

Match analyses of the 2006 and 2008 Super 14 Rugby Union Tournaments



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FOREWORD

I want to start this section to express my sincere appreciation to the following people. I acknowledge that this dissertation would have never materialized without your input in my life.

First of all, I would like to thank my **Heavenly Father** for the heaps of patients, all the love, tons of blessings and continuous direction I receive from Him daily.

Secondly, I would like to thank all of my family and friends for their continuous support and love. Particularly my wife **Gayle**, my *iron man* **Möller** and *little princess Ataya* (The 3 most important people in my life).

Thirdly, I would like to thank my supervisor, **Prof Dawie Malan** for his advice and belief in me, as well as the expertise and effort that he so selflessly has shared with me over the past eight years.

Then I want to thank all my **colleagues** as well as **Dr Suria Ellis** for her contribution with the statistical data processing and **Mrs Cecilia van der Walt** for her assistance with the language editing.

DEDICATION

This dissertation is dedicated to my mother,
LINDA VAN DEN BERG,
Who always believed in me, endlessly praying for me, continuously
loving me, and financially supported my studies, even during
difficult times.

John 3:27

“A man can receive nothing unless it has been given to him from
heaven.”

Pieter van den Berg

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DECLARATION

The co-author of the two articles, which form part of this dissertation, Prof, D.D.J. Malan (Supervisor), hereby gives permission to the candidate, Mr. P.H. van den Berg to include the two articles as part of the Masters dissertation. The contribution (advisory and supportive) of the co-author was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as partial fulfilment of the requirements for the Magister Artium degree in Sport Science within the school of Biokinetics, Recreation and Sport Science in the Faculty of Health Sciences at the North-West University (Potchefstroom Campus).

Prof. D.D. J. Malan
Supervisor and co-author

CONGRESS PRESENTATION

The following presentation, based on this dissertation, has been delivered:

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Van den Berg, P.H. & Malan, D.D.J. Video analysis in rugby union. *Poster presentation at the 3^{ed} SARECON congress held in Durban, South Africa, 2010.*

SUMMARY

Video analysis and more specifically, computer notational analyses (CNA), are considered by many scientists to be of great value for research purposes. It has also provided proof of the ability and contribution of CNA to evaluate the way match-play in a sport such as rugby has evolved through the years and to determine which performance indicators (PIs) are present in this sport code. CNA can also assist in determining the influence of such PIs on match performance. Based on this research application, rugby union turning professional in 1995 and the regular introduction of new laws in the game brought about the necessity for a more scientific approach in rugby union match analysis. This led the research team to the following objectives: To determine a) The effect of the experimental law variations (ELVs) introduced in rugby during 2008 on the PI-s; b) The frequency of the different PIs during matches played in the 2006 season; and c) The ability to evaluate performance (match outcome) and ranking of the teams.

All the Super 14 rugby games (n=370) in the 2006 and 2008 seasons were recorded on video and analysed. The following PIs were analysed: turn-overs, percentage good scrums, percentage good line-outs, percentage tackles made, drop goals, penalty goals, rucks lost, rucks won, tries scored, line breaks, passes made, turn-overs, off-loads in the tackle, meters gained, penalties conceded, kicks from hand and percentage tries converted.

Descriptive statistics were calculated of each PI for each of the rugby teams, followed by independent t-tests to determine significance of differences between the 2006 and 2008 data. Additionally, forward stepwise discriminant analysis and forward stepwise multiple regression analysis were performed to determine which of the PIs influenced the ranking and performance of the different teams. Due to the fact that this was an inferential study, significance of differences were reflected by practical significance as determined by means of effect sizes.

With regard to the ELVs, the study determined that a large practical significant decrease occurred in the frequency of scrums and line-outs from the 2006 to 2008 competition.

In contrast to this, the number of tackles made, meters gained and penalties conceded all showed a large practically significant increase over the same compared competition seasons.

Meters gained, kicks from hand, line breaks and percentage tackles made were identified as the PIs which discriminated most accurately between successful and less successful Super 14 rugby union teams. Furthermore, meters gained, kicks from hand and line breaks were identified as the PIs which emerged as the best predictors (practical significant) of team ranking among the Super 14 rugby union teams during the competition.

In conclusion, the results from this study therefore outlined the importance of the different PIs as predictors of performance and the ranking of the Super 14 rugby union teams. The increase in action activities and decrease in static activities between the 2006 and 2008 season suggests that the IRB have succeeded in addressing their objective of increasing the appeal of the game with the introduction of the ELVs.

OPSOMMING

Video-analise en meer spesifiek, rekenaarnotasie-analise (RNA), word deur talle wetenskaplikes beskou as van groot waarde vir navorsingsdoeleindes. Dit het ook bewyse gelewer van die vermoë van RNA om die evolusie van die spel in 'n sport soos rugby deur die jare te evalueer, en om vas te stel watter prestasie-indikatore (PI's) in dié sportsoort voorkom. RNA kan ook meehelp om die invloed van sodanige PI's op wedstrydprestasie te bepaal. Omrede rugby-unie in 1995 professionele status verkry het en die reëls gereëld verander, het die noodsaaklikheid en behoefte vir 'n meer wetenskaplike benadering in rugby-unie ontstaan. *Dit het die navorsingsplan tot die volgende doelwitte gelei, naamlik om te bepaal: a) wat die effek is van die "experimental law changes (ELVs)" wat gedurende 2008 geïmplementeer was; b) wat die frekwensie is van die verskillende PI's tydens wedstryde wat in die 2006-en 2008 seisoene gespeel is; en c) wat die vermoë is van PI's om prestasie (wedstryduitkoms) en rangorde van die spanne te voorspel.*

Al die Super 14 rugbywedstryde ($n=370$) in die 2006-seisoen en die 2008-seisoen is op video vasgelê en geanaliseer. Die volgende PI's is geanaliseer: omgekeerde balbesit, persentasie goeie skrumme, persentasie goeie lynstane, persentasie doodvatte, skepskoppe, strafdoelle, skrumme verloor, skrumme gewen, drieë gedruk, lynbreuke, aangeë gemaak, omgekeerde balbesit, uitgee in die doodvatte, meters gewen, strafkoppe verdoel, skoppe uit die hand en persentasie drieë verdoel.

