

# Positional match statistics in Currie Cup and Super Rugby competitions between winning and losing teams



By  
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## *Declaration*

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Signed on this \_\_\_\_\_ day of \_\_\_\_\_ 2017.

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Supervisor

\_\_\_\_\_  
R. Schoeman

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## *Summary*

### Positional match statistics in Currie Cup and Super Rugby competitions between winning and losing teams

#### **Background**

Rugby union (here after referred to as rugby), as most other team sports, is becoming more aware of statistics as a reliable method to evaluate players and match variables during match play. This non-invasive evaluation method provides coaches and conditioning coaching with much needed information regarding player attendance to match situations and the successful execution of these match situations. Winning and losing teams from all levels of competitions use statistics to not only evaluate the team's performance, but to determine which variables might be responsible for the outcome of the game. It is accepted that teams from a winning side might perform better in certain areas of play than losing teams, and players from higher levels of participation can execute certain skills more effectively. Previous research has been conducted on various teams from different participation levels on the physiological differences, mental toughness and match variables. The increased professionalism of rugby players may also indicate an increased ability of players from one season to the next. The ability of players will also vary from one position to the next and may be approximately exposed to certain match variables.

#### **Aims**

The first aim of this study was to determine the tackle and collision count for Super Rugby players during the 2013 competition. The second was to analyse the passing and kicking statistics that discriminate between winning and losing teams during the

2014 Super Rugby season. Thirdly, the study attempted to differentiate between the Super Rugby competition and the Currie Cup competition according to the occurrence of match activities and lastly to evaluate the evolution of the Super Rugby competition from 2011 to 2015 by the use of regression statistics.

### **Method**

#### **Sample**

The first aim consisted of conducting an analysis of 1,900 players from 30 games played during the 2013 Super Rugby competition. Two games from each of the participating franchises were used and selected in regards to number of matches available and balance of the sample. The second aim included an analysis of 1298 players from the 2013 Super Rugby season, whilst the third aim involved 1800 players with n=900 players from Super Rugby and n=900 players from the Currie Cup competition. Furthermore, aim 4 consisted of 4500 players and included n=900 from each of the Super Rugby seasons from 2011 to 2015.

#### **Measuring instruments**

Data was supplied by the Cheetahs Super Rugby Franchise, Bloemfontein, South Africa, using the Verusco *TryMaker Pro*. Verusco has provided Super Rugby teams with *TryMaker Pro* since the year 2000. *TryMaker Pro* is the most advanced analysis system custom-made for rugby, and it is the preferred system for the professional teams using Verusco. The Verusco coding centre codes all the games for registered teams and delivers high-detail, high-speed analysis within hours of the game having been played.

#### **Data analysis**

All data were captured in Microsoft Excel 2007 and subsequently converted into an SAS data set.

For aim 1 the following analysis was done: The *GLIMMIX* procedure of the SAS Version 9.22 statistical software package was used for further statistical analysis (SAS, 2009). Means and standard deviations were used for numerical data. Individual tackle counts for each position, team and game were analysed using a generalised linear mixed model (*GLIMM*) with position and team as fixed effects, the natural

logarithm of individual time played in minutes as offset, and position-by-team and game-by-team interaction terms as random effects. Regarding the fitted random effects, it seemed reasonable to allow for correlation between tackle counts for a specific individual across several games (modelled by the *position-by-team* random effect), and for correlation between tackle counts across players in a given team and game (modelled by the *team-by-game* random effect).

Furthermore, the *GLIMM* was specified with *Poisson* error distribution and the natural logarithm as link function. Individual collision counts for each position, team and game were analysed in the same manner. In both cases – tackle counts and collision counts – the model fitted the data well and there was no evidence of residual over-dispersion. Based on the *GLIMM*, the mean rate of tackles and mean rate of collisions per 80 minutes (that is, normalised to a full-length rugby game) were estimated for each playing position, with 95% confidence intervals (CIs) of the mean rates. Similarly, in order to compare the mean rates of tackles and collisions between different playing positions, rate ratios (that is, the ratio of tackle and collision rates between playing positions) were estimated, with 95% CIs for the rate ratios.

