Original Article

Profiling half-back play in rugby union and the impact of substitutions

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ABSTRACT

An exploratory method of quantifying the impact of individual players in rugby union was developed and applied to both half-back positions in 2015 Rugby World Cup matches with a view to firstly test the validity of these systems by profiling players, and secondly, if successful, to assess the impact of substitutions. A match impact scoring system was devised using questionnaire responses of an expert group of professional rugby analysts and experienced international coaches. The scoring system weighted each game action in a positive or negative manner according to the impact on team performance. It was found that the proposed method produced valid and reliable data concerning player performance. It was applied to half-backs substituted with more than 20 mins playing time left, the two 20 min period, before and after substitution, were compared. A "non-substituted" control group were also analysed, in both the first and final 20 minutes of competition. It was found that for the scrum-half position, the starting players produced a higher median 'efficacy' score than replacement players 27.46, (std. dev. +10.06) and 20.42, (+12.45). The best performing scrum-half group were the 60-80-minute non-replaced players 29 (+9.0). For the out-half position, it was found that the highest median 'efficacy' was achieved by the replacement player group 18.80, (+ 11.00), with the non-replaced 60-80-minute group performing worst 14.40, (+ 7.09). Future research should develop the methods applied in this study to define player profiles for each position on the rugby field. It is suggested that these profiles should use score difference between the teams to take into account the strength of the teams involved. The concept of a weighted individual player efficacy system has been demonstrated in the sport of rugby union, but could be applied in any team sport where greater individual player performance data is required.
Keywords: Player profiling; Substitutions; Rugby union.

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INTRODUCTION

Performance indicators and rugby

In order to place athlete performance levels in context, it is necessary to firstly identify what specific factors of performance indicate success and secondly, to compare single performances against previous performances. This will provide feedback, which, if successfully identified and applied, will lead to improved future performance. Such factors are referred to as performance indicators (Hughes and Bartlett, 2002). The process of developing a method to objectively gather performance information and subsequently weight this information in relation to its importance to game outcome one that will increase our understanding of the most important, or key performance indicators. This process will be developed in this study to quantify individual player performance levels in the 2015 Rugby World Cup tournament.

Table 1.1. Team PI's discriminating between winning and losing performances

Authors and Year of Study	Title	Number of games Analysed	Discriminating K.P.I. Between Winning and Losing Performances
Vaz et al. (2010)	Rugby game-related statistics that discriminate between winning and losing teams in I.R.B. and Super Twelve close games.	324	Kicked More Possession More Passes Completed More Mauls Won More Turnovers Won Fewer Errors Made
Jones et al. (2004)	Team performance indicators as a function of winning and losing in rugby union.	20	Lineouts Won On Opposition's Throw More Tries Scored
Bremner et al. (2013)	A retrospective evaluation of team performance indicators in rugby union.	65	More Territory inside the 22m line More Quick ruck ball
Prim et al. (2006)	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?	9	None
Hughes M.T. et al. (2012a)	Performance indicators in rugby union.	48	None

Since the inaugural tournament in 1987, rugby has developed into a major world professional sport. The narrow margin between winning and losing performances was identified by Vaz et al. (2010) who found that statistically significant differences in team performance indicators between winning and losing teams in professional rugby in the southern hemisphere were unlikely when the difference between the final score is 15 points or less. This is most likely due to the similarities in preparation and technical proficiency of the players at this level of competition. Indeed, there is little consensus in the available studies regarding which team performance indicators discriminate between winning and losing performance, as can be seen in Table 1.1.

Such inconclusive evidence means that it is logical to examine performance on an individual rather than a team level in order to gain an insight into the key performance indicators in rugby.

Individual player analysis

Heasman et al. (2008) developed a methodology to assess individual player impact ranking in Australian football. This was done by giving each player action a numerical score for each game involvement. Positive and negative contributions were given an agreed scores. It was found that midfielders recorded significantly higher scores than defenders or forwards. Therefore, midfielders have significantly greater opportunities to influence the match outcome. Similarly, in rugby, the half-back positions have a major influence over the match outcome due to the amount of possession that these players enjoy, as quantified by James et al. (2005). It is important to note that the ability of the half-backs to influence the game through their use of possession will be heavily influenced by the amount and quality of possession that the half-backs receive from their forwards.

Lim et al. (2009) constructed a player impact matrix for rugby and analysed individual player involvement of all rugby positions over three seasons. It was found that the scrum-half (13%), out-half (28%) and back-row forwards (16%) had the most net game involvement as a percentage of team total, confirming the findings of James et al. (2005). Therefore, examining these individual positions in greater detail gives a better understanding of how they affect team performance. A player match impact (or efficacy) weighting, similar to that devised by Lim et al. (2009) is a key aspect of this study.

Villarejo et al. (2015) used performance indicators to measure the characteristics of player performance by position in winning and losing teams. The data were gathered from all 48 matches of the Rugby World Cup in 2011. They found that the scrum-half on a winning team was responsible for significantly more kicks, metres gained per kick and try assists. This study grouped the out-half with the centre positions, as opposed to the study by Lim et al. (2009) who considered the positions individually, restricting the ability to compare data between them. The large number of games analysed by Villarejo et al. (2015), whilst providing greater data stability, may also obscure important data due to a number of mismatches during that tournament. The average points gap in matches between tier one and tier two nations was 20 points, and seven games had a winning margin of greater than 50 points (World Rugby, Formerly International Rugby Board, 2011), therefore the importance of specific performance indicators to match outcome may change, relative to the strength of the opponents. This finding was also identified by Carroll (2013) with reference to Gaelic football.

Whilst all players are required to perform a range of skills, some positions require a greater proficiency in specific areas. World Rugby (2015) defined the tactical requirements of the scrum-half and out-half positions. The scrum-half is required to:

- Link forwards and backs to maintain continuity of play.
- Communicate with team members, especially directing and organisation of attack.
- Create, identify, communicate, manipulate and exploit space in attack.

The out-half is required to:

- Link with the scrum-half to maintain continuity of play.
- Set and communicate attacking line width and depth.
- Select, implement and communicate correct decisions during attack.
- Create, identify, communicate, manipulate and exploit space in attack.
- Support team members in attack and defence.

From these positional requirements, it is clear that the major responsibilities of the half-back players are attack rather than defence orientated, however the defensive capability of these positions is also assessed in this study with a view to demonstrating the potential of the player efficacy to other positions.

The match-day tactics employed by the half-backs will vary depending on the skills of the available players, the perceived weaknesses in the opposition defence and other confounding variables, such as match location and weather conditions. Tactics may also change when substitutions are made, making a comparison of individual performance profiles problematic. Replacement players may bring different strengths to the team in relation to their ability to pass, kick or run with the ball. James et al. (2005), with reference to the out-half position, found that intra-positional differences may be due to an individual's style of play and the effects of confounding variables. They suggest that multiple profiles of the same position may be needed to take these factors into account.

Player profiling

Hughes et al. (2012a) analysed all games at the Rugby World Cup tournament in 2011 and found that using only frequency data of team performance indicators are insufficient to identify significant performance indicators. They recommended that more qualitative analysis of individual player skill sets for each position be undertaken to understand how performance indicators reflect performance. This paper seeks to apply this finding by presenting individual player data for the half-back positions to quantify how substitutions affect match performance in these positions.

After quantifying the game actions undertaken by the players, the data can be used to develop a positional profile of the key skills of the half-back positions. Hughes et al. (2012b) suggested that combining the identification of key positional skills in soccer with a weighting system for the effective use of these skills, presents an opportunity to develop an objective profile to assess how effective players are in their position. Such qualitative data could be used by coaches when deciding on the tactics to be employed on a game to game basis or, on a wider scale, be used to identify individuals for scouting and recruitment criteria, as suggested by Hughes et al. (2012a).

Vaz et al. (2010) found that statistically significant differences in team performance indicators are unlikely in games where the points difference between the teams is 15 or less. This finding has not been extensively examined with reference to individual performance indicators. Thus, this study will quantify the individual player efficacy of the half-backs and also assess how the replacement of these players impacts on performance, relative to the player that started the match.

