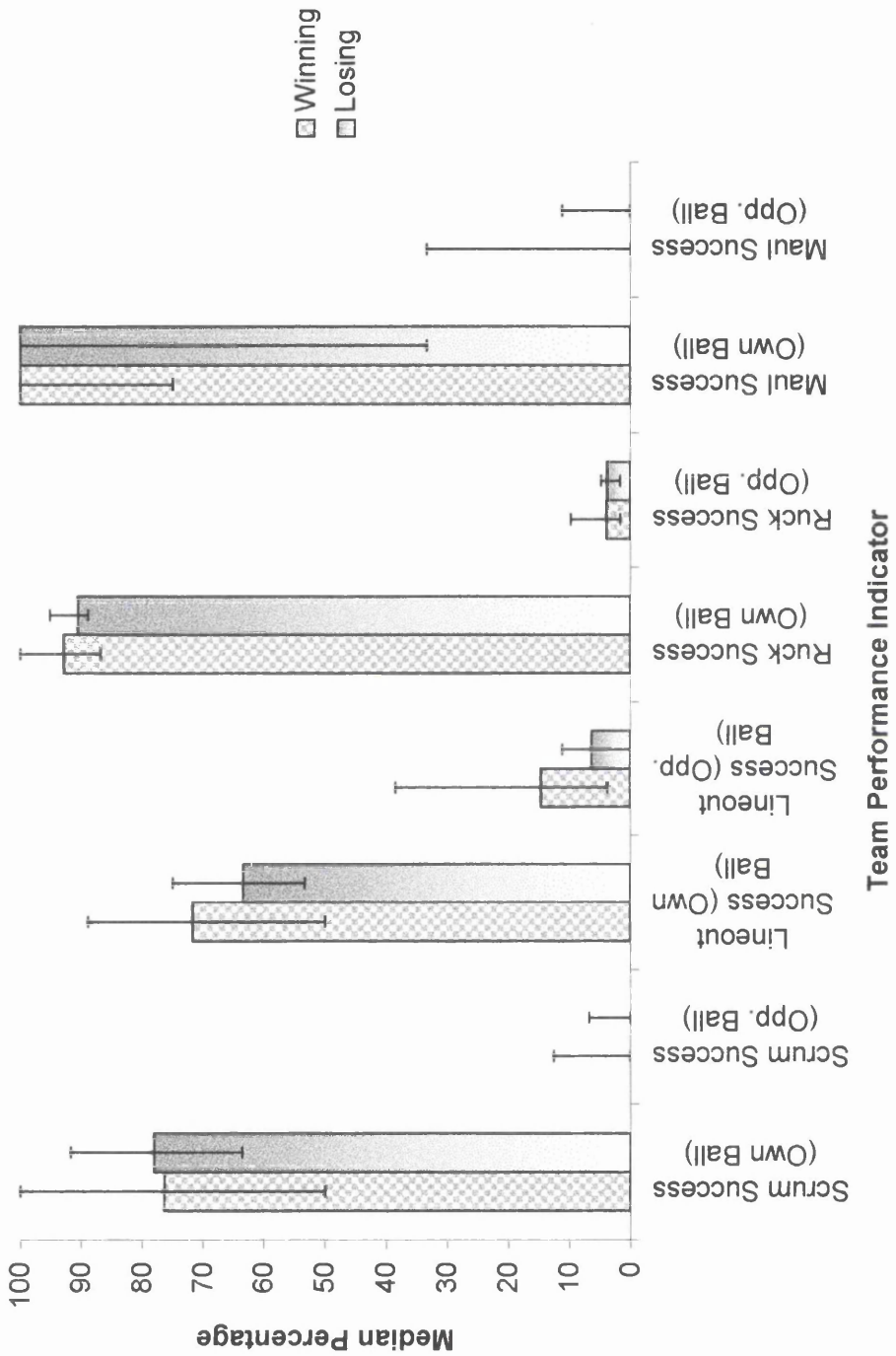


Figure 4.3: Median percentages and 95% confidence limits of the set-piece and breakdown as a function of winning (n= 8) and losing (n= 12) from the 2002/2003 season of the analysed professional team.

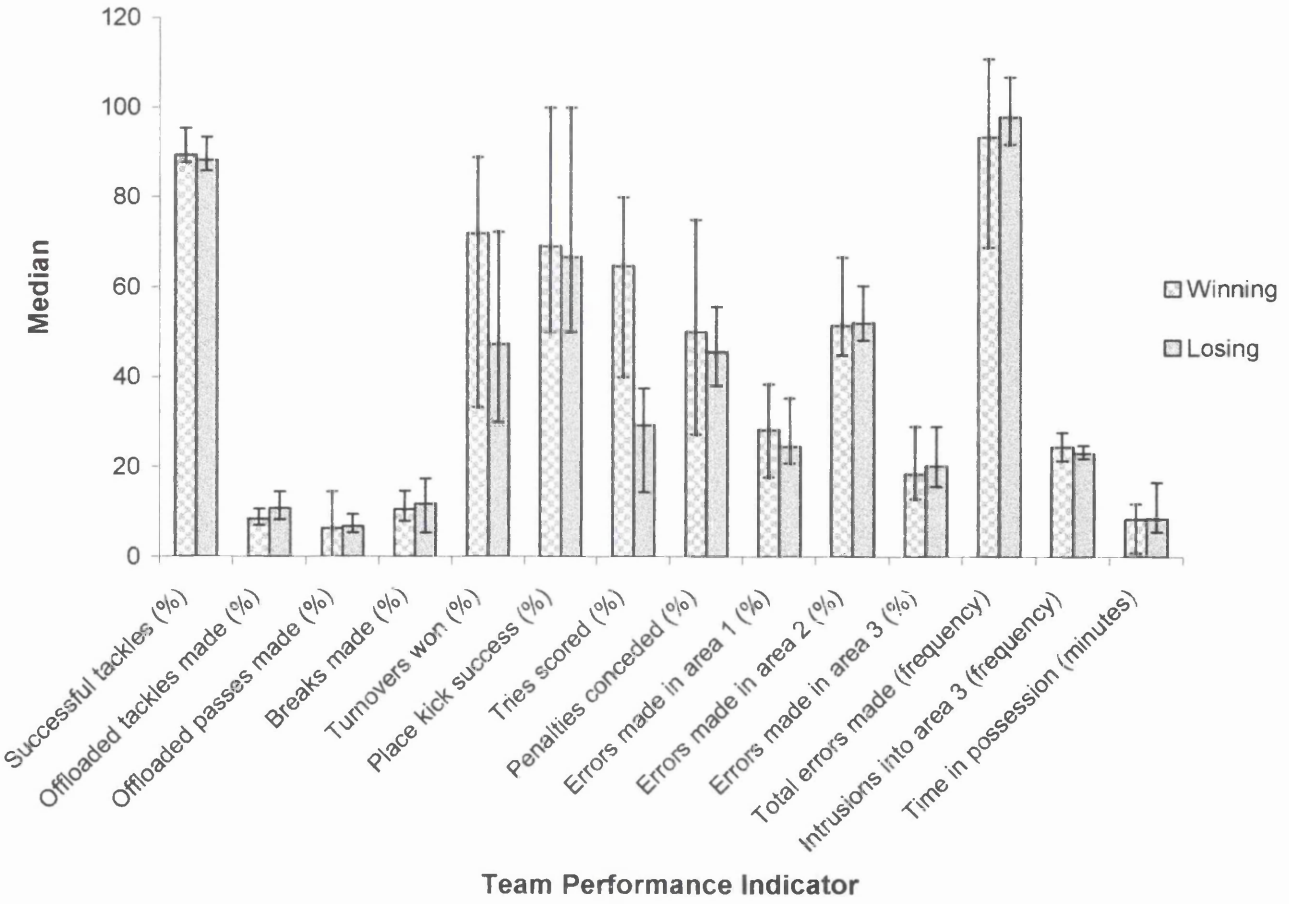


Figure 4.4: Medians and 95% confidence limits of team performance indicators[2] that were not concerned with the set-piece or breakdown from winning (n= 8) and losing (n= 12) performances from the 2002/2003 season of the analysed professional team.

[2] The team performance indicators are expressed as either percentages, frequencies or minutes. This is identified within the figure.

4.3.2 The Development of the Analysis System

The amendment of existing codes and the introduction of the off-the-ball behaviour 'cleaning out' provided a more comprehensive view of individuals' roles within the team. This was particularly relevant for the playing positions of prop and lock whose profiles in study 1 provided little information for one of their key positional roles, supporting the ball carrier at the breakdown and securing possession. Figure 4.5 illustrates the difference between the profile of player 3 (a prop) during study 1 (without off-the-ball activity) and study 2 (once 'cleaning out' had been introduced). Although forward positions were found to perform higher frequencies of this additional PI than backs, it was also found that 'cleaning out' played an important role within the profile of positions such as outside-half. Figure 4.6 displays the presence of the behaviour 'cleaning out' within the profile of player 21 (an outside-half) for the second season of analysis. The individual performance profiles illustrating medians and 95% CLs for the 26 analysed players from the season 2002/2003 are displayed in Appendix I.

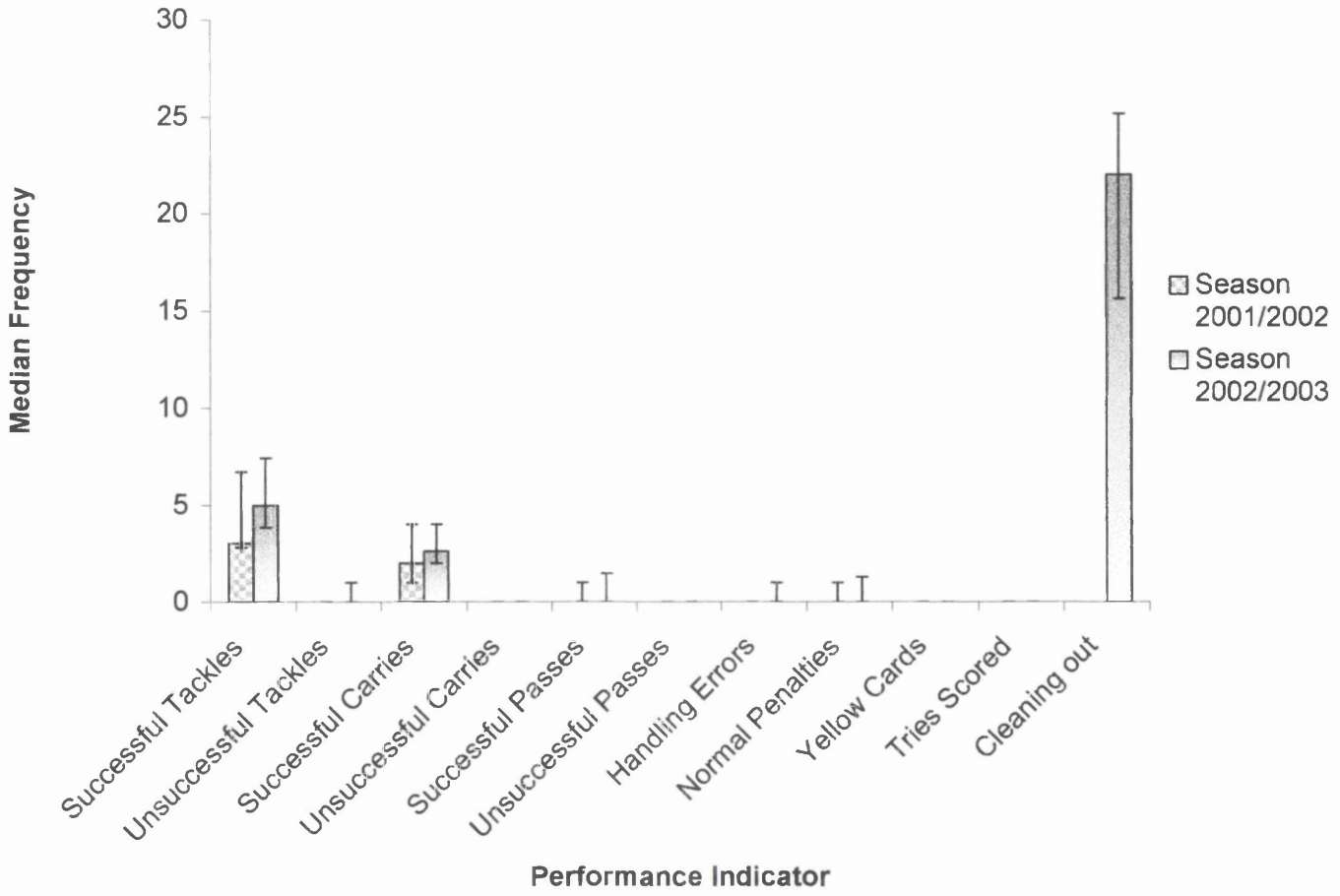


Figure 4.5: Comparison of player 3's profile (a professional prop) between the seasons 2001/2002 (22 matches) and 2002/2003 (13 matches), illustrating the importance of the behaviour 'cleaning out' to the positional role of prop.

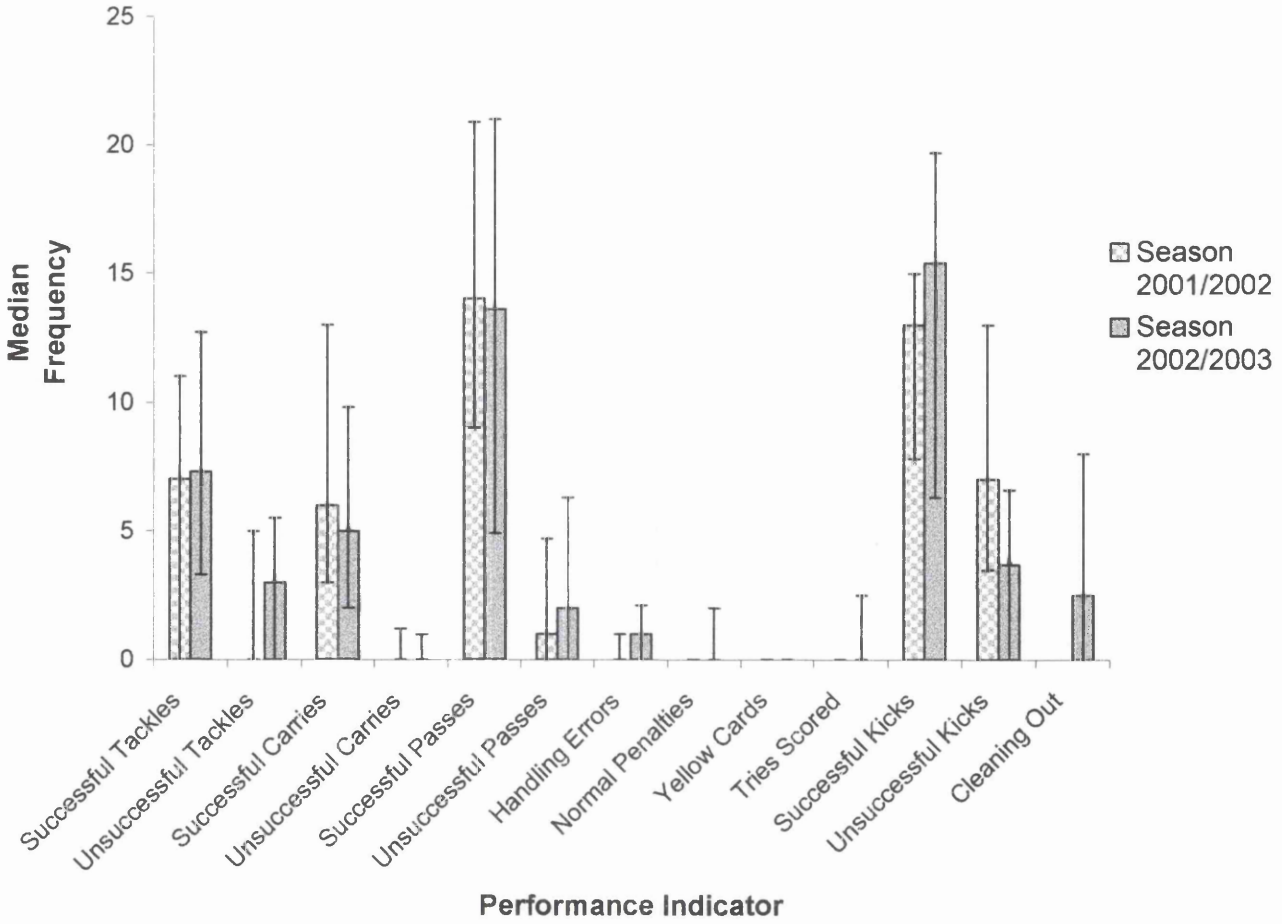


Figure 4.6: Comparison of player 21's profile (a professional outside-half) between the seasons 2001/2002 (11 matches) and 2002/2003 (11 matches), illustrating the presence of the behaviour 'cleaning out' within the profile of an outside-half.

4.3.3 Analysis of Individuals between Two Seasons

The ball-in-hand behaviours of the 13 players who had participated in both season one (2001/2002) and season two (2002/2003), were analysed using a chi-square test. Table 4.6 displays the results of the chi-square test on the frequency data. Medians of the percentages of individuals' behaviours and their 95% CLs are also shown to illustrate similarities or differences in ball-in-hand decision making over the two seasons. To allow accurate comparisons to be made, those behaviours that had been further delineated for this study (e.g. the lineout being split into front, middle and back ball) were grouped together as in study 1.

4.3.3.1 Forwards

There were no significant differences found between the two seasons' ball-in-hand behaviours for the positions of prop, lock, and open-side flanker. Indeed, for certain individuals the percentage profiles displayed very similar results when behaviours were compared between the two seasons. For example, player number 25 (lock) passed the ball a median of 50% during season one (+/- CLs= 83.3% and 33.3%), and 50% of the time during season two (+/- CLs= 100% and 25%).

However, a significant difference was found between player number 6's (blind-side flanker) behaviours for the two seasons ($p < 0.01$). This player carried the ball over 20% more (out of the total frequency of behaviours with the ball-in-hand) in season one (*mdn*= 80%, +/- CLs= 89.5% and 71.4%) than in season two (*mdn* = 57.2%, +/- CLs= 100% and 37.5% respectively).

4.3.3.2 Backs

No significant differences were found between the two seasons' frequency data for the behaviours of the eight analysed backs (Table 4.6). As with the forward positions, certain individuals had similar percentage profiles for both seasons. For example, player 20 (centre) had medians for the percentages of 57.14% carries (+/- CLs= 77.3% and 50%), 33.3% passes (+/– CLs= 45.5% and 20%) and 0% kicks (+/– CLs= 25% and 0%) for season one, and 59.1% carries (+/- CLs= 72.7% and 53.3%), 33.3% passes (+/– CLs= 38.5% and 25%) and 4.6% kicks (+/– CLs= 10% and 0%) for season two. These similarities, and those between player 13's (wing) ball-in-hand profile for the two seasons are illustrated in Figure 4.7.

Table 4.6: Medians (*Mdn*) and 95% confidence limits for the percentages of ball-in-hand behaviours of individuals who had participated in more than five whole matches in both seasons for the analysed professional team (season 2001/2002, and season 2002/2003).

					Percentage carries out of total ball-in-hand behaviours			Percentage passes out of total ball-in-hand behaviours			Percentage kicks out of total ball-in-hand behaviours (for backs)		
Squad No.	Position	p Value	Season	Matches	*Mdn*	+ CL	- CL	*Mdn*	+ CL	- CL	*Mdn*	+ CL	- CL
24	Prop	0.997	1	15	**50**	77.8	28.6	**50**	71.4	22.2	-	-	-
			2	13	**44.4**	66.7	33.3	**55.6**	66.7	33.3	-	-	-
3	Prop	0.92	1	22	**100**	100	71.4	**0**	20	0	-	-	-
			2	13	**100**	100	66.7	**0**	33.3	0	-	-	-
25	Lock	0.859	1	14	**50**	50	0	**50**	83.3	33.3	-	-	-
			2	10	**50**	75	0	**50**	100	25	-	-	-
7	Open-Side	0.086	1	22	**58.6**	66.7	50	**41.4**	50	33.3	-	-	-
			2	15	**50**	50	33.3	**50**	66.7	50	-	-	-
6	Blind-Side	< 0.01	1	13	**80**	89.5	71.4	**20**	28.6	10.5	-	-	-
			2	8	**57.2**	100	37.5	**42.8**	62.5	0	-	-	-
10	Outside-Half	0.253	1	14	**6.7**	11.1	3.33	**46.9**	62.2	38.6	**44.8**	52.8	33.3
			2	17	**3.5**	7.4	0	**50.9**	64	37.1	**42.9**	50	29
21	Outside-Half	0.082	1	11	**15**	31	6.8	**36.4**	48.8	25.7	**47.2**	62.9	32.6
			2	11	**16.3**	30	7.7	**50**	58.6	14.3	**38.5**	57.1	10
20	Centre	0.582	1	11	**57.1**	77.3	50	**33.3**	45.5	20	**0**	25	0
			2	13	**59.1**	72.7	53.3	**33.3**	38.5	25	**4.6**	10	0
12	Centre	0.118	1	21	**47.4**	55	35.3	**46.7**	62.5	40	**0**	7.1	0
			2	14	**42.6**	60	25	**57.4**	64.3	40	**0**	0	0
13	Wing	0.709	1	13	**71.4**	83.3	50	**20**	37.5	14.3	**0**	16.7	0
			2	10	**67**	75	56.3	**25**	42.9	20	**0**	11.1	0
14	Wing	0.571	1	11	**63.6**	80	50	**28.6**	37.5	20	**0**	30	0
			2	9	**66.7**	81.8	62.5	**20**	33.3	12.5	**0**	23.1	0
11	Wing	0.614	1	11	**63.6**	100	38.5	**12.5**	33.3	0	**12.5**	36.4	0
			2	12	**57.7**	71.4	42.9	**20**	27.3	0	**27.9**	40	8.3
15	Full Back	0.615	1	17	**41.7**	46.2	33.3	**35.3**	43.8	26.1	**29.4**	36.4	16.7
			2	6	**34.6**	42.3	23.1	**39.9**	52.2	23.5	**29.7**	41.7	7.7

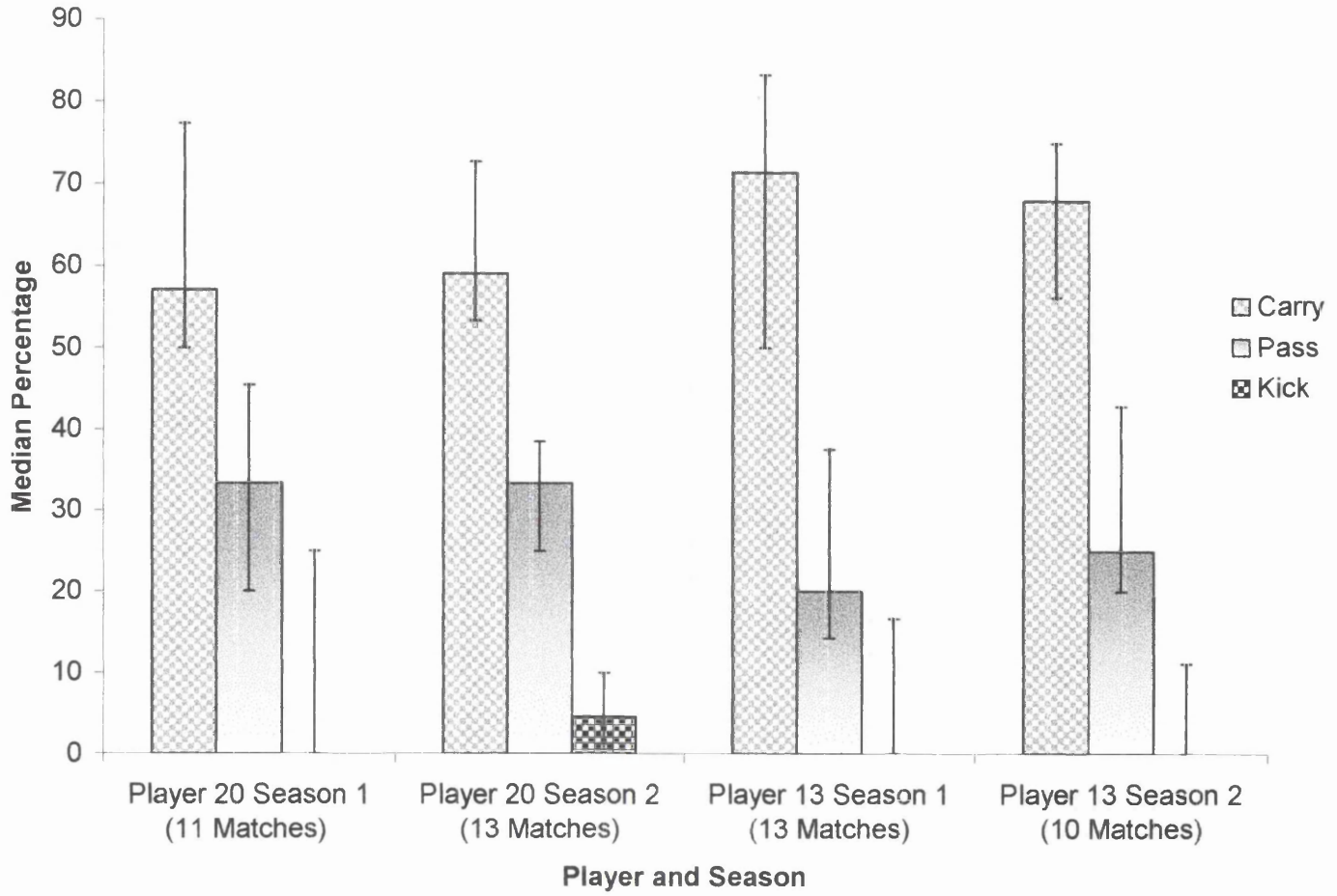


Figure 4.7: A comparison between season one (2001/2002) and season two (2002/2003) showing the medians and 95% confidence limits of ball-in-hand behaviours for player 20 (a professional centre) and player 13 (a professional wing).