Beskrywende statistiek is van elke PI vir elk van die rugbyspanne bereken, gevolg deur onafhanklike t-toetse om betekenisvolheid van verskille tussen die 2006- en 2008-data te bepaal. Hierbenewens is voorwaarts stapsgewyse diskriminantanalise en voorwaartse stapsgewyse meervoudigeregressie-analise gedoen om vas te stel watter van die PI's die rangorde-prestasie van die verskillende spanne beïnvloed het. Weens die feit dat dit 'n inferensiële studie was, is betekenisvolheid van verskille weergegee deur praktiese betekenisvolheid soos bepaal deur middel van effekgroottes.

Ten opsigte van die ELV's het hierdie studie vasgestel dat 'n groot praktiese betekenisvolle afname in die frekwensie van skrums en lynstane van die 2006- tot 2008-kompetisie voorgekom het. In teenstelling hiermee het die aantal doodvatte, meters gewen en strafskoppe verdoel almal 'n groot prakties betekenisvolle toename oor dieselfde vergeleke kompetisie-seisoene getoon.

Meters gewen, skoppe uit die hand lynbreuke en persentasie doodvatte is as die PI's wat die akkuraatste tussen suksesvolle en minder suksesvolle Super 14-uniespanne onderskei het. Verder is meters gewen, skoppe uit die hand uit en lynbreuke geïdentifiseer as die PI's wat as die beste voorspellers (prakties betekenisvol) van 'n span se rangorde is.

Ten besluite het die resultate van hierdie studie dus die belangrikheid van die verskillende PI's as voorspellers van prestasie en die rangorde van die Super 14 rugbyunie-spanne uitgestippel. Die toename in aksieaktiwiteite en afname in statiese aktiwiteite tussen die 2006-seisoen en die 2008-seisoen dui daarop dat die IRB daarin geslaag het om hul doelwit om die aantreklikheid van die spel te verhoog met die inbring van die ELV's.

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Figure 1: Organigram of factors and relevant PIs involved in the success of rugby union

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ABBREVIATIONS

PI	-	Performance Indicator
PIs	-	Performance Indicators
ELV	-	Experimental Law Variation
ELVs	-	Experimental Law Variations
IRB	-	International Rugby Board

CHAPTER 1



PROBLEM STATEMENT, OBJECTIVES AND HYPOTHYSES

1. PROBLEM STATEMENT
 2. OBJECTIVES
 3. HYPOTHESIS
 4. STRUTURE OF THE DISSERTATATION
 5. REFERENCES
-

1. PROBLEM STATEMENT

Internationally, Rugby Union is renowned as a winter sport, ranked second in capaciousness after soccer (Bathgate *et al.*, 2002:265). The extent of participation in rugby union, together with the fact that the sport has turned professional in 1995 has increased the need for a more scientific approach that explores the different elements in the game of rugby union (Duthie *et al.*, 2003:974; James *et al.*, 2005:63 and Mellalieu *et al.*, 2008:791). Newell (2002:1) and Mallet (2006:122) consider technology, and more specifically video analysis, as one such a scientific approach. Hughes and Franks (2007:81) state that video analysis can be used to analyse general match, technical, tactical and biomechanical indicators. To analyse general match indicators, Hughes and Williams (1988:254), Botha (2005:16) and White (2005:104) recommended that computer notational analysis (CNA) should be used in this regard. Despite the concerns of, Handcock (1993:7) and Greenwood (2004:33) who pointed out that CNA is complex and difficult to use as well as Lames and McGarry (2007:65) who questioned the reliability of CNA results due to variation in conditions and other factors, Rees (1996:26), Reed and O'Donoghue (2005:13) as well as Eaves *et al.* (2005:59) argued the value and advantages of CNA, such as objectivity to be considered essential for team sports that strive to enhance performance.

The major purposes of notational analysis are to indicate which areas or activities in a match requires improvement as well as the evaluation of players, to name but two (Hughes, 1988:1587). Hughes and Bartlett (2007:167) indicated that notational analysts are inclined to study the patterns of play by analysing the action variables that should relate to performance. These action variables are known as performance indicators (PIs) and it is suggested that research should focus on the development and utilization of these PIs (Hughes & Bartlett, 2002:740; Baca, 2006:148; O'Donoghue, 2006:2; Pool, 2006:117).

In a recent study Coetzee and Van den Berg (2007:60) identified the importance of such PIs as performance predictors in South African tertiary institution rugby teams. The following diagram indicates which factors, including PIs (underlined), are considered by several researchers (also in table) as important for rugby union teams to achieve success.