Substitutions in rugby

Currently, World Rugby regulation 3.4(a) (World Rugby, 2016) permits teams to replace up to eight players in international competition, with three of the replacements being able to play in the three front-row positions, leaving the remaining five players to provide cover for the other 12 positions on the field as the coaching staff see fit. World rugby defined a "replacement" as a player who enters play in the place of an injured player and a "substitute" as a tactical change of personnel made by the coach. As this study does not have access to the information regarding the nature of the player change, whether a player is a "replacement", or a "substitute" is not taken into account. This information has implications for this study as a "replacement" is enforced by injury, and therefore not a tactical decision taken by the coach with a view to influencing match outcome.

There is a limited amount of research on the role of substitutes in rugby. However, there have been comparable studies undertaken in soccer. Pearce and Hughes (2001) conducted a study to analyse the effect of substitute players relative to the players that they replaced. A weighting system was devised for player actions and the cumulative score for 15 minutes of the replaced player compared with the first 15 minutes of the substitute player. This allowed for a "match impact" score for comparison of the two players. It was found that 37.5% of substitutes performed better than the player that they replaced, 25% of players performed worse than the player they replaced and 37.5% had no impact. The concept of comparing the impact of substitutes relative to the players that they replaced is a core component of this study.

World Rugby, (2011) provided statistics on the increasing numbers of substitutes used in Rugby World Cup competition. It was found that the mean number of substitutes and the number of points scored by the substitutes of both teams had steadily increased between the 1995 and 2011 tournaments, as shown in Figure 1.1:

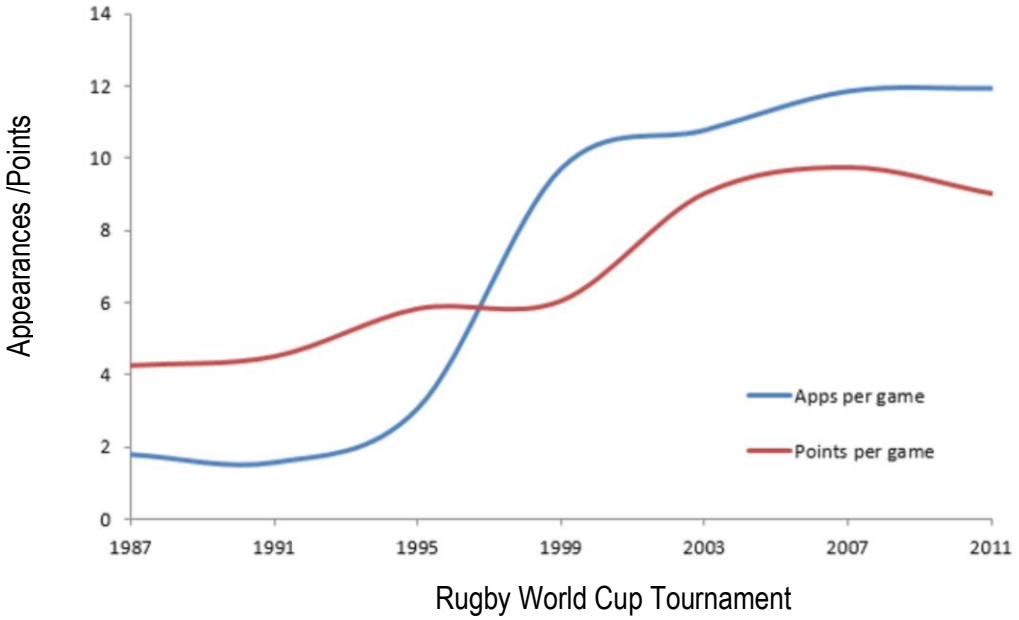

Figure 1.1. Replacement appearances and the number of points scored at Rugby World Cup tournaments up to 2011(World Rugby, 2011)

The growing importance of substitute players and their effect on match outcome can be seen in Figure 1.1. To date, the effect of player substitution on match outcome has not been quantified. However, it can be hypothesised that replacement players will have greater game impact than the player they replaced. This could be due to the replacement player having higher reserves of energy, relative to those players who have played the entire match. A further aspect to this study is to ascertain if the replacement players perform the same "game actions" as the starting player, or if the replacement player attempts to influence the attack by using different tactics, for example by altering the amount of possession that is kicked in order to gain a territorial benefit at the expense of keeping possession by passing and running with the ball.

Aims

This is an experimental study designed to quantify individual player performance. The information gathered will be used to address the efficacy of replacement players relative to those players who started the game

for both half-back playing positions. Knowledge gained in undertaking this study will help to better inform coaches and players as to the effectiveness of substitutions. By quantifying the game actions performed by the starting and replacement player it will be possible to observe tactical changes during the match. The method proposed to assess the performance of substitutes relative to starting players should be used to assess the performance of all starting and replaced players participating in a game, providing a clear picture of player contributions. Such information is the first step towards developing a player profile that can be utilised to inform future tactical substitutions by the coaching staff.

Limitations and de-limitations

Limitations

1. This study examined a period of time of 20 minutes of play, according to the match clock. In instances after an infringement occurred, the referee would play advantage. If advantage is accrued any actions that the observed players performed was included in this study, however if no advantage accrued, play was re-started from the original infringement, however this "game time' was lost to the study as the match clock was not re-set to the time of the initial infringement.
2. This study used recordings of live broadcast matches. On occasions a short passage of play may have been missed due to a previous incident being replayed.
3. It was not possible to determine whether players were replaced for tactical or injury reasons, therefore it is unclear if the change was a voluntary act by the coach or enforced as the starting player was unable to continue.

De-limitations

1. The scrum-half and out-half positions were chosen in order to demonstrate the potential of this system to identify the efficacy of the starting and substitute players. As previously identified by Lim et al. (2009), both these positions have a major game involvement. Other positions, for example the wings, would have less game involvement, and therefore be less effective in demonstrating this method of assessing player efficacy.
2. The minimum period of analysis was 20 minutes, one quarter of a game. This was selected to allow sufficient time for the replacement players to have an opportunity to affect the match.
3. Each action had to be able to be performed by any player during a match. Actions that were not 'in play' such as re-start kicks or place kicks while potentially important to match outcome, were not included. This will allow for clearer inter-player comparison of game efficacy results. For example, a valid comparison can be made between a goal kicking out-half and a non-goal kicking out-half with a view to their player efficacy score in general play.

METHODS

Subjects

The subjects in this study were half-backs in Rugby World Cup 2015. All games in which a substitute played at least 20 minutes were analysed. The final 20 minutes of the starting player's time on the field was measured against the first 20 minutes of the replacement player, using an agreed player efficacy scoring system. Data were gathered for the scrum-half and out-half positions to demonstrate the potential for the selected methods to assess tactical changes in the use of possession by the replacement players relative to the starting players in these matches.