4.4 DISCUSSION

The first objective of this study was to develop a framework of team PIs that could be tested for differences between winning and losing matches. The use of median percentages and 95% CLs as a method of expressing team PIs presented detailed information concerning the analysed team's performance throughout the season (Hughes and Bartlett, 2002). Whilst only two indicators differed significantly between winning and losing performances, winning performances were generally characterised by slightly higher percentage success rates. This distinction between practical and statistical significance has been highlighted previously (Martin and Bateson, 1993; Atkinson, 2003). The non-significant, higher percentage success rates on the opposition's throw-in for winning performances, corresponded with the results of Hughes and White (1997) who found that the forwards of successful teams were more dominant in the lineout. Commonality was also evident between the increase in ruck and maul success when winning, and Hughes and White's (1997) finding of successful teams being more dominant in driving areas of the game. However, it must be noted that Hughes and White (1997) investigated forward play in rugby union before the advent of professionalism. Studies have since found a significant difference between the frequency of rucks in matches before and after the introduction of professionalism (Eaves and Hughes, 2003; Long and Hughes, 2004). Although these studies explored ruck and maul frequencies rather than success rates (with which the current study is concerned), caution should be drawn when making comparisons between the amateur and professional games.

A further observed difference that corresponded with previous research was the increased ratio of turnovers won for winning matches. McCorry *et al.* (2001) had previously found that the ratio of turnovers won reflected the final rankings of the four

semi-finalists in the 1995 World Cup. Although no significant difference was found within the current study for this particular PI, an increase of >20% when winning (as opposed to losing) indicated that the ability to win the opposition's ball at the breakdown may have affected the outcomes of matches. It seems therefore that subtle, usually non-significant differences between winning and losing performances have consistently been found. However, inconsistencies with previous literature also exist. For example, the number of intrusions into the opposition's third of the field and the number of breaks made did not provide higher percentage rates when winning and thus differed with Hunter and O'Donoghue (2001). This type of comparison should be considered with caution though, as other studies have often used more than one team for their analysis (e.g. Hughes and White, 1997; Hunter and O'Donoghue, 2001; McCorry *et al.*, 2001). The use of one team's success and failure provides consistent data that is not always achievable when comparing two or more different teams who may possess dissimilar styles of play. However, it must be noted that the analysis of one team provides a profile of that single team when winning and losing rather than a winning profile gained from the average of a number of teams. A delimitation of this study is that the winning profile of one team may not necessarily correspond with the winning profile of another (i.e. different strengths within teams). Additionally, although every attempt was made to acquire a representative data sample containing matches played at different venues and in varied weather conditions, a further delimitation was that the sample size was relatively small (n= 20). Extra data could have been taken from the matches analysed during the previous season (study 1), but this would have further confounded the team PIs due to changes in playing personnel.

A second objective was to refine and develop the analysis system utilised in study 1 through the modification of existing codes and the addition of further individual PIs.

This was achieved through the amendment of certain behaviours such as the 'carry' (whether a break was made or not), and through the incorporation of the off-the-ball behaviour; 'cleaning out'. This additional behaviour provided an effective indicator of performance off-the-ball, thus presenting more informative individual performance profiles. Although all positions were found to perform 'cleans', the high frequencies that were evident in certain players' profiles concurs with the findings of Parsons and Hughes (2001) who found that playing positions such as prop and hooker were involved in supporting roles to a greater extent than ball carrying.

The final objective of this study was to compare the individual profiles generated during study 1 with those created during study 2 to further investigate the intra-positional differences and individuality found by study 1. Decision making profiles of elite rugby union players from a professional team over two seasons were analysed via ball-in-hand behaviours. The findings revealed that the team possessed similar win profiles for the two seasons (45.45% in season one, 40% in season two). However, the points for and against differed somewhat between the two seasons suggesting some variability in performance (average 21 points for and 20 against in season one and 24 for and 36 against in season two). In addition, a new coach was introduced in season two which resulted in a considerable change in playing personnel, with only 13 of the season two squad of 58 players having played more than five whole matches in both seasons. A large turnover in playing and coaching personnel has previously been reported to disrupt a team, causing changes in team and individual effectiveness (*cf.* Carron and Hausenblas, 1998). However, this was not found to be the case in this study as only one player's ball-in-hand behaviours (of the 13) differed significantly between the two seasons.

Among the 12 players who displayed similar percentage ratios for the two seasons were the key decision making positions of outside-half and centre (Greenwood, 1997). This suggests that players have a pre-determined plan to perform certain behaviours in different situations based on an individual's strengths and weaknesses. For example, the two outside-halves had very different physical statures (player 10 weighing 73kgs compared to player 21 who weighed 95kgs). This may explain why player 10 consistently favoured passing and kicking rather than carrying, while player 21 exhibited the opposite profile. These results reinforce the findings of study 1 concerning the observations of individuality within playing positions.

A potential limitation of this study was the absence of the individual and team PI of metres gained. Although this indicator has been utilised in previous research (e.g. Bracewell, 2003a), it was deemed unreliable as a performance measure when using the 'Observer Video-Pro' (Noldus Information Technology, 1995) as this particular software package did not incorporate a pitch measurement tool, thereby resulting in a high level of operator subjectivity. In addition, there was some degree of subjectivity regarding how many metres gained should be attributed to an individual or team. For example, should the metres gained by a full-back receiving a long kick begin when the player catches the ball (20 metres away from any opposition player), or when they reach the first line of defence? Through discussion with the expert coaches, a more reliable indicator (whilst not as detailed) was used by assessing the team's movement across the territorial thirds of the pitch. This provided data concerning frequencies of errors and the number of occasions the team entered specific territorial areas. In order to provide detailed measures of both team and individual performance, future research should attempt to incorporate a reliable assessment of the indicator of metres gained via methods such as the utilisation of multiple camera angles and detailed operational

definitions. An additional limitation was the minor changes between the two seasons concerning the coding structure and individual PIs. Although techniques were employed to allow comparisons to be made between the two seasons (e.g. grouping of front, middle and back lineouts), there was no adjustment to counter the change in the time coding of the yellow card. However, as there were only nine occasions when a player from the analysed team was sent to the sin-bin during the season, it was not considered to be detrimental to the analysis system's overall reliability.

Whilst the presentation of team PIs as percentages highlighted the performance of each PI, there was no code to illustrate the importance of specific behaviours (or critical incidents) within those percentage figures. For example, no missed tackle is the same, and whilst one may lead to a team mate having to make a follow-up tackle, another may lead directly to a try. Critical incidents may be linked to a number of factors such as pitch position or the player/position performing the PI. Although the current study attempted to investigate whether making errors in certain areas of the pitch (thirds) affected the result of a match, future research should endeavour to explore the effects of both positive (e.g. breaks made) and negative (e.g. missed tackles) critical incidents.

The findings from studies 1 and 2 have provided detailed information concerning individuality within positions and invariance between individual performances over two seasons. However, the presence of only two significant differences within the team PIs for winning and losing performances suggests the need to combine these team measures to form a unitary representation of performance. This may enable significant differences between winning and losing performances to emerge from the group of non-significant behaviours which had slightly higher percentage success rates for winning performances. Additionally, a depiction of performance in the form of a single score or

a combination of comparative scores may provide in depth data concerning the relative weightings and therefore influence of specific team PIs.

CHAPTER 5

STUDY 3

THE DEVELOPMENT OF OBJECTIVE METHODOLOGIES FOR SCORING TEAM PERFORMANCE IN ELITE RUGBY UNION

CHAPTER 5: STUDY 3

5.1 INTRODUCTION

The findings of studies 1 and 2 provided detailed information concerning methodologies to assess both individual and team performance profiles. The similarities between individual performance profiles over two differing seasons and the statistical and practical differences (*c.f.* Martin and Bateson, 1993; Atkinson, 2003) between team performance indicators (PIs) for match outcome, provide the first progression towards the objective assessment of team performance within elite rugby union. Although a large number of observable differences were found within team PIs for winning and losing performances (study 2), only two were statistically significant. The question therefore arises as to whether the team PIs can be combined in some way, using some form of weighting, to adequately represent different levels of team performance. However, as with previous research (e.g. Hunter and O'Donoghue, 2001; McCorry *et al.*, 2001), study 2 utilised the distinction between winning and losing teams as the sole measure of performance. Whilst this can often indicate the level of team performance, it may be of more practical benefit to coaches to use a performance measure that is independent of match outcome and accounts for potential confounding variables that may affect performance, e.g. match venue, weather, and the opposition (Bracewell, 2002; James *et al.*, 2002). The ability to provide an objective score for match performance would thus provide this.

Although previous research within rugby union profiling has successfully constructed methodologies to assess performance scores for individuals (Bracewell, 2003a), there is no published research that assesses team performance through the construction of match scores. Indeed, to date, performance analysis in rugby union has not provided simple, objective measures of team performance that coaches can utilise in the practical setting.

This is not surprising given that rugby union is a complex sport containing many different skills that can be analysed and presented in a variety of ways (e.g. timed, frequency and percentage data). When these skills or areas of the game are combined to analyse team performance, different scales and frequencies therefore prevent simple comparisons from being made. The ability to instantly assess the performance of skills in a match through comparative scores, or even compare an overall match performance with previous scores would provide a valuable and objective analysis tool for coaches. Additionally, investigations into the construction of a single score for team performance would reveal important information concerning the relative worth (or weightings) of specific PIs. Training sessions could then be adapted to target an improvement in the PIs that are most influential to performance.

Consequently, the aim of this final study is to develop methodologies for objectively scoring team performance in rugby union. Specifically, the validity of two approaches will be investigated. The first will attempt to provide a single match score (study 3a), whilst a second (study 3b) will investigate the provision of a combination of comparative scores for a match. The assessment of two separate methodologies aims to identify the most accurate and viable technique of scoring team performance which can subsequently be used by coaches within a practical setting. This, it is suggested, will present an objective appraisal of team performance in matches which is superior to the less precise global measure of match outcome. It is however, important to focus on the fact that the aim of studies 3a and 3b is to investigate methodological advances in the scoring of team performance in rugby union. The results shown (e.g. PI weightings) may not necessarily be applicable to any other team. A delimitation of this study therefore is that the results are probably unique to the analysed team. Further studies

could then be used to assess the truth of this statement and thus the applicability of these methodologies for other teams or sports.

STUDY 3a

5.2 METHODOLOGY

5.2.1 STUDY DESIGN: BIVARIATE CORRELATION MODELS

This first methodology investigated the applicability and accuracy of creating a single score measure of team performance in rugby union. The objective was to provide a performance score for a match in the form of a model using a recognisable scale (0 to 100), which was determined using relative weightings of PIs (i.e. derived from their importance to performance). These weightings were acquired using the correlation values between PIs and performance scores for matches allocated by elite coaches. Weightings (correlations) were then used as multipliers for PI performance, which were then combined to form a single score for match performance. A number of different models were tested for agreement and difference with the coach scores using specific criteria for the inclusion of PIs (i.e. the level of correlation between the PI and the coach scores). The computerised data collection system and 20 match sample from study 2 (2002/2003 season) was used.

5.2.2 SCORING OF THE DATA SET BY THE ELITE COACHES

In order to measure performance and gain weightings of PIs, two elite coaches of a European professional rugby union team (combined elite playing and coaching experience= 51 years) subjectively rated the 20 matches via a score out of 100 whereby 50 represented an average performance. Although the vast playing and coaching experience of the elite coaches did not necessarily represent their analytical abilities, the two individuals were the coaches of the analysed team and were therefore in an excellent position to rate their performances. The coaches were asked to provide one score between them for each match and to focus upon their perceptions of actual team performance against the match opposition rather the final score. These coach scores

(Table 5.1) provided a scale from which the relative importance and thus weightings of PIs could be derived.

Table 5.1: Coach scores for match performances and resultant match rankings from the 2002/2003 season of the analysed professional team.

Match No.	Coach Score (0 to 100)	Rank (1= best)	Result (Analysed Team's Perspective)	Score (Analysed Team First)
1	45	12	Lost	16 – 20
2	85	1	Won	38 – 10
3	50	10	Lost	27 – 38
4	25	20	Lost	6 – 62
5	29	19	Lost	10 – 51
6	62	6	Won	33 – 20
7	77	3	Won	26 – 19
8	39	15	Lost	23 – 41
9	54	8	Won	20 – 19
10	72	4	Won	23 – 14
11	37	16	Lost	23 – 45
12	33	18	Lost	19 – 48
13	59	7	Lost	19 – 24
14	48	11	Lost	19 – 32
15	68	5	Won	46 – 21
16	52	9	Won	21 – 17
17	41	14	Lost	27 – 44
18	42	13	Lost	29 – 56
19	34	17	Lost	14 – 42
20	80	2	Won	52 – 40

5.2.3 Performance Indicators and Correlations with the Coach Scores

Team PIs from study 2 were examined and adapted by the elite coaches, and presented as frequencies (with the exception of time in possession) for use within the model. As previously discussed in section 2.8.4 of this thesis, the various methods of presenting PI data possess both advantages and disadvantages. The rationale for using frequencies in this case was that the number of PIs included in the model was immaterial and therefore not a disadvantage. Furthermore, whilst ratios provide combined proportionate values (e.g. tackles made and tackles missed combine to form tackle success), frequencies provide an indication of the magnitude of both positive (e.g. tackles made) and negative (e.g. tackles missed) PIs. It was important that the model provided the most detailed depiction of performance through the use of raw frequency data.

Thirty-one PIs were subsequently identified and correlated against the coach scores to determine the extent to which each accounted for the variation in coach scores. Of the 31 Spearman's rho correlation values, 23 were less than ± 0.3 and therefore deemed small (Cohen, 1988). Consequently, in an attempt to account for a greater proportion of the variation in coach scores, the data were re-examined for the potential confounding variables, weather and match venue (opposition strength was taken into account by the elite coaches when scoring match performance). Unlike the findings of a number of studies concerned with soccer (*c.f.* Pollard, 1986; Sasaki *et al.*, 1999), investigations within the data set presented little evidence of match venue being linked to team performance (correlations between the coach scores and the PIs differed minimally between home and away matches; seven correlation values were greater than ± 0.3 for home and eight for away matches). A possible explanation for this lack of a previously found relationship (albeit in different sports) may have been an inadvertent inclusion of match venue as a factor in the coach scores. Although the coaches were asked not to take match venue into consideration when scoring performance, they may have included it as a natural assessment of their team. However, a more effective split of the data resulted in 14 correlation values greater than ± 0.3 for wet and only seven for dry conditions (Table 5.2). Matches in wet and dry weather and their corresponding correlation values (Table 5.2) were subsequently considered independently, resulting in two separate models (wet and dry).

Table 5.2: Performance indicators and their corresponding correlation coefficients with the coach scores for dry (n= 14) and wet (n= 6) weather matches from the 2002/2003 season of the analysed professional team.

	Performance Indicators	Dry Weather *r*	Wet Weather *r*
1	Scrums won analysed team ball	0.02	-0.15
2	Scrums lost analysed team ball	-0.33	-0.28
3	Scrums won opposition all	0.02	0.00
4	Scrums lost opposition ball	-0.04	0.26
5	Lineouts won analysed team ball	0.49	-0.23
6	Lineouts lost analysed team ball	-0.27	-0.88
7	Lineouts won opposition ball	0.78	0.12
8	Lineouts lost opposition ball	-0.19	-0.15
9	Rucks won analysed team ball	0.04	0.49
10	Rucks lost analysed team ball	-0.28	-0.64
11	Rucks won opposition ball	-0.04	0.74
12	Rucks lost opposition ball	-0.30	0.09
13	Mauls won analysed team ball	0.71	0.53
14	Mauls lost analysed team ball	-0.02	-0.21
15	Mauls won opposition ball	-0.04	0.13
16	Mauls lost opposition ball	-0.19	-0.27
17	Tackles made by the analysed team	-0.21	-0.03
18	Tackles missed by the analysed team	-0.22	-0.71
19	Offloads made by the analysed team	0.00	0.37
20	Offloads against the analysed team	-0.40	-0.03
21	Breaks made by the analysed team	0.09	0.64
22	Carries where no break was made by the analysed team	0.13	-0.31
23	Turnovers for the analysed team	-0.09	0.82
24	Turnovers against the analysed team	0.09	-0.82
25	Place kicks made by the analysed team	0.72	0.74
26	Place kicks missed by the analysed team	0.26	0.68
27	Penalties for the analysed team	0.28	0.03
28	Penalties against the analysed team	0.18	0.29
29	Errors made by the analysed team	-0.22	-0.60
30	Intrusions into area 3 by the analysed team	0.20	0.09
31	Time in possession (mins)	0.13	0.03

5.2.4 PERFORMANCE SCORING USING BIVARIATE CORRELATIONS

A stepwise multiple regression indicated that all of the variance in the coach scores could be accounted for by the PIs (R^2= 1). To calculate a single score for performance, individual PI scores were calculated using the R^2 values for each PI multiplied by a rating which quantified each PI value in relation to previous matches. The use of this rating, as opposed to the value, was necessary for two reasons. Firstly, the total performance score was required to have a maximum value of 100 and thus simply using individual PI values from games would result in unknown maximum performance scores. Secondly, individual PIs are not based on similar scales to one another and consequently if PI values were used then the contribution of each PI to the total score would be largely influenced by the magnitude of the PI value and not the relative contribution to the variance of coach scores.

The PI values for a match were thus compared with the median and 95% confidence limits (CLs) calculated for the 20 match data sample (Appendix J). Medians were used as opposed to means due to the non-parametric nature of the data (*c.f.* Zar, 1999). Each PI was then given a rating based on the following criteria:

1 = Lower than the lower CL.
2 = Higher than the lower CL but lower than the median.
3 = Equal to the median.
4 = Higher than the median but lower than the upper CL.
5 = Higher than the upper CL.

The resultant rating was usually high for a good performance. However, some PIs, such as tackles missed by the analysed team, were negatively correlated with performance. Consequently, the scale was reversed so that a 'five' was awarded to a frequency lower than the lower CL.

Each PI rating was multiplied by its correlation coefficient squared (R^2), i.e. the proportion of variance in coach scores predicted by the PI to give a PI score. The sum of the PI scores from a match was then converted to a proportion of the maximum possible score (i.e. a rating of five for each PI), thus creating a model score.

Four models (wet and dry weather for each) of performance were subsequently investigated using set criteria for the inclusion or exclusion of specific PIs. This was designed to investigate the effects of those indicators possessing small correlation coefficients whilst locating the most accurate model for measuring performance. Model 1 included all 31 of the PIs, model 2 excluded indicators possessing a correlation coefficient with the coach scores of less than ± 0.1, model 3 excluded indicators with a correlation coefficient of less than ± 0.3, and model 4 excluded indicators with a correlation coefficient of less than ± 0.5. The indicators that were included in each model are displayed in Appendix K.

5.2.5 Model Analysis

In order to assess the accuracy of each model, the model scores for each match were tested for agreement with the coach scores using Bland and Altman plots (Bland and Altman, 1986). Mean biases and 95% limits of agreement were calculated as mean ± 1.96 S.D. of the between method difference (Bland and Altman, 1999). In addition, models were tested for correlation (Spearman's rho) and difference (Wilcoxon-signed ranks) with the original coach scores.

5.3 RESULTS

5.3.1 BLAND AND ALTMAN MEASUREMENT OF STATISTICAL AGREEMENT

Mean biases and 95% limits of agreement for the between method differences (model against coach scores) indicated that all four models tended to over estimate performance (compared to the coach scores) for both wet and dry conditions (Table 5.3). Model and coach scores for each match are displayed in Appendix L.

Table 5.3: Mean biases and 95% limits of agreement for models 1 to 4 when compared with the coach scores for matches from the 2002/2003 season of the analysed professional team.

Model	Mean Bias	Upper Limit	Lower Limit
Model 1 Dry (all indicators)	**8.6**	28.5	-11.3
Model 1 Wet (all indicators)	**13.7**	27.3	0.1
Model 2 Dry (≥ ± 0.1)	**9.1**	27.3	-9.1
Model 2 Wet (≥ ± 0.1)	**12.7**	25.1	0.3
Model 3 Dry (≥ ± 0.3)	**9.4**	26.6	-7.9
Model 3 Wet (≥ ± 0.3)	**12.8**	26.5	-1
Model 4 Dry (≥ ± 0.5)	**12.3**	30.8	-6.2
Model 4 Wet (≥ ± 0.5)	**13.1**	26.8	-0.7

The Bland and Altman plots revealed a number of moderate to large linear relationships (Cohen, 1988) between the mean of the model and coach scores, and the difference between the model and coach scores. Negative correlations between the mean and the difference (Pearson) for dry weather models 1 to 3 (model 1, r= -0.74, model 2, r= -0.44, model 3, r= -0.34), and positive correlations for model 4 dry (r= 0.03) and all four wet weather models (model 1, r= 0.53, model 2, r= 0.64, model 3, r= 0.7, model 4, r= 0.72) were present. These correlations indicated that in general, the dry weather models predicted performance more accurately when higher performance scores were made,

whilst the wet weather models predicted more accurately when lower performance scores were made. Theoretically, no linear relationship between the mean and difference of the two measures should be present when carrying out analyses using Bland and Altman plots. However, no attempt was made to log transform the data as the presence of these linear relationships indicated that the method used to construct the single score measure of performance was inaccurate. Figure 5.1 illustrates the negative linear relationship present for model 1 dry. Bland and Altman plots for all four models in the dry and wet are shown in Appendix M.

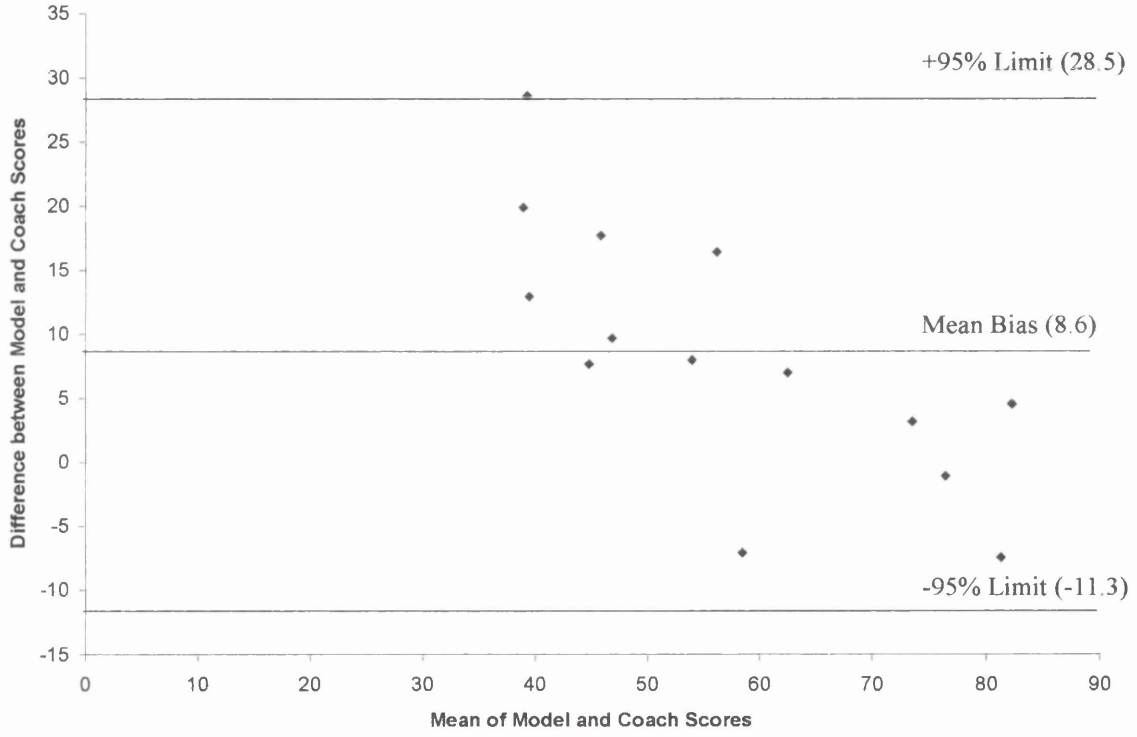


Figure 5.1: Bland and Altman plot illustrating the agreement between the coach scores and those of model 1 dry for matches from the 2002/2003 season of the analysed professional team (r= -0.74).

5.3.2 BIVARIATE CORRELATION MODELS 5 AND 6

The Bland and Altman plots and mean biases for models 1 to 4 (wet and dry weather) demonstrated how performance was more accurately predicted for low scoring wet matches and high scoring dry matches, but was over or under-scored for others. To try to improve this, the rating of each individual PI, based upon their respective median score and 95% CLs, was amended to provide more sensitive multipliers:

0 = Lower than the lower CL.
1 = Higher than the lower CL but lower than the median.
3 = Equal to the median.
4 = Higher than the median but lower than the upper CL.
5 = Higher than the upper CL.

Two new models were then subjected to the same tests as previously. Model 5 utilised all the PIs (as model 1), whilst model 6 excluded indicators with a correlation coefficient of $< \pm 0.5$ with the coach scores (as model 4).

All mean biases, particularly for model 5 dry, were considerably lower than previous models suggesting reasonable agreement with the coach scores for both wet and dry weather conditions. However, large upper and lower limits still existed, suggesting over or under-estimation of performance against the coach scores was still present (Table 5.4). The previously found positive relationship between the means and differences of the model and coach scores (see Bland and Altman plots, Appendix M) was again present for model 5 wet ($r= 0.86$), model 6 wet ($r= 0.89$) and model 6 dry ($r= 0.52$) but was absent for model 5 dry ($r= 0.07$). As with the original method of rating PIs in matches, the presence of these linear relationships indicated that the method used to construct the single score measure of performance was inaccurate. The scores generated by models 5 and 6 for all 20 matches are displayed together with the scores of models 1 to 4 in Appendix L.

Table 5.4: Mean biases and 95% limits of agreement for models 5 and 6 when compared with the coach scores for matches from the 2002/2003 season of the analysed professional team.

Model	Mean Bias	Upper Limit	Lower Limit
Model 5 Dry (all correlations)	**1.1**	20.7	-18.4
Model 5 Wet (all correlations)	**4.2**	25.7	-17.3
Model 6 Dry ($\geq \pm 0.5$)	**4.5**	30	-21.9
Model 6 Wet ($\geq \pm 0.5$)	**4.6**	28.3	-19

5.3.3 Correlation and Differences between Model and Coach Scores

All models were tested for correlation (Spearman's rho) and difference (Wilcoxon-signed ranks) with the original coach scores. Although strong correlations (Cohen, 1988) were evident for all six models ($r \geq 0.77$), difference statistics suggested that model 5 predicted coach scores most accurately for dry weather, whilst models 5 and 6 differed least with the coach scores for wet weather (Table 5.5).

Table 5.5: Difference statistics (p) and correlation coefficients (r) comparing the model and coach scores for matches from the 2002/2003 season of the analysed professional team.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
			Dry Weather			
Difference (p)	0.011	0.005	0.003	0.002	0.875	0.245
Correlation (r)	0.88	0.86	0.86	0.83	0.85	0.85
			Wet Weather			
Difference (p)	0.028	0.028	0.028	0.028	0.345	0.345
Correlation (r)	0.77	0.89	0.823	0.77	0.77	0.77

5.4 DISCUSSION

Investigations into relationships between PI values and the match scores made by elite coaches resulted in wide ranging correlations for different PIs ($0 \leq r \leq 0.88$). It was also clear from analysis that these correlations were to some extent determined by the weather conditions the match was played in. Indeed, the use of PIs in the form of frequencies illustrated how wet or dry weather seemed to dictate the pattern of a match.