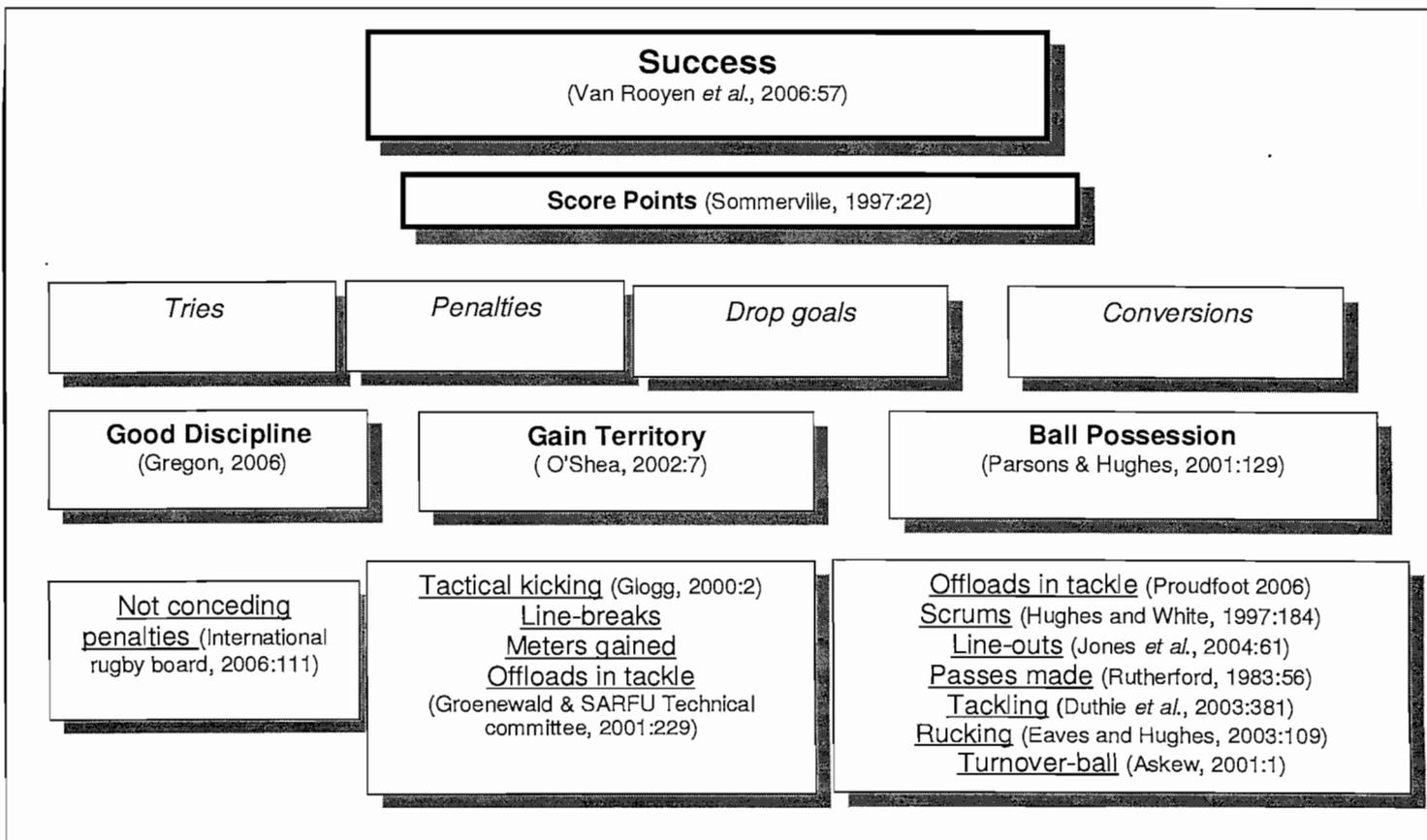


Figure 1: Table representing the organigram of success in rugby union and the relevant PI.

Van Rooyen *et al.* (2006:57) states that success in rugby is measured by winning the match and in order to do so, teams must score points; thus beating the opposition. Points can be accumulated by the following number of ways: *tries, conversions, penalties* and *drop goals*. All of these can be decisive in determining the outcome of a game (Phythian, 1995:51; Sommerville, 1997:22). Research suggested that three aspects need to be considered when rugby teams wish to score points namely: a) a team needs **ball possession** (Rutherford, 1983:56; Parsons & Hughes, 2001:129), b) they need to **gain territory** in such a way that they can score points (O'Shea, 2002:7) and c) they need good **discipline** to prevent the opposition from gaining points through penalties (Gregon, 2006). Thus for a team to score points and be successful they need **ball possession**, good **discipline** and **to gain territory**. All achieved by specific PI.

When a team concedes penalties, the opposition may gain an opportunity to kick a goal, which in turn can lead directly to points for the opposition (International Rugby Board, 2006:111). Conceding penalties due to bad **discipline** therefore does have an effect on the outcome of the match. Laird and Lorimer (2004:78) determined that 75% of tries scored in the international matches during the 2003 rugby season came from ball possession gained in the opponents' half; thus emphasizing the importance for a team to **gain territory**. This is done with good tactical kicking (Glogg, 2000:2) or maintaining continuity by means of either line-breaks, meters gained or off-loading in the tackle, (Groenewald & SARFU Technical Committee, 2001:229).

Off-loading in the tackle can also be seen as a way to retain **ball possession**. Other PIs that enable a team to gain good ball possession includes scrums and line-outs (set pieces) which were also highlighted by Hughes and White (1997:184) in their analysis of the 1991 Rugby World Cup. They found that successful teams managed their set pieces significantly better than those of the less successful teams. A study done on European rugby teams showed that only two out of twenty two variables, namely opposition line-outs won and number of tries scored significantly discriminated between more and less successful teams (Jones *et al.*, 2004:61), hence the remark that activities such as set pieces have a definite influence on the final outcome of a rugby game (Hutchinson, 2005).

Other PIs that might influence a team's number of **ball possessions** included passes made, rucks and turnovers (Groenewald & SARFU Technical Committee,

2001:12). According to Rutherford (1983:56), teams that mastered handling skills best will have an advantage over their opponents. Rucking is another facet of play that has a direct influence on the amount of ball possessions a team can obtain. Teams that are not able to protect the ball during rucks will lose their **ball possession** to the opposing team and may even concede points against them due to the turn-over ball (Rugby Football Union, 2004). This was supported by Askew (2001:1) who determined that 17 out of the 19 tries scored during the first weekend of the 2001 Six Nations Rugby tournament were the direct result of turn-over balls. In addition to this Eaves and Hughes (2003:109) have determined that the number of rucks during a match from the 1992-1998 season had doubled by the 2000 period; hence emphasizing the importance of rucking.

Good defence (tackling) is also regarded as a critical component for success in the game of rugby (Biscombe & Drewett, 1998:45; Duthie *et al.*, 2003:381). Good defence may improve a team's chances of gaining good **ball possession** and preventing the opposition from **gaining territory**. Luger and Pook (2004:116) determined that rugby players are making twice as many tackles during a game than was the case during the 1996 Five Nations Championships. Good defence also emerged as the best predictor of ranking among the top eight ranked tertiary institution rugby teams in South Africa (Coetzee & Van den Berg, 2007:60).

In an interview with Matthew Proudfoot (2006) international player and a very successful South African club rugby coach, all the above-mentioned PIs were confirmed to be considered very important by coaches and trainers striving for success. Eaves and Hughes (2003:104) explained that in the strive for success in rugby it is important for coaches and trainers to adapt their current training programs, especially when changes occur in the profile of the sport. When the IRB (International Rugby Board) decided to implement new experimental law variations (ELVs) during the 2008 Super 14 Rugby Union Tournament, the possibility of change in the profile of the sport became apparent (IRB, 2008). The main purpose of these changes was to ensure that the game evolves to comply with the needs of the players, coaches and spectators and also to address certain safety issues. These ELVs have been on trial in several other small rugby competitions around the world for example, Scotland - Scottish Super Cup, England - County Championship, Australia – Australian Rugby Championship and South Africa – Currie Cup.