Selection using these criteria produced 39 eligible substitutions. These are presented in Table 2.1 and 2.2. A minus sign in the winning margin column indicates that the analysed player's team lost the match:

Table 2.1. Substituted scrum-half players analysed. (n=24)

Match	Team	Player Off	Player On	Winning Margin
England V Fiji	England	9	21	24
Ireland V Canada	Canada	9	21	-43
South Africa V Japan	South Africa	9	21	-2
France V Italy	France	9	21	22
Australia V Fiji	Fiji	9	21	-15
New Zealand V Namibia	New Zealand	9	21	44
Argentina V Georgia	Georgia	9	21	-45
Argentina V Georgia	Argentina	9	21	45
Italy V Canada	Canada	9	21	-5
England V Wales	England	9	21	-3
Scotland V U.S.A.	U.S.A.	9	22	-23
Scotland V U.S.A.	Scotland	9	21	23
Tonga V Namibia	Tonga	9	21	14
France V Canada	France	9	21	23
New Zealand V Georgia	Georgia	9	21	-33
England V Australia	England	9	21	-20
Canada V Romania	Romania	9	21	2
Canada V Romania	Canada	9	21	-2
Argentina V Namibia	Argentina	9	21	45
Italy V Romania	Romania	9	21	-10
France V Ireland	France	9	21	-15
Ireland V Argentina	Argentina	9	21	23
Australia V Argentina	Argentina	9	21	-14
Argentina V South Africa	Argentina	9	21	-11

Table 2.2. Substituted out-half players analysed. (n=15)

Match	Team	Player Off	Player On	Winning Margin
Ireland V Canada	Ireland	10	22	43
South Africa V Japan	South Africa	10	22	-2
U.S.A. V Samoa	Samoa	10	22	9
Ireland V Romania	Ireland	10	22	34
Romania V France	Romania	10	12	-27
South Africa. V Samoa	Samoa	10	22	-40
Scotland V U.S.A.	Scotland	10	22	23
Tonga V Namibia	Tonga	10	22	14
England V Australia	England	10	22	-20
Canada V Romania	Romania	10	23	-2
South Africa V U.S.A.	South Africa	10	22	64

Argentina V Namibia	Argentina	10	22	45
Italy V Romania	Romania	10	23	-10
France V Ireland	Ireland	10	22	15
France V Ireland	France	10	22	-15

In addition to the quantification of starting and replacement player actions, analysis was conducted on a control group of 13 instances, (eight scrum-half and five out-half performances) in which the starting half-back was not substituted. The first 20 minutes and the last 20 minutes of matches were analysed to provide a comparison with replaced players. The games analysed for this aspect of the study are identified in Table 2.3 below:

Table 2.3. Non-Replaced players analysed (n=13)

Match	Team	Pos.	Round	Result	Winning Margin
England V Wales	Wales	9	Pool A	28-25	3
Samoa V Scotland	Scotland	9	Pool B	33-36	3
Ireland V Italy	Ireland	9	Pool D	9-16	7
Italy V Canada	Italy	9	Pool D	23-18	5
Australia V Scotland	Scotland	9	Quarter-Fin.	34-35	-1
South Africa V Wales	South Africa	9	Quarter-Fin.	23-19	4
South Africa V New Zealand	South Africa	9	Semi-Fin.	20-18	2
South Africa V New Zealand	New Zealand	9	Semi-Fin.	20-18	2
England V Wales	Wales	10	Pool A	28-25	3
Samoa V Scotland	Scotland	10	Pool B	33-36	3
Ireland V Italy	Ireland	10	Pool D	9-16	7
Australia V Scotland	Australia	10	Quarter-Fin.	35-34	1
South Africa V New Zealand	New Zealand	10	Semi-Fin.	20-18	2

The cases selected involved matches with a score difference of seven points or less. The criteria are deliberately applied as in these matches the coaching staff had the option of replacing the starting player, but chose not to do so, removing the possibility of a potential player management substitution for future matches as a factor.

In total this provided 104 instances of 20 minutes of play to be analysed using the weighted player efficacy system, divided between starting, replacement, non-replaced players 0-20 minutes and non-replaced players 60-80 minutes.

Operational definitions and player efficacy ratings

The operational definitions used were adapted from the study conducted by Lim et al. (2009). Since the Lim et al. paper was published in 2009, changes were made to take into account the evolution of current tactics, for example a 'contestable kick' category was included to reflect the current importance of this action. The definitions of various player actions were presented to an expert group of nine players, coaches and analysts with experience of international rugby at senior and/or age grade level. This group individually considered the operational definition of each player action and applied a numerical weighting for each action relative to how important it was to the match outcome. The actions were grouped by category e.g.: "scoring actions",

"use of possession" to allow for greater depth analysis of game actions. The following player action weightings presented in Table 2.4 were applied.

Table 2.4. Operational definitions and player efficacy ratings

Game Action	Operational Definition	Player Efficacy Rating
Scoring Actions		
Try	5 points awarded to the scoring team when the ball is placed down in the try area	5
Drop Goal	3 points awarded when the ball is drop kicked between the posts from open play	3
Ball Carrying Actions		
Ball Carry	Carrying the ball into the opposition defensive line causing more than one opposition player to commit to a tackle situation	2
Ball Carry (No Fight)	Carrying the ball into the opposition defensive line requiring only one opposition player to commit to the tackle situation	1
Ball Carry (Leading to loss of possession)	Turn-over of possession due to poor technique in contact	-2
Breach	Carrying the ball through the opposition defensive line resulting in at least one opposition player having to turn around to make the tackle	3
Offload	Passing the ball on to a supporting player when being tackled, thus maintaining the forward flow of play	3
Offload (Leading to loss of possession)	Incomplete passing of the ball on to a supporting player when being tackled.	-3
Post Tackle Actions		
Ball Placement (Fast)	Quick placement (<3s) of ball when tackled, making the ball available for quick recycling	2
Ball Placement (Medium)	Medium speed (3-5s) placement of ball when tackled, allowing for average recycling of the ball	1
Ball Placement (Slow)	Slow placement (>5s) of ball when tackled, causing slow recycling of the ball	-1
Ball Support Actions (Post Contact)		
Attack Support Effective	First supporting player to arrive at a tackle situation to lend attacking support. (Tackle made but ruck not formed) positively affecting the speed or quality of possession	1
Attack Support Ineffective	First supporting player to arrive at a tackle situation to lend attacking support. (Tackle made but ruck not formed) not affecting the speed or quality of possession	-1
First Arrival (Ruck) Effective	First player to arrive in a tackle situation to clear out the ruck positively affecting the speed or quality of possession	2
First Arrival (Ruck) Ineffective	First player to arrive in a tackle situation to clear out the ruck not affecting the speed or quality of possession	-2
Second Arrival (Ruck) Effective	Second player to arrive and secure the ruck positively affecting the speed or quality of possession	2
Second Arrival (Ruck) Ineffective	Second player to arrive and secure the ruck not affecting the speed or quality of possession	-2
Third or Fourth Arrival Effective	Third or fourth player to arrive to the ruck positively affecting the speed or quality of possession	1
Third or Fourth Arrival Ineffective	Third or fourth player to arrive to a ruck not affecting the speed or quality of possession	-1
Defensive Actions		
Turnover Tackle	A tackle that results in the turnover of possession	3
Dominant Tackle	A tackle that drives the opposition player backwards	2
Jackal	To steal or slow down possession by >3 seconds in a tackle situation.	3
Passive Tackle	Tackling of opposition player with the ball carrier maintaining forward momentum	1

Tackle Assist	Assisting in a tackle situation	1
Missed tackle	Missing a tackle	-3
Use of Possession		
Pass/catch (Under Pressure)	Passing/catching the ball under opposition pressure (a defender advancing within 2 metres of the ball carrier)	2
Pass/catch (No Pressure)	Passing/catching the ball under no opposition pressure (no defender advancing within 2 metres of the ball carrier)	1
Error in play (No Pressure)	Errors made in play (e.g. handling, kicking errors etc.) (no defender advancing within 2 metres of the ball carrier)	-3
Error in play (Under Pressure)	Errors made in play (e.g. handling, kicking errors etc.) (a defender advancing within 2 metres of the ball carrier)	-2
Kick Receipt (Under Pressure)	Successfully kicking the ball under opposition pressure (a defender advancing within 2 metres of the ball carrier)	3
Kick Receipt (No Pressure)	Receiving a kick under no pressure (no defender within 2 metres of the ball carrier)	1
Return Kick	Successfully Kicking the ball through zones of the field	1 point per zone kicked
Tactical Kick -Contestable	A kick providing the opportunity to regain possession	3
Turnover Event	Error in play that directly results in turnover of possession to the opposition with no law infringement committed	-3
Law Infringements		
Free Kick	Infringement of the laws of the game resulting in free kick	-2
Penalty	Infringement of the laws of the game resulting in a penalty	-3
Yellow Card	Results in the carded player being sent off the field for 10 minutes, leaving their team one player down for that duration	-5
Red Card	Results in carded player being sent off, having no further participation in the game, leaving their team one player down for the rest of the game	-10