Aim 2 included the following statistical analysis: Means and standard deviations were used for numerical data. Individual tackle counts for each position, team and game were analysed using a generalised linear mixed model (*GLIMM*) with *position* and *team* as fixed effects, the natural logarithm of individual time played in minutes as offset, and *position-by-team* and *game-by-team* interaction terms as random effects. Regarding the fitted random effects, it seemed reasonable to allow for correlation between tackle counts for a specific individual across several games (modelled by the *position-by-team* random effect), and for correlation between tackle counts across players in a specific team and game (modelled by the *team-by-game* random effect). Furthermore, the *GLIMM* was specified with *Poisson* error distribution and the natural logarithm as link function. Team rates for passing and kicking were analysed in the same manner. In both cases, passing and kicking rates, the model fitted the data well and there was no evidence of residual over-dispersion. Based the *GLIMM*, the mean rate of passing and mean rate of kicking per 80 min were estimated for each team, with 95% confidence intervals (CIs) of the mean rates.

Aim 3 consisted of each count variable (number of lineouts, scrums, rucks, mauls etc.) to be analysed using a generalised linear mixed model (GLIMM) with *season* (2011 versus 2015) as fixed effect, and both *winning team* and *losing team* as random effect. (The fitting of the variables *winning team* and *losing team* as random effects allowed for correlation between the counts in question for a given team across several games.) Furthermore, the *GLIMM* was specified with *Poisson* error distribution and the natural logarithm as link function; residual over-dispersion was allowed for in the model. Based on the *GLIMM*, the mean rates of lineouts, scrums, rucks, mauls etc. per game were estimated for the 2011 and 2015 seasons. Similarly, in order to compare the mean rates between the 2011 and 2015 seasons, ratios of lineout rates etc. between the 2015 and 2011 seasons were estimated, together with 95% CIs for the rate ratios.

The above analyses were carried out separately for the data of the winning teams, for the data of the losing teams, and for the data of two teams involved in each game combined (that is, for the game). The analysis was carried out using SAS procedure *GLIMMIX* (SAS, 2013).

Aim 4 used descriptive statistics for the count and percentage data calculated for the 2011 to 2015 seasons. Descriptive statistics were calculated per season for the winning teams, for the losing teams, and for the two teams involved in each game combined (that is, for the total count per game).

Each count variable (number of lineouts, scrums, rucks, mauls etc.) was analysed using a generalised linear mixed model (GLIMM) with *Season* (2011 versus 2015) as fixed effect, and both *winning team* and *losing team* as random effect. (The fitting of the variables *winning team* and *losing team* as random effects allowed for correlation between the counts in question for a given team across several games.) Furthermore, the *GLIMM* was specified with *Poisson* error distribution and the natural logarithm as link function; residual over-dispersion was allowed for in the model. Based on the *GLIMM*, the mean rates of lineouts, scrums, rucks, mauls etc. per game were estimated for the 2011 and 2015 seasons. Similarly, in order to compare the mean rates between the 2011 and 2015 seasons, rate ratios, that is, ratios of lineout rates etc. between the 2015 and 2011 seasons were estimated, together with 95% CIs for the rate ratios. The above analyses were carried out separately for the data of the

winning teams, for the data of the losing teams, and for the data of two teams involved in each game combined (that is, for the game).

Percentage territory and percentage possession of the winning team in each game were analysed using a linear mixed model with *Season* as fixed effect, and both *Winning Team* and *Losing Team* as random effects. Based on the linear mixed model, the mean percentage territory (and possession) was estimated for each season, together with a 95% CI for the mean percentage. Similarly, in order to compare the mean percentage between the 2011 and 2015 seasons, mean differences, that is, differences of mean percentage territory and possession between the 2015 and 2011 seasons were estimated, together with 95% CIs for the mean differences. The analysis was carried out using SAS procedure *MIXED* (see SAS, 2013).