Of the six bivariate correlation models tested, model 5 (using all PIs with the modified ranking scale) was found to have the smallest mean bias (1.1 for dry weather, 4.2 for wet weather), a high correlation (r= 0.85 for dry weather, r= 0.77 for wet weather), and the least difference (p= 0.875 for dry weather, p= 0.345 for wet weather) when compared against the coach scores. However, although the Bland and Altman plots displayed no relationship between the difference and the mean of the model and coach scores for dry weather (r= 0.07), a positive linear relationship was still evident for wet weather (r= 0.86) indicating a lack of agreement for certain magnitudes of scores. Large upper and lower limits for both weather conditions also demonstrated inaccuracies within the model.

An additional factor to consider was that performance scores for all models were created from correlation weightings derived from elite coaches' scores for matches. The extent to which these derived correlation values are applicable to other teams has not been determined. Clearly errors evident in the models tested may have been due to errors in these correlation values. Indeed the number of matches in the data sample (14 dry and six wet weather matches) meant that, particularly for the wet weather models, the confidence intervals for each PI were relatively large. This would have affected the subsequent ranking of PIs based upon their medians and CLs. Additional wet weather

matches could have been taken from the matches analysed during the previous playing season, but it was thought that the vast changes in playing and coaching personnel between the two seasons would not alleviate the problem sufficiently to warrant this procedure. It is rather suggested that future studies should improve these findings with results obtained from a completely different data set.

A second issue arising from the use of coach scores relates to the accuracy of this endeavour. For example, some form of bias may have been present within the coaches' scoring process since they knew the final result of the matches in question when allocating scores. Prior research within applied psychology has found that observed behaviours thought to result in poor performance were scored significantly lower than the same behaviour thought to result in good performance (Lord *et al.*, 1978). This, unavoidable issue may have made the coaches' scoring methods more subjective than they would otherwise have been, thereby resulting in perhaps relatively conservative scores. This is known as the central tendency effect, i.e. the tendency for an individual to prefer figures towards the centre of the presented range (Kennedy, 1961).

The practical benefit of a single score produced for team performance is questionable at present, because the reason for the discrepancies between coach and model scores is unknown. It should also be noted that the accuracy of any match score will be affected by confounding variables that may contribute to performance e.g. an unusual bounce of the ball or an influential refereeing decision (James *et al.*, 2002). Furthermore, it may also be the case that the relative contribution of any PI may be affected by particular strengths or weaknesses of the opposition. For example, when playing against a team possessing a strong lineout, the performance within the lineout by the analysed team may have a greater contributory weighting to performance. This unquantifiable and

natural variability makes precision impossible and compounds the difficulty of testing the effectiveness of any derived model. Further research is needed on larger data sets, particularly the determination of relative weightings for PIs, across different teams to develop this methodology. Indeed, a delimitation of this study is that data taken from other teams may present PI weightings that differ somewhat from those generated during this case study. However, other methods such as those based on a combination of comparable scores for separate skills or aspects of play, could provide an alternative and more accurate profile of team performance.

STUDY 3b

5.5 METHODOLOGY

5.5.1 STUDY DESIGN: STANDARDISATION OF PERFORMANCE INDICATORS

This second methodology used comparative standardised scores for PIs to assess team performance in rugby union. The objective was to provide match data on one visual scale that could be utilised by coaches within a practical setting through the use of standardised scores for each PI. The 20 match data sample from the 2002/2003 season (from study 2) was again used.

5.5.2 IDENTIFICATION OF PERFORMANCE INDICATORS FOR STANDARDISATION

Whilst it was necessary to include a comprehensive list of PIs for the bivariate correlation models, it was thought that the number of PIs used in the standardisation process should be reduced to provide a less complex depiction of performance. As previously discussed in section 2.8.4, presenting raw PI data in the form of percentages or ratios reduces their number (i.e. tackle success is made up of two frequencies, tackles made and tackles missed). Therefore, where possible, PIs were expressed as percentages (relative success) which enabled the presentation of team performance on a single visual scale. Furthermore, no discrimination was necessary between wet and dry weather matches as investigations into correlations between percentage PIs and the coach scores used in study 3a displayed similar r values for the two weather conditions ($6 > \pm 0.3$ for wet matches, $5 > \pm 0.3$ for dry matches). Consequently 18 PIs were selected, after further validation from the elite coaches, to enable a full interpretation of performance on one scale. The full list of PIs used for standardisation is shown in Table 5.6.

Table 5.6: Team performance indicators that were identified for the purpose of standardisation.[1]

	Performance Indicator
1	Analysed Team Scrum Success % (+)
2	Opposition Scrum Success % (+)
3	Analysed Team Lineout Success % (+)
4	Opposition Lineout Success % (+)
5	Analysed Team Ruck Success % (+)
6	Opposition Ruck Success % (+)
7	Analysed Team Maul Success % (+)
8	Opposition Maul Success % (+)
9	Analysed Team Successful Tackles % (+)
10	Offload Percentage % (+)
11	Breaks Made % (+)
12	Turnover Percentage % (+)
13	Analysed Team Open-Play and Restart Kick Success % (+)
14	Analysed Team Goal Kick Success % (+)
15	Penalty Percentage Given Away % (-)
16	Analysed Team Total Errors (freq) (-)
17	Analysed Team No. of Intrusions into Area 3 (freq) (+)
18	Analysed Team Time in Possession (seconds) (+)

[1] The + and – signs represent whether an excellent performance for the specific behaviour should result in a high or low score. A + equates to a high score for an excellent performance. Each PI is displayed from the perspective of the analysed team. For example, opposition lineout success equates to the percentage of lineouts won by the analysed team on the opposition's throw.

5.5.3 NON-PARAMETRIC STANDARDISATION

Standardisation is a common linear transformation that typically rescales data and centres the mean of a distribution at zero and the standard deviation at one (Howell, 1992). Due to the non-parametric nature of the rugby union data (typically skewed), medians were used as a more accurate measure of central tendency to means when standardising PIs. However, on this occasion, CLs were not used alongside the median (as previously advocated in this thesis) as their purpose is to show how accurate a sample median is in relation to the true population median (Campbell and Gardner, 2000). CLs should not be used as a measure of the spread of the data and as an alternative to standard deviation (Hopkins, 2000). As this study required a non-parametric measure of the spread of the data for standardisation, the inter-quartile range (IQR) was utilised.

To create a recognisable scale for coaches, standardisations were calculated resulting in distributions with medians of 50, IQRs of 15, and a range of scores typically between 0 and 100. Thus the typical *z* score transformation was amended with the mean and standard deviation being replaced by the median and IQR, the subsequent standardised score being multiplied by 15, and 50 added to gain the desired average score and range. The resultant formula for the standardisation of the data was:

$$Transformed\ Score = (15)\left(\frac{X - Mdn}{IQR}\right) + 50$$

Where X= the PI value for a specific match, Mdn= the sample median, and IQR= the inter-quartile range of the sample.

Substantial testing with the data set showed that when standardising values, medians and IQRs produced more sensible values than means and standard deviations for PIs where very high or low percentage scores were regularly achieved (e.g. opposition

scrum success). This can be explained using the following example. When standardising the performance of the 20th match against the previous 19, the mean of 'opposition scrum success' was 1.7% compared to the median of 0%. Typical of the skewed data collected, 15 of the 20 performances for this PI were 0%, whilst a relatively small number of extreme values produced the mean value of 1.7%. Thus, if the mean was used as the 'average' for the standardisation then all performances of 0% (most of them) would be considered as lower than average (since they fall below the mean value). Using the median however, provides a more realistic depiction of this variable whereby the 'average' performance by the team, i.e. 0% of the scrums on the opposition ball being won would be standardised to a value of 50. Of course using the median approach means that a poor performance for this variable is impossible as a score of less than 0% cannot occur. However, this accurately portrays the situation for this variable.

5.5.4 Data Samples Used for Standardisation

Two different sized data samples were used to investigate variations between the team's performances over the season, i.e. the previous 19 matches and their current 'form' (last 5 matches). The 18 PIs (Table 5.6) from the 20th match of the data set were thus standardised relative to the previous 19 and 5 matches. In each case the 20th match was not included in the sample as this match was to be compared with the previous *n* matches. It was deemed necessary to use at least a five match sample based upon prior research (*cf.* Hughes *et al.*, 2001; Vivian *et al.*, 2001) and the results from study 1, concerning the size of sample needed to gain an accurate representation of typical performance.

5.5.5 Construction of the Standardised Performance Report

The standardised data were presented as a graphical and novel 'form chart' with tabulated descriptive statistics beneath completing a 'performance report'. The median line (y= 50) was displayed on the form chart to visually illustrate those PIs that were above or below previously accomplished standards. The IQR was also plotted to provide further detail on PI performance. However, due to the variation in skewness values for the different PIs, it was impossible to determine a common standardised value where performance was above the 75th or below the 25th percentile. For example, when PI samples were extremely skewed there were instances when either the 75th or 25th percentiles were equal to the median (depending upon whether the sample was positively or negatively skewed). This in turn meant that when the median was standardised to a value of 50, the interquartile range of 15 was at times entirely below or above that median value. The absolute limits for the 25th and 75th percentiles on standard scores were therefore plotted (y= 65 (50 + 15) for an extremely positively skewed sample, i.e. PIs with a median of 0%, and y= 35 (50 – 15) for an extremely negatively skewed sample, i.e. PIs with a median of 100%). Thus, a standardised PI value greater than 65 was always above the 75th percentile whilst a value less than 35 was always below the 25th percentile.

5.5.6 Validation of the Performance Report

In order to obtain a suitable degree of content validity, a protocol was developed whereby a standardised performance report was examined by the head coach (elite coaching experience= 12 years) of a European regional rugby union team. The report was compiled using the data collected and PIs identified (n= 13) by their full-time performance analyst. Whilst being similar in nature to the indicators outlined in Table

5.6, small differences in the operational definitions of certain PIs were evident. This, however, exhibits the versatility of the standardisation system in a practical setting.

The coach was asked to complete a questionnaire (Appendix N) rating his team's last match out of five for each of the 13 PIs with comparison to their recent form (one= very poor, three= average, five= very good). He was then shown the performance report of the match in question (using their previous five matches as the data sample). Differences between the subjective view of the coach and the objective view of the performance report were subsequently explored.

The elite regional coach agreed that the form chart provided a clear visual depiction of team performance compared with previously accomplished standards. Indeed he described the form chart as; *"a potential analysis tool that provides instant information on one scale that would normally be obtained from several pages of statistics."* The importance of providing objective feedback on performance was further illustrated by the coach's subjective answers to the match questionnaire. Total agreement was achieved on only three PIs out of 13, whilst seven differed on the five point scale by a single point. However, more substantial variance was present for three of the answers where disagreement between the coach and the objective performance report was greater than two points. On seeing this disparity (i.e. whilst looking at the objective performance report), the coach expressed surprise and suggested inaccuracy in his recognition exclaiming *"I didn't think my answers would be so different, but thinking about it, there is a great deal to remember in a match, especially when comparing it with previous matches".* Coach error of this type is not too surprising however, given that coaches have previously been shown to have difficulty in recalling and comparing past performances in a multi-faceted sport (*c.f.* Franks and Miller, 1993).

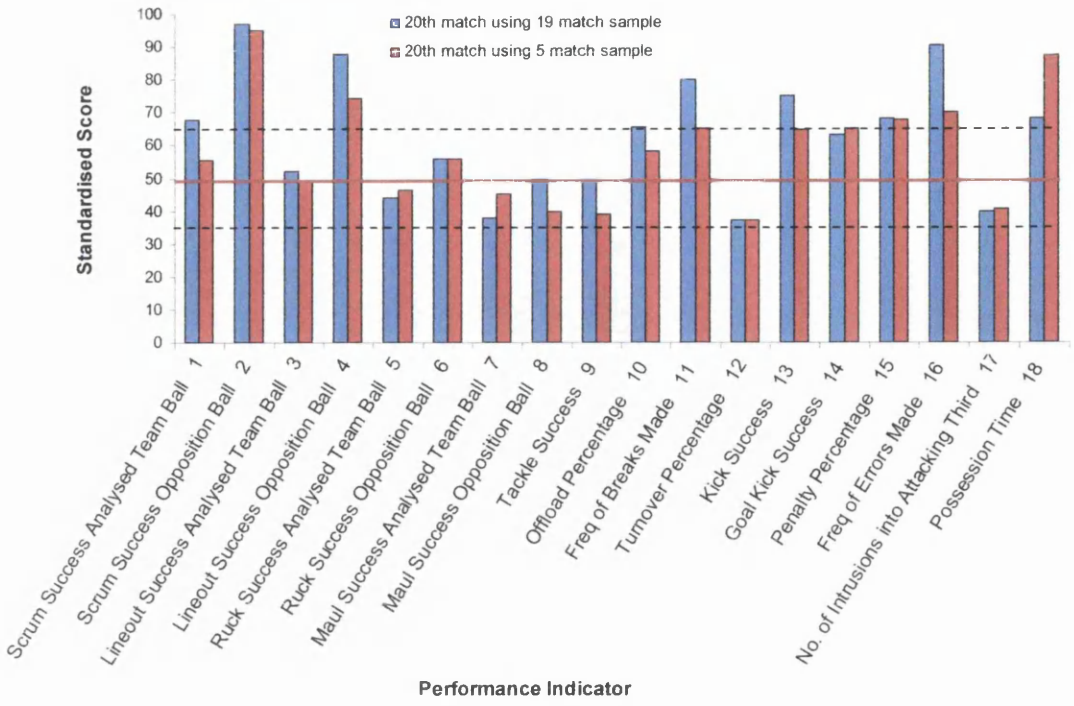
5.6 RESULTS

5.6.1 THE STANDARDISED PERFORMANCE REPORT

The actual match data of the 20th match were standardised relative to the previous 5 and 19 matches and presented as a form chart. This resulted in comparable PIs with distributions of median 50 and IQR 15. The standardisation of the PIs made it possible to objectively present all of the relevant data from a match on one scale (Figure 5.2). The non-standardised statistics for each PI and the median values for the previous *n* matches (presented in the table at the bottom of Figure 5.2), provided further clarification and allow fine-grained analysis by coaches through the use of 'actual' match data.

Figure 5.2 illustrates how differently a match can be interpreted depending on the data sample it is compared with. Match 20 is depicted as a better performance when compared with the previous 19 matches as opposed to with the previous five through higher standardised scores. It is therefore apparent that the form of the analysed team was far better towards the end of the season thereby reducing the positive effects of match 20's performance, i.e. lower standardised scores resulted when using the five match sample. This is also apparent in the descriptive statistics as 10 of the 18 PIs possessed higher median values in the five match sample compared to the 19 match sample.

Standardised Form Chart



Actual Descriptive Statistics

	Performance Indicator	Actual Match Value	Median 19 Matches	Median 5 Matches
1	Scrum Success Analysed Team Ball	100%	72.7%	84.6%
2	Scrum Success Opposition Ball	12.5%	0%	0%
3	Lineout Success Analysed Team Ball	70.6%	68.2%	71.4%
4	Lineout Success Opposition Ball	38.5%	7.1%	9.1%
5	Ruck Success Analysed Team Ball	88.2%	90.9%	89.3%
6	Ruck Success Opposition Ball	5%	3.9%	3.9%
7	Maul Success Analysed Team Ball	80%	100%	100%
8	Maul Success Opposition Ball	0%	0%	11.1%
9	Tackle Success	88.5%	88.9%	92.7%
10	Offload Percentage	43.8%	27.8%	21.4%
11	Freq of Breaks Made	15	7	7
12	Turnover Percentage	33.3%	63.6%	72.2%
13	Kick Success	84.2%	70.6%	73.8%
14	Goal Kick Success	90%	66.7%	57.1%
15	Penalty Percentage (Given Away)	27.3%	48.4%	52%
16	Freq of Errors Made	69	96	93
17	No. of Intrusions into Attacking Third	20	24	27
18	Possession Time	694 secs	509 secs	485 secs

Figure 5.2: Performance report of match 20 from the 2002/2003 season of the analysed professional team, displaying standardised scores relative to the previous 19 and 5 matches, together with actual data from match 20 and the median values of the previous 19 and 5 matches.

5.7 DISCUSSION

The standardisation of PIs satisfied the aim of creating an objective view of rugby union performance that could be utilised in a practical setting. Combining the standardised values contained in the form chart with actual data displayed in a table, provides the reader with both a graphical depiction of PI performance and the potential for more finely-grained investigation. Although previous research (e.g. Eaves and Hughes, 2003; Hunter and O'Donoghue, 2001; Potter and Carter, 2001b) has displayed and compared extensive rugby union data gathered from various matches and tournaments, the current study presents a method which simplifies vast quantities of data within a clear visual scale. The form chart provides the opportunity to instantly compare PIs that are normally analysed or presented in different formats (e.g. timed, frequency and percentage data). Exceptional performances can then be scrutinised using the actual data for each PI.

Indeed, as the content validation by the elite coach showed, the assessment of rugby union performance through standardisation is a versatile analysis tool. When asked to compare PIs from his team's last match with previous performances, the coach had difficulty recalling the exact details despite having previously viewed weekly statistical reports for each match. The coach's subjective view on performance was found to differ with the objective view of the performance report for 10 of the 13 identified PIs. These errors are consistent with previous research which found that coaches have difficulty recalling and comparing past performances in multi-faceted sports (*c.f.* Franks and Miller, 1993). A sport such as rugby union contains many different variables and to expect a coach to memorise every aspect of play without some form of objective statistical report is unrealistic.

Additionally, the elite coach stated within his interview that the form chart provided instant and detailed information concerning performance on a single scale that would otherwise be reported using several pages of statistics. The form chart allows coaches to isolate areas where performance levels were lower or higher than previously accomplished standards and could be modified if so wished, to include different combinations of PIs for both team and individual feedback. This method of presenting and disseminating performance data has the potential to evolve and is transferable to other multi-faceted sports such as soccer and hockey. For example, the data sample can be modified to incorporate only those matches applicable to current form (most recent matches), or specific competitions (e.g. European matches).

The form chart of match 20 illustrated how the issue of sample size (*cf.* Hughes *et al.*, 2001; Vivian *et al.*, 2001) can markedly alter the way in which a match performance is perceived. When standardised values were calculated, match 20 was depicted as a better performance when compared with the previous 19 matches as opposed to the previous five. This indicated that the analysed team's form improved towards the end of the season (more desirable medians for the five match sample), thus lessening the positive impact of match 20. However, this five match sample may not have been truly representative as the team may have played exceptionally well towards the end of the season. On the other hand, it has been previously reported that the majority of rugby union behaviours stabilise by the 5th match in a sample (Hughes *et al.*, 2001; Vivian *et al.*, 2001). Additionally, as was the case within the current study, standardising a match against a larger data sample may conceal improvements or trends within a team's performance. Whilst a coach may sometimes wish to compare their team's 20th match of the season with the preceding 19, it may be more beneficial to only utilise the most recent performances. In the field of economics and business, using the most recent data

and disregarding statistics from the start of the sample as more data are generated is known as a moving average (Roberts, 2003). This methodology of giving more weight to the most recent data (Mosteller, 1979; Bracewell, 2001, 2003a) could be adapted, in conjunction with the form chart, to provide coaches with an objective, consistent and reliable means of defining their performance trend.

Whilst frequency data had a propensity to demonstrate the type of match being played (study 3a) (i.e. the frequencies of rucks, mauls and set-pieces), it was found that percentages were better suited to the assessment of actual performance (*cf.* Hughes and Bartlett, 2002). The use of percentages also helped to simplify the form chart by reducing the number of PIs presented upon the scale. Furthermore, combining indicators such as penalties for and against the analysed team eliminated any bias of over or under awarding penalties between matches by different officials.

A potential limitation of the standardisation system is that due to the nature of league structures, the strength of the opposition differs from match to match within the sample. It is therefore important that the standardisation sample encompasses a range of matches relevant for the intended purpose. For example, comparing a match played against a weak team with a sample consisting solely of matches against very strong teams would not provide an accurate depiction of performance. Indeed, the effect of the opposition on performance is a potential confounding variable that has thus far not been quantified. To characterise a team as weak or strong has, as yet, not been achieved in the literature and offers scope for future research.

CHAPTER 6

GENERAL DISCUSSION

CHAPTER 6: GENERAL DISCUSSION

Having provided methodologies for constructing and assessing individual and team performance profiles within rugby union, three objectives remain. First, the findings of this research are discussed in relation to the thesis aims and objectives. Secondly, the practical implications for the coach or performance analyst are considered. Finally, the potential limitations within the three studies and directions for future investigations are provided.

The primary motive for undertaking this research was the deficiency within prior literature concerning the construction and assessment of individual and team performance indicators (PIs), and their resultant profiles. Indeed, chapter 2 highlighted that whilst previous research had attempted to create both individual (e.g. Vivian *et al.*, 2001) and team (e.g. Hunter and O'Donoghue, 2001) profiles within elite rugby union, the data and findings were limited to specific positions or indicators of winning and losing sides. Furthermore, previous performance analysis research also suffered from several methodological issues including a lack of reliability and inappropriate data analysis procedures (Atkinson and Nevill, 1998; Hughes *et al.*, 2002; Nevill *et al.*, 2002).

Consequently, a clear need to identify and investigate positional profiles across an entire rugby union team using appropriate reliability, data analysis and data sampling measures was present. This was achieved through the utilisation of common and position-specific PIs using a number of novel statistical techniques (e.g. a transformation to account for time spent on the field of play). Study 1 presented an explicit process for constructing individual profiles, together with validated operational definitions for performed behaviours. The use of medians and confidence limits (CLs)

as an appropriate method of presenting data was justified given the non-parametric nature of the data and better represented the consistency apparent in performances compared to the more commonly used means (e.g. Hughes and White, 1997; Vivian *et al.*, 2001; Deutsch *et al.*, 2002; Boddington and Lambert, 2004). CLs also provided the opportunity to construct profiles within a relatively small data set. This enabled the comparison of individuals within the analysed team who played the same position. Findings suggested that while general positional profiles existed for certain positions, individuality within decision making roles such as outside-half were apparent.

Study 2 provided a detailed methodology for the construction of team performance profiles whilst examining team PIs as predictors of success. Previous research had investigated partial profiles of either successful and unsuccessful, or winning and losing teams (e.g. Hughes and White, 1997; Stanhope and Hughes, 1997; Jackson and Hughes, 2001; Hunter and O'Donoghue, 2001; McCorry *et al.*, 2001), whereas study 2 provided an in-depth investigation into PIs as a function of winning and losing for a single team across an entire season. The previously highlighted distinction between significant and practical differences (Martin and Bateson, 1993; Atkinson, 2003) was also apparent in study 2. Whilst only two PIs differed significantly between winning and losing performances, practical differences were evident across a number of PIs. It was suggested that whilst a reduction (significant or otherwise) in the performance of one PI may not necessarily result in a loss for the analysed team, a combination of certain PIs may contribute to a losing performance. This led to the question as to whether team PIs could be combined in some way to assess performance independently of match outcome.

Study 1 excluded off-the-ball PIs from analysis which led to low frequencies of performed behaviours for positions such as prop and lock. Study 2 amended this by developing individual profiles that incorporated the off-the-ball PI 'cleaning out'. This achieved more comprehensive and meaningful profiles for forward positions whilst concurring with the findings of Parsons and Hughes (2001) who found that playing positions such as prop were involved in supporting roles to a greater extent than ball carrying.

Having identified intra-positional profiles in study 1, study 2 investigated whether individuality prevailed within players' decision making across two seasons. Despite the change in playing and coaching personnel, only one player (of 13) was found to differ significantly between the two seasons. This further supported the finding of study 1 that suggested players exhibit a pre-determined intent to perform certain behaviours based upon their physical and technical strengths and weaknesses.

Consequently, the robust individual and team performance profiles developed in studies 1 and 2 were used to create an objective method for scoring team performance in rugby union. Two methodologies were compared for accuracy and applicability (study 3). The first approach provided a single score for match performance (study 3a), whilst the second utilised a combination of comparative scores (study 3b). The single score approach was tested a number of times using the mean bias, correlation and difference statistics between the scores created by different models and comparable scores provided by coaches. The best models provided relatively accurate methods of scoring match performance although some variability in estimation (discrepancies in upper and lower limits) was present. A further weakness in this approach was the subjectivity

present in the calculation of the initial PI weightings which were obtained from correlation coefficients between PIs and coach scores.

An objective assessment of performance through the use of combinations of comparative scores (study 3b) was achieved using standardised scores for PIs. Form charts indicated specific areas where performance was higher or lower than previously accomplished standards. Content validation of the form chart by an elite regional coach suggested the practical potential of this approach. As with studies 1 and 2, the use of non-parametric statistical techniques provided valid and accurate results. Medians and CLs (study 3a), and medians and interquartile ranges (study 3b) were appropriate for the data and consequent analysis, having the effect of reducing the influence of outliers which are a natural consequence of the sport of rugby union.

Collectively, the findings provide further knowledge concerning methodologies for the analysis of team and individual performance in rugby union, with specific reference to the use of appropriate reliability and statistical procedures for non-parametric data.

6.1 Practical Implications

As a consequence of this research, several practical implications have been derived for the applied analyst or coach in relation to performance profiling in rugby union. Firstly, procedures have been suggested that enable the collection of valid and reliable data for rugby union performance, but these are also applicable to other similar sports. This methodology has also been shown to enable performance behaviours of individual positions to be objectively compared. This can allow coaches to monitor the impact of any intervention strategy (technical, tactical, mental or physical) upon team or individual performance in a more rigorous manner than would otherwise be possible. Additionally, this objective assessment of performance behaviours can be utilised by

other sports science disciplines, for example, psychologists implementing a goal-setting intervention. Here, stabilised positional performance profiles can be used to enhance motivation and performance amongst players through the setting of performance goals that allow the assessment of goal achievement and feedback on the goal attainment process in a systematic and objective manner (*cf.* Larder, 1988; Mellalieu *et al.*, 2006).

The methodology identified for constructing individual performance profiles can facilitate the objective assessment of individuals for the purpose of team selection. For example, individuals experiencing a dip in 'form' could be replaced by a player of the same position with a more desirable performance profile at a given time. In addition, examination of individual profiles may assist the coach when selecting a specific match strategy. Players could be included or excluded based upon the technical and physical strengths of other members of their own team or the opposition. For example, an open-side flanker exhibiting strong tackle and turnover elements within their profile could be selected to supplement other members of the back-row who possessed particularly strong ball carrying profiles. This 'horses for courses' selection strategy could provide balance within a team specifically designed to target known weaknesses of opposition teams (Taylor *et al.*, 2004).