The results of these trials indicated that more tries were scored, contesting for the ball increased and positive feedback from players and referees indicated that the enjoyment of the game increased. On the other hand the number of PI stayed more or less the same (IRB, 2008). These findings led to the following research question: a) Did the ELVs succeed in changing the flow of play during matches in order to make rugby more appealing to spectators? Other research questions that emerged due to the value of the data examining the nature of PI in rugby and its relationship to rugby performances are posed: b) What is the frequency of the different PI during the 2006 and 2008 Super 14 Rugby Union Tournaments?, c) Which PI discriminate significantly between successful (top seven) and less successful (bottom seven) Super 14 rugby union teams?, d) Which PI significantly predict the ranking of the Super 14 rugby union teams?

The analyses of these PI might give coaches, players and sport scientists a better understanding of which PI occur in a rugby game, how often each PI appears and the effect it has on the outcome of the game. These answers may help the role-players to prioritize the amount of time they intend spending on the different PIs in their training programs, depending on the importance of these different PIs towards competitive match play, which may lead to the evaluation of players and teams accordingly. The answer to the last question could enable coaches, players and sport scientists to classify rugby teams of different performance levels.

2. OBJECTIVES

The objectives of this study are to:

- ⊗ Determine if the ELVs succeeded in changing the flow of play during matches in order to make rugby more appealing to spectators?
- ⊗ Determine the frequency of different PIs in the 2006 and 2008 Super 14 Rugby Union Tournaments.
- ⊗ Determine which PIs discriminate between the successful (top seven) and less successful (bottom seven) Super 14 rugby union teams.
- ⊗ Determine which PIs significantly predict the ranking of the Super 14 rugby union teams.

3. HYPOTHESES.

The study is based on the following hypotheses:

- ⊗ The ELVs succeeded in changing the flow of play during matches in order to make rugby more appealing to spectators.
- ⊗ The frequency of different PIs will differ significantly between the 2006 and 2008 Super 14 Rugby Union Tournaments.
- ⊗ Offloads in the tackle and good defence will discriminate significantly between successful (top seven) and less successful (bottom seven) Super 14 rugby union teams.
- ⊗ Offloads in the tackle, tactical kicking and good defence will predict the ranking of the Super 14 rugby union teams.

4. STRUCTURE OF THE DISSERTATION

The dissertation is presented in an article format that was approved by the Senate of the North-West University and consists of five chapters: References is provided at the end of the chapter in accordance with the guidelines of the North–West University.

- Chapter 1** Research proposal that includes the problem statement, objectives and hypothesis.
- Chapter 2** Literature overview: Video analyses of rugby union. References are provided at the end of the chapter in accordance with the guidelines of the North –West University.
- Chapter 3** Match analysis of the 2006 Super 14 rugby tournament. This article will be submitted for publication in the African journal for physical, health education, recreation and dance. References are provided at the end of the chapter in accordance with the guidelines of the North – West University.
- Chapter 4** The effect of the ELVs on the Super 14 Rugby Union Tournament. This article will be submitted for publication in the South African journal for research in sport, physical education and recreation. References are provided at the end of the chapter in accordance with the guidelines of the North –West University.
- Chapter 5** Summary, conclusions and recommendations.

Appendix All the instructions for authors from the two relevant journals and an explanation of the ELVs.

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CHAPTER 2



VIDEO ANALYSIS IN RUGBY UNION

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1. INTRODUCTION

Change towards the improvement of sport performance can only occur with the player experiencing some form of feedback (Coker *et al.*, 2006:29). This feedback may be intrinsic or extrinsic. Intrinsic feedback can be defined as information that is gained by the athlete's own sensory system (Coker *et al.*, 2006:29). Extrinsic feedback, on the other hand, can be divided into knowledge of performance or knowledge of results, where knowledge of performance focuses on the patterns of actions that are needed to complete a skill while knowledge of results concentrates on information regarding the results of an action (Franks, 2007:59). Traditionally, these extrinsic forms of feedback were given by the coaches and the accuracy of the feedback depended on the efficiency of the relevant coach to identify the tactical and technical flaws of the relevant players. When introduced in the sporting world, this method was regarded as being very subjective and the potential of videos and computer software programmes were immediately recognised as a more reliable method for analysing sport (Rees, 1996:26 and Newell, 2004:54). Baca (2006:148) also encouraged the use of modern information and communication technologies due to its contribution to the effectiveness towards the improvement of sport performance.

The introduction of video analysis can be regarded as the most common form of communication technology currently used to assist with the improvement of performance in sport.

2. THE USE OF VIDEO ANALYSIS IN RUGBY UNION

Video analysis can be used for either notational or biomechanical analysis in sport (Bartlett, 2001:123). Even though the systematic techniques of observation are used by both forms of analysis to provide feedback to the coaches and athletes, there are marked differences. Computer notational analysis (also referred to as CNA) focuses on gross movement patterns in team sports, investigating strategy and tactics by means of technical and tactical performance indicators. In contrast to CNA, biomechanical analysts prefer to focus on the fine details of the movement technique of individual athletes/players (Bartlett, 2001:123).

Despite biomechanical analysts having focussed mainly on athletes in individual sports, some studies were also done on the biomechanical analysis of rugby union. From the literature it seems that biomechanical research focused mainly on three major topics in rugby union. Firstly, studies were done on the forces present during scrums to determine the most effective scrum techniques and the possible dangers related to the incidence of injuries. These studies were all conducted where a force plate was mounted on the scrum machine (Milburn, 1990:47; Milburn 1993:168 & Gianotti *et al.*, 2008:427). The second group of studies concentrated on the occurrence/incidence of injuries and its prevention, especially with regard to the contact events during a match (Wilson *et al.*, 1999:153; McIntosh *et al.*, 2003:63 & Patton *et al.*, 2006:185). The third group of biomechanical research focused on the technical application of different skills in order to improve performance, such as the studies done by Phythian (1995:51) Griffiths and Hughes (2005:102), Bezodis *et al.* (2007:171), Young (2007:185), Trewartha *et al.* (2008:845) and Pavely *et al.* (2009:136). It is important to note that the present study only refers to the importance and place of biomechanics in rugby union research, but does not elaborate on it, since it does not form part of the scope of the study.