### Results

The results from aim one underlined the importance of specific demands on the various playing positions regarding the tackles and collisions sustained by Super Rugby players. Clearly, loose forwards (6: = 16.65 tackles/80 min; 7: = 17.30 tackles/80 min; 8: = 14.68 tackles/80 min) had the highest tackling rates, followed by the locks (4: = 13.74 tackles/80 min; 5: = 14.07 tackles/80 min). Amongst the backs, the inside centre (12: = 12.89 tackles/80 min) was the player with the highest tackling rates, followed by the outside centre (13: = 9.96 tackles/80 min). The results showed that the open-side flanker (7) had the highest tackle rate of all playing positions (17.30 tackles/80 min). The open-side flanker (7) was involved in the most collisions (50.91), followed by the blind-side flanker (6), loosehead lock (4) and eighthman (8), with collision rates of 46.08, 44.81 and 43.03 respectively, per 80 minutes collision count per game. The results showed significant differences between positional groups for tackles, except for the front row players and the second row (1, 2, 3 vs 4, 5;  $p=0.0715$  to  $p=0.6324$ ). Within a positional group, namely the backline players, the tackling rate of the inside centre differed significantly from the tackling rate of the other backline players (9 vs 12,  $p=0.0029$ ; 10 vs 12,  $p=0.0045$ ; and 12 vs 13,  $p=0.0100$ ).

Aim two indicated that losing teams tend to pass the ball more (157.41) than winning teams (127.02). The results illustrated a significant difference between winning teams and losing teams regarding total passes, bad passes, and good passes ( $p<0.05$ ).

Winning teams tend to kick the ball more (25.77) than losing teams (20.23). Results indicated a significant difference between winning teams and losing teams regarding total kicks, long kicks, short kicks, and kicking metres ( $p < 0.05$ ). Winning teams kicked more long kicks (18.55) than losing teams (14.19). Winning teams also used the short kick (7.22) more effectively and more often than losing teams (6.04). Losing teams gain a mean total of 660.01m per game in comparison to winning teams who gain 901.4m per game.

In the third aim it was discovered that, when the two competitions are compared, it is evident that only two variables can be distinguished. The mauls and tackles missed are the only two variables that show remarkable difference, with 3.23 mauls and 8.9 tackles missed per game more in Currie Cup competition than the Super Rugby. The results of this study underline the importance of measuring and analysing specific performance indicators on a regular basis as these performance indicators can increase or decrease as the level of competition change. The greatest increase occurred with rucking, as this variable increased from 139.63 in Currie Cup to 143.13 in Super Rugby. Super Rugby teams lose fewer lineouts, and have less missed tackles, while Currie Cup teams utilise mauls more as an offensive weapon.

Aim 4 identified playing time, lineouts lost, scrums, scrums lost, tackles and penalties decreased from 2011 to 2015, while lineouts, mauls and the number of missed tackles increased. The results of this study underline the importance of measuring and analysing specific performance indicators on a regular basis as these performance indicators can increase or decrease in a short time frame. From 2011 to 2015 winning teams consistently lost fewer lineouts than losing teams, even with an overall increase in the number of lineouts per game. The study indicates a slight decrease in the number of tackles, but still supports the fact that winning teams have higher tackle rates than losing teams.

### **Conclusions**

The results of the study show that there are significant differences between individual playing positions within the same positional group with regard to tackling and collision rates sustained during match play. The study confirms that losing teams pass more than winning teams and that winning teams kick more than losing teams during match

play. The study also discovered a greater distance gained through kicks by winning teams. The higher or lower numbers of performance indicators performed by teams over competitions emphasise the different physiological demands for teams. The study concluded that playing time, lineouts lost, scrums, scrums lost, tackles and penalties decreased from 2011 to 2015, while lineouts, mauls and the number of missed tackles increased. The findings may be important for future research as they indicate a constant shift in statistics and outcomes of teams over seasons within a particular competition.