Ball in play

"Ball in play" was measured from the time that the ball was available to either team. The exact criteria from each game scenario is shown in Table 2.5:

Table 2.5. Operational definitions applied to "Ball in Play"

Game Scenario	Operational Definition
From a kick off/ 22 metre drop out	When the team receiving the kick gather the ball
Scrum	When the ball is available at the number 8's feet
Line-out	When the receiver gathers the ball
Failed kick at goal	When the receiver gathers the ball
Kick in open play	When the receiver gathers the ball
Free kick/tap penalty	When the ball is tapped and play recommences

The impact score achieved by the starting and substitute player is influenced by the amount of possession that their team had during the period of the game being analysed. Accordingly, the time of 'ball in play' for both teams was recorded. The player "in possession" actions were categorised as "scoring", "ball carrying", "post tackle" and "use of possession". The player efficacy score for attacking actions was divided by the number of seconds that the team was in possession to provide a figure of player attacking efficacy. For reasons of clarity, this figure was then multiplied by 100 to present the player efficacy score for attacking actions as a whole number. Player defensive actions were categorised as "defensive actions" and opposition time in possession to present a measure of defensive efficacy. There were two categories of player action – "ball support" and "law infringements" that could be performed regardless of which team had possession. These actions were of limited importance to half-back play and consequently not included. Future studies

should re-categorise these two groups according to which team was in possession of the ball at the time of the "ball support" or "law infringement".

Data analysis procedure and equipment

Match footage was obtained from live television broadcast coverage of the games. This was analysed using Sportscode Pro software, Version 10.3.17 (Sportstec Inc. Warriewood, New South Wales, Australia) on a MacBook Pro laptop with 13" Pro retina Screen.

Each game was analysed on a separate day to prevent analyst fatigue compromising reliability. Matches were analysed in a silent, well-lit environment. This presented the optimum conditions for accurate analysis.

The Sportscode analysis system produced metrics for each player analysed in the study. The data were exported into Microsoft Excel using the 'Excel edit list' function of Sportscode and the efficacy rating applied to each player action. The results of each starting player and replacement player were summarised in a master spreadsheet using the 'pivot table' function and descriptive statistics applied. The study data were then imported into the SPSS package (IBM Corporation, Armonk, N.Y., Version 24) for further analysis and the application of statistical tests.

Reliability and validity

The reliability and validity of the process was tested by conducting intra and inter-operator reliability tests. The intra-operator test involved the coding of a starting and replacement player in the same match three times over the course of three weeks. This schedule of analysis was chosen to minimise memory effect. The recording was taken from a pre-tournament friendly between England and Ireland, providing four players for reliability assessment. Percentage error calculations (Hughes et al., 2002) were conducted between the first and second viewing of the footage and a third viewing was compared with the second. Percentage error was then calculated by individual player action according to the formula below to reveal the reliability of player actions:

S1 = Test 1

$$\text{Re}liability = \frac{\sum Mod(S1 - S2)}{\sum (S1)} \times 100$$

S2 = Test 2 Σ = Sum of the difference between S1 and S2

The "ball in play" reliability was assessed using the same process. Ball in play was measured in seconds and percentage error calculations were applied.

The inter-operator validity test involved an independent, experienced analyst coding player actions of the same performance as the intra-operator test. This analyst undertook a training session with the lead analyst, involving examining match footage and visual examples of the various operational definitions being applied.

Statistical analysis

The first aspect of this study involved the demonstration of the reliability and validity of the developed method of assessing player performance, including the specific game actions performed by the players: The second aspect required using the system to quantify the performance of the substitute player relative to the starting player in each position. In order to test for significant differences between the actions performed by the four

groups of players analysed: starting, replacement, the non-replaced players first and final 20 minutes on the field, a Kruskal–Wallis one-way analysis of variance was performed on the data.

RESULTS

Reliability and validity results

Table 3.1 shows the intra-observer reliability count of actions performed by the scrum-half position. The main areas of difference are between the "catch/pass no pressure" and "catch/pass under pressure" categories, however the total number of passes recorded on each of the three observations is the same for both the starting and replacement scrum-half position. Whilst some percentage error figures may appear large (several figures of 200.00 appear in the following tables), the actual number of instances are low – a difference of one action being observed.

The intra-observer reliability for the count of actions performed by the out-half position showed that the "catch/pass no pressure" and "catch/pass under pressure" categories were areas of difference for the replacement out-half. The starting out-half was credited with a "tackle assist" in view one which was subsequently registered as a "passive tackle" on view two and three.

Table 3.1. Intra-observer reliability of performance - scrum-half

	Starting Scrum-Half					Replacement Scrum-Half				
Game Actions	S 1	S 2	S 1-2	S 3	S 2-3	S 1	S 2	S 1-2	S 3	S 2-3
Cat/Pass No Press	20	19	5.13	18	5.41	21	22	4.65	22	0.00
Cat/Pass Und Press	2	3	40.00	3	0.00	3	2	40.00	2	0.00
Error Under Press.	1	1	0.00	1	0.00	1	1	0.00	1	0.00
Ret. Kick 2 Zones	1	1	0.00	1	0.00	0	0	0.00	0	0.00
Ret. Kick 3 Zones	0	0	0.00	0	0.00	0	0	0.00	1	200
2nd Arr. Negative	1	1	0.00	1	0.00	0	0	0.00	0	0.00
Positive Carry	2	1	66.67	1	0.00	0	0	0.00	0	0.00
Missed Tackle	0	0	0.00	0	0.00	1	1	0.00	0	200
Passive Tackle	1	1	0.00	1	0.00	1	0	200	0	0.00
Tackle Assist	0	0	0.00	0	0.00	1	0	200	0	0.00
Sum of Actions	28	27		26		28	26		26	

The data showed that the "ball in play" totals varied by a maximum of six seconds for Ireland possession during the England replacement section. This demonstrated good reliability in this aspect of the study across all three observations.

The inter-observer validity study showed that "catch/pass no pressure" and "catch/pass under pressure" are the major areas of difference between the analysts, particularly for the replacement scrum-half where observer one registered 24 passes in total and observer two registered 22 passes. A further area of difference was that observer one registered one play by the starting scrum-half as a "positive carry" and observer two registered as a "breach".

Player performance and substitution status

The following data are presented as the mean "game efficacy" score for each positional grouping:

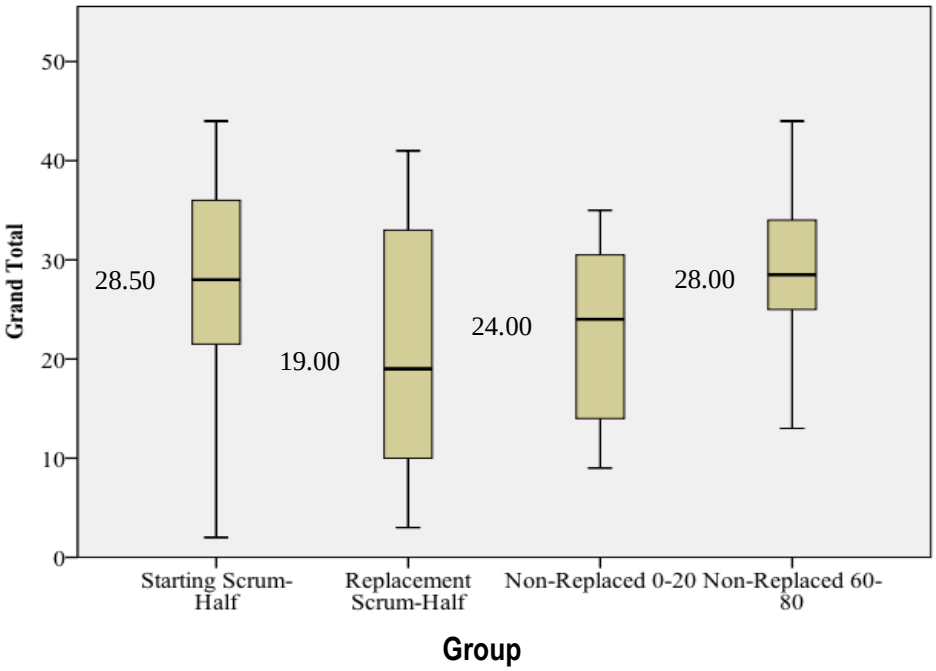

Figure 3.1. Mean game efficacy by group – scrum-half

Figure 3.1 shows the highest median game efficacy score was achieved by the starting scrum-half group (28.). The replacement scrum-half group had the lowest median score (19). In the non-replaced categories, the second period of analysis, 60-80 minutes had a higher median impact score (28.50).