The large differences in some PIs observed between winning and losing performances, i.e. turnovers won and lineout success on the opposition ball for the team analysed in this study, suggest that emphasis could be placed on specific areas in training sessions. However, this suggestion may sometimes be based on practical and not statistical differences observed within the PIs (*c.f.* Martin and Bateson, 1993; Atkinson, 2003). Some caution is advised for this as subjectively deciding that differences are evident between PIs is questionable. Whilst coaches routinely make this sort of decision it is

typically from a perspective lacking in statistical fluency. The goal of performance analysts should be to provide statistical assurance and thus some form of consensus opinion for what practical significance means.

The practical implications for a single score measure of team performance is limited at present due to the inadequacies of the methods used and the need for further research to confirm the viability of such an approach. The alternative approach of using simple combinations of comparative standardised PI scores did provide useful and objective information for use within a practical environment. This presentation of match data as a form chart permits instant and simple comparison between PIs, allowing the coach to intervene in areas where performance was lower or higher than previously accomplished standards. This standardisation method for PIs is directly useful for other multi-faceted team sports such as soccer and hockey.

In addition, a number of the other methodological approaches outlined within the thesis may have further applications that lie within other sports or in other aspects of the analysis of behaviour. Indeed, the transformation used by study 1 to account for the time spent on the field by individuals, has already been utilised within the analysis of soccer performance (*c.f.* Taylor *et al.*, 2004). Furthermore, the innovative methods used for the analysis and presentation of non-parametric data provide a basis from which other sports or behavioural analysts can work from.

6.2 Thesis Limitations and Recommendations for Future Research

Whilst this thesis has contributed to the development of methodologies applicable to performance analysis, the findings should be viewed with respect to inherent limitations. In acknowledging these limitations, this section suggests areas where further research can extend the findings of this thesis.

In order to provide a detailed analysis of performance, video playback using a terrestrial television companies' coverage was used. Whilst this proved to be advantageous in some cases (e.g. reverse camera angles used for replays provided further clarity), there were instances when the replays hindered the data collection as some play was missed. On some occasions, camera angles made it impossible to identify a player performing a behaviour and so no codes were recorded. This eliminated the need for guesswork and thus increased the reliability, but meant that inaccuracies were present in the coding. In future, if time and funds allowed, the use of multiple camera angles, recorded independently of television cameras, would increase the accuracy of analysis. For example, cameras behind each set of posts could be referred to if interruptions in coverage occurred.

Whilst operational definitions were written for all codes used, some degree of subjectivity was still a feature of the analyses. For example, uncertainty was present when deciding whether the thrower or the jumper was at fault when a lineout was lost, or identifying whether a player was kicking for touch or long for territory. These subjective decisions resulted in inaccuracies in the coding which, whilst found to be acceptable when tested for intra-observer reliability ($< 5\%$), were sometimes unacceptable for inter-observer reliability ($\leq 18.42\%$ errors for all PIs). In this research project the only other observers used, apart from the experimenter, were solely for the reliability tests and consequently they had limited experience of the system in comparison to the experimenter. Although, this may have resulted in the high error rates for the inter-observer reliability tests, future research should utilise more than one observer to properly protect against errors associated with single observers, i.e. bias or consistent mistakes. These observers should be sufficiently trained to use the analysis system, whilst comparisons between coding should be conducted post-analysis.

The individual and team PIs reported in this thesis were obtained from one elite team. Consequently the profiles presented are not necessarily indicative of all levels of rugby union. It is likely that different levels of performance (e.g. school, club, International) will exhibit diverse profiles of PIs due to the structure of the game and standard of play at each level (Bracewell, 2002). However, given the similarities between players' profiles across two differing seasons, it would be interesting to investigate whether individuality and a predisposition to perform certain behaviours is retained when players perform in International competition compared to club matches. Whilst Vivian *et al.* (2001) found behavioural differences between these two levels of competition, a repeated measures analysis at the level of play may provide further information on these differences.

Scoring rugby union performance independently of match outcome represents an interesting and important area of investigation due to a lack of prior research. This thesis presented one method deriving PI weightings based on correlation coefficients with coach scores for one team's matches in a single season (study 3a). The determination of relative weightings for PIs across different quality teams and seasons is clearly needed to further develop the single score measure of performance. A more sizeable sample, particularly for wet weather matches may also provide additional information concerning the variability of PI correlations.

An alternative approach to the single score for team performance was suggested, i.e. the presentation of combinations of comparative scores (study 3b). However, the methodology used only made comparisons with previous matches of the analysed team. Future research should consider comparing the performances of two different teams, involving different numbers of matches. This would enable the identification of

strengths and weaknesses of one team compared to another, or between individuals, enabling the introduction of specific interventions to enhance preparation for competition. Some efforts were made to compare the effect of different sample sizes on the standardisation process but this requires further investigation. The use of an entire season's matches provided a relatively stable data set but it also had the effect of concealing current form. The issue of current form and potentially the use of moving averages (Bracewell, 2001, 2003a; Roberts, 2003) represents an interesting area for further work.

REFERENCES

REFERENCES

Atkinson, G. (2003). Does size matter for sports performance researchers? *Journal of Sports Sciences*, **21**, 73-74.

Atkinson, G. and Nevill, A.M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine*, **26**, 217-238.

Atkinson, G. and Nevill, A.M. (2001). Selected issues in the design and the analysis of sport performance research. *Journal of Sports Sciences*, **19**, 811-827.

BBC Sport (2001). *Position Guide: The Six Nations* [online]. BBC Sport. Available from: http://www.news.bbc.co.uk/sport/hi/english/static/in_depth/rugby_union/2001/six_nations/positions.stm [Accessed 03/02/2004].

Biddle, S.J.H., Markland, D., Gilbourne, D., Chatzisarantis, N.L.D. and Sparkes, A.C. (2001). Research methods in sport and exercise psychology: quantitative and qualitative issues. *Journal of Sports Sciences*, **19**, 777-809.

Bland, J.M. and Altman, D.G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *The Lancet*, **1**, 307-310.

Bland, J.M. and Altman, D.G. (1999). Measuring agreement in method comparison studies. *Statistical Methods in Medical Research*, **8**, 135-160.

Boddington, M. and Lambert, M. (2004). Quantitative and qualitative evaluation of scoring opportunities by South Africa in World Cup rugby 2003. *International Journal of Performance Analysis in Sport*, **4** (2), 32-49.

Bouthier, D., Barthed, D., David, B. and Grehaigne, J.F. (1997). Tactical analysis of play combinations in rugby union with video-computer technology – rationalising French "flair". In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 135-144. Cardiff: UWIC.

Bracewell, P.J. (2001). Perception of individual rugby player performance and the impact of non-performance on statistical analyses. *Research Letters in the Information and Mathematical Sciences*, **2**, 19-22.

Bracewell, P.J. (2002). Implementing statistics in a diagnostic coaching structure for rugby. *Research Letters in the Information and Mathematical Sciences*, **3**, 79-84.

Bracewell, P.J. (2003a). Monitoring meaningful rugby ratings. *Journal of Sports Sciences*, **21**, 611-620.

Bracewell, P.J. (2003b). Creating and monitoring meaningful individual rugby ratings. *Research Letters in the Information and Mathematical Sciences*, **4**, 19-22.

Brackenridge, C.H. and Alderson, G.H. (1985). *Match Analysis.* Leeds: National Coaching Foundation.

Campbell, M.J. and Gardner, M.J. (2000). Medians and their differences. In *Statistics with Confidence: Second Edition* (edited by D.G. Altman, D. Machin, T.N. Bryant and M.J. Gardner), pp. 36-44. London: BMJ Books.

Carron, A.V. (1988). *Group Dynamics in Sport.* Spodym Publishers.

Carron, A.V. and Hausenblas, H.A. (1998). *Group Dynamics in Sport: Second Edition.* Morgantown, WV: Fitness Information Technology.

Carter, A. (1997). Time and motion analysis and heart rate monitoring of a back row forward in first class rugby union football. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 145-160. Cardiff: UWIC.

Carter, A. and Potter, G. (2001a). The 1995 Rugby World Cup Finals: Where does all the time go? In *Notational Analysis of Sport III* (edited by M.D. Hughes), pp. 220-223. Cardiff: UWIC.

Carter, A. and Potter, G. (2001b). The 1995 Rugby World Cup Finals: 187 tries. In *Notational Analysis of Sport III* (edited by M.D. Hughes), pp. 224-229. Cardiff: UWIC.

Cohen. J. (1988). *Statistical Power Analysis for the Behavioral Sciences: Second Edition.* New Jersey: Lawrence Erlbaum.

Croucher, J.S. (1997). The use of notational analysis in determining optimal strategies in sports. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 3-20. Cardiff: UWIC.

Deci, E.L. and Ryan, R.M. (1985). *Intrinsic Motivation and Self-determination in Human Behaviour.* New York: Plenum.

Deutsch, M.U., Kearney, G.A. and Rehrer, N.J. (2002). A comparison of competition work rates in elite club and super 12 rugby. In *Science and Football IV* (edited by W. Spinks, T. Reilly and A. Murphy), pp. 160-166. London: Routledge.

Eaves, S. and Hughes, M.D. (2003). Patterns of play of international rugby union teams before and after the introduction of professional status. *International Journal of Performance Analysis in Sport*, **3**(2), 103-111.

Fast Multimedia AG (1999). *Fast Multimedia Clipmaster, Software User's Guide.* Munich: Fast Multimedia AG.

Flemming, M.L. and Nellis, J.G. (1994). *Principles of Applied Statistics.* London: Routledge.

Franks, I.M. (1988). The use of computer interactive video technology in sport analysis. *Journal of Sports Sciences*, **6**, 252.

Franks, I.M. (2004). The need for feedback. In *Notational Analysis of Sport: Systems for better Coaching and Performance in Sport: Second Edition* (edited by M. Hughes and I.M. Franks), pp. 8-16. New York: Routledge.

Franks, I.M., Hodges, N. and More, K. (2001). Analysis of coaching behaviour. *International Journal of Performance Analysis in Sport*, **1**, 27-35.

Franks, I.M. and McGarry, T. (1996). The science of match analysis. In *Science and Soccer* (edited by T. Reilly), pp. 363-375. London: E&FN Spon.

Franks, I.M. and Miller, G. (1993). Training coaches to observe and remember. *Journal of Sports Sciences*, **9**, 285-297.

Greenwood, J. (1997). *Total Rugby.* London: A&C Black Ltd.

Grehaigne, J.F., Bouthier, D. and David, B. (1997). Dynamic-system analysis of opponent relationships in collective actions in soccer. *Journal of Sports Sciences*, **15**, 137-149.

Grehaigne, J.F., Mahut, B. and Fernandez, A. (2001). Qualitative observation tools to analyse soccer. *International Journal of Performance Analysis of Sport*, **1**, 52-61.

Herbert, P. and Tong, R.J. (1997). A comparison of the positional demands of wingers and back row forwards using movement analysis and heart rate telemetry. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 177-182. Cardiff: UWIC.

Hill, A. and Hughes, M.D. (2001). Corners in the European Championships for association football, 2000. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 285-294. Cardiff: UWIC.

Hook, C. and Hughes, M.D. (2001). Patterns of play leading to shots in 'Euro 2000'. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 295-302. Cardiff: UWIC.

Hopkins, W.G. (2000). *New View of Statistics* [online]. Available from: http://www.sportsci.org/resource/stats/. [Accessed 26/01/2005].

Hopkins, W.G., Hawley, J.A. and Burke, L.M. (1999). Design and analysis of research on sport performance enhancement. *Medicine and Science in Sports and Exercise*, **31**(3), 472-485.

Howe, P.D. (1999). Professionalism, commercialism and the rugby club: The case of Pontypridd RFC. In *Making the Rugby World: Race, Gender, Commerce* (edited by T.J.L. Chandler and J. Nauright), pp. 165-180. London: Frank Cass Publishers.

Howell, D.C. (1992). *Statistical Methods for Psychology: Third Edition.* Belmont: Duxbury Press.

Hughes, C. (1973). *Football: Tactics and Teamwork.* Wakefield: E.P. Publishing Co. Ltd.

Hughes, M.D. (1988). Computerised notation analysis in field games. *Ergonomics*, **31**, 1585-1592.

Hughes, M.D. (1996). Notational Analysis. In *Science and Soccer* (edited by T. Reilly), pp. 343-361. London: E&FN Spon.

Hughes, M.D. (2004). Notational analysis: a mathematical perspective. *International Journal of Performance Analysis in Sport*, **4** (2), 97-139.

Hughes, M.D. and Bartlett, R.M. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences*, **20**, 739-754.

Hughes, M.D. and Charlish, F. (1988). The development and validation of a computerised notation system for American football. *Journal of Sports Sciences*, **6**, 253-254.

Hughes, M.D. and Clarke, A. (1994). Computerised notation analysis of rugby union to examine the effects of law changes upon the patterns of play by international teams. *Journal of Sports Sciences*, **12**, 180.

Hughes, M.D., Cooper, S.M. and Nevill, A. (2002). Analysis procedures for non-parametric data from performance analysis. *International Journal of Performance Analysis in Sport*, **2**(1), 6-20.

Hughes, M.D., Evans, S. and Wells, J. (2001). Establishing normative profiles in performance analysis. *International Journal of Performance Analysis*, **1**(1), 1-26.

Hughes, M.D. and Franks, I.M. (2004a). Notational analysis – a review of the relevant literature. In *Notational Analysis of Sport: Systems for better Coaching and Performance in Sport: Second Edition* (edited by M. Hughes and I.M. Franks), pp. 59-106. New York: Routledge.

Hughes, M.D. and Franks, I.M. (2004b). Sports analysis. In *Notational Analysis of Sport: Systems for better Coaching and Performance in Sport: Second Edition* (edited by M. Hughes and I.M. Franks), pp. 107-117. New York: Routledge.

Hughes, M.D. and Hill, J. (1997). An analysis of referees in the men's Rugby Union World Cup, 1991. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 161-167. Cardiff: UWIC.

Hughes, M.D. and Jones, R. (2005). Patterns of play of successful and unsuccessful teams in men's 7-a-side rugby union. In *Science and Football V* (edited by T. Reilly, J. Cabri and D. Araujo), pp. 247-252. Oxford: Routledge.

Hughes, M.D., Kitchen, S. and Horobin, A. (1997). An analysis of women's International rugby union. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 125-134. Cardiff: UWIC.

Hughes, M.D. and White, P. (1997). An analysis of forward play in the 1991 rugby union world cup for men. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 183-191. Cardiff: UWIC.

Hughes, M.D. and Williams, D. (1988). The development and application of a computerized rugby union notation system. *Journal of Sports Sciences*, **6**, 254-255.

Hunter, P. and O'Donoghue, P. (2001). A match analysis of the 1999 rugby union World Cup. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 85-90. Cardiff: UWIC.

Jackson, N. and Hughes, M.D. (2001). Patterns of play of successful and unsuccessful teams in elite women's rugby union. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 111-118. Cardiff: UWIC.

James, N., Garnish, M. and Hughes, G. (2004). How predictable are possession strategies in rugby union? *Proceedings of the World Congress of Performance Analysis of Sport VI.* Belfast, Northern Ireland, p. 12.

James, N., Mellalieu, S.D. and Hollely, C. (2002). Analysis of strategies in soccer as a function of European and domestic competition. *International Journal of Performance Analysis in Sport*, **2**, 85-103.

Jones, G.W., Peters, D.M. and Donovan, M. (2004). Critical evaluation of the impact of the 'bonus point' scoring system on the final pool positions in the 2003 Rugby World Cup. In *Performance Analysis of Sport VI* (edited by P. O'Donoghue and M.D. Hughes), pp. 142-149. Cardiff: UWIC.

Jones, N.M.P. (2001). *The Relationship Between Professionalism and Motivation: A Qualitative Study.* Unpublished Undergraduate Dissertation, UWIC.

Jones, P.D., James, N. and Mellalieu, S.D. (2004). Possession as a performance indicator in soccer. *International Journal of Performance Analysis in Sport,* **4**(1), 98-102.

Kawai, K. (1997). Development of a computerised notational analysis system of soccer allowing for accurate reproduction of players and feedback effects. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 257-266. Cardiff: UWIC.

Kennedy, J.E. (1961). The paired-comparison method and central tendency effect in esthetic judgements. *Journal of Applied Psychology*, **45**(2), 128-129.

Kitchen, S.J. (1994). *A Computerised Notation Analysis Comparing the Passages of Play in Men's and Women's Rugby Union with Particular Reference to the Forwards.* Unpublished Undergraduate Dissertation, UWIC.

Laird, P. and Lorimer, R. (2004). An examination of try scoring in rugby unuion: a review of International rugby statistics. *International Journal of Performance Analysis in Sport,* **4**(1), 72-80.

Lames, M. and Hansen, G. (2001). Designing observational systems to support top-level teams in game sports. *International Journal of Performance Analysis in Sport*, **1**, 83-90.

Larder, P. (1988). *Rugby League Coaching Manual.* London: Crowood Press.

Long, R. and Hughes, M. (2004). Performance profiles of back-row forwards in elite men's rugby union, before and after the introduction of professionalism. In *Performance Analysis of Sport IV* (edited by P. O'Donoghue and M.D. Hughes), pp. 130-141. Cardiff: UWIC.

Lord, R.G., Binning, J.F., Rush, M.C. and Thomas, J.C. (1978). The effects of performance cues and leader behaviour on questionnaire ratings of leadership behaviour. *Organizational Behaviour and Human Performance*, **21**, 27-39.

Luhtanen, P., Belinskij, A., Häyrinen, M. and Vänttinen, T. (2001). A comparative tournament analysis between the Euro 1996 and 2000 in soccer. *International Journal of Performance Analysis in Sport*, **1**, 74-82.

Lynch, G., Wells, J. and Hughes, M.D. (2001). Performance profiles of elite under 17 and under 19 female juniors. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 195-202. Cardiff: UWIC.

Lyons, K. (1997). Lloyd Lowell Messersmith: Pioneer of notational analysis of performance in sport. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 49-57. Cardiff: UWIC.

Marshall, K. and Hughes, M.D. (2001). A comparison of elite level women's rugby from 1994 to 2000. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 119-128. Cardiff: UWIC.

Martin, M., Thomas, C. and Williams, J. (2001). Mapping the world game of rugby union. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 91-110. Cardiff: UWIC.

Martin, P. and Bateson, P. (1993). *Measuring Behaviour: Second Edition.* Cambridge: Cambridge University Press.

McCorry, M., Saunders, E.D., O'Donoghue, P.G. and Murphy, M.H. (2001). A match analysis of the knockout stages of the 1995 rugby union World Cup. In *Notational Analysis of Sport III* (edited by M.D. Hughes), pp. 230-239. Cardiff: UWIC.

McGarry, T. and Franks, I.M. (1994). A stochastic approach to predicting competition squash match-play. *Journal of Sports Sciences*, **12**, 573-584.

Mellalieu, S.D., Hanton, S. and O'Brien, M. (2006). The effects of goal-setting on rugby performance. *Journal of Applied Behavior Analysis*, **39**(2), 101-107.

More, K. (2002). Observation and analysis. *Sports Coach UK: Faster, Higher, Stronger*, **16**, 10-11.

Mosteller, F. (1979). A resistant analysis of 1971 and 1972 professional football. In *Sports, Games, and Play: Social and Psychological Viewpoints* (edited by J.H. Goldstein), pp. 371-399. New Jersey: Lawrence Erlbaum Associates.

Murakami, J., Shinozono, H. and Yamamoto, T. (2004). Time analysis of scoring tries in rugby union. In *Performance Analysis of Sport IV* (edited by P. O'Donoghue and M.D. Hughes), pp. 130-141. Cardiff: UWIC.

Nevill, A.M., Atkinson, G., Hughes, M.D. and Cooper, S.M. (2002). Statistical methods for analysing discrete and categorical data recorded in performance analysis. *Journal of Sports Sciences*, **20**, 829-844.

Noldus Information Technology (1995). *The Observer Version 3.0, Base Package for Windows Reference Manual.* Wageningen: Noldus Information Technology.

Noldus (2001). The Scottish Rugby Union. *Noldus News*, **8**, 7.

O'Donoghue, P. (2005). Normative profiles of sports performance. *International Journal of Performance Analysis in Sport*, **5**(1), 104-119.

O'Donoghue, P. and Parker, D. (2001). Time-motion analysis of FA Premier League soccer competition. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 263-266. Cardiff: UWIC.

Parsons, A. and Hughes, M.D. (2001). Performance profiles of male rugby union players. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 129-136. Cardiff: UWIC.

Partridge, D. and Franks, I.M. (1989a). A detailed analysis of crossing opportunities from the 1986 World Cup (Part I). *Soccer Journal*, **May/June**, 47-50.

Partridge, D. and Franks, I.M. (1989b). A detailed analysis of crossing opportunities from the 1986 World Cup (Part II). *Soccer Journal*, **June/July**, 45-48.

Peacock, S.J. (2001). Notational/Performance Analysis. *The National Sports Medicine Institute of the United Kingdom Newsletter*, **24** (Autumn), 12-14.

Pollard, R. (1986). Home advantage in soccer: A retrospective analysis. *Journal of Sports Sciences*, **4**, 237-248.

Potter, G. (1997). A case study of England's performance in the five nations championship over a three year period (1992-1994). In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 193-202. Cardiff: UWIC.

Potter, G. and Carter, A. (2001a). The 1995 Rugby World Cup Finals: From whistle to whistle: A comprehensive breakdown of the total game contents. In *Notational Analysis of Sport III* (edited by M.D. Hughes), pp. 209-215. Cardiff: UWIC.

Potter, G. and Carter, A. (2001b). The 1995 Rugby World Cup Finals: The four year cycle: A comparison of the 1991 and 1995 Rugby World Cup Finals. In *Notational Analysis of Sport III* (edited by M.D. Hughes), pp. 216-219. Cardiff: UWIC.

Potter, G. and Hughes, M.D. (2001). Modelling in competitive sports. In *Notational Analysis of Sport III* (edited by M.D. Hughes), pp. 58-74. Cardiff: UWIC.

Reep, C. and Benjamin, B. (1968). Skill and chance in association football. *Journal of the Royal Statistical Society, Series A*, **131**, 581-585.

Reilly, T. and Gilbourne, D. (2003) Science and football: a review of applied research in the football codes. *Journal of Sports Sciences*, **21**, 693-705.

Reilly, T. and Thomas, V. (1976). A motion analysis of work-rate in different positional roles in professional football match-play. *Journal of Human Movement Studies*, **2**, 87-97.

Roberts, P. (2003). Moving averages – The heart of trend analysis. *The Alchemist*, **33**, 12-14.

Robertson, K. (1999). *Observation, Analysis and Video.* Leeds: The National Coaching Foundation.

Roxio Inc. (1999). *Roxio Easy CD Creator 5 Platinum, User's Guide.* California: Roxio Inc.

Rue, H. and Salvesen, Ø. (2000). Prediction and retrospective analysis of soccer matches in a league. *The Statistician*, **49**(3), 399-418.

Sasaki, K., Murakami, J., Shimozono, H., Furukawa, T., Katuta, T. and Kono, I. (2002). Contributing factors to successive attacks in rugby football games. In *Science and Football IV* (edited by W. Spinks, T. Reilly and A. Murphy), pp. 167-170. London: Routledge.

Sasaki, K., Murakami, J., Shimozono, H., Furukawa, T., Miyao, M., Saito, T., Yamamoto, T., Nakayama, M., Hirao, S., Hanaoka, N., Katuta, T. and Kono, I. (2005). Defence performance analysis of rugby union: The turnover-play structure. In *Science and Football V* (edited by T. Reilly, J. Cabri and D. Araujo), pp. 243-246. Oxford: Routledge.

Sasaki, Y., Nevill, A. and Reilly, T. (1999). Home advantage: A case study of Ipswich Town football club during the 1996-97 season. *Journal of Sports Sciences*, **17**, 831.

Shephard, R.J. (1990). Verbal and non-verbal feedback from coaches. *Canadian Journal of Sports Science*, **15**, 3-4.

Silberberg, J. and Wlodarczyk, J. (2003). Australia versus New Zealand: an emotional meta-analysis of rugby, *BMJ*, **327**, 1475.

Smyth, G., O'Donoghue, P.G. and Wallace, E.S. (2001). Notational analysis of contact situations in rugby union. In *Notational Analysis of Sport IV* (edited by M.D. Hughes and F. Tavores), pp. 156-164. Portugal: Centre for Team Sports Studies, University of Porto.

SPSS Inc. (2000). *SPSS for Windows Version 10: User's Guide.* Chicago: SPSS Inc.

Stanhope, J. and Hughes, M.D. (1997). An analysis of scoring in the 1991 rugby union World Cup. In *Notational Analysis of Sport I and II* (edited by M.D. Hughes), pp. 167-176. Cardiff: UWIC.

Taylor, J.B., Mellalieu, S.D. and James, N. (2004). Behavioural comparisons of positional demands in professional soccer. *International Journal of Performance Analysis in Sport*, **4**, 81-97.

Thomas, C. (2003). Patterns of play in elite women's rugby union. In *Book of Abstracts: Science and Football, 5th World Congress, Portugal 2003*, pp. 86. Lisbon: Editorial Gymnos.

Thomas, J.R. and Nelson, J.K. (2001). *Research Methods in Physical Activity.* Champaign, IL: Human Kinetics.

Treadwell, P.J. (1987). Computer aided match analysis of selected ball games (soccer and rugby union). In *Science and Football* (edited by T. Reilly, A. Lees, K. Davids and W.J. Murphy), pp. 282-287. London: E&FN Spon.

Treadwell, P.J. (1992). The predictive potential of match analysis systems for rugby union football. In *Science and Football II* (edited by T. Reilly), pp. 150-158. London: E&FN Spon.

Vincent, W.J. (1999). *Statistics in Kinesiology: Second Edition.* Leeds: Human Kinetics Publishers.

Vivian, R., Mullen, R. and Hughes M.D. (2001). Performance profiles at league, European Cup and International levels of male rugby union players, with specific reference to flankers, number 8s and number 9s. In *Pass.com: Fifth World Congress of Performance Analysis of Sport* (edited by M.D. Hughes and I. Franks), pp. 137-143. Cardiff: UWIC.

Wells, J., O'Donoghue, P. and Hughes, M.D. (2004). The need to use representative player data from multiple matches in performance analysis. In *Performance Analysis of Sport VI* (edited by P. O'Donoghue and M.D. Hughes). pp. 241-244. Cardiff: UWIC.