### **Keywords**

Tackle rates, collision rates, passing, kicking, Super Rugby, Currie Cup, performance indicators, match activities, metres gained

### **References**

SAS Institute Inc. *SAS/STAT 9.2 User's Guide, 2nd ed.* Cary, NC: SAS Institute Inc.



# *Opsomming*

## Possisionele wedstryd statistiek in Currie Beker en Super Rugby kompetisies tussen wen en verloor spanne

### **Agtergrond**

Soos die meeste ander spansporte begin rugby die waarde van statistiek besef as 'n betroubare metode om spelers en wedstrydveranderlikes gedurende wedstryde te evalueer. Hierdie nie-indringende evaluasiemetode voorsien waardevolle inligting aan afrigters en kondisioneringsafrigters rakende spelerbetrokkenheid by spelpatrone en die suksesvolle uitvoering van spelpatrone. Alle spanne, hetsy wen- of verloorspanne wend statistiek aan, nie slegs om die span se werksverrigting en prestasie te evalueer nie, maar ook om die veranderlikes te bepaal wat verantwoordelik is vir die speluitslag. Daar word geglo dat wenspanne in sekere areas beter presteer as verloorspanne en dat spelers met hoër vlakke van deelname sekere vaardighede meer effektief kan uitvoer. Vorige navorsing op verskeie spanne van verskillende vlakke van deelname het die fisiologiese verskille, geestelike uithouvermoë en wedstrydveranderlikes bepaal. Toenemende professionalisme onder rugbyspelers mag ook toenemende kundigheid van een seisoen na 'n volgende aandui. Die spelers se vermoë sal ook van een posisie tot 'n ander verskil en mag as gevolg van sekere wedstrydveranderlikes, meer of minder blootstelling ontvang.

### **Doelwitte**

Die eerste doelwit van die studie was om die duik- en kontaktelling van Super Rugbyspelers tydens die 2013 kompetisie te bepaal. Die tweede doelwit was om die uitgee- en skopstatistieke van beide wen- en verloorspanne te analiseer. Derdens het die studie ook ten doel om te probeer differensieer tussen die verspreiding van

wedstrydaktiwiteite van Super Rugby- en die Curriebekerkompetisie. Die laaste doelwit is om die evolusie van die Super Rugbyreeks van 2011 tot 2015 te evalueer.

### **Metode**

#### **Deelnemers**

Vir doelwit een is 900 spelers ontleed wat in 30 wedstryde gespeel het tydens die 2013 Super Rugbyreeks. Vir doelwit twee is 1298 spelers wat ook tydens die 2013 Super Rugbyreeks gespeel het, ontleed. Vir doelwit drie is 1800 spelers ontleed, waarvan  $n=900$  spelers vanuit die Super Rugbyreeks en  $n=900$  spelers vanuit die Curriebekerkompetisie. Doelwit vier het 4500 spelers ontleed wat  $n=900$  spelers vanuit elk van die Super Rugbyreeksse vanaf 2011 tot 2015 ingesluit het.

#### **Meetinstrumente**

Data is ingesamel deur van die *Verusco TryMaker Pro* gebruik te maak en is deur die Cheetahs Super Rugby Maatskappy, Bloemfontein, Suid-Afrika, aan die navorser verskaf. Verusco het sedert 2000 Super Rugbyspanne van *TryMaker Pro* voorsien. *TryMaker Pro* is 'n uiters gevorderde ontledingstelsel wat spesiaal vir rugby ontwerp is. Dit is ook die voorkeurstelsel vir professionele spanne wat Verusco gebruik. Die Verusco koderingsentrum kodeer al die wedstryde vir geregistreerde spanne en binne ure nadat die wedstryd gespeel is, word topgehalte detail-, asook hoëspoed-analises gelewer.