Efficacy scores for the out-half position show that the median impact score is similar across all groups. The non-replaced groups displayed the lowest range of scores (21 and 18 respectively) The replacement out-half displayed the largest range of scores of all the out-half groups (43). There are two outlier performances in the replacement out-half group, who achieved the highest game impact scores in the study (49).

Figure 3.3 and 3.4 present the "ball in play" adjusted player efficacy score for both half-back positions (calculated by dividing the impact score by the number of seconds in possession and multiplying by 100):

The best attacking and defensive performances were from the replacement scrum-half group (23.23 and 4.08 respectively). The worst attacking and defensive performances were also from the replacement scrum-half group (2.73 and -5.21 respectively).

Figure 3.4 presents each individual out-half performance score relative to the amount of possession that each team had during the period of analysis. The best attacking and defensive performances recorded both came from the starting out-half group (20 and 7.77 respectively). The worst attacking and defensive performances also came from the starting scrum-half group (1.56 and -2.71 respectively).

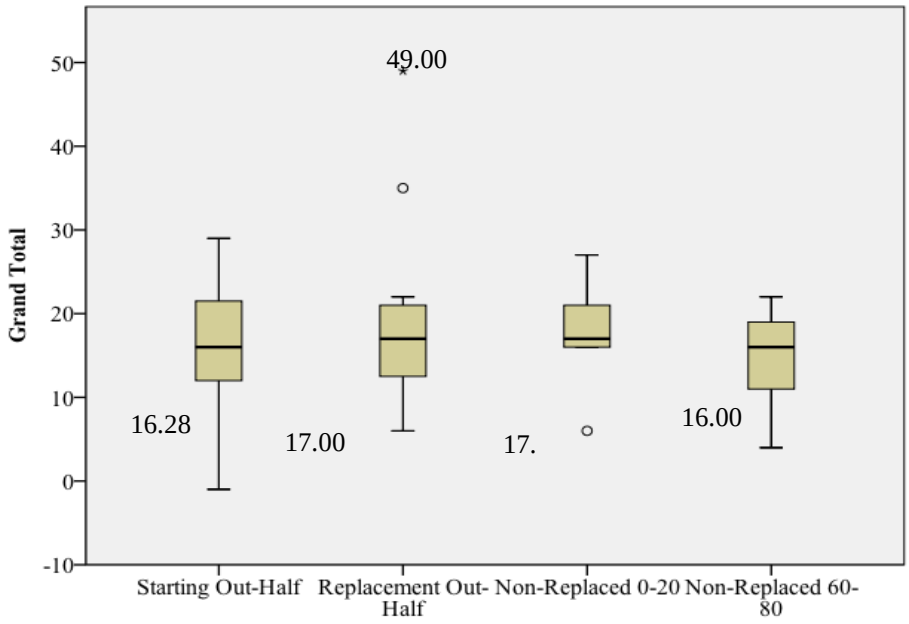

Figure 3.2. Mean game efficacy by group – out-half

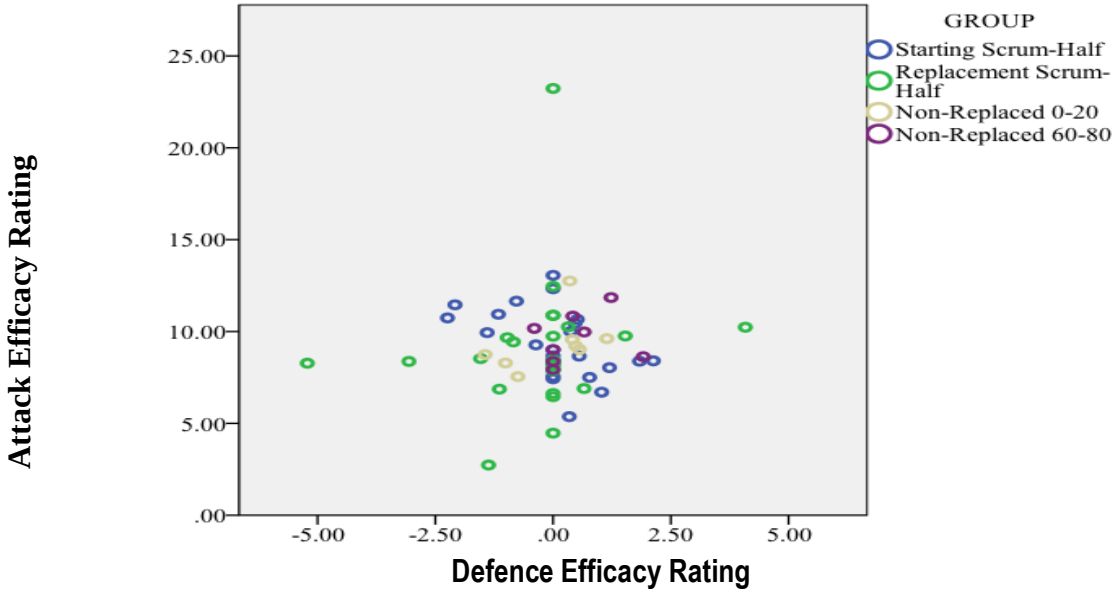

Figure 3.3. "Ball in play" adjusted attack and defence efficacy – scrum-half

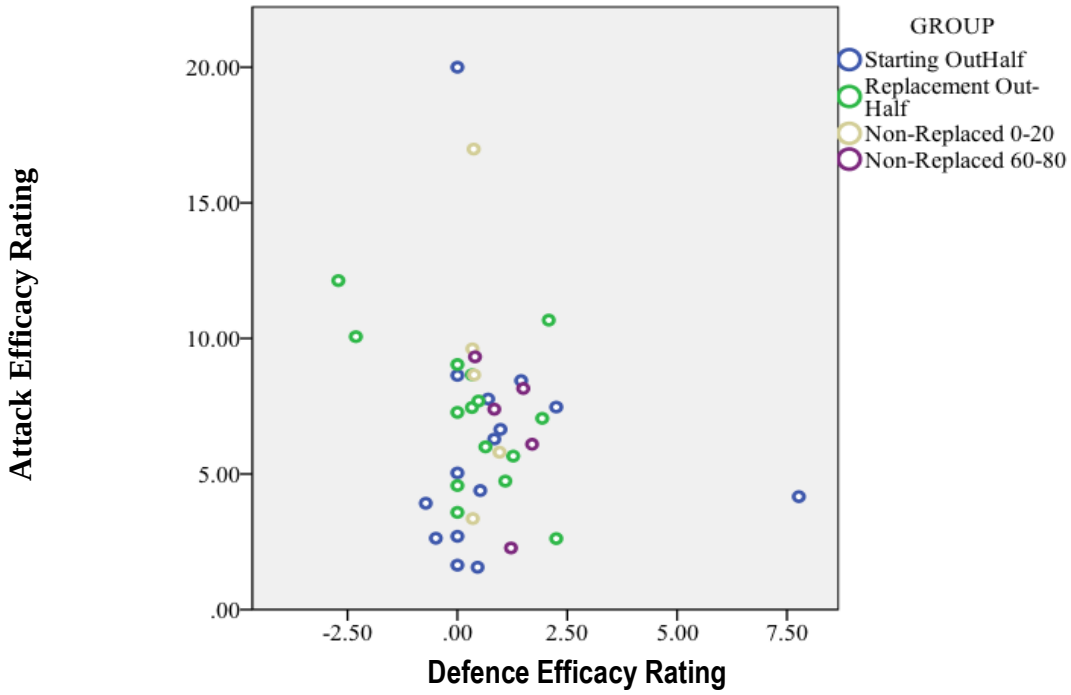

Figure 3.4. "Ball in play" adjusted attack and defence efficacy - out-half

The Kruskal-Wallis test was applied to starting, replacement, non-replaced 0-20 minutes and non-replaced 60-80-minute groups for both half-back positions No statistically significant differences were identified between the four groups of players for either half-back position.