As previously mentioned, one can make use of notational analysis in order to analyse sport, and especially team sports. Two basic forms of notational analyses exist. The one is done by hand and the other by means of computers (software packages).

Hand notation is considered the cheapest method and very accessible, due to the fact that only pen and paper are required. However, the biggest disadvantage of hand notational analysis was highlighted by Hughes and Franks (2007:80) who explained the time consuming nature of the process. This might be the main reason why the only noteworthy research available on hand notation, was a study done by Eaves *et al.* (2008b:44). They investigated the effect of rule changes in rugby league and found that the rules implemented in both 1993 and 1996 significantly increased the time it took players to clear a ruck. CNA, on the other hand, has been used extensively in three specific research fields, namely: 1) Time-motion analysis; 2) The use of performance indicators to determine success; and 3) The use of performance indicators to investigate how the game has evolved due to its professional status and regular law changes. However, Bartlett (2001:123) did warn that all researchers should be wary of the reliability and danger issues related to these types of research.

3. RELIABILITY ISSUES OF CNA

Handcock (1993:7) identified how difficult it is to analyse team sports. Since then, several reliability issues related to CNA have been investigated. Hughes *et al.* (2001:20) did a study to answer questions on the reliability of the performance profile of teams. They found that at least seven matches had to be analysed before the results could be considered a normative representation of the specific population. In a time-motion analysis study done by Duthie *et al.* (2003:973) they investigated the reliability of the analysis done on stationary, walking, jogging, striding, sprinting and static activities. In the study, the same matches were analysed twice, a month apart. Moderate to poor reliability was found for the total time spent on each activity and good to poor reliability was found when the frequency of each activity was investigated. They concluded that time-motion analysis could be considered as a good method to evaluate performances in sport as long as the time that elapsed between the matches as well as the reliability of the observations were taken into consideration. Roberts *et al.* (2006:388) and Dogramaci and Watsford (2006:73) compared two different methods of time-motion analysis to determine which one is the most reliable. Roberts *et al.* (2006:388) compared the reliability factor between the traditional notational system and a digitizing method of analysis. With the digitizing method several cameras were placed around the field, each one concentrating on a specific area of the field. The study found the digitizing method to be more reliable, but because of the costs involving this specific method, most

studies dealing with video analysis still use the traditional notational method of analysis with the camera/s following one specific player or players in a game. Dogramaci and Watsford (2006:73), on the other hand, compared the results of the different activities between match-play time and clock-play time in team sports. They found that match-play time could be considered more accurate than clock-play time and that overall distance covered was significantly more in match-play time than that of clock-play time.

Lames and McGarry (2006:62) investigated the reliability of studies that used performance indicators to predict performance. They found that such performance indicators could not be considered reliable due to the huge amount of interaction of activities that affect them. O'Donoghue (2007:46) did a similar study, and despite sharing the concerns of the previous researchers, believed that with certain recommendations a fairly reliable outcome from CNA could be possible. These recommendations were as follows:

- a) Identify the performance indicators of interest as precisely as possible;
- b) Indicate the values of each performance indicator;
- c) Use reliable statistics;
- d) Train the operators;
- e) Make use of inter and intra-operator tests;
- f) If the level of reliability is poor, one should try to simplify the selected performance indicators.

The most recent study, in which CNA was used to determine reliability of sport techniques, was done by Williams *et al.* (2007:85) who compared the reliability of real-time and lapsed-time analysis. They found that lapsed-time analysis could be considered more reliable than real-time analysis and argued that the ability of lapsed-time analysts to examine the same footage several times should be considered the biggest advantage. Despite this argument, Van der Vliet (2008:9) still considered real-time analysis in sport as the key to success in sport performance.

Several other researchers such as Hughes and Williams (1988:255), Rees (1996:26), Newell (2004:54), Pope (2004:38), Botha (2005:16), Reed and O'Donoghue

(2005:12) and Baca, (2006:148) emphasized the importance of video analysis in sport and added objectivity as the biggest advantage. Mallett (2006:122), the international coach of the Italian rugby team since 2006, and White (2005:106), coach of the Rugby World Cup winning team, the South African Springboks in 2007, concurred with the previous studies and believe that performance in a game such as rugby could directly be improved by making use of video analysis. Reed and O'Donoghue (2005:12) also investigated the development and application of CNA and determined that the ability of computer systems to handle vast amounts of data simultaneously would be more reliable than any possible human attempt. The aforementioned literature does therefore indicate that the reliability of CNA could be considered acceptable when specific guidelines are followed. The possibilities of CNA as research tool is therefore palpable when the advantages there-of are taken into consideration.

4. THE ROLE OF CNA IN RUGBY UNION

It was indicated in the previous paragraph that CNA plays an important role in the video analysis of rugby union matches. Based on this assumption, a total of thirty eight (38) relevant articles will be used in the rest of the discussion. The summary of the articles will be divided into three groups with regard to their respective outcomes in mind. Each group will include a table that lists the title, authors, year of publication, the population and either activities or performance indicators, followed by a discussion on the corresponding findings by the selection of articles in the group.

4.1 Time-motion analysis

Time-motion analysis is used when the duration, type and frequency of the different activities are analysed in order to determine the work-to-rest (work:rest) ratio's of the corresponding team. The information gathered from the analysis is then used to give feedback to the coach and players and to assist in the construction of sport-specific conditioning programmes. Table 1 presents the studies that were done on time-motion analysis followed by a discussion on the findings of the relevant literature.