Williams, A.M., Horn, R.R. and Hodges, N.J. (2003). Skill acquisition. In *Science and Soccer: Second Edition* (edited by T. Reilly and A.M. Williams), pp. 198-213. London: Routledge.

Williams, J., Thomas, C., Brown, R. and Jones, N. (2005). The effect of the wheeled scrum law in rugby union. In *Science and Football V* (edited by T. Reilly, J. Cabri and D. Araujo), pp. 262-267. Oxford: Routledge.

Wilson, K. and Barnes, C.A. (1998). Reliability and validity of a computer based notational analysis system for competitive table tennis. In *Science and Racket Sports II* (edited by A. Lees, I. Maynard, M. Hughes and T. Reilly), pp. 265-268. London: E&FN Spon.

Wither, R.T., Maricic, Z., Wasilewski, S. and Kelly, L. (1982). Match analysis of Australian professional soccer players. *Journal of Human Movement Studies*, **8**, 158-176.

Yamanaka, K., Hughes, M. and Lott, M. (1993). An analysis of playing patterns in the 1990 World Cup for association football. In *Science and Football II* (edited by T. Reilly, J. Clarys and A. Stibbe), pp. 205-214. London: E&FN Spon.

Zar, J.H. (1999). *Biostatistical Analysis: Fourth Edition.* New Jersey: Prentice-Hall, Inc.

APPENDICES

APPENDIX A

ETHICAL APPROVAL FORM

PRIFYSGOL CYMRU ABERTAWE UNIVERSITY OF WALES SWANSEA

Department of Sports Science
Departmental Ethical Advisory Committee

From : Mrs V-M George, Administrator

To : Nick Jones, Nic James, Steve Mellalieu

Subject : Application for Ethics Committee Approval

Date : 5 Feb 03

Title of Project : An exploratory investigation into the development of performance indicators in professional rugby union.

Your application for ethical approval for SR-311 has been considered by Departmental Ethical Advisory Committee (DEAC) staff members.

Your application has been approved via Chairman's action.

UNIVERSITY OF WALES SWANSEA
DEPARTMENT OF SPORTS SCIENCE
DEPARTMENTAL ETHICAL ADVISORY COMMITTEE

APPLICATION FOR ETHICAL COMMITTEE APPROVAL OF A RESEARCH PROJECT

In accordance with Departmental Safety Policy, all research undertaken in the department must obtain ethical committee approval **prior to** undertaking data collection. Complete this form in consultation with the project supervisor. Where appropriate, your application must include the following appendices: (A) **subject information sheet**; (B) **subject consent form**; and (C) **subject health questionnaire.** After completing all sections of the form (including signatures) seven complete copies must be handed into the Department Administrator by the appropriate due date for consideration by the committee.

N.B. All questions should be answered. Answers should be typewritten.

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1. TITLE OF PROJECT

An exploratory investigation into the development of performance indicators in professional rugby union

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2. NAMES AND STATUS OF RESEARCH TEAM

Nick Jones (Postgraduate Student)
Dr. Nic James (Supervisor)
Dr. Steve Melalieu (Supervisor)

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3. OBJECTIVE

Specifically the study has three objectives. Firstly, to propose a framework of technical performance indicators for each position within rugby union. Secondly, to examine whether position specific normative data can be produced for these performance indicators over a period of one season. Finally, it is intended to examine the sensitivity and variability of the performance indicators in distinguishing between the performances of different individuals of the same position.

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4. SCIENTIFIC BACKGROUND

The ever continuing development of professionalism in sport has led to an increased emphasis upon the importance of coaching and technical support. A key area that has emerged through this transition is the comprehensive analysis of sports performance and tactical formation, known as match or notational analysis (Lyons, 1997). One such sport which has recently experienced the conversion from amateurism to professionalism is that of rugby union. As a consequence of this introduction, rugby union is developing and evolving, whilst individual importance within the sport is shifting rapidly from the players, to the coaching and management staff (Vivian, Mullen and Hughes, 2001). However, while other team sports such as soccer have utilised the benefits of notational analysis, there still appears to be a reluctance by rugby union coaches to apply objective and computerised match analysis procedures (Hughes and White, 1997). This is surprising given the interactive nature of the sport, its similarities in game structure with soccer, and its potential to benefit from the quality feedback that in-depth analysis can provide.

Existing research using notational analysis in rugby union has in general been both limited and descriptive in nature. Early studies predominantly explored patterns of play and positional workrates (e.g. Hughes and Williams, 1988; Treadwell, 1987). More recently, in an attempt to enhance notational research, investigators have suggested that studies should focus upon the development and utilisation of performance indicators (specific behaviours designed to assess performance) within analysis (Hughes and Bartlett, 2002).

Despite the work of the likes of Vivian et al. (2001) and Parsons and Hughes (2001), there is currently insufficient data regarding the performance profiling (utilizing performance indicators) of elite rugby union. In particular there is a dearth of research concerning individual performance indicators and their consequent profiles for all members of a rugby union team. Research has instead focused on the typical role of notational analysis, the analysis of play (Hughes and Williams, 1988), and indicators of successful teams (Hunter and O'Donoghue, 2001). For this reason, the formation of individual performance profiles through the utilisation of key performance indicators and a computerised notation system rigorously tested for reliability, represents an important area for investigation.

References:

- Hughes, M.D. & Bartlett, R.M. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences*, 20, 739-754.
- Hughes, M.D. & White, P. (1996). An analysis of forward play in the 1991 rugby union world cup for men. In M.D. Hughes (Ed.) *Notational Analysis of Sport- I & II.* (pp. 183-191) Cardiff, UK: University of Wales Institute, Cardiff.
- Hughes, M.D. & Williams, D. (1988). The development and application of a computerized rugby union notation system. *Journal of Sports Sciences*, 6, 254-255.
- Hunter, P. & O'Donoghue, P. (2001). A match analysis of the 1999 Rugby Union World Cup. In M.D. Hughes and I. Franks (Eds.) *Pass.com: Fifth World Congress of Performance Analysis of Sport.* (pp. 85-90) Cardiff, UK: Centre for Performance Analysis, University of Wales Institute, Cardiff.
- Lyons, K. (1997). Lloyd Lowell Messersmith: Pioneer of notational analysis of performance in sport. In M.D. Hughes (Ed.) *Notational Analysis of Sport - I & II.* (pp. 49-57) Cardiff, UK: University of Wales Institute, Cardiff.
- Parsons, A. & Hughes, M.D. (2001). Performance profiles of male rugby union players. In M.D. Hughes and I. Franks (Eds.) *Pass.com: Fifth World Congress of Performance Analysis of Sport.* (pp. 129-136) Cardiff, UK: Centre for Performance Analysis, University of Wales Institute, Cardiff.
- Treadwell, P.J. (1987). Computer aided match analysis of selected ball games (soccer and rugby union). In T. Reilly, A. Lees, K. Davids & W.J. Murphy (Eds.) *Science and Football.* (pp. 282-287) London, UK: E&FN Spon.
- Vivian, R., Mullen, R. & Hughes M.D. (2001). Performance profiles at league, European Cup and international levels of male rugby union players, with specific reference to flankers, number 8s and number 9s. In M.D. Hughes and I. Franks (Eds.) *Pass.com: Fifth World Congress of Performance Analysis of Sport.* (pp. 137-143) Cardiff, UK: Centre for Performance Analysis, University of Wales Institute, Cardiff.

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5. SUBJECTS

The games will be obtained from commercially filmed videos via the analysed club's resources. The subjects used are all male professional rugby players from the same elite rugby union club. Permission has been obtained to use the match data although player and team names will not be used so that confidentiality remains throughout.

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6. METHODS

Games will be recorded from terrestrial television and transferred onto digital CD format. A computerised video analysis system will be devised, using a proprietary software package and will be used for post match analysis of the entire seasons games. Using the devised key performance indicators and clear definitions of the analysed behaviours the data will then be compiled to create performance profiles for each of the playing position. The data will be analysed using the SPSS software package.

7. LOCATION AND ADDRESS OF THE PREMISES WHERE THE RESEARCH WILL BE CONDUCTED.

The data collection and analysis will take place on the 7th floor of the Vivian Tower, Motion Analysis Lab, University of Wales Swansea, Singleton Campus, Swansea.

8. SUBJECT RISKS AND DISCOMFORTS

No team or individual names will be disclosed therefore any psychological effects will not exist.

9. INFORMED CONSENT

The submission should be specific about the type of consent that will be sought:

Have you included an information sheet for the participants of the study? YES / **NO**

Will consent be given in written or verbal form? YES / **NO**

10. COMPUTERS

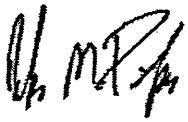
Are computers to be used to store data? **YES** / NO

If so, is the data registered under the Data Protection Act? **YES** / NO

11. STUDENT DECLARATION

Please read the following declarations carefully and detail below any ways in which your project deviates from them. Then each student listed in section 2 is required to sign where indicated.

1. I have ensured that there will be no active deception of participants.
2. I have ensured that no data will be personally identifiable.
3. I have ensured that no participant should suffer any undue physical or psychological discomfort
4. I certify that there will be no administration of potentially harmful drugs, medicines or foodstuffs.
5. I will obtain written permission from an appropriate authority before recruiting members of any outside institution as participants.
6. I certify that the participants will not experience any potentially unpleasant stimulation or deprivation.
7. I certify that any ethical considerations raised by this proposal have been discussed in detail with my supervisor.
8. I certify that the above statements are true with the following exception(s):

Student signature:  Date: 29/11/02

12. SUPERVISOR'S DECLARATION

In the supervisor's opinion, this project (delete those that do not apply):

- Does not raise any significant issues.
- Raises some ethical issues, but I consider that appropriate steps and precautions have been taken and I have approved the proposal.
- Raises ethical issues that need to be considered by the Departmental Ethics Committee.
- Raises ethical issues such that it should not be allowed to proceed in its current form.

Supervisor's signature: N Jones. Date: 29/11/02

13. ETHICS COMMITTEE DECISION (COMMITTEE USE ONLY)

ETHICAL APPROVAL: GRANTED REJECTED (delete as appropriate)

The ethical issues raised by this project have been considered by members of the Departmental Ethical Approval Committee who made the following comments:

.....

.....

.....

.....

.....

.....

Please ensure that you take account of these comments and prepare a revised submission that should be shown to your supervisor/ resubmitted to the Department Ethical Approval Committee (delete as appropriate).

Signed: Date: 31/01/03

(Chair, Departmental Ethical Approval Committee)

APPENDIX B

RESULTS OF SELECTED MATCHES FROM THE 2001/2002 SEASON OF THE ANALYSED PROFESSIONAL TEAM

Appendix B: Results of selected matches from the 2001/2002 season of the analysed professional team.

Match No.	Home/ Away	Result (Analysed Team's Perspective)	Score (Analysed Team First)
1	Home	Lost	13 – 21
2	Away	Won	27 – 21
3	Home	Lost	18 – 24
4	Away	Lost	13 – 25
5	Home	Won	21 – 16
6	Away	Lost	9 – 38
7	Away	Lost	19 – 25
8	Home	Won	15 – 10
9	Home	Won	22 – 14
10	Home	Won	36 – 21
11	Home	Lost	3 – 12
12	Home	Won	35 – 9
13	Away	Lost	15 – 31
14	Home	Lost	12 – 24
15	Away	Lost	20 – 30
16	Away	Won	38 – 3
17	Away	Lost	14 – 16
18	Home	Lost	22 – 27
19	Home	Won	52 – 13
20	Away	Won	21 – 6
21	Home	Won	20 – 16
22	Away	Lost	20 – 37

APPENDIX C

DEFINITIONS OF POSITIONAL ROLES WITHIN RUGBY UNION

Appendix C: Definitions of positional roles within rugby union.

Position	Description of Main Positional Roles
1 Prop (Loosehead)	Responsible for supporting the hooker on the left side of the scrum, supporting the jumpers in the lineout, tackling, carrying and supporting the ball carrier.
2 Hooker	Responsible for throwing the ball into the lineout, winning the ball when it is fed into the scrum, tackling, carrying and supporting the ball carrier.
3 Prop (Tighthead)	Responsible for supporting the hooker on the right side of the scrum, supporting the jumpers in the lineout, tackling, carrying and supporting the ball carrier.
4 Lock/Second Row	Responsible for winning ball at lineouts and restarts, providing the main impetus to the scrum, tackling, carrying and supporting the ball carrier.
5 Lock/Second Row	Responsible for winning ball at lineouts and restarts, providing the main impetus to the scrum, tackling, carrying and supporting the ball carrier.
6 Flanker (Blindside)	Responsible for winning the ball in loose play, supporting the jumpers in the lineout, tackling, carrying and supporting the ball carrier. Binds onto the scrum on whichever side is closest to the touchline.
7 Flanker (Openside)	Responsible for winning the ball in loose play, supporting the jumpers in the lineout, tackling, carrying and supporting the ball carrier. Binds onto the scrum on the side furthest from the touchline.
8 Number Eight	Responsible for providing the scrum-half with good ball from the base of the scrum, launching attacks from the scrum, winning ball in the lineout, tackling, carrying and supporting the ball carrier.
9 Scrum-Half	Responsible for linking between forwards and backs, feeding the ball to the scrum, passing from the base of the set-piece or breakdown, tackling, kicking, carrying and supporting the ball carrier.
10 Outside-Half	Responsible for key decision making within the team, distributing the ball or kicking for territory, tackling, carrying and supporting the ball carrier.
11 Left Wing	Responsible for attacking the opposition with pace, tackling, kicking, fielding kicks and supporting the ball carrier.
12 Inside Centre	Responsible for attacking the opposition and setting up the ball in midfield, tackling, kicking and supporting the ball carrier.
13 Outside Centre	Responsible for attacking the opposition and setting up the ball in midfield, tackling, kicking and supporting the ball carrier.
14 Right Wing	Responsible for attacking the opposition with pace, tackling, kicking, fielding kicks and supporting the ball carrier.
15 Full-Back	Responsible for being the last line of defence against runners and kicks, carrying, kicking, fielding kicks and supporting ball carrier.

(Adapted from BBC Sport Online, 2001)

APPENDIX D

OPERATIONAL DEFINITIONS OF THE CODING STRUCTURE FOR THE SEASON 2001/2002

Appendix D: Operational definitions of the coding structure for the season 2001/2002.

Notes:

- Player's squad numbers are as per the squad numbers sheet for the entire season.
- Play during advantage should be coded unless the referee blows immediately.
- The only opposition actions that should be coded (and are coded as an opposition team event rather than an individual event) are their restarts, charged down kicks, lineouts, scrums, tries, turnovers and penalties, as these have the most bearing upon the analysed team's plays.
- The coding structure is fully explained by the detailed flow diagram.

OPERATIONAL DEFINITIONS			
BEHAVIOUR		**OUTCOME**	
PASS	A throw of the ball from a player's hands to another player of the same team.	**Successful**	• A pass that goes straight to the receiving player's hands (regardless of whether or not the ball is caught).
		Unsuccessful	• When the ball hits the floor before reaching the receiving player. • If the pass is intercepted. • When the ball is passed and the receiving player has to alter their running speed, or move their hands to above their shoulders or below their knees in order to catch the ball.
GOAL KICK	A place-kick attempt at the posts in the form of a penalty or conversion.	**Successful**	• If the kick goes through the posts.
		Unsuccessful	• If the kick fails to go through the posts.
TOUCH KICK	A kick out of the hands of a player with the aim of putting the ball into touch.	**Successful**	• If the ball reaches touch.
		Unsuccessful	• If the ball fails to make touch (however, if a player clearly kicks long over the top of the opposition, it should be coded as a successful, long kick).
DROP KICK	A drop kick attempt at the posts during open play.	**Successful**	• If the kick goes through the posts.
		Unsuccessful	• If the kick fails to go through the posts.

LONG KICK	A kick out of the hands with the aim of gaining territorial advantage through the length of the kick.	**Successful**	• If possession is regained, if the ball bounces into space, into touch with more than forty metres gained, or if heavy pressure is applied to the opposition as they gather the ball.
		Unsuccessful	• If the ball is miss-kicked straight into touch, or straight to the opposition.
HACK KICK	A kick from the floor not from the hand in open play.	**Successful**	• If possession is regained, if the ball bounces into space, into touch with territorial gain, or if heavy pressure is applied to the opposition as they gather the ball.
		Unsuccessful	• If the ball is miss-kicked straight into touch, or straight to the opposition.
GRUBBER KICK	A kick from the hand that is deliberately kicked along the floor.	**Successful**	• If possession is regained, if the ball bounces into space, into touch with territorial gain, or if heavy pressure is applied to the opposition as they gather the ball.
		Unsuccessful	• If the ball is miss-kicked straight into touch, or straight to the opposition.
CHIP KICK	A delicate kick that is just put over an opposing player's head with the intention of regaining possession.	**Successful**	• If possession is regained, if the ball bounces into space, into touch with territorial gain, or if heavy pressure is applied to the opposition as they gather the ball.
		Unsuccessful	• If the ball is miss-kicked straight into touch, or straight to the opposition.
UP 'N' UNDER	A high hanging kick which allows team-mates to get underneath the ball as it comes down.	**Successful**	• If the ball can be challenged for when it comes down, and the chasers do not have to significantly check their run.
		Unsuccessful	• If it is not possible to challenge for the ball when it comes down, or if the chasers have to significantly check their run.

CARRY	When a player makes an intentional run to gain ground with the ball, a carry is coded, irrespective of what subsequently occurs (e.g. player passes the ball after running with it).	**Successful**	• If a player carries the ball and is knocked back in the first line of defence but the ball is made available. • If a break (breaking a tackle) is made (however, if the ball is not made available, or lost, when eventually tackled, an opposition turnover should be coded rather than reverting to an unsuccessful carry). • In addition, if there is a handling error at the end of a player's break: a successful carry should be coded along with a handling error at the relevant point.
		Unsuccessful	• Losing the ball when carrying into the first line of defence. • Getting tackled at the first line of defence, and either getting turned over or conceding a scrum. • If a player gets tackled into touch whilst carrying the ball. However if the player has made at least 10 metres before carrying into touch a successful carry should be recorded.
TACKLE	An attempt to physically bring an opposition player to the ground or stop them running.	**Successful**	• Bringing an opposing player to the ground or to a standstill. • The tackle should then be coded appropriately as to whether or not the ball was offloaded in the tackle. • However if a pass is made before the tackle, the tackle should not be coded. • If there is a double tackle situation, both tackling players should be coded as having made a tackle.
		Unsuccessful	• A failed attempt to bring an opposing player to the ground or to a standstill.
RESTART TAKE	A collection of the ball from a kick-off.	**Successful**	• If the ball is won cleanly, or deliberately tapped back from a restart.
		Unsuccessful	• If a player is in position to make a restart take but an error is made. • However, if an unsuccessful restart take is coded, a handling error should not be coded as only one mistake has been made.

LONG KICK-OFF	If kick-off is from the halfway and the ball is kicked past an imaginary line, 2 metres before the 22. If kick-off is a 22 drop out and the ball is kicked past the halfway line. When it is an opposition kick-off it should be coded as an opposition kick off. When it is the analysed team's kick-off it should be coded to a particular player (e.g. outside-half).	**Successful**	• On the opposition's kick-offs, if the analysed team retain the ball. • On the analysed team's kick-offs if pressure is applied by the players following up the kick so that the opposition are not able to get back beyond the halfway line with their first phase of play.
		Unsuccessful	• On the opposition's kick if the ball is not retained by the analysed team. • On the analysed team's kick-offs, if pressure is not applied by the players following up on the kick and the opposition reach the analysed team's half with their first phase of play.
		Incomplete	• If the kick-off (either side's) does not go ten metres (halfway kick off), or over the 22 line (22 metre drop outs). • The kick goes straight into touch. • The kick is made with players in front of the ball. • The kick goes over the dead ball line.
SHORT KICK-OFF	If kick off is from the halfway and the ball is kicked between the opposing 10 metre line and two metres from the 22 metre line. If kick off is a 22 drop out and the ball is not kicked past the halfway line. When it is an opposition kick-off it should be coded as an opposition kick off. When it is the analysed team's kick-off it should be coded to a particular player (e.g. outside-half).	**Successful**	• If the ball is won by the analysed team (on both the opposition and their own kick offs) within the first phase of play.
		Unsuccessful	• If the opposition win the ball (on both the opposition and their own kick offs) within the first phase of play.
		Incomplete	• If the kick-off (either side's) does not go 10 metres (halfway kick off), or over the 22 line (22 metre drop outs). • The kick goes straight into touch. • The kick is made with players in front of the ball. • The kick goes over the dead ball line.

LINEOUT	A set piece lineout resulting from the ball having been played into touch.	**Successful**	• A lineout that is won by the analysed team (regardless of who's throw in it is). • The lineout should be coded as a team event before the individual skills are coded. For example, on an analysed team lineout it should be coded as whether it is successful or not before the hooker and the lineout jumper are labelled for their individual skills.
		Unsuccessful	• A lineout that is lost by the analysed team (regardless of who's throw in it is). • If an analysed team lineout is given as not straight by the referee (along with a coding for an unsuccessful throw by the hooker).
		Incomplete	• If an opposition lineout is given as not straight. • When a penalty or free-kick is awarded due to foul-play during the lineout (on either side's throw).
LINEOUT THROW	A throw from the analysed team hooker into the lineout.	**Successful**	• If the throw goes straight and to the lineout jumper.
		Unsuccessful	• If the throw is not straight. • If the throw is too high or low, and does not go to the lineout jumper. • However, if the hooker's throw is unsuccessful and the ball is lost due to this, then there should not be a subsequent entry for the jumper.
SCRUM	A set piece scrummage resulting from a breakdown in open play.	**Successful**	• A scrum that is won by the analysed team (regardless of who's put in it is). • When the scrum is turned on the oppositions put in and the referee applies the 'use it or lose it' law. • Any reset scrums should be ignored, coding should only be applied to a scrum which results in a free-kick or a penalty, or an ensuing passage of play.
		Unsuccessful	• A scrum that is lost by the analysed team (regardless of who's put in it is). • When the scrum is turned on an analysed team put in and the 'use it or lose it' law is applied.
		Incomplete	• If a penalty or free-kick is awarded to either side during the scrum (e.g. collapsing the scrum or the hooker lifting his leg before the ball is put in).

HIGH BALL TAKE	An attempt to catch a kicked ball by a player.	**Successful**	• A clean catch of the ball from an opposition kick (not restart kick) by a player.
		Unsuccessful	• If a player is in position to catch the ball from a kick but they make an error in the process. • However, if an unsuccessful high ball take is coded, a handling error should not be coded in addition as only one mistake has been made.
LINEOUT TAKE	An attempt to claim the ball in a lineout by a player.	**Successful**	• If a lineout is taken cleanly or deliberately tapped back by a player.
		Unsuccessful	• If an error is made by a player whilst trying to claim a lineout (however a handling error should not be coded in addition, as only the one mistake has been made).

The table of Operational Definitions continues on the next page with those behaviours where the coding of an outcome is not necessary.

BEHAVIOUR	DEFINITION
A TIDY	• A touch of the ball by a player which is neither a pass nor a carry. • No movement is made by the player, except to 'tidy' the ball (for example diving down to the ball on the floor to set up a ruck). • When the ball is put down by a player from the analysed team over their own try line for a 22 drop out. • When the ball is deliberately tapped back along the floor to another player from the analysed team.
HANDLING ERROR	• When a player touches the ball with their upper body, and the ball goes to ground (the ball does not have to go forward for it to be a handling error). • However, if the ball is tapped back deliberately then this should be coded appropriately as a pass or a tidy.
CHARGE DOWN	• If a kick is charged down it should not be coded as a kick, instead as a charge down to the player who was attempting the kick. • It should only be coded as an unsuccessful kick if the ball does not go where the player intended to kick it (for example if a kick is charged down when a player is kicking for touch and the ball still reaches touch a charge down should be coded as well as a successful kick). • If a player from the analysed team makes a charge down it should simply be coded as an opposition charge down.
PENALTY	• Penalties should be coded as who has given them away. For example if a player from the analysed team infringes, he should be coded as giving away a penalty. If it is not clear which player infringed then it should be coded as an analysed team penalty. If the analysed team are given a penalty it should be coded as an opposition penalty as they gave it away. • Penalties should be coded as normal, yellow or red card offences. • A penalty is an offence by a player. For example if two players are yellow carded at the same time then code as two yellow penalties. • A free-kick should also be labelled appropriately as a penalty.
TURNOVER	• Turnovers should only be coded to an individual from the analysed team if the turnover is made by an analysed team player. If there is uncertainty about who has won the turnover it should be coded as an analysed team turnover. • If a turnover is against the analysed team it should be coded as an opposition turnover. • An interception by a player should also be coded as a turnover. The aforementioned turnover coding rules also apply for this situation. • A turnover should only be coded if play continues. If the referee blows and gives a scrum to the opposition when the analysed team are attacking, or if the analysed team receive a scrum after an opposition attack, a turnover should not be coded. • In addition, the side that lose the turnover must have had control of the ball before it was lost.

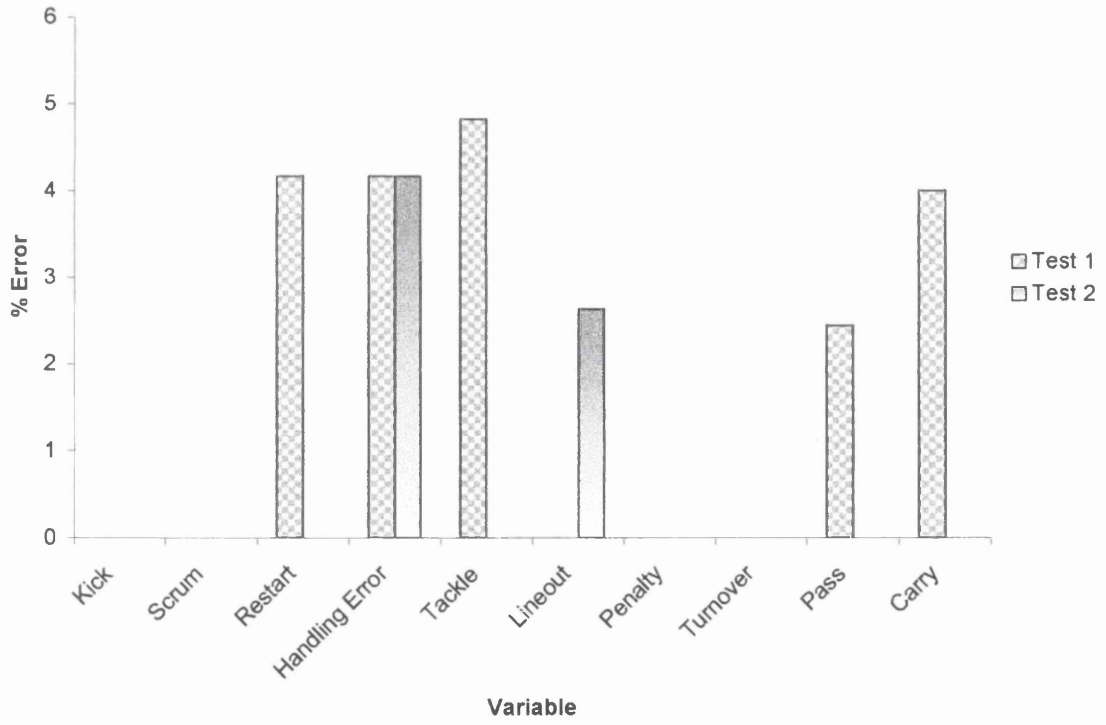
TRY	• A try from the analysed team should be coded to the player who scored it. • A penalty try for the analysed team should be coded as a team try. • A try by the opposition should be coded as 'an opposition try'. • A penalty try against the analysed team should be coded as a penalty and an opposition try.