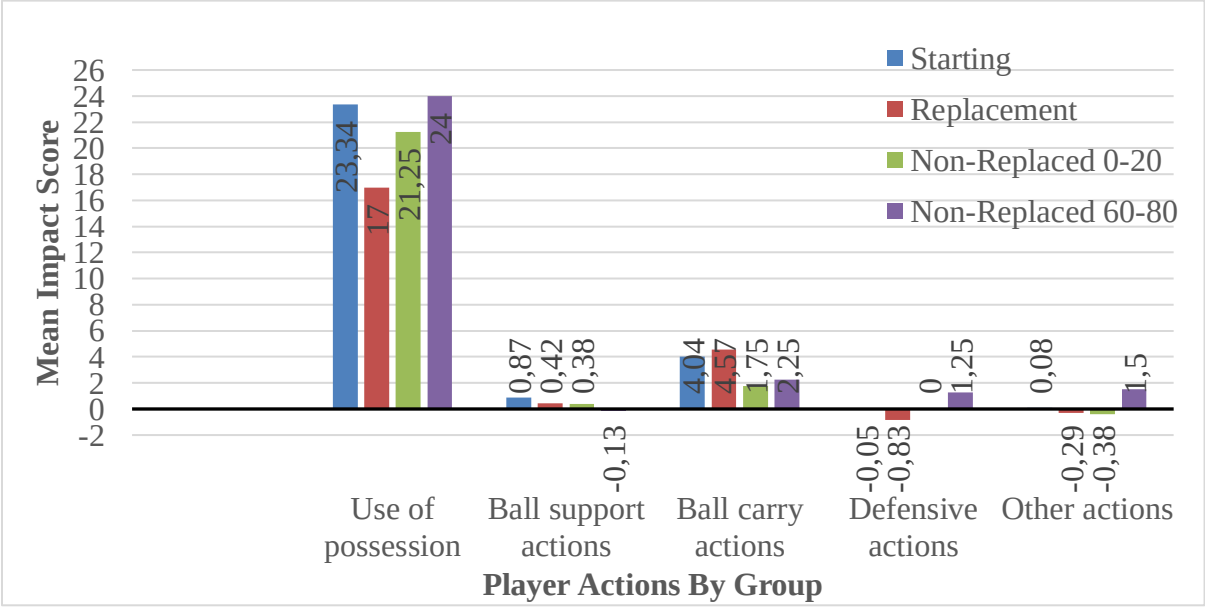

Figure 3.5. Mean efficacy score by player action - scrum-half

Figure 3.5 shows that the replacement scrum-half group performed less "use of possession" actions than the other three groups with a mean game efficacy score of 17, compared with the non-replaced 60-80-minute group who recorded the highest "use of possession" actions (24). Defensively, the non-replaced 60-80 group

performed best (1.25), with the replacement scrum-half group scoring the lowest defensive score (-0.83). The replacement scrum-half group recorded the highest "ball carry" score of the four groups (4.57). Actions performed in the "other actions" group were tries scored and penalties conceded as no players received a red or yellow card during the games analysed. The data presented in Figure 3.6 represents the mean efficacy score achieved by each group of out-halves by game action type:

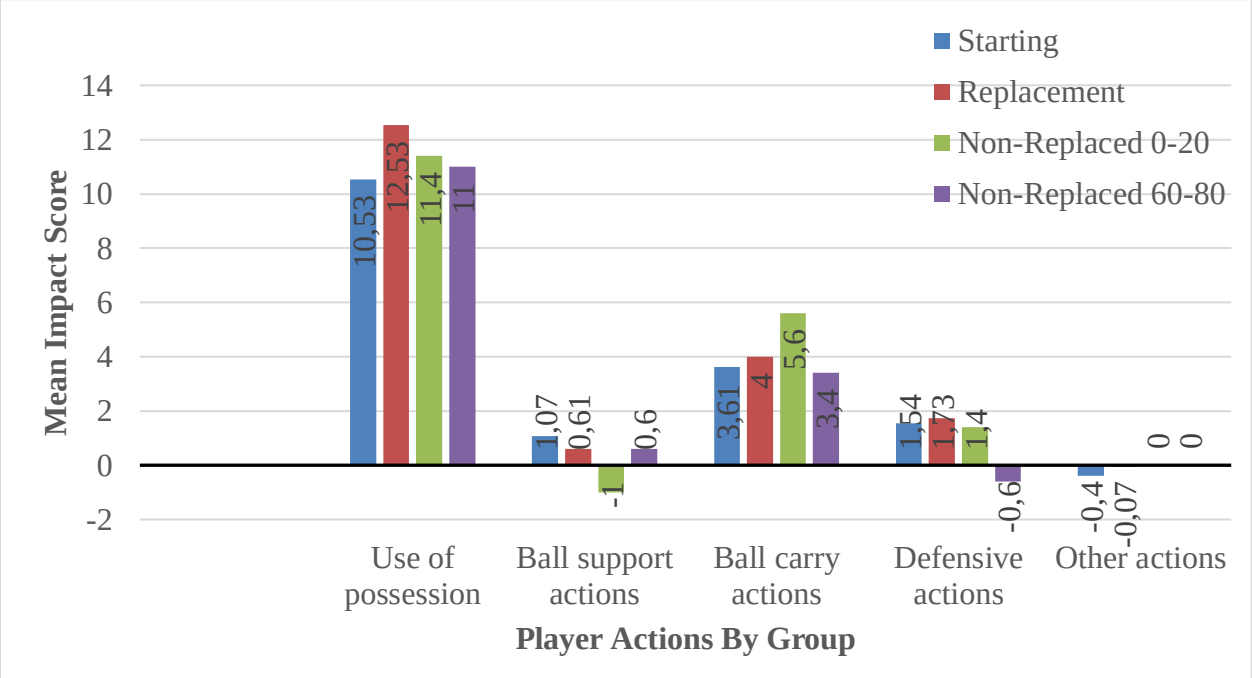

Figure 3.6. Mean efficacy score by player action – out-half

Figure 3.6 shows that the replacement out-half group achieved the highest "use of possession" score, (12.53) compared with the starting out-half group who scored lowest in this category (10.53). Non-replaced players in the 0-20-minute period of analysis scored highest in the "ball carry" category (5.6) and non-replaced players in the 60-80-minute category scored lowest of the groups for "ball carry" actions (3.4). The Non-replaced 60-80-minute group produced a negative score in the "defensive actions" category (-0.6). No "other actions" were performed by each of the non-replaced groups.

Figure 3.7 and 3.8 present the net effect of replacing the scrum-half and out-half respectively. In each case, the player being replaced is from the first named team. Figure 3.7 shows that the replacement scrum-half produced a net positive effect on ten of 24 occasions. The highest net effect was achieved by the Argentina replacement against Ireland (+18). The worst net impact was achieved by the U.S.A. scrum-half against Scotland (-37). On one occasion, the impact score of the starting and replacement player were the same.

The highest net effect was achieved by the Ireland replacement out-half against France (+38). The worst net effect was achieved by the same player when coming on as a replacement against Canada (-19). In nine of the fifteen substitutions the replacement player had a positive effect on the out-half position.