Table 1: The use of time-motion analysis to determine various match-play activities of rugby union

Title	Authors	Year	Population	Match-play activities
Analysis of the physical demands of international rugby union.	McLean, D.A.	1992	5 Games 1989-1990 five Nations rugby tests	Standing Walking Run with elongated stride Jogging Sprint Non-run intense activity
Applied physiology of rugby league.	Brewer, J & Davis, J	1995	2 x Elite rugby matches 4 x 13 Players 4 playing positions	Standing Walking forward & backward Cruise forward & backward Jog forward & backward Sprint Scrum Play the ball Sprint/Tackle Sprint/Step/Tackle Sprint/Pass Sprint/Step/Pass Sprint to Tackle Jog to Tackle Stand and Tackle Jog and Pass Stand and pass
Heart rate, blood lactate and kinematic data of elite colts (under 19) rugby union players during competition.	Deutsch, M.U.; Maw, G.J.; Jenkins, D. & Reaburn, P.	1998	24 players from U/19 Brisbane rugby competition 4 sets of playing positions	Utility Cruising Walking Sprinting Jogging
Activity analysis of English premiership rugby football union refereeing.	Martin, J.; Smith, N.C.; Tolfrey, K. & Jones, A.M.	2001	9 elite referees	Standing Walking Jogging Sprinting Running with elongated stride Walking backward
Time-motion analysis of elite touch players.	O'Connor	2002	30 male +20 female Australian squad 2 matches @ gender	Stationary Walking Jogging forward Running Backward Sideways Sprint Recovery
Time-motion analysis of 2001 and 2002 Super 14 tournament.	Duthie, G.M.; Pyne, D.B. & Hooper, S.L.	2005	16 Games 3 Australian based rugby teams 4 sets of playing positions	Standing Striding Walking Sprinting Jogging Static exertion Tackling Jumping Lifting
Characteristics of effective ball carries in Super 14 rugby.	Sayers, M.G.L. & Washington-King, J.	2005	48 Super 14 rugby matches 90 players 4 sets of playing positions	Stationary Cruising Walking Sprinting Jogging
Sprint patterns in rugby union players during competition.	Duthie, G.M.; Pyne, D.B.; Marsh, D.J. & Hooper, S.L.	2006	17 rugby players	Standing Walking Jogging Striding
Motion analyses of adolescent rugby union players: Linking training and game demands among under 16 players.	Hartwig, T., Naughton, G. & Searl, J.	2006	Training: 14.5 hours @ 22 players Game: 11 hours @ 12 players	Stationary, Walk, Jog, Stride, Sprint, Maxim sprinting. Exercise load.
Time-motion analysis of professional rugby union players during match-	Deutsch, M.U.; Kearney, G.A.	2007	8 Super 12 rugby games 29 Otago players	Jumping Cruising Scrummaging Utility Sprinting Jogging

play.	& Rehrer, N.J.			
Defining the volume and intensity of sport participation in adolescent rugby union players.	Hartwig, T., Naughton, G. & Searl, J.	2008	75 players Motion analysis 2@week 14-18 years	Elite group 10 weeks Representatives 6 weeks School boys 12 weeks
The physical demands of elite English rugby union.	Roberts, S. P., Trewartha, G., Higgitt, R.J., El-ABD, J & Stokes, K.A.	2008	Tight forwards (n=8), Loose forwards (n=6), Inside backs (n= 7), Outside backs (n=8)	Standing, walking, jogging, static exertion, low intensity running and high intensity running.

From the above-mentioned research indicated in Table 1 it is necessary to elaborate more on the findings of the relevant research as to how it related to the match-play activities and the flow of the games. McLean (1992:285) found that the work:rest ratio between the teams differed from 1:1 to 1:1.9. A scrum, line-out, ruck and maul (all considered high-intensity activities) occurred every 33 seconds on average and the ball was in play for 29 of the 80 minutes of the match. Brewer and Davis (1995:129) determined that individual players covered a total distance ranging from 5 km to 8 km. Hartwig *et al.* (2008:94) used time-motion analysis in their study to determine the work rate (by determining the distance the players covered during practice) of three different groups of adolescent rugby players. Their findings indicated that the group with the most other physical activity responsibilities covered significantly less distance during training sessions. They concluded that rugby players could increase their work rate if they would decrease other physical orientated activities (Hartwig *et al.*, 2008:94). Hartwig *et al.* (2006:16) also did a study on adolescent rugby players to investigate the work done during training sessions compared with work required during match-play. They found that the players had to travel significantly longer distances during matches than was the case during practice sessions. Deutch *et al.* (1998:561) found that outside backs covered a significantly longer total distance (~5 750 m) than any of the forwards (~4 400 m). They also found that forwards are more involved in high-intensity static activities than backline players. Outside backs cover a significantly longer distance *sprinting* than inside backs and the backline players cover a significantly longer distance *walking and sprinting* than the forwards. A study done by Duthie *et al.* (2005:523) correlates with the previous findings and determined that forwards spend more time with static exertion than the backs. The backline players *sprint* more often and for more extended periods than the forwards, but also enjoy longer *rest periods*. This also correlates very well with the study done by Roberts *et al.* (2008:825) who also determined that the forwards spent more time on static exertion activities and that the backs covered longer distances and spent more time running at high intensities. Another interesting fact found was that all the players

travelled longer distances in the first 10 minutes than thereafter. Martin *et al.* (2001:1069), who investigated the time movement of rugby union referees, found that the total distance covered during a match was approximately 8 581 m. There was a total of 672 transitions of activities throughout the match. The referees spent 76% of the time during a match either standing still or walking. O'Connor (2002:126), on the other hand, investigated touch rugby players and found that both male and female touch players spent 66.5% to 69.6% of their time predominantly either running or jogging. Sayers and Washington-King (2005:92) used time-motion analysis in a different way. They determined that successful teams received passes at a higher speed and continued that specific speed with more ease than the less successful teams. They also found that players tend to more than often receive a ball at a cruising speed and *run* with moderate intensity. Another study undertaken by Duthie *et al.* (2006:208) determined that forwards reached a *sprint* speed of above 90% maximum 5 times during a match on average whilst backline players achieved the same –intensity of play 9 times per match on average. This higher frequency of *sprinting* of the backs was seen by the researchers as a definite indication to Sport Scientists to differentiate when they do speed training with a team. Deutch *et al.* (2007:461) used the activities listed in the table to look into the correlation between those activities and the different positions. A definite correlation was found between the players' positions and the activities that specific position was most involved in. From the above-mentioned literature review it can be concluded that rugby can be regarded as a sport with intermittent high- intensity play for the different positions of play and that players should be conditioned accordingly.

The literature review also revealed that time-motion analysis is not the only aspect that is investigated with CNA. As previously mentioned, CNA, in conjunction with performance indicators, is used to determine changes in the game as well as to predict the success in the outcome of the game.