APPENDIX E

RESULTS OF THE INTRA AND INTER-OBSERVER RELIABILITY TESTS CONDUCTED DURING STUDY 1

Appendix E.1: Summary of errors for each variable during the intra-observer reliability test conducted during study 1.

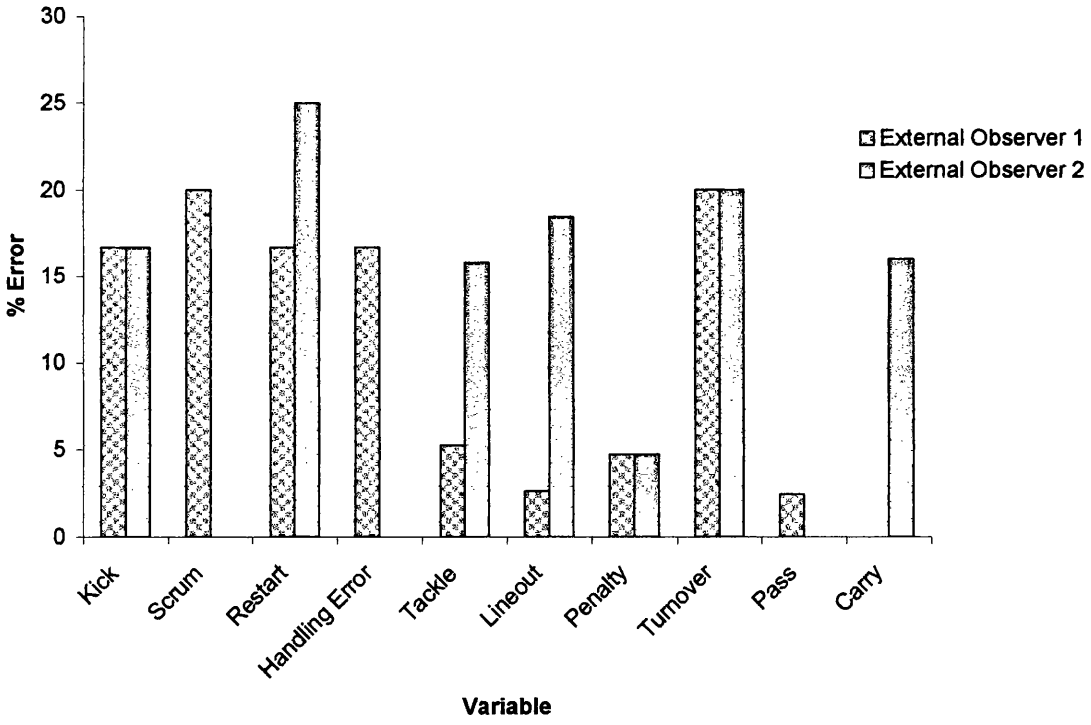
Intra-Observer Reliability			
Area of Error	Total no. of entries in area	Test 1 Errors	Test 2 Errors
Kick	108	0 **(0%)**	0 **(0%)**
Scrum	60	0 **(0%)**	0 **(0%)**
Restart	72	3 **(4.16%)**	0 **(0%)**
Handling Error	72	3 **(4.16%)**	3 **(4.16%)**
Tackle	228	11 **(4.82%)**	0 **(0%)**
Lineout	228	0 **(0%)**	6 **(2.63%)**
Penalty	126	0 **(0%)**	0 **(0%)**
Turnover	30	0 **(0%)**	0 **(0%)**
Pass	246	6 **(2.44%)**	0 **(0%)**
Carry	150	6 **(4%)**	0 **(0%)**
Totals	1320	29 **(2.2%)**	9 **(0.68%)**



Appendix E.2: Percentage errors for the intra-observer reliability test conducted during study 1.

Appendix E.3: Summary of errors for each variable during the inter-observer reliability test conducted during study 1.

Inter-Observer Reliability			
Area of Error	Total no. of entries in area	External Observer 1 Errors	External Observer 2 Errors
Kick	108	18 **(16.67%)**	18 **(16.67%)**
Scrum	60	12 **(20%)**	0 **(0%)**
Restart	72	12 **(16.67%)**	18 **(25%)**
Handling Error	72	12 **(16.67%)**	0 **(0%)**
Tackle	228	12 **(5.26%)**	36 **(15.79%)**
Lineout	228	6 **(2.63%)**	42 **(18.42%)**
Penalty	126	6 **(4.76%)**	6 **(4.76%)**
Turnover	30	6 **(20%)**	6 **(20%)**
Pass	246	6 **(2.44%)**	0 **(0%)**
Carry	150	0 **(0%)**	24 **(16%)**
Totals	1320	90 **(6.82%)**	150 **(11.36%)**



Appendix E.4: Percentage errors for the inter-observer reliability test conducted during study 1.

APPENDIX F

MEDIANS AND 95% CONFIDENCE LIMITS FOR INDIVIDUAL PERFORMANCE INDICATORS FROM THE 2001/2002 SEASON OF THE ANALYSED PROFESSIONAL TEAM

Appendix F.1: Medians (*Mdn*) and 95% confidence limits of PIs for players 1, 3, 24 and 2 from the 2001/2002 season of the analysed professional team.

	Player 1 (Prop) 13 Matches			Player 3 (Prop) 22 Matches			Player 24 (Prop) 15 Matches			Player 2 (Hooker) 13 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5**	6.2	1	**3**	6.7	2.8	**3**	4	1	**4**	6.3	1.9
Unsuccessful Tackles	**0**	4	0	**0**	0	0	**1**	1.8	0	**0**	1.2	0
Successful Carries	**6.2**	15.5	2.1	**2**	4	1	**4**	6	2	**2.5**	5.8	1.2
Unsuccessful Carries	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1.1	0
Successful Passes	**0**	3	0	**0**	1	0	**3**	5.7	2	**0**	2	0
Unsuccessful Passes	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0
Handling Errors	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0
Normal Penalties	**0**	2.1	0	**0**	1	0	**0**	1	0	**0**	1.1	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Successful Throw-ins	-	-	-	-	-	-	-	-	-	**9**	11.3	7
Unsuccessful Throw-ins	-	-	-	-	-	-	-	-	-	**2.5**	4	1.3

Appendix F.2: Medians (*Mdn*) and 95% confidence limits of PIs for players 4, 5, 25 and 29 from the 2001/2002 season of the analysed professional team.

	Player 4 (Lock) 20 Matches			Player 5 (Lock) 14 Matches			Player 25 (Lock) 14 Matches			Player 29 (Lock) 11 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**6.1**	8	5.1	**3**	7	2.3	**4.3**	12.4	2.6	**5**	10	2.9
Unsuccessful Tackles	**0.5**	1.3	0	**0**	2.3	0	**0**	1.8	0	**0**	1	0
Successful Carries	**1.7**	3	1	**2**	4	0	**1.3**	2.7	0	**3**	4.4	0
Unsuccessful Carries	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Successful Passes	**0**	1	0	**1.5**	3.3	0	**0**	3	0	**0**	2.5	0
Unsuccessful Passes	**0**	0	0	**0**	1	0	**0**	1.1	0	**0**	0	0
Handling Errors	**1**	1.3	0	**0**	1.8	0	**0**	0	0	**0**	2.2	0
Normal Penalties	**1.2**	2.1	0	**0.5**	2	0	**0**	0	0	**0**	2.9	0
Yellow Cards	**1.2**	2.1	0	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Successful Lineout Takes	**3.1**	5	1.3	**4.8**	7	2	**5.8**	9	0	**3**	6.3	0
Unsuccessful Lineout Takes	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1.2	0
Successful Restart Takes	**0**	1.8	0	**0**	2	0	**0**	1.6	0	**0**	1	0
Unsuccessful Restart Takes	**0**	1	0	**0**	1.8	0	**0**	1	0	**0**	1.2	0

Appendix F.3: Medians (*Mdn)* and 95% confidence limits of PIs for players 6, 26, 7 and 8 from the 2001/2002 season of the analysed professional team.

	Player 6 (Blind-Side) 13 Matches			Player 26 (Blind-Side) 9 Matches			Player 7 (Open-Side) 22 Matches			Player 8 (Number Eight) 12 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**12.9**	15.4	8	**7**	8	3	**10.6**	14	9	**7**	9	4
Unsuccessful Tackles	**1**	1	0	**1**	2	0	**1**	2	0	**1**	2	0
Successful Carries	**9**	13.6	6	**7**	9	0	**2.3**	4	1	**8.4**	10	6.2
Unsuccessful Carries	**0**	0	0	**0**	8	0	**0**	0	0	**0**	1	0
Successful Passes	**2**	3.4	1	**7.7**	13	5	**1.3**	2	0	**4.3**	7	0
Unsuccessful Passes	**0**	0	0	**0**	1.2	0	**0**	0	0	**0**	2	0
Handling Errors	**1**	2	0	**1**	3	0	**0**	1	0	**0.5**	1.1	0
Normal Penalties	**1**	2.1	0	**1**	2.4	0	**1**	2	0	**1**	1.1	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Turnovers Won	**2**	2	0	**0**	0	0	**0.5**	1	0	**0**	0	0

Appendix F.4: Medians (*Mdn*) and 95% confidence limits of PIs for players 17, 10, 21 and 12 from the 2001/2002 season of the analysed professional team.

	Player 17 (Scrum-Half) 16 Matches			Player 10 (Outside-Half) 14 Matches			Player 21 (Outside-Half) 11 Matches			Player 12 (Centre) 21 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**10.4**	11.7	4	**3**	5	1	**7**	11	0	**7**	9	4
Unsuccessful Tackles	**1.7**	3.2	0	**1**	2	0	**0**	5	0	**1**	2	0
Successful Carries	**9.9**	11.8	8	**2**	5	1	**6**	13	3	**8**	10	6
Unsuccessful Carries	**0**	1.3	0	**0**	1	0	**0**	1.2	0	**0**	1	0
Successful Passes	**45.1**	53.2	37.7	**20**	28	14.2	**14**	20.9	9	**8.6**	10	5
Unsuccessful Passes	**2.9**	5.2	1	**1**	2	0	**1**	4.7	0	**1**	2	0
Handling Errors	**1.2**	2.5	1	**0**	2	0	**0**	1	0	**1**	2	0
Normal Penalties	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0
Successful Kicks	**3.1**	4.4	1	**15.5**	17	12	**13**	15	7.8	**0**	1	0
Unsuccessful Kicks	**2**	3	1	**5**	6	3	**7**	13	3.5	**0**	0	0

Appendix F.5: Medians (*Mdn*) and 95% confidence limits of PIs for players 20, 11 and 13 from the 2001/2002 season of the analysed professional team.

	Player 20 (Centre) 11 Matches			Player 11 (Outside-Back) 11 Matches			Player 13 (Outside-Back) 13 Matches		
	Mdn	+CL	-CL	*Mdn*	+CL	-CL	*Mdn*	+CL	-CL
Successful Tackles	**5**	6	3	**3**	5	0	**3**	4.2	2
Unsuccessful Tackles	**1**	2.5	0	**0**	1.3	0	**0**	1.1	0
Successful Carries	**8**	12	3	**4**	5.5	1	**6**	9	4
Unsuccessful Carries	**0**	0	0	**0**	2	0	**0**	1	0
Successful Passes	**4**	7.4	0	**0**	2	0	**2**	3	1
Unsuccessful Passes	**0**	1	0	**0**	0	0	**0**	0	0
Handling Errors	**0**	3	0	**0**	2	0	**0**	1	0
Normal Penalties	**0**	2	0	**0**	1.7	0	**0**	0	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	1	0	**0**	0	0	**0**	0	0
Successful Kicks	**0**	1	0	**0**	2.1	0	**0**	1	0
Unsuccessful Kicks	**0**	0	0	**0**	1	0	**0**	0	0
Successful High Ball Takes	-	-	-	**0**	2	0	**0**	2	0
Unsuccessful High Ball Takes	-	-	-	**0**	1	0	**0**	1	0

Appendix F.6: Medians (*Mdn*) and 95% confidence limits of PIs for players 14, 18 and 15 from the 2001/2002 season of the analysed professional team.

	Player 14 (Outside-Back) 11 Matches			Player 18 (Outside-Back) 9 Matches			Player 15 (Outside-Back) 17 Matches		
	Mdn	+CL	-CL	*Mdn*	+CL	-CL	*Mdn*	+CL	-CL
Successful Tackles	**4**	7	2	**4**	7	3	**4**	5.5	2
Unsuccessful Tackles	**1**	2	0	**1**	2	0	**1**	1	0
Successful Carries	**4**	7	3	**7**	9	5	**6**	6	5
Unsuccessful Carries	**0**	1	0	**0**	1	0	**0**	1	0
Successful Passes	**2**	4	1	**1**	2	0	**5**	7	3.7
Unsuccessful Passes	**0**	1	0	**0**	1	0	**1**	1	0
Handling Errors	**0**	2	0	**0**	1	0	**1**	1	0
Normal Penalties	**0**	1	0	**0**	1	0	**0**	1	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0
Successful Kicks	**0**	1	0	**0**	1	0	**3**	5	2
Unsuccessful Kicks	**0**	1	0	**0**	0	0	**1**	2	0
Successful High Ball Takes	**0**	1	0	**0**	2	0	**1**	3	1
Unsuccessful High Ball Takes	**0**	1	0	**0**	0	0	**0**	1	0

APPENDIX G

RESULTS OF SELECTED MATCHES FROM THE 2002/2003 SEASON OF THE ANALYSED PROFESSIONAL TEAM

Appendix G: Results of selected matches from the 2002/2003 season of the analysed professional team.

Match No.	Home/ Away	Result (Analysed Team's Perspective)	Score (Analysed Team First)
1	Home	Lost	16 – 20
2	Home	Won	38 – 10
3	Away	Lost	27 – 38
4	Away	Lost	6 – 62
5	Home	Lost	10 – 51
6	Home	Won	33 – 20
7	Home	Won	26 – 19
8	Away	Lost	23 – 41
9	Home	Won	20 – 19
10	Away	Won	23 – 14
11	Away	Lost	23 – 45
12	Away	Lost	19 – 48
13	Home	Lost	19 – 24
14	Home	Lost	19 – 32
15	Away	Won	46 – 21
16	Home	Won	21 – 17
17	Away	Lost	27 – 44
18	Away	Lost	29 – 56
19	Away	Lost	14 – 42
20	Home	Won	52 – 40

APPENDIX H

OPERATIONAL DEFINITIONS OF THE CODING STRUCTURE FOR THE SEASON 2002/2003

Appendix H: Operational definitions of the coding structure for the season 2002/2003.

Notes:

- Player's squad numbers are as per the squad numbers sheet for the entire season.
- Play during advantage should be coded unless the referee blows immediately.
- The only opposition actions that should be coded (and are coded as an opposition team event rather than an individual event) are their restarts, charged down kicks, lineouts, scrums, rucks, mauls, tries, attempts at goal, and penalties, as these have the most bearing upon the analysed team's plays.
- The coding structure is fully explained by the detailed flow diagram.
- Operational definitions are only included if they were amended or added to the operational definitions for study 1 (Appendix D).

OPERATIONAL DEFINITIONS			
BEHAVIOUR		**OUTCOME**	
GOAL KICK	A place-kick attempt at the posts in the form of a penalty or conversion.	**Successful**	• If the kick goes through the posts. • Opponent's goal kicks should also be coded as successful or unsuccessful.
		Unsuccessful	• If the kick fails to go through the posts.
TOUCH KICK	A kick out of the hands of a player with the aim of putting the ball into touch.	**Successful**	• If the ball reaches touch. A touch kick from a penalty should be coded as a penalty touch kick.
		Unsuccessful	• If the ball fails to make touch (however, if a player clearly kicks long over the top of the opposition, it should be coded as a successful, long kick).
DROP KICK	A drop kick attempt at the posts during open play.	**Successful**	• If the kick goes through the posts. • Opponent's drop kicks should also be coded.
		Unsuccessful	• If the kick fails to go through the posts.
LINEOUT THROW	A throw from the analysed team hooker into the lineout.	**Successful**	• If the throw goes straight and to the lineout jumper. • The throw should also be coded as either a back, middle or front throw.
		Unsuccessful	• If the throw is not straight. • If the throw is too high or low, and does not go to the lineout jumper. • However, if the hooker's throw is unsuccessful and the ball is lost due to this, then there should not be a subsequent entry for the jumper.

LINEOUT	A set piece lineout resulting from the ball having been played into touch.	**Successful**	• A lineout that is won by the analysed team (regardless of who's throw in it is). • The lineout should be coded as a team event before the individual skills are coded. For example, on an analysed team lineout it should be coded as whether it is successful or not before the hooker and the lineout jumper are labelled for their individual skills. • In addition the lineout should be coded as a back, middle or front throw.
		Unsuccessful	• A lineout that is lost by the analysed team (regardless of who's throw in it is). • If an analysed team lineout is not straight from the referee (along with a coding for an unsuccessful throw by the hooker).
		Incomplete	• Opposition lineout is given as not straight. • A penalty or free-kick from foul-play during the lineout (on either side's throw).
LINEOUT TAKE	An attempt to claim the ball in a lineout by a player.	**Successful**	• If a lineout is taken cleanly or deliberately tapped back by a player. • In addition the lineout take should be coded as whether it was a back, middle or front lineout take.
		Unsuccessful	• If an error is made by a player whilst trying to claim a lineout (however a handling error should not be coded in addition, as only the one mistake has been made).
PHASE	A passage of play within a passage of possession of a team which is ended by a breakdown (ruck, maul, scrum etc.).	**Phase No.**	• A phase number should be inputted for each phase. For example during a passage of play on the second phase, phase 2 should be inputted. • In addition a code should be entered to indicate whether the particular phase was the last of that movement or whether there was an ensuing phase.

CARRY	When a player makes an intentional run to gain ground with the ball, a carry is coded, irrespective of what subsequently occurs (e.g. player passes the ball after running with it).	**Successful**	• If a player carries the ball and is knocked back in the first line of defence but the ball is made available. • If a break (breaking a tackle) is made (however, if the ball is not made available, or lost, when eventually tackled, an opposition turnover should be coded rather than reverting to an unsuccessful carry) a break should also be coded. • In addition, if there is a handling error at the end of a player's break: a successful carry should be coded along with a handling error at the relevant point.
		Unsuccessful	• Losing the ball when carrying into the first line of defence. • Getting tackled at the first line of defence, and either getting turned over or conceding a scrum. • If a player gets tackled into touch whilst carrying the ball. However if the player has made at least 10 metres before carrying into touch a successful carry should be recorded.
RUCK	A breakdown where a player is tackled and the ball is at ground level.	**Successful**	• If the ball is won by the analysed team. • If the whistle is blown but play is retained for the following set-piece by the analysed team.
		Unsuccessful	• If the ball is lost in that passage of play by the analysed team (a turnover against should also be coded). • If a ruck is formed but the whistle is blown and the set-piece is awarded to the opposition.
		Incomplete	• If a penalty is awarded to either side during a ruck.

MAUL	A breakdown where a player is tackled and the ball is not at ground level but in the air.	**Successful**	• If the ball is won by the analysed team. • If the whistle is blown but play is retained for the following set-piece by the analysed team.
		Unsuccessful	• If the ball is lost in that passage of play by the analysed team (a turnover against should also be coded). • If a maul is formed but the whistle is blown and the set-piece is awarded to the opposition.
		Incomplete	• If a penalty is awarded to either side during a maul.

The table of Operational Definitions continues below with those behaviours where the coding of an outcome is not necessary.

BEHAVIOUR	DEFINITION
CLEANING OUT	• The code used for a player who follows a ball carrier into a ruck or maul to ensure that possession is retained. If three players follow the ball carrier into the ruck, three separate codes of clean should be made. A clean should not be coded if the player is simply leaning at the back of a ruck, the emphasis is purely on work rate to secure possession.
AREA 1/2/3	• The field is split up into thirds with area one being the defending third, and area three being the attacking third. When the ball crosses into an area it should be coded as doing so. Another code should then be entered when the ball travels into a different area.
ERRORS MADE	• Unsuccessful carries, unsuccessful tackles, unsuccessful passes, unsuccessful throws, unsuccessful lineout takes, unsuccessful restart takes, unsuccessful kicks, unsuccessful high ball takes, unsuccessful analysed team rucks, mauls, scrums and lineouts, opposition turnovers, handling errors and penalties given away.

APPENDIX I

MEDIANS AND 95% CONFIDENCE LIMITS FOR INDIVIDUAL PERFORMANCE INDICATORS FROM THE 2002/2003 SEASON OF THE ANALYSED PROFESSIONAL TEAM

Appendix I.1: Medians (*Mdn*) and 95% confidence limits of PIs for players 24, 3 and 36 from the 2002/2003 season of the analysed professional team.

	Player 24 (Prop) 13 Matches			Player 3 (Prop) 13 Matches			Player 36 (Prop) 16 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**3.7**	6	2.6	**5**	7.4	3.8	**5.1**	6	2.7
Unsuccessful Tackles	**0**	1	0	**0**	1	0	**0**	1.2	0
Successful Carries	**4**	5.5	2.3	**2.6**	4	2	**2**	5.4	0
Unsuccessful Carries	**0**	0	0	**0**	0	0	**0**	0	0
Successful Passes	**4**	5	2	**0**	1.5	0	**0**	3	0
Unsuccessful Passes	**0**	2	0	**0**	0	0	**0**	0	0
Handling Errors	**0**	0	0	**0**	1	0	**0**	0	0
Normal Penalties	**0**	1	0	**0**	1.3	0	**0**	1.2	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0
Cleaning Out	**12.4**	20.8	9	**22**	25.2	15.6	**15.5**	22.4	9.2

Appendix I.2: Medians (*Mdn*) and 95% confidence limits of PIs for players 16, 27 and 32 from the 2002/2003 season of the analysed professional team.

	Player 16 (Prop) 11 Matches			Player 27 (Hooker) 18 Matches			Player 32 (Lock) 16 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5.8**	10	0	**5.9**	7.9	4.5	**6**	9.1	4.1
Unsuccessful Tackles	**0**	1.4	0	**0**	1	0	**0**	0	0
Successful Carries	**9**	12.1	2.9	**3.4**	4.3	2.6	**4**	5	3
Unsuccessful Carries	**0**	0	0	**0**	0	0	**0**	0	0
Successful Passes	**0**	2.9	0	**2.1**	4.3	1	**0**	1	0
Unsuccessful Passes	**0**	0	0	**0**	0	0	**0**	0	0
Handling Errors	**0**	1	0	**0**	0	0	**0**	0	0
Normal Penalties	**0**	0	0	**0**	1.2	0	**0**	1	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0
Cleaning Out	**4.4**	46	0	**13.3**	17.4	10.9	**17.3**	25.1	13
Successful Throw-ins	-	-	-	**9.8**	10.9	7.9	-	-	-
Unsuccessful Throw-ins	-	-	-	**3.1**	5	2.4	-	-	-
Successful Lineout Takes	-	-	-	-	-	-	**2**	3	0
Unsuccessful Lineout Takes	-	-	-	-	-	-	**0**	0	0
Successful Restart Takes	-	-	-	-	-	-	**0**	1	0
Unsuccessful Restart Takes	-	-	-	-	-	-	**0**	0	0

Appendix I.3: Medians (*Mdn*) and 95% confidence limits of PIs for players 25, 35 and 28 from the 2002/2003 season of the analysed professional team.

	Player 25 (Lock) 10 Matches			Player 35 (Lock) 15 Matches			Player 28 (Lock) 10 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5.4**	8.8	3	**11.2**	13	7.9	**8.5**	13	0
Unsuccessful Tackles	**0.5**	1.8	0	**0**	1	0	**0**	2	0
Successful Carries	**2.5**	4	0	**3.2**	7.8	2	**2.5**	7	0
Unsuccessful Carries	**0**	0	0	**0**	0	0	**0**	0	0
Successful Passes	**2**	3	0	**1.1**	2	0	**0**	2	0
Unsuccessful Passes	**0**	1.3	0	**0**	0	0	**0**	0	0
Handling Errors	**0**	1.1	0	**0**	0	0	**0**	1	0
Normal Penalties	**0**	1	0	**0**	1.1	0	**0**	0	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0
Cleaning Out	**16.1**	26.9	12.9	**28**	37.9	26	**25.5**	37.6	15
Successful Lineout Takes	**4.5**	6.2	0	**3**	5	1.8	**2.1**	6	0
Unsuccessful Lineout Takes	**0**	1	0	**0**	1.1	0	**0**	0	0
Successful Restart Takes	**0**	1	0	**0**	1.1	0	**0**	1	0
Unsuccessful Restart Takes	**0**	0	0	**0**	0	0	**0**	1	0

Appendix I.4: Medians (*Mdn*) and 95% confidence limits of PIs for players 6, 19, 7 and 33 from the 2002/2003 season of the analysed professional team.