Examining the out-half "use of possession" actions in greater detail, figure 3.9 shows that the replacement out-half group score highest for "passes under pressure" (7.2), compared to the starting out-half group (5.2). The non-replaced 0-20 minute out-half group make most "contestable" kicks (3). The next highest score is

the non-replaced 60-80-minute group (2.4). This compares with the starting player (1.2) and the replacement (0.2) in the "contestable" kick category. The non-replaced out-half group also make most errors in play, both under pressure (-1.4) and no pressure (-1.2). The highest score for zones kicked by all groups of out-halves is two field zones, with non-replaced 0-20 players kicking three zones of the field, scoring the same points (1.2).

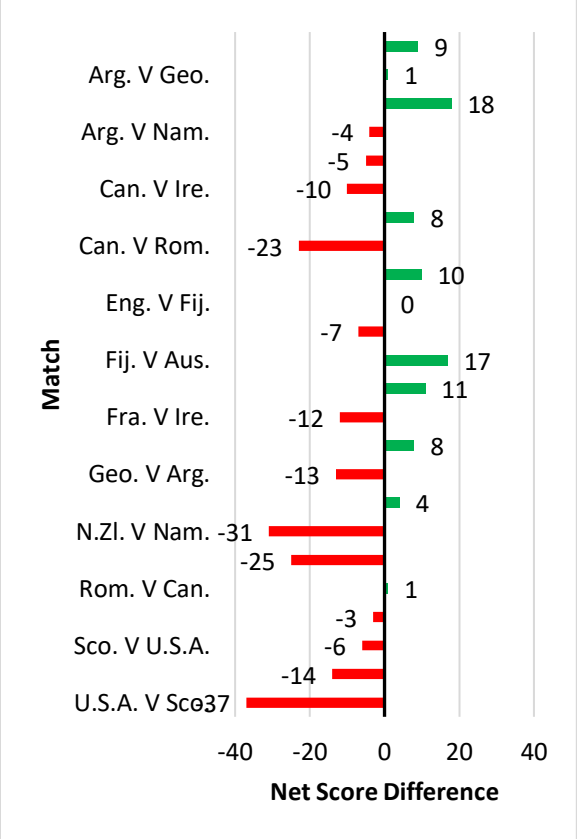

Figure 3.7. Net effect of substitution - scrum-half

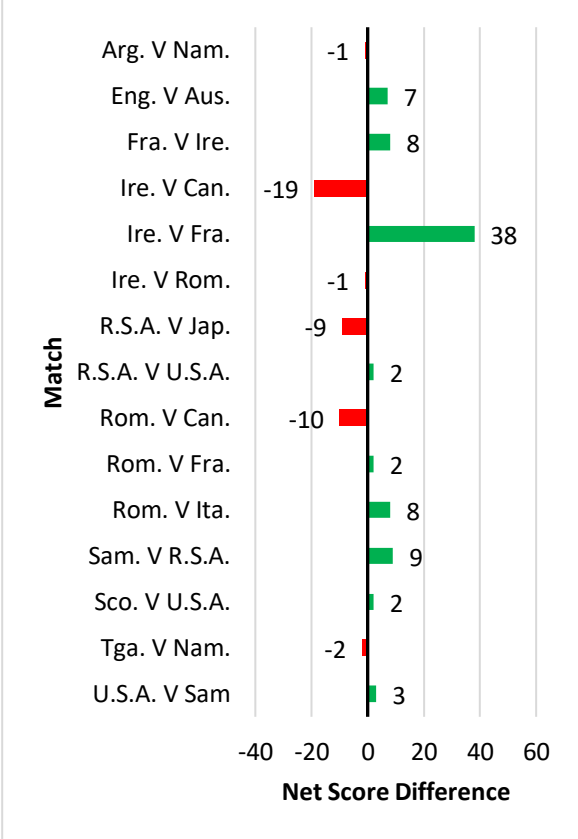

Figure 3.8. Net effect of substitution – out-half

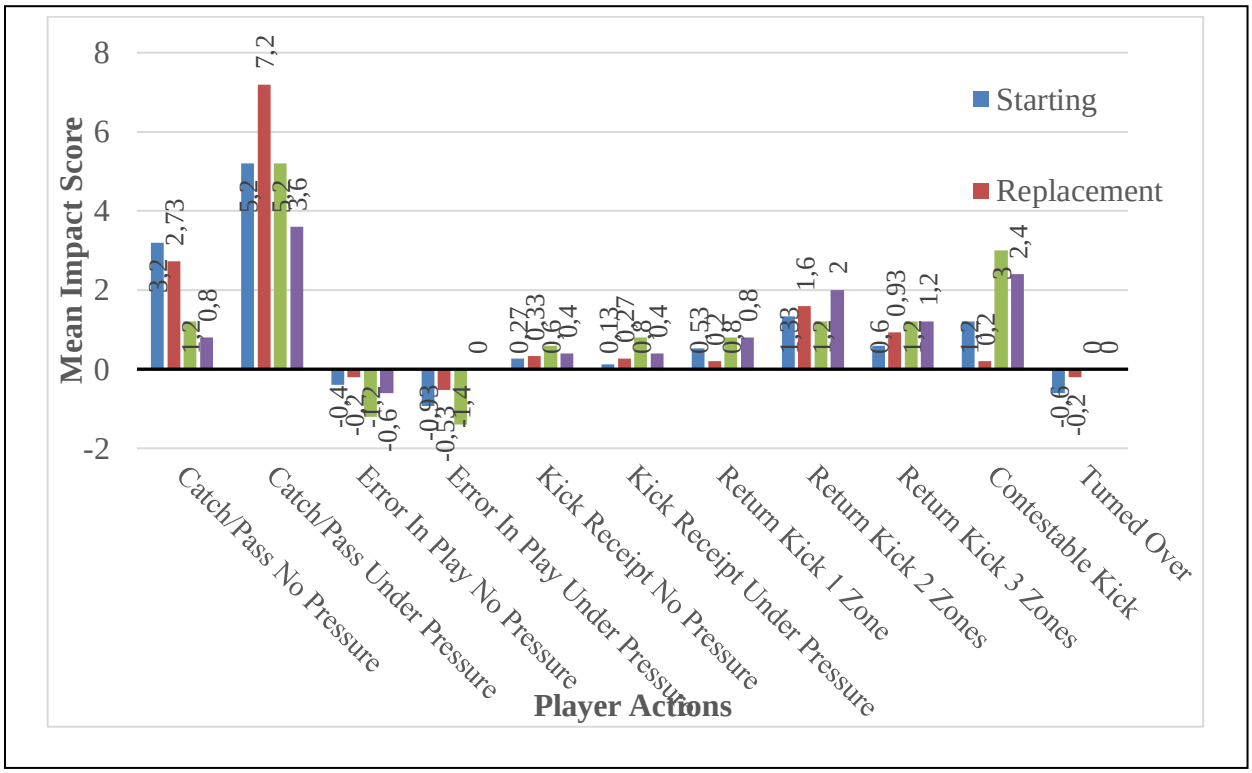

Figure 3.9. Examining the out-half "use of possession" actions in greater detail

DISCUSSION

Process, reliability and validity

Percentage error calculations were used to measure the reliability and validity of the study, as advised by O'Donoghue (2010). The most significant area of difference was between "catch/pass no pressure' and "catch/pass under pressure", however the total number of passes recorded was almost entirely consistent – 22 passes across the three performance observations for the starting scrum-half and 24,23,23 passes respectively for the replacement scrum-half. This reveals the issue in coding data is that it is difficult to quantify consistently. However, given the relatively large number of passes recorded, an error rate of 5.13 to 4.65 is acceptable, in the margins of tolerance. The same issue arises with regard to the inter-operator reliability. Whilst training was undertaken with the other analyst involved, in defining the player actions as used in this study, further work in this area would reduce the percentage error further.

The player profiles generated through applying this process were then presented to the expert group of coaches and analysts who agreed that the profiles were a valid measure of player performance.

The close agreement of the intra-operator results indicates that the operational definitions used in this study are clear and have been consistently applied, showing a high degree of reliability. The inter-operator reliability results are also consistent, but would benefit from further training to ensure consistent application of the operational definitions, particularly with regard to the "catch/pass under pressure" and "catch/pass no pressure" categories.