4.2 The effect of performance indicators on match-play success and changes in rugby union matches

Performance indicators can be defined as “a selection or combination of action variables that aims at defining some or all aspects of a performance” – specifically applicable to rugby matches (Hughes & Bartlett, 2002:739). They can be classified into scoring indicators and indicators related to the quality of the performance during play (Hughes & Bartlett, 2007:169). Performance indicators can also be used to compile performance profiles for a specific sport code (Hughes *et al.*, 2001:4).

Hughes and Bartlett (2002:739) and O'Donoghue (2008:145) suggested that the performance indicators used in any study should be chosen with care and that ratio's rather than frequency should be used in this regard.

Table 2: The effect of performance indicators on the match-play success and changes in rugby union

Title	Authors	Year	Population	Performance indicators (amount)
Developmental and application of a computerized rugby union notational system.	Hughes, M. & Williams, D.	1988	5 matches France, Scotland, Ireland, England & Wales	Passes, ran the ball & possessions
Computerized notation analysis of rugby union to examine the effects of law changes upon the patterns of play by international teams.	Hughes, M. & Clarke, A.	1994	18 matches	Possessions Rucks and Mauls Tries scored Rucks by 6 men Mauls by 7 men
Team performance indicators as a function of winning and losing in rugby union.	Jones, N.M.P., Mellalieu, S.D. & James, N.	2002	20 Matches	% successful scrums, % successful line-outs, % successful rucks, % successful mauls, % successful tackles, % successful offloads, % successful turnovers won, % successful line breaks, successful place kicks, errors made in three zones, tries scored, time in possession & errors made
Creating and monitoring meaningful individual ratings	Bracewell, P.J., Meyer, D. & Ganesh, S.	2003	130 actions	Tackles, turnovers, meters gained, kicks & beaten defence
Patterns of play of international rugby union teams before and after the introduction of professional status.	Eaves, S.J. & Hughes, M.	2003	16 matches from the 6 Nations tournaments	Rucks, time of rucks, activities & time of activities
Quantitative and qualitative evaluation of scoring opportunities by South Africa in World Cup Rugby 2003.	Boddington, M. & Lambert, M.	2004	5 matches in 2003 World Cup	Position on field where movement started before scoring points, Time when points were scored
The consequences of the introduction of professional playing status on game action variables in International Northern Hemisphere rugby union football.	Eaves, S.J., Hughes, M. & Lamb, K.L.	2005	24 Five nation matches	Line-outs, kicks , passes, offloads, rucks, mauls, scrums, Phase activities and Set pieces
The development of position-specific performance indicators in professional rugby union.	James, N., Mellalieu, S.D. & Jones, N.M.P.	2005	22 matches European rugby	% successful tackles % successful ball carries, % successful passes, turnovers won,

				tries scored & penalties
The effect of rule changes on match and ball in play time in rugby union.	Williams, J., Hughes, M. & O'Donoghue, P.	2005	469 Matches	Match time & Ball in time play
Re-Examination of importance of kick-off and 50m restart kick in play in rugby union.	Nakagawa, A.	2006	20 International matches	Kick offs and restarts
A comparison of performance indicators between the four South African teams and the winners of the 2005 Super 12 Rugby competition. What separates top from bottom?	Prim, S., Van Rooyen, M. & Lambert, M.	2006	9 Super 12 matches	Defensive recycle time, Offensive recycle time, % tackles made, offloads, opposition offloads, turnovers, turnovers conceded, points difference and tries scored.
Movement time as a predictor of success in the 2003 rugby world cup tournament.	Van Rooyen, M.K. & Noakes, T.D.	2006	25 matches 4 Countries	Time ball in possession of team
A retrospective analysis of the IRB statistics and video analysis of match play to explain the performance of four teams in the 2003 Rugby world cup.	Van Rooyen, M.K., Lambert, M.I. & Noakes, T.D.	2006	26 Matches at world Cup	Tries scored, Conversions scored, Penalties scored, drop goals scored, Scrum for, Possession for and territory for
Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004.	Quarrie, Q.L. & Hopkins, W.G.	2007	26 matches	Scrum, rucks, mauls, tackles, line-outs, passes, kicks, scores, penalties awarded, ball in play time and match time
Game analysis of the eight top ranked tertiary institution rugby teams in South Africa.	Coetzee, B. & van den berg, P.H.	2007	14 games University teams	Time in play, % good line-outs, & good scrums, & good tackles, Kick offs and contact with ground
Scoring profiles and defence performance analysis in rugby union.	Sasaki, K., Furukawa, T., Murakami, J., Shimozone, H., Nagamatsu, M., Miyao, M., Yamamoto, T., Watanabe, I., Yasugahira, I., Saito, T., Ueno, Y., Katsuta, T. & Kono, I.	2007	198 matches of the top Japanese league	Tries, Start area for try, phases for a try, time spend in each phase
Ruck frequency as a predictor of success in the 2007 rugby world cup tournament.	Van Rooyen, M.K., Diedrick, E. & Noakes, T.	2010	48 matches of the 2007 rugby world cup	Rucks, points scored

Based on the literature cited in Table 2, the following related findings can be reflected. Hughes and Williams (1988: 255) found no significant differences when they compared the frequency of performance indicators between the Five Nations rugby teams taking part in the 1986/1987 seasons. However, when they paired the England and Wales teams and compared their data of those of the other nations combined, a significant difference was found for the number of passes made during a match. Their conclusion was that the five nation teams made use of different game plans to play different types of rugby. Hughes and Clarke (1994:180) investigated how the performance indicators were affected by the law changes implemented in 1993. They found that the frequency of rucks formed by six men, the frequency rucks formed by seven men and the number of passes made throughout a match rose significantly. The other performance indicators did not show any significant changes due to the related changes in the laws of the game. In using certain performance indicators, Jones *et al.* (2002:61) found that only tries scored and percentage successful line-outs discriminated significantly between successful and less-successful teams. Bracewell *et al.* (2003:19) analysed the performance indicators to determine specific ratings for each player according to their involvement in the identified performance indicators. They found this method of analysis to be reliable and a possible option for coaches to use with player selections. Professionalism also had an impact on the performance indicators in rugby. Eaves and Hughes (2003:103) determined that rucks, time of rucks and the frequency of activities increased after the introduction of professionalism; hence a more compelling demand on the physiological preparation of the players since the sport turned professional. Another study done on the effect the professional era had on the performance indicators, found that significantly less line-outs, kicks, mauls, set pieces and phase positions took place after rugby turned professional. Significantly more rucks and passes also occurred after the sport turned professional (Eaves *et al.*, 2005:58). Boddington and Lambert (2004:32) found that during the 2003 Rugby World Cup Tournament, South Africa needed more time in possession in the first half than in the second half to score points. South Africa also scored most of their points from line-outs on the left side of the field more or less on the half-way line. James *et al.* (2005:63) investigated positional differences with regards to performance indicators. They found significant differences between all the positions and their involvement in the performance indicators listed in the table. They also found significant differences when they looked into a number of different players in a specific position with regard to the performance

indicators. The researchers therefore suggested that due to individuality, a larger sample size of players should be used, than was the case for this specific study.