	Player 6 (Blind-Side) 8 Matches			Player 19 (Blind-Side) 9 Matches			Player 7 (Open-Side) 15 Matches			Player 33 (Number Eight) 15 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**10.8**	17.8	7.8	**11.3**	11.6	7.4	**13**	17	10	**10.8**	11	6
Unsuccessful Tackles	**0**	2.1	0	**1.2**	1.2	0	**0**	2	0	**0**	0	0
Successful Carries	**6.1**	10	2.6	**6**	7.1	2.5	**1**	2.7	0	**9**	11	7
Unsuccessful Carries	**0**	1.1	0	**0**	1.2	0	**0**	0	0	**0**	1	0
Successful Passes	**3.6**	7	0	**2.4**	5.8	0	**1.5**	2.2	0	**3**	5	2
Unsuccessful Passes	**0**	2.1	0	**0**	0	0	**0**	0	0	**0**	1	0
Handling Errors	**0**	2	0	**0**	0	0	**0**	1	0	**0**	1	0
Normal Penalties	**0**	2	0	**1.2**	2.4	0	**0**	1.1	0	**0**	1	0
Yellow Cards	**0**	1.2	0	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0
Cleaning Out	**17.5**	26	10	**16.2**	29.4	12.4	**23.1**	26	18	**18**	22	13
Turnovers Won	**1**	3.6	0	**0**	2.5	0	**1**	1.5	0	**0**	1	0

Appendix I.5: Medians (*Mdn*) and 95% confidence limits of PIs for players 9, 34, 10 and 21 from the 2002/2003 season of the analysed professional team.

	Player 9 (Scrum-Half) 15 Matches			Player 34 (Scrum-Half) 18 Matches			Player 10 (Outside-Half) 17 Matches			Player 21 (Outside-Half) 11 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5.5**	10.5	4	**7.6**	9.9	5.2	**5**	6	2.4	**7.3**	12.7	3.3
Unsuccessful Tackles	**0**	4.7	0	**0**	1	0	**2.4**	3.5	1	**3**	5.5	0
Successful Carries	**3.5**	7.6	0	**1.9**	4.1	1.1	**2**	3	0	**5**	9.8	2
Unsuccessful Carries	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0
Successful Passes	**47.2**	80.7	30.4	**37.8**	44.2	32	**16.2**	33	11.4	**13.6**	21	4.9
Unsuccessful Passes	**0**	1.5	0	**2.2**	3.1	0	**2**	3	0	**2**	6.3	0
Handling Errors	**0**	1.3	0	**0**	1	0	**0**	1	0	**1**	2.1	0
Normal Penalties	**0**	0	0	**0**	1	0	**0**	0	0	**0**	2	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	0	0	**0**	0	0	**0**	0	0	**0**	2.5	0
Cleaning Out	**2.8**	6.3	0	**1.6**	3.7	0	**2**	6	0	**2.5**	8	0
Successful Kicks	**1.3**	3.2	0	**1.6**	3	1	**12.7**	15.5	11.1	**15.4**	19.7	6.3
Unsuccessful Kicks	**0**	0	0	**0**	1.3	0	**3**	3.1	1	**3.7**	6.6	0

Appendix I.6: Medians (*Mdn*) and 95% confidence limits of PIs for players 12, 20 and 22 from the 2002/2003 season of the analysed professional team.

	Player 12 (Centre) 14 Matches			Player 20 (Centre) 13 Matches			Player 22 (Centre) 13 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5.5**	10	3.4	**11**	13.8	7.7	**8.3**	10	5
Unsuccessful Tackles	**0**	2	0	**1**	2	0	**1**	1	0
Successful Carries	**5.8**	9.1	1.1	**8**	13	6	**5.2**	8	4
Unsuccessful Carries	**0**	1	0	**0**	2	0	**0**	1	0
Successful Passes	**6**	9	3	**3.3**	5	1	**4.1**	6	1
Unsuccessful Passes	**0**	1.1	0	**1**	1.1	0	**0**	1	0
Handling Errors	**1**	1.1	0	**0**	1	0	**0**	1	0
Normal Penalties	**0**	1	0	**0**	1	0	**0**	1	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	1	0	**0**	1	0	**0**	0	0
Cleaning Out	**9.5**	14	6	**6**	9	1.1	**8**	14	6
Successful Kicks	**0**	0	0	**0**	1	0	**0**	0	0
Unsuccessful Kicks	**0**	0	0	**0**	0	0	**0**	0	0

Appendix I.7: Medians (*Mdn*) and 95% confidence limits of PIs for players 11, 13 and 14 from the 2002/2003 season of the analysed professional team.

	Player 11 (Outside-Back) 12 Matches			Player 13 (Outside-Back) 10 Matches			Player 14 (Outside-Back) 9 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5**	8	3	**3**	5.2	2	**2.2**	6.6	1
Unsuccessful Tackles	**1**	1	0	**0**	1	0	**0**	1	0
Successful Carries	**3.2**	5	2	**6.5**	9	4	**6**	6.6	4
Unsuccessful Carries	**0**	2	0	**0**	1	0	**0**	1	0
Successful Passes	**1**	2	0	**2**	4	1	**1**	2	0
Unsuccessful Passes	**0**	0	0	**1**	1	0	**1**	2.2	0
Handling Errors	**1**	1.1	0	**0**	1	0	**0**	2	0
Normal Penalties	**0**	1	0	**0**	0	0	**0**	1	0
Yellow Cards	**0**	0	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	1	0	**0**	1.1	0	**0**	0	0
Cleaning Out	**3**	6	2	**4.6**	8	2	**5**	9	3
Successful Kicks	**1**	1.1	0	**0**	1	0	**0**	2	0
Unsuccessful Kicks	**0**	2	0	**0**	1	0	**0**	0	0
Successful High Ball Takes	**0**	1.2	0	**0.5**	1	0	**0**	1	0
Unsuccessful High Ball Takes	**0**	0	0	**0**	0	0	**0**	0	0

Appendix I.8: Medians (*Mdn*) and 95% confidence limits of PIs for players 15, 30 and 37 from the 2002/2003 season of the analysed professional team.

	Player 15 (Outside-Back) 6 Matches			Player 30 (Outside-Back) 7 Matches			Player 37 (Outside-Back) 10 Matches		
	Mdn	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**	***Mdn***	**+CL**	**-CL**
Successful Tackles	**5.6**	9.5	1	**6**	7	0	**2**	7	0
Unsuccessful Tackles	**0**	0	0	**1**	2	0	**0**	3	0
Successful Carries	**8.6**	11.4	3	**4**	10.8	0	**4.5**	12.7	0
Unsuccessful Carries	**0**	1.5	0	**0**	2	0	**0.5**	2	0
Successful Passes	**7.2**	12.4	3	**1**	3	0	**3.5**	7	0
Unsuccessful Passes	**1.3**	4	1	**0**	5.4	0	**0**	1	0
Handling Errors	**1.3**	3	0	**0**	2	0	**0.5**	1	0
Normal Penalties	**0.5**	1.5	0	**0**	1	0	**0**	1	0
Yellow Cards	**0**	1	0	**0**	0	0	**0**	0	0
Tries Scored	**0**	1.5	0	**0**	1	0	**0**	1	0
Cleaning Out	**3.1**	10	2	**4**	9	2	**5**	12.7	0
Successful Kicks	**4.9**	9.1	2	**0**	1	0	**0.5**	2	0
Unsuccessful Kicks	**0.5**	3.2	0	**0**	0	0	**0**	2	0
Successful High Ball Takes	**2**	6	0	**1**	5.4	0	**0**	1	0
Unsuccessful High Ball Takes	**0**	1.6	0	**0**	2	0	**0**	1	0

APPENDIX J

MEDIANS AND 95% CONFIDENCE LIMITS FOR THE PROFESSIONAL TEAM'S PERFORMANCE INDICATORS IN WET AND DRY WEATHER FROM THE SEASON 2002/2003

Appendix J: Medians and 95% confidence limits for the professional team's performance indicators in wet and dry weather from the season 2002/2003.

	Performance Indicator	Dry Matches (n=14)			Wet Matches (n= 6)		
		Median	Upper	Lower	**Median**	Upper	Lower
1	Scrums Won Analysed Team Ball	**9**	11	7	**9.5**	13	8
2	Scrums Lost Analysed Team Ball	**0**	1	0	**0.5**	2	0
3	Scrums Won Opposition Ball	**0**	1	0	**0**	1	0
4	Scrums Lost Opposition Ball	**8.5**	12	7	**10**	13	4
5	Lineouts Won Analysed Team Ball	**9**	12	6	**12.5**	16	8
6	Lineouts Lost Analysed Team Ball	**4**	6	2	**4.5**	6	3
7	Lineouts Won Opposition Ball	**1**	2	0	**1.5**	5	0
8	Lineouts Lost Opposition Ball	**13**	16	8	**11**	13	8
9	Rucks Won Analysed Team Ball	**54**	75	40	**63**	71	48
10	Rucks Lost Analysed Team Ball	**1.5**	3	0	**1.5**	7	0
11	Rucks Won Opposition Ball	**3**	4	1	**1.5**	2	0
12	Rucks Lost Opposition Ball	**59.5**	72	54	**49.5**	89	19
13	Mauls Won Analysed Team Ball	**2**	4	1	**3**	6	1
14	Mauls Lost Analysed Team Ball	**0**	1	0	**0**	1	0
15	Mauls Won Opposition Ball	**0**	1	0	**0**	1	0
16	Mauls Lost Opposition Ball	**6**	8	4	**7**	7	1
17	Tackles Made	**116**	132	100	**100.5**	139	54
18	Tackles Missed	**13.5**	17	10	**12.5**	18	6
19	Offloads Made	**6.5**	8	4	**4.5**	10	0
20	Offloads Against	**13.5**	17	11	**9**	13	7
21	Breaks Made from a Carry	**8**	15	6	**6**	15	2
22	No Breaks Made from a Carry	**65.5**	85	49	**66.5**	85	58
23	Turnovers For	**7**	11	3	**7**	8	3
24	Turnovers Against	**5**	9	3	**7**	9	1
25	Place Kicks Made	**4.5**	5	2	**3.5**	8	2
26	Place Kicks Missed	**1.5**	3	0	**3**	3	0
27	Penalties For	**12.5**	16	9	**11.5**	19	6
28	Penalties Against	**10.5**	15	7	**11.5**	15	8
29	Errors Made	**96**	107	90	**94.5**	110	69
30	Intrusions Into Area 3	**22**	28	20	**24.5**	34	17
31	Time in Possession (Secs)	**505.5**	694	423	**550.5**	624	411

APPENDIX K

PERFORMANCE INDICATORS INCLUDED IN MODELS 2 TO 4 BASED UPON THEIR CORRELATION COEFFICIENTS WITH THE COACH SCORES FOR MATCHES FROM THE 2002/2003 SEASON OF THE ANALYSED PROFESSIONAL TEAM

Appendix K: Performance indicators included in models 2 to 4 based upon their correlation coefficients with the coach scores for matches from the 2002/2003 season of the analysed professional team (dry matches, n= 14; wet matches, n= 6).

	Performance Indicator	Model 2 (≥ 0.1)		Model 3 (≥ 0.3)		Model 4 (≥ 0.5)	
		Dry	Wet	Dry	Wet	Dry	Wet
1	Scrums Won Analysed Team Ball		√				
2	Scrums Lost Analysed Team Ball	√	√	√			
3	Scrums Won Opposition Ball						
4	Scrums Lost Opposition Ball		√				
5	Lineouts Won Analysed Team Ball	√	√	√			
6	Lineouts Lost Analysed Team Ball	√	√		√		√
7	Lineouts Won Opposition Ball	√	√	√		√	
8	Lineouts Lost Opposition Ball	√	√				
9	Rucks Won Analysed Team Ball		√		√		
10	Rucks Lost Analysed Team Ball	√	√		√		√
11	Rucks Won Opposition Ball		√		√		√
12	Rucks Lost Opposition Ball	√		√			
13	Mauls Won Analysed Team Ball	√	√	√	√	√	√
14	Mauls Lost Analysed Team Ball		√				
15	Mauls Won Opposition Ball		√				
16	Mauls Lost Opposition Ball	√	√				
17	Tackles Made	√					
18	Tackles Missed	√	√		√		√
19	Offloads Made		√		√		
20	Offloads Against	√		√			
21	Breaks Made from a Carry		√		√		√
22	No Breaks Made from a Carry	√	√		√		
23	Turnovers For		√		√		√
24	Turnovers Against		√		√		√
25	Place Kicks Made	√	√	√	√	√	√
26	Place Kicks Missed	√	√		√		√
27	Penalties For	√					
28	Penalties Against	√	√				
29	Errors Made	√	√		√		√
30	Intrusions into Area 3	√					
31	Time in Possession (seconds)	√					
	Total PIs Used	**20**	**24**	**7**	**14**	**3**	**11**

APPENDIX L

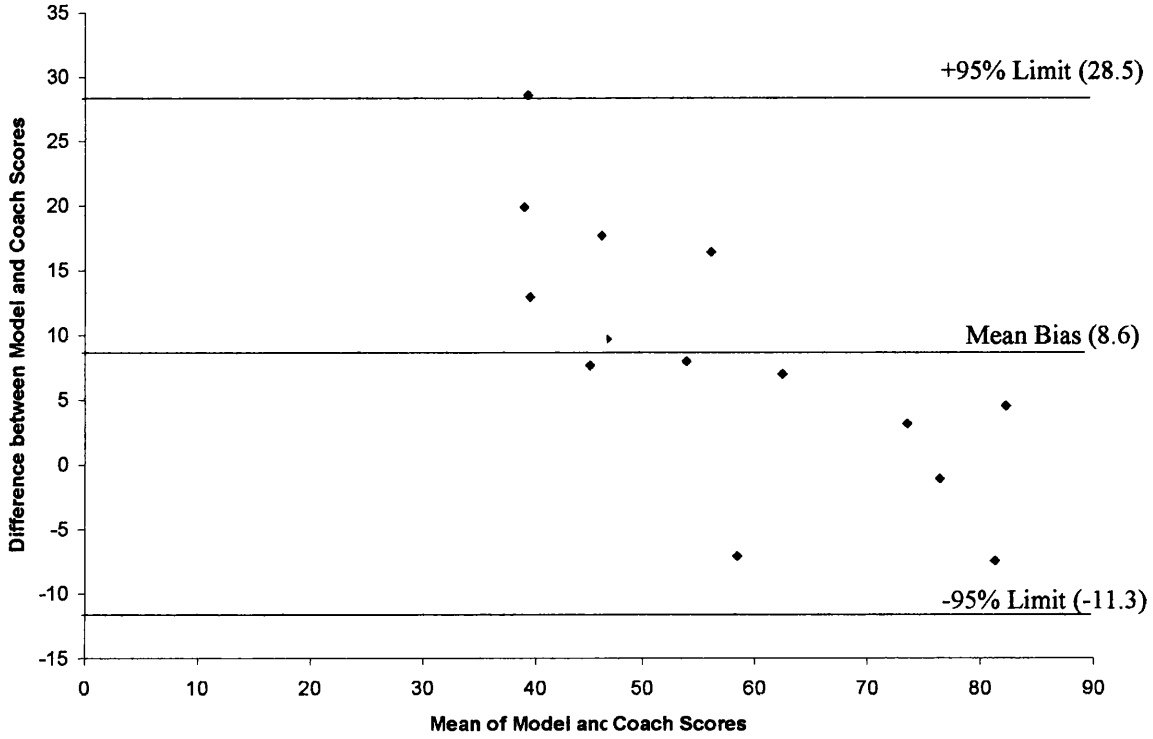
COMPARISON BETWEEN THE COACH SCORES FOR MATCHES FROM THE 2002/2003 SEASON OF THE ANALYSED PROFESSIONAL TEAM AND THE SCORES CREATED BY MODELS 1 TO 6

Appendix L: Comparison between the coach scores for matches from the 2002/2003 season of the analysed professional team and the scores created by models 1 to 6.

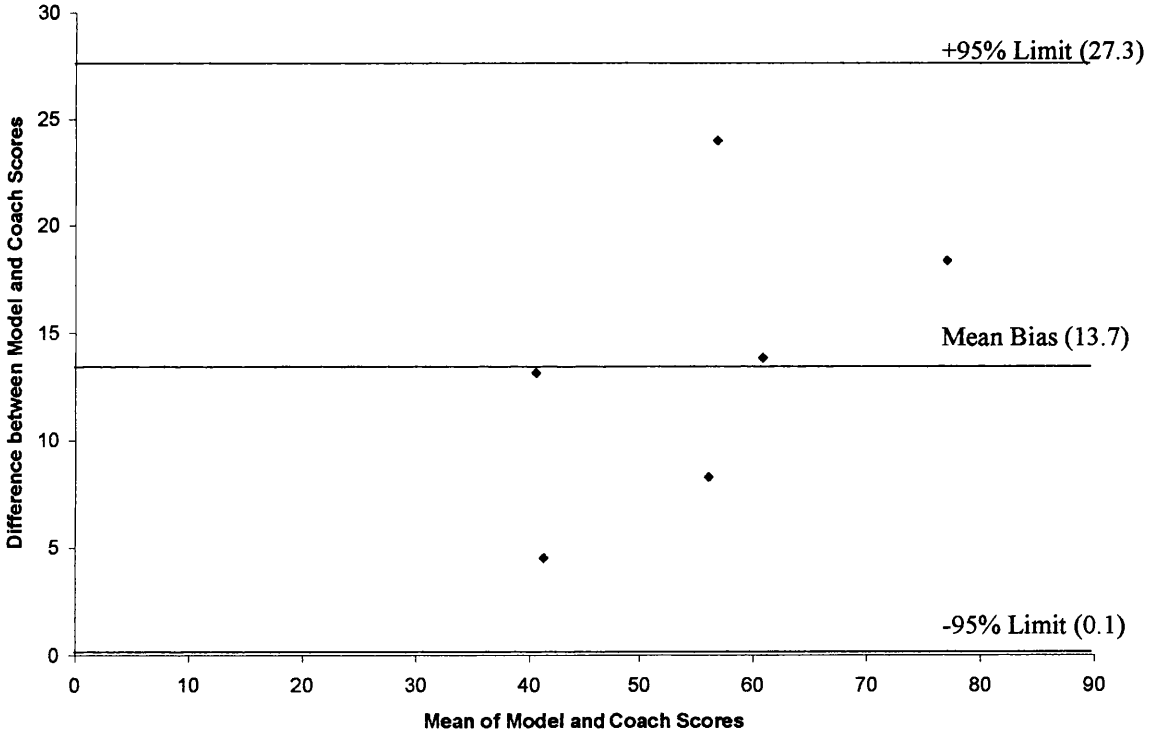
		Model 1 (all indicators)		Model 2 ($r \geq 0.1$)		Model 3 ($r \geq 0.3$)		Model 4 ($r \geq 0.5$)		Model 5 (all indicators)		Model 6 ($r \geq 0.5$)	
Game	Coach Score	Score	Difference	Score	Difference	Score	Difference	Score	Difference	Score	Difference	Score	Difference
						Dry Weather Matches (n= 14)							
2	**85**	77.6	**-7.4**	85.2	**0.2**	85.0	**0.0**	95	**10**	83.5	**-1.5**	95	**10**
3	**50**	58	**8**	65.3	**15.3**	66.1	**16.1**	69.6	**19.6**	58.2	**8.2**	63.2	**13.2**
4	**25**	53.6	**28.6**	53.5	**28.5**	51.4	**26.4**	48.6	**23.6**	44.5	**19.5**	37.2	**12.2**
5	**29**	48.9	**19.9**	45.2	**16.2**	45.6	**16.6**	40	**11**	29.3	**0.3**	20	**-9**
6	**62**	54.9	**-7.1**	62.1	**0.1**	64.8	**2.8**	73.6	**11.6**	52.9	**-9.1**	68.6	**6.6**
7	**77**	75.9	**-1.1**	72.5	**-4.5**	72.5	**-4.5**	74.8	**-2.2**	69.2	**-7.8**	71.9	**-5.1**
10	**72**	75.2	**3.2**	71.5	**-0.5**	74.7	**2.7**	72.1	**0.1**	64	**-8**	62.7	**-9.3**
11	**37**	54.7	**17.7**	51.1	**14.1**	50.3	**13.3**	54.1	**17.1**	38.4	**1.4**	40.5	**3.5**
12	**33**	46	**13**	38.7	**5.7**	38	**5**	37.1	**4.1**	21.8	**-11.2**	17.1	**-15.9**
13	**59**	66	**7**	69.7	**10.7**	70.9	**11.9**	80.7	**21.7**	66.3	**7.3**	80.7	**21.7**
14	**48**	64.4	**16.4**	68.1	**20.1**	66.3	**18.3**	75.7	**27.7**	65	**17**	75.7	**27.7**
17	**41**	48.7	**7.7**	48.6	**7.6**	47.7	**6.7**	43.6	**2.6**	38	**-3**	32.2	**-8.8**
18	**42**	51.7	**9.7**	44.4	**2.4**	42.2	**0.2**	47.8	**5.8**	34.2	**-7.8**	38.4	**-3.6**
20	**80**	84.5	**4.5**	92.1	**12.1**	95.6	**15.6**	100	**20**	90.7	**10.7**	100	**20**
						Wet Weather Matches (n= 6)							
1	**45**	69	**24**	66.2	**21.2**	67.4	**22.4**	67.2	**22.2**	59.7	**14.7**	61	**16**
8	**39**	43.5	**4.5**	43.4	**4.4**	43.1	**4.1**	42.9	**3.9**	28.7	**-10.3**	28	**-11**
9	**54**	67.8	**13.8**	67.7	**13.7**	66.6	**12.6**	67.1	**13.1**	61.4	**7.4**	60.3	**6.3**
15	**68**	86.4	**18.4**	86.3	**18.3**	87.8	**19.8**	88.4	**20.4**	85.8	**17.8**	88.4	**20.4**
16	**52**	60.3	**8.3**	60.2	**8.2**	60.8	**8.8**	61.7	**9.7**	51.1	**-0.9**	53.1	**1.1**
19	**34**	47.1	**13.1**	44.4	**10.4**	43	**9**	43.4	**9.4**	30.4	**-3.6**	29.1	**-4.9**

APPENDIX M

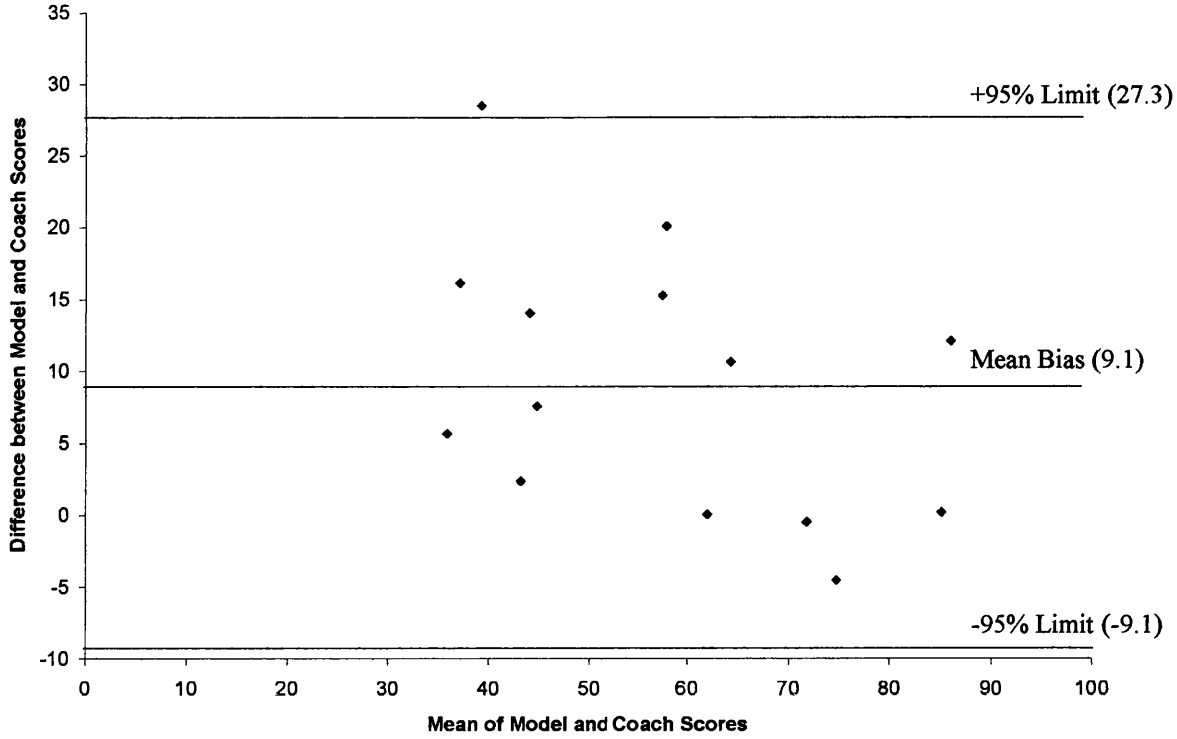
BLAND AND ALTMAN PLOTS ILLUSTRATING THE LEVEL OF AGREEMENT BETWEEN THE COACH AND MODEL SCORES FOR WET AND DRY WEATHER MATCHES FROM THE 2002/2003 SEASON OF THE ANALYSED PROFESSIONAL TEAM



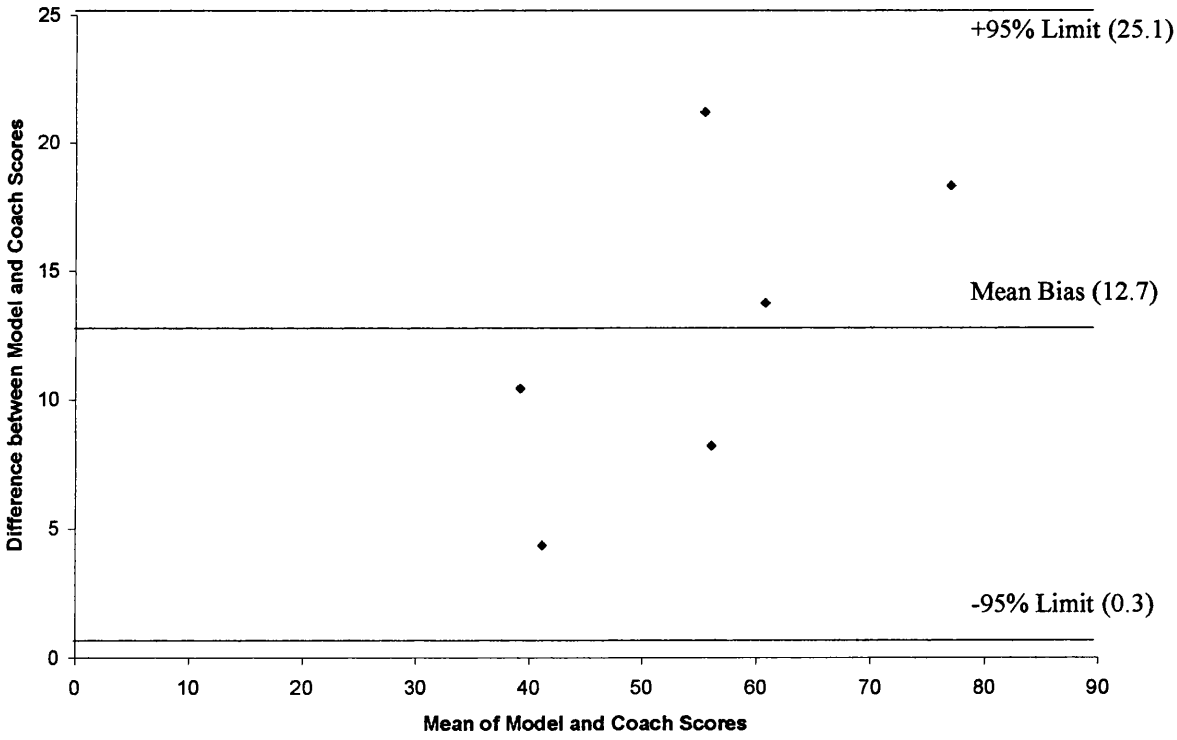
Appendix M.1: Bland and Altman plot illustrating the agreement between the coach scores and those of model 1 dry for matches from the 2002/2003 season of the analysed professional team (r= -0.74).