The data of the non-replaced players should be treated with caution due to the limited sample size of eight scrum-halves and five out-halves. However, it is included for comparative purposes. Of the replaced scrum-half group, ten of the 24 players analysed in this group were from tier two countries. This may be a further cause of the wide range of scores in the starting and replacement scrum-half groups as the clear majority of tier one players are full time athletes competing in the major world competitions, many tier two players compete in semi-professional competitions, and are therefore not as well developed in terms of their skills or physical conditioning. This is reflected in the wide variation of the replaced scrum-half performances.

The data presented in Figure 3.5 and 3.6 represent a profile of all actions undertaken by the scrum-half and out-half positions respectively. Given that the "use of possession" category is particularly important for the half-backs, this is further profiled in figure 3.9 and 3.10. Were this system to be applied to data from other positions on a rugby team, it would enable greater analysis of how players perform according to the requirements of their position. For example, a back-row player's contribution to team performance would be more accurately judged on "defensive actions" or "ball support actions" than on "use of possession". The ability to focus on the area of play that is deemed important to the playing position is an important aspect of this study.

Player performance and substitution status

The first hypothesis examined in this study was that replacement players would score more highly than the players they replaced. Based on the results obtained, for the scrum-half position, this hypothesis can be rejected. Figure 3.1 demonstrates that the starting scrum-half has a higher median efficacy score and that the upper and lower quartiles are higher than the replacement player. It can be speculated that the reason for this result is that the normal method of selecting a team requires that the best player starts in each position. It would seem that in the case of the players in this study, there was a gap in performance levels between the starting and replacement player. The large range of performance scores for the starting and replacement scrum-halves across all teams may be due to differences in the skill levels of the competing teams, a hypothesis which is given further weight by the narrower range of scores for the non-replaced scrum-half group. These players were all performing for teams ranked in tier one by World Rugby. The non-replaced players performed better in the second period of analysis later in the game. This would seem to confirm that these players were having the effect on the match that the team management required of them, and they were therefore not replaced.

The hypothesis for the out-half position, based on the results obtained, can be accepted. The replacement out-half group performed more "catch/pass under pressure" (7.2) than starting or non-replaced players. This would indicate that these players are presenting a different tactical challenge which involves playing the game closer to the opposition defence, rather than simply passing the ball. The fact that the replacement out-half group also produce more mean "ball carry actions" (4.0, compared with the starting group score of 3.61) would seem to confirm this. This would concur with a key aspect of the positional responsibilities as identified by World Rugby (2015) that the out-half was required to: Create, identify, communicate, manipulate and exploit space in attack. The out-half may choose to do this by kicking, running or passing the ball, and individual players will adopt different approaches to this task, as identified in Figure 3.10.

When considering the ball in play adjusted efficacy score in Figure 3.6, it can be seen that the scrum-half position frequently presented a negative figure for the defensive game actions. This would be in keeping with the low tackling priority given to the scrum-half role. Normally, the defensive responsibilities entrusted to the scrum-half consist of 'sweeping' behind the front defensive line to gather short kicks and organise the more physical members of the team, rather than as a first-choice tackler. This means that a scrum-half's ability to

tackle is only exposed when the first line of the defence is penetrated. Therefore, the large amount of zero defence efficacy for this group reflects the tackling excellence of the rest of the team resulting in little opportunity for the scrum-half to be exposed.

The starting and replacement out-half groups displayed a smaller efficacy range between the four groups. Given that of the 15 cases examined, nine were from tier one countries, it is possible that this skewed the performance data. As was the case with the scrum-half position, the defensive efficacy scores were lower than the attacking efficacy, reflecting the key responsibilities of the out-half position. These findings reflect the findings of Lim et al. (2009) who found that the scrum-half position was involved in more game actions than the out-half position, but that this difference was not statistically significant.

Player management is an important factor in how and when substitutions are performed. When there is a large score difference between the teams, replacing a half-back will not normally affect the outcome of the game. This would confirm the findings of James et al. (2005) who advised that multiple profiles be developed to take account of factors such as relative strength of the opposition and weather conditions.

Potential future applications

This paper has sought to develop a player profiling system in rugby to quantify individual player efficacy. Hughes (2012) suggested that frequency data were insufficient to model performance in rugby and that a more qualitative approach was required. This study addresses elements of qualitative analysis, for example quantifying a pass performed under pressure or no pressure. The next step would be to apply this process to the other positions in a team. This may help to improve understanding of other key positions within the rugby team, for example Lim et al (2009) cited the "loose forwards" group as performing a similar number of game actions to the scrum-half and out-half positions (82±37, 84±51 and 81± 36 respectively). A further application may lie in profiling combinations, for example the development of a combined profile of both half-back players. Such information could inform team recruitment, selection and substitution policy, ensuring that the selected combination have a complimentary skill set. It also raises the possibility of substituting the half-backs together to ensure that the most effective combinations play together.

Further applications of the process applied in this paper could be used to produce detailed player positional profiles. This could be performed using the process suggested by Hughes et al. (2001) who suggested that a percentage error plot showing mean variation across performances would be a suitable method of establishing that the performance profile had 'stabilised' sufficiently to be considered a reliable guide to performance.

Profiling the performance of a replacement player relative to the player that was replaced, is another aspect of this study that could be applied to any sport where substitutions are part of the game. Hughes and Pearce (2001) found that midfield players were most likely to be substituted in soccer. It was theorised that this may be due to the high physical demands of these positions. This would seem to reflect the situation in rugby, where the scrum half was replaced 24 times during the 2015 Rugby World Cup, compared to the replacement of the out-half on 15 occasions. The higher replacement rate of the scrum-half position could be due to the greater physical demands of the position. Quarrie et al., (2013) in a study of international rugby matches found that the scrum-half position (starting and substitute players) travelled 6200m ± 360, when compared to the out-half position 5700m ±910 per match. Furthermore, the scrum-half ran a higher number of metres than the out-half across all speed categories (0-2, 2-4, 4-6, 6-8 and >8 metres per second). The increased physical exertion of the scrum-half position would make replacing this player a logical proposition, particularly in a tournament such as the Rugby World Cup, when players must perform in a number of games to win the

tournament, 7 matches in 44 days with uneven scheduling of matches. However, this option is only viable if there are two players available of comparable ability in the tournament squad.

The demonstrated method of profiling individual player efficacy would be transferable to other sports. It would be most effective in sports where there are a limited number of substitutions available to the coach, rather than a rotating player multi-substitution sport, such as basketball or Australian Rules, due to the restricted ability to correct the situation should a replacement player drastically under-perform. The method also has the potential to be used as a tool to develop a profile of future opponents with a view to assessing the strategies and tactics likely to be employed in competition.

CONCLUSIONS

The purpose of this study was two-fold. Firstly, to develop a player efficacy weighting system to objectively quantify individual player performance, and secondly to apply this system to performances from the 2015 Rugby World Cup to assess the performance of starting, replacement and non-replaced half-back players.

The system developed was found to be a valid and reliable method of measuring player performance. With regard to the playing groups, it was found that the starting scrum-half group had a higher median efficacy score than their replacements. It was also found that the non-replaced scrum-half group performed better in the second period of analysis than the first 20 minutes of a game. For the out-half position, it was found that the replacement out-half group scored higher than the starting group. Overall, there was greater consistency of performance amongst the four out-half groups than the scrum-half groups, although it should be noted that the sample size for the non-replaced player groups was only one third of the substituted player groups. It is proposed that the greater variation of performance levels between the scrum-half groups is due to the higher number of performances from tier two countries in the matches analysed.

Future research should develop the methods applied in this study to develop player profiles for each position on the rugby field. It is suggested that these profiles should use score difference between the teams to consider the strength of the teams involved. The concept of a weighted individual player efficacy system has been demonstrated in the sport of rugby union, but could be applied in any team sport where greater individual player performance data is required.

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