Williams *et al.* (2005:1) found that both match-time and ball-time-in-play increased significantly since the law changes that were introduced by the International Rugby Board in 1999. Nakagawa (2006:273) determined that despite all the law changes and professionalism which occurred between 1994 and 2005, the relevance of the kick-off as important performance indicator remained the same. In a study done by Prim *et al.* (2006:132) performance indicators of all the South African teams were compared with those of the New Zealand Crusaders team (tournament champions). Of all the performance indicators listed, only number of tries scored differed significantly between the groups. Van Rooyen and Noakes (2006:31) found that all movements (team has ball in hand) during the 2003 Rugby World Cup, observed by the research team were less than 20 seconds and that a team could greatly enhance their chance of scoring points if they could extend a movement to longer than 80 seconds. In this case the time a team managed to keep the ball in possession during attack was considered a performance indicator. Van Rooyen *et al.* (2006:57) did a study where the performance indicators of the top three rugby nations during the 2003 Rugby World Cup were compared with that of South Africa. However, no significant differences were found between the performance indicators of the various teams. Quarrie and Hopkins (2007:895) examined the changes in performance indicators during the Bledisloe Cup from 1972 up to 2004. They found results similar to those of Eaves and Hughes (2003:103) and Eaves *et al.* (2005:58) with an increase in the number of rucks and passes made. Quarrie and Hopkins (2007:895) also found an increase in tackles, tries and ball-in-play time, with a decrease in the number of line-outs, mauls and kicks. Coetzee and Van den Berg (2007:49) investigated the direct effect of performance indicators on team performance and found that the percentage good defence, line-outs, scrums and kick-offs contributed most towards the ranking of the respective teams. This correlates with findings of Nakagawa (2006:273), who also emphasized the importance of the kick-offs. Sasaki *et al.* (2007:46) determined that despite the performance indicators listed during the game, only the time spent on an activity before tries were scored, differentiated significantly. Tries scored from set pieces took longer than those from turn-over ball, even though the set pieces were closer to the try line. The most recent study using performance indicators to analyse rugby union matches was done by Van Rooyen *et al.* (2010:33). They found a correlation between the percentage rucks formed and the

points difference between the two teams. This meant that the more rucks a team could form, the better their chances of scoring points. From the above-mentioned literature review it can be concluded that rugby union consist of various different performance indicators which make the analysis of the sport far more difficult than most other types of sport. It has also indicated that performance indicators can be used to determine both performance and the effect certain types of change have on the game.

4.3 The use of CNA to investigate other role players relevant to rugby union

O'Donoghue (2006:12) investigated the different applications of computer analysis that are present in sport. He found that although most research focused on the fields of time-motion analysis and the identification of performance indicators, the officials, coaches and all other facets relevant to rugby union could benefit from CNA research. The following section will report on and discuss other CNA-relevant research.

Table 3: The use of other CNA-relevant research related to rugby union.

Title	Authors	Publication year	Population	Additional
The accuracy, agreement and coherence of decision-making in rugby union officials.	Mascarenhas, D.R.D., Collins, D. & Mortimer, P.	2002	45 male referees and 13 referee coaches and 47 touch judges and 27 referee assessors	Dissicion making
Pre-performance routine consistency: temporal analysis of goal kicking in the rugby World Cup	Jackson, R.C.	2003	572 place kick during 1999 rugby world cup	Concentration time, situational pressure & physical preparation times
A comparative analysis of professional rugby league football playing pattms between Australia and the United Kingdom	Eaves, S. & Broad, G.	2007	12 Rugby League Matches from both the English super league and the Australian national rugby league	Zone on field where most time is spend, Types of tackles used.
Contact events in rugby union and their	Fuller, C.W., Brooks, J.H.M., Cancea, R.J., Hall, J.H. & Kemp, S.P.T.	2007	50 matches English premier rugby clubs	Tackle, Ruck, Maul, Collision and Scrum

propensity to cause injury.				
Assessing the impact of the season and rule changes on specific match and tactical variables in professional rugby league football in the United Kingdom	Eaves, S.J., Hughes, M.D. & Lamb, K.L.	2008a	48 matches	Passes, Tackles & Kicking
Playing demands of sevens rugby during the 2005 rugby world cup sevens tournament	Van Rooyen, M., Lombard, C. & Noaks, T.D.	2008a	47 matches of 2005 World Cup	Time ball in possession, movements per match, scoring movements & turnover movements
Tackle injuries in professional rugby union	Quarrie, K.L.	2008	434 matches	Height and direction of tackle, speed of tackler and ball carrier
The quantification of contacts with impact during professional rugby matches.	Van Rooyen, M., Rock, K., Prim, S. & Lambert, M.	2008b	7 Matches in professional provincial competition	Frequency contact situation for each player.
Impact of the International Rugby Board's experimental law variations on the incidence and nature of match injuries in southern hemisphere professional rugby union	Fuller, C.W., Raftery, M., Readhead, C., Targett, S.G.R. & Molloy, M.G.	2009	27 Teams in 2008 Super 14 and Vodacom matches	Injury incidence, severity, location, type and cause = New Laws

Based on the research reflected in Table 3, several CNA-related issues were identified and need to be highlighted. Mascarenhas (2002:253) did a study in which the ability of referees to make the correct decision based on a video clip was evaluated. All the participants watched a real-time video clip and had to explain how they would act on what they saw as if it was a live match. The results indicated a very low accuracy count. Jackson (2003:803) examined 572 place kicks during the 1999 Rugby World Cup. Concentration and physical preparation time were analysed from