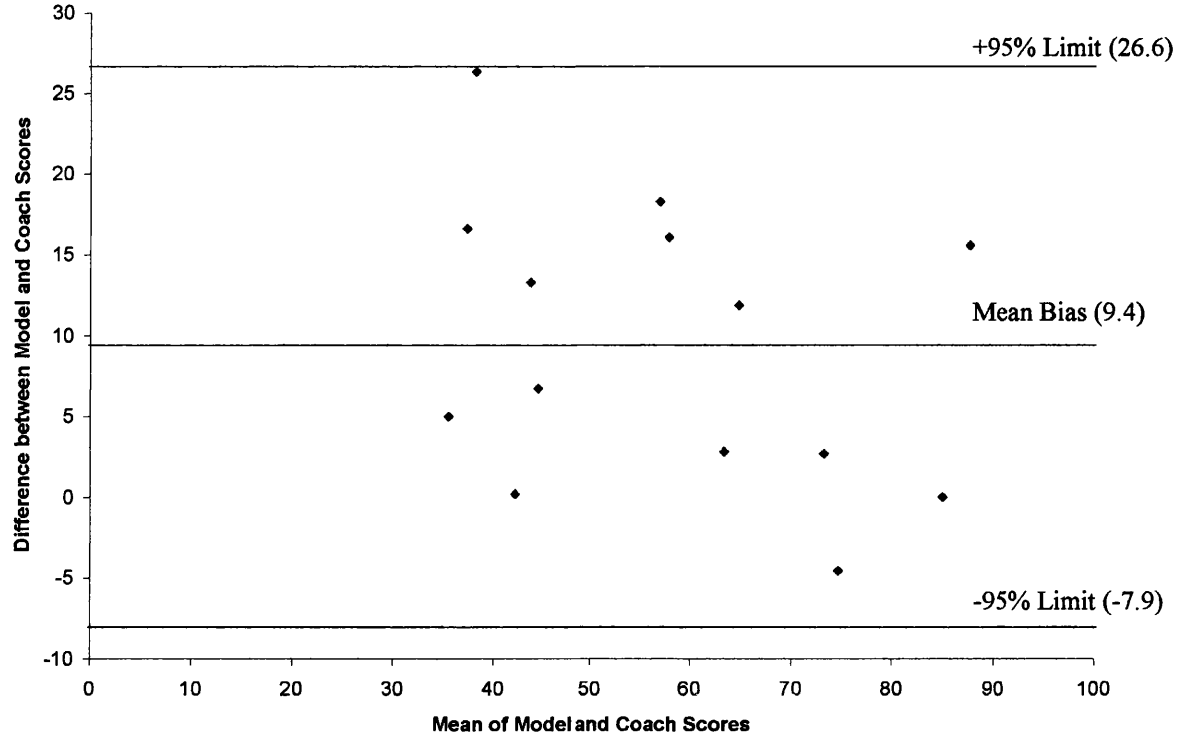
Appendix M.2: Bland and Altman plot illustrating the agreement between the coach scores and those of model 1 wet for matches from the 2002/2003 season of the analysed professional team (r= 0.53).



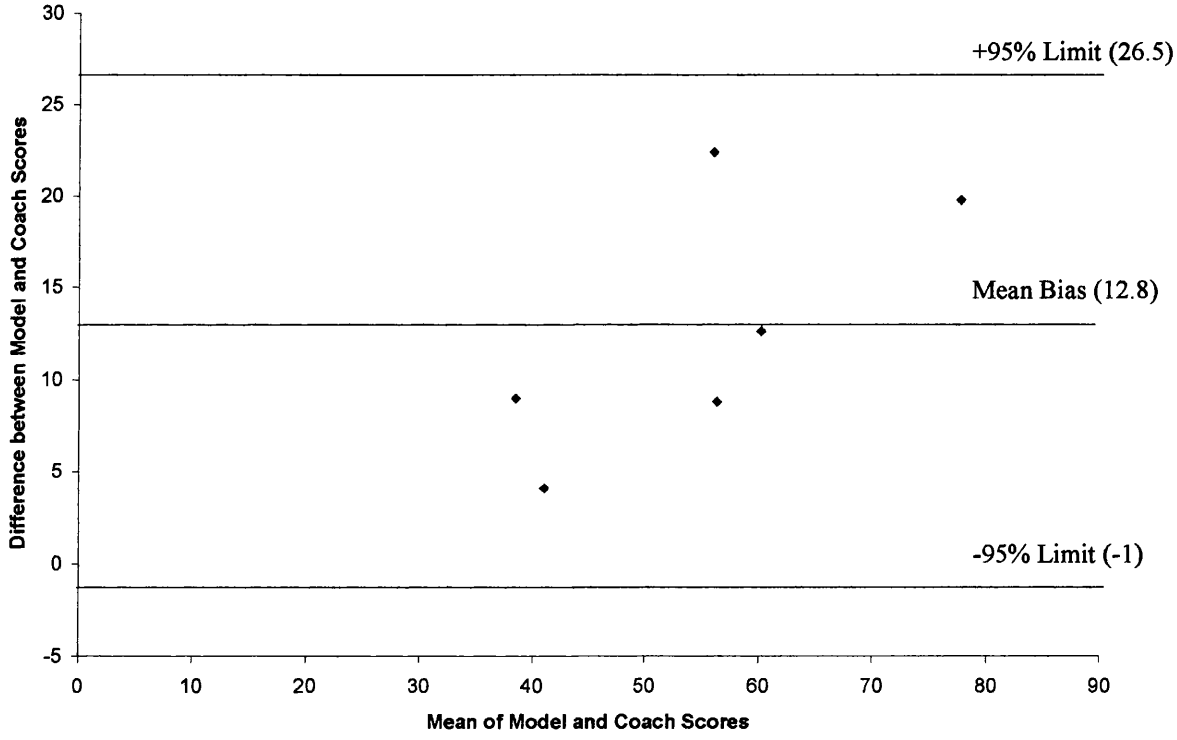
Appendix M.3: Bland and Altman plot illustrating the agreement between the coach scores and those of model 2 dry for matches from the 2002/2003 season of the analysed professional team (r= -0.44).



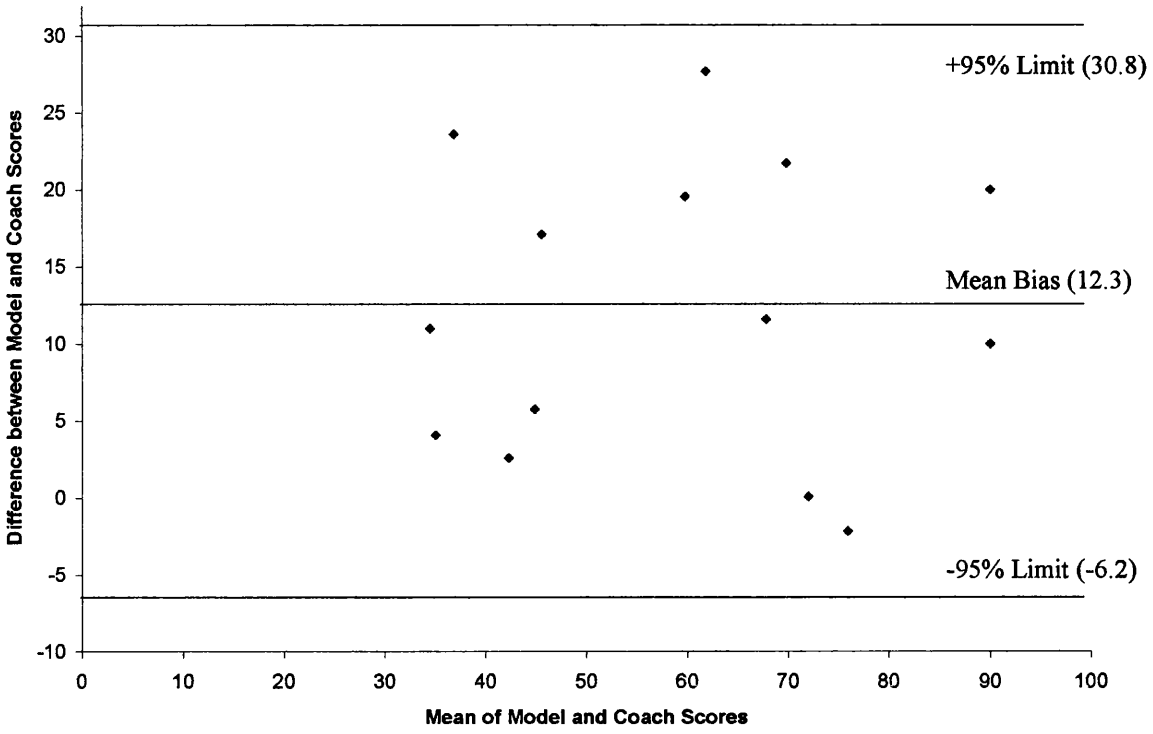
Appendix M.4: Bland and Altman plot illustrating the agreement between the coach scores and those of model 2 wet for matches from the 2002/2003 season of the analysed professional team (r= 0.64).



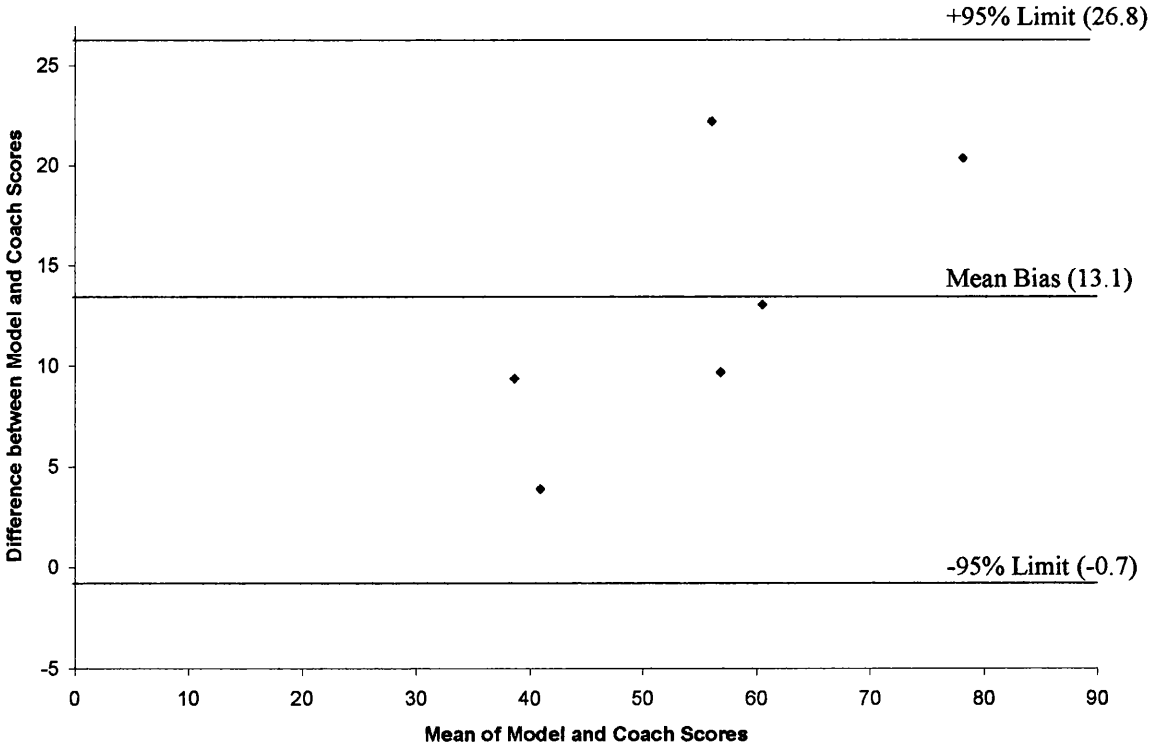
Appendix M.5: Bland and Altman plot illustrating the agreement between the coach scores and those of model 3 dry or matches from the 2002/2003 season of the analysed professional team (r= -0.34).



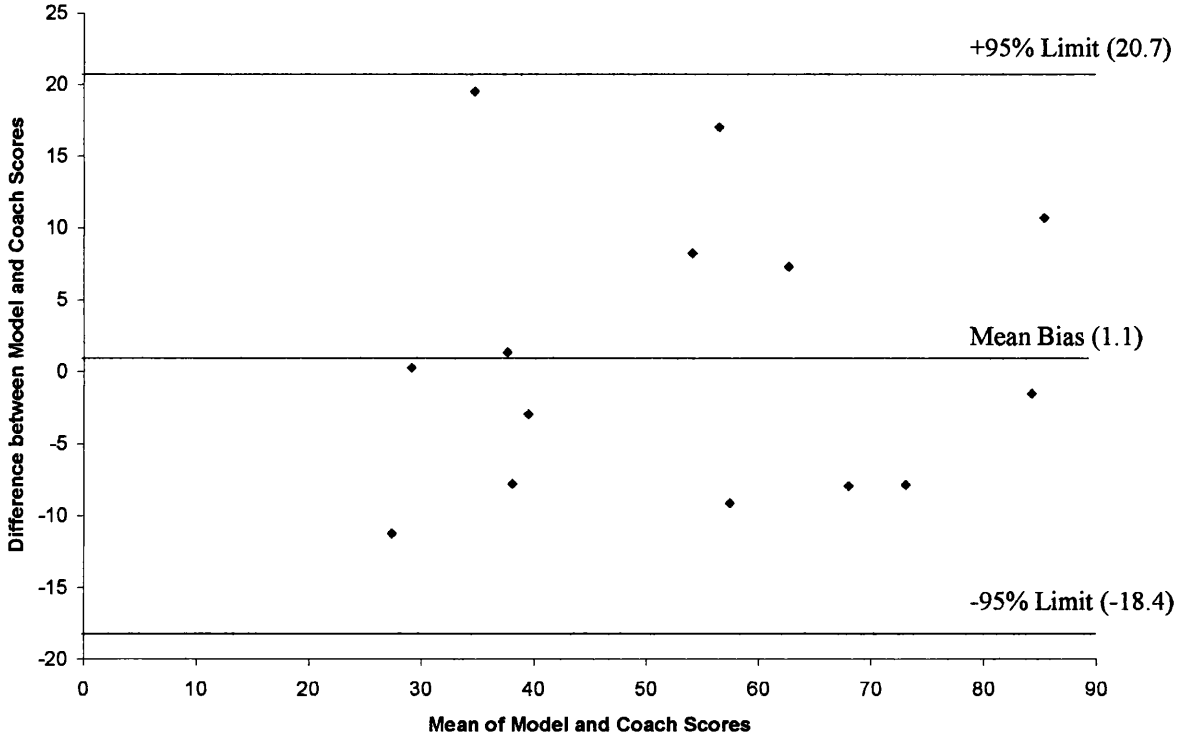
Appendix M.6: Bland and Altman plot illustrating the agreement between the coach scores and those of model 3 wet for matches from the 2002/2003 season of the analysed professional team (r= 0.7).



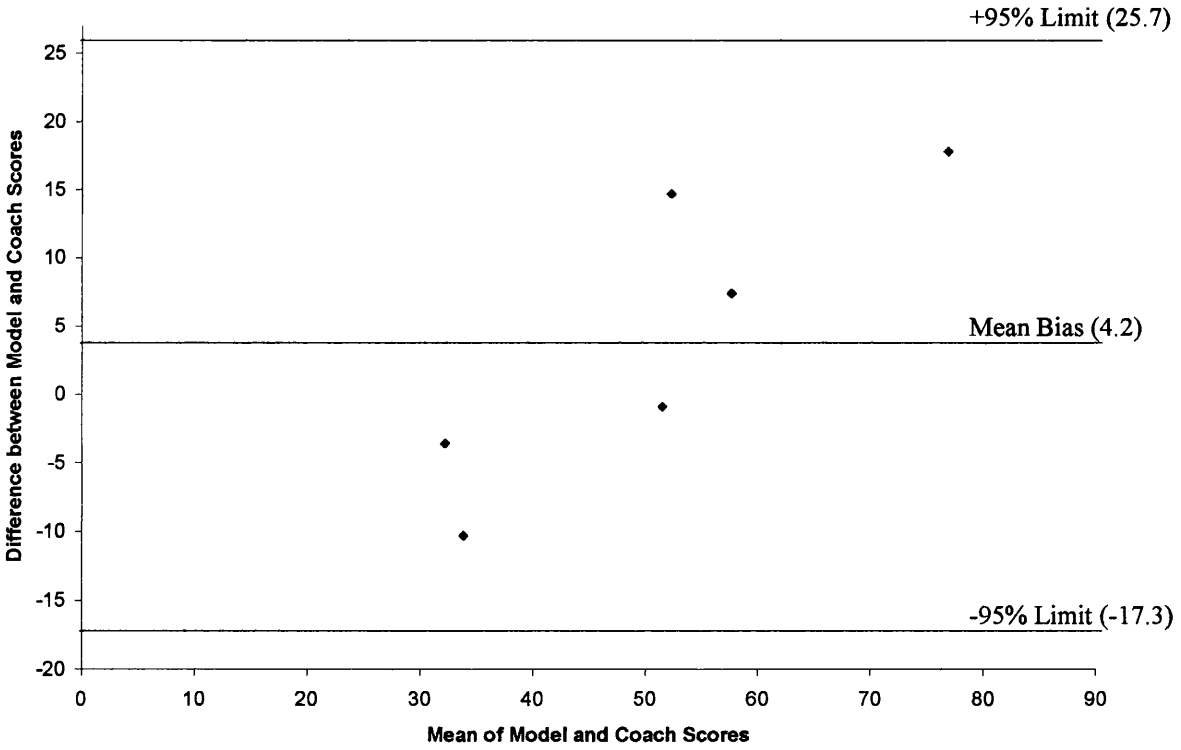
Appendix M.7: Bland and Altman plot illustrating the agreement between the coach scores and those of model 4 dry for matches from the 2002/2003 season of the analysed professional team (r= 0.03).



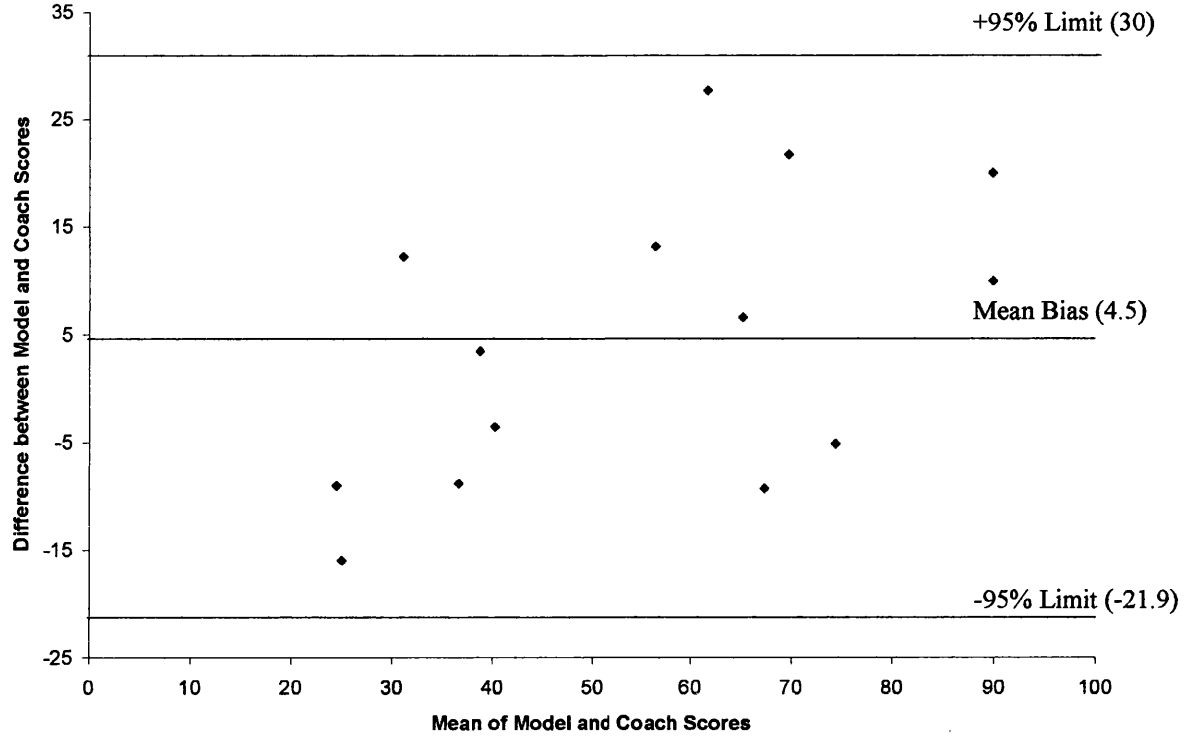
Appendix M.8: Bland and Altman plot illustrating the agreement between the coach scores and those of model 4 wet for matches from the 2002/2003 season of the analysed professional team (r= 0.72).



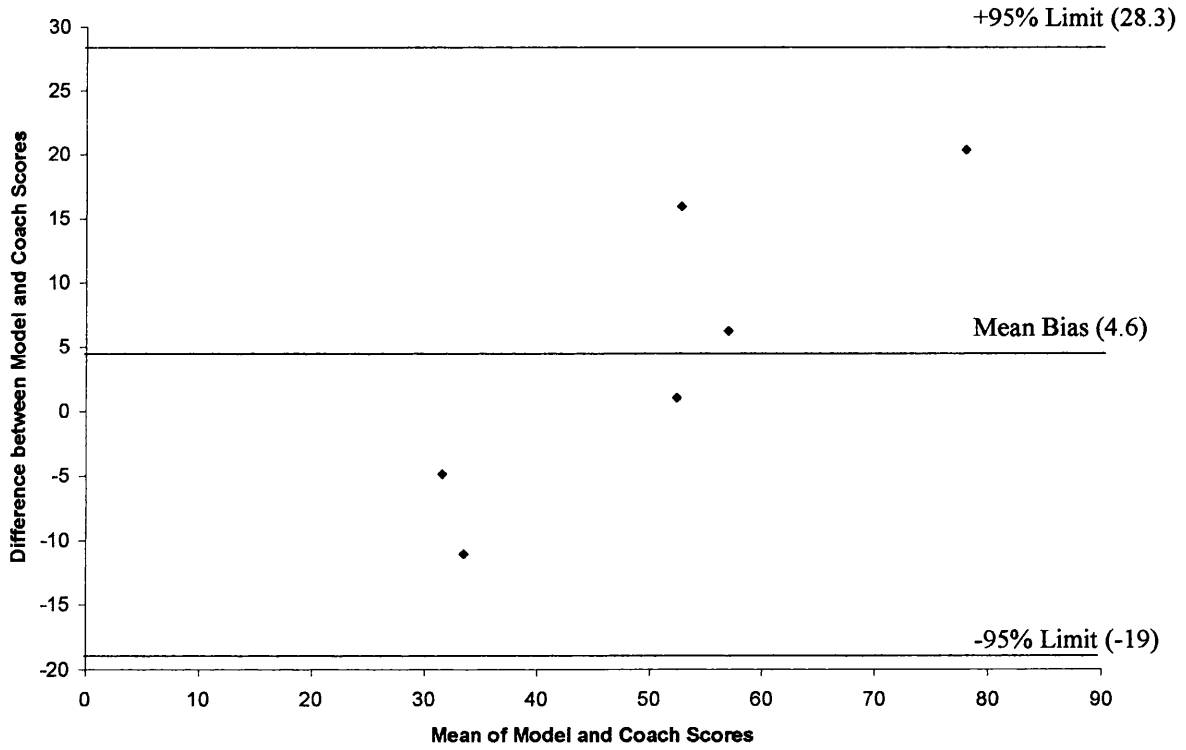
Appendix M.9: Bland and Altman plot illustrating the agreement between the coach scores and those of model 5 dry for matches from the 2002/2003 season of the analysed professional team (r= 0.07).



Appendix M.10: Bland and Altman plot illustrating the agreement between the coach scores and those of model 5 wet for matches from the 2002/2003 season of the analysed professional team (r= 0.86).



Appendix M.11: Bland and Altman plot illustrating the agreement between the coach scores and those of model 6 dry for matches from the 2002/2003 season of the analysed professional team (r= 0.52).



Appendix M.12: Bland and Altman plot illustrating the agreement between the coach scores and those of model 6 wet for matches from the 2002/2003 season of the analysed professional team (r= 0.89).

APPENDIX N

MATCH QUESTIONNAIRE FOR THE VALIDATION OF THE STANDARDISED PERFORMANCE REPORT

Appendix N: Match questionnaire for the validation of the standardised performance report.

Match Questionnaire for Elite Coaches

Below are a number of specific performance areas which you use for your weekly match analysis. Please could you rate Saturday's performance in each area comparing the performance against recent form (i.e. your last five matches). Please circle the score you feel is a correct appraisal.

PERFORMANCE AREA	VERY POOR	POOR	AVERAGE	GOOD	VERY GOOD
Scrums on your put-in (percentage won)	1	2	3	4	5
Scrums on their put-in (percentage won)	1	2	3	4	5
Scrum gainline made percentage	1	2	3	4	5
Lineouts on your throw (percentage won)	1	2	3	4	5
Lineouts on their throw (percentage won)	1	2	3	4	5
Lineout gainline made percentage	1	2	3	4	5
Penalties awarded (as a percentage of total match penalties)	1	2	3	4	5
Turnovers won (as a percentage of total match turnovers)	1	2	3	4	5
Effective tackles (as a percentage of your total tackles)	1	2	3	4	5
Missed tackles (as a percentage of your total tackles)	1	2	3	4	5
Handling errors	1	2	3	4	5
Possession percentage	1	2	3	4	5
Territory percentage	1	2	3	4	5