#### **Data analise**

Alle data is met Microsoft Excel 2007 verwerk en daaropvolgend na 'n SAS data sisteem omgeskakel.

Vir doelwit een is gebruik gemaak van SAS 9.2 statistiese sagteware pakket se *GLIMMIX* metode vir verdere statistiese ontleding (SAS, 2009). Vir die numeriese data is spesifieke en standaardafwykings gebruik. Individuele duikslagtellings in elke posisie, span en wedstryd, is ontleed deur van die algemene lineêre gemengde model (*GLIMM*) gebruik te maak, met *posisie* en *span* as vaste effekte, terwyl die natuurlike logaritmes van individuele tyd gespeel in minute as die aanvang, en *posisie-in-span* en *wedstryd-deur-span* interaksies as lukrake veranderlike effekte. Met betrekking tot die geskikte veranderlike effekte is dit net redelik om die korrelasie tussen duiktellings

van gegewe individue, versprei oor verskeie wedstryde, (gemoduleer op *posisie-in-span* lukrake veranderlike effek) en duikslagtelling tussen spelers in gegewe span en wedstryd (gemoduleer op *wedstryd-deur-span* lukrake veranderlike effek) toe te laat.

Verder is die *GLIMM* gespesifiseer met die *Poisson* foutverspreiding en natuurlike logaritmes as skakelfunksie. Individuele kontaktellings vir elke posisie, span en wedstryd is op dieselfde manier geanaliseer. In beide gevalle, naamlik die duik- en kontaktellings, het die model die data goed gepas en was daar geen bewyse van residuele oorverspreiding nie. Gebaseer op *GLIMM* is die gemiddeldes van duikslae en gemiddeldes vir kontak per 80 minute (aangepas soos in 'n vollengte rugbywedstryd) bepaal, vir elke speler posisie, met 'n 95% vertrouensinterval (VI) van gemiddeldes. Insgelyks, ten einde die gemiddelde duikslag en kontak tussen verskillende spelposisies te vergelyk, is die verhoudingskoerse (dit is, die verhouding van duikslae en kontaksyfers tussen onderskeie speelposisies) geskat, met 95% VI vir die verhoudingskoerse.

Doelwit twee het die volgende statistiese analise ingesluit deur spesifieke en standaard afwykings vir numeriese data te gebruik. Individuele duikslagtelling vir elke posisie, span en wedstryd is ontleed deur van die algemene lineêre gemengde model ("generalised linear mixed model" – *GLIMM*) gebruik te maak, met *posisie* en die *span* as vaste effekte en die natuurlike logaritme van individuele tyd gespeel in minute as afwyking en *posisie-deur-span* en *wedstryd-deur-span* interaksies as lukrake veranderlike effekte. Met betrekking tot die geskikte veranderlike effekte is dit net redelik om die korrelasie tussen duikslae van gegewe individue in verskeie wedstryde (gemoduleer op *posisie-deur-span* lukrake veranderlike effek) en duikslae tussen spelers in 'n gegewe span en wedstryd (gemoduleer op die *wedstryd-deur-span* lukrake veranderlike effek) te analiseer. Verder is *GLIMM* met die *Poisson*-foutverspreiding en natuurlike logaritmes as skakelfunksie toegerus. Spanwaardes vir die aangee en skop is op dieselfde manier geanaliseer. In beide gevalle, naamlik aangee- en skopwaardes, het die model die data goed gepas en was daar geen bewyse van residuele oorverspreiding nie. Gebaseer op *GLIMM* is die gemiddelde syfers van aangee en skop per 80 minute vir elke span met 95% VI van gemiddelde syfer bepaal.

Doelwit drie het die ontleding van elke veranderlike (dit wil sê, die aantal lynstane, skrums, losskrums, en losgemale ens) ingesluit, deur van *GLIMM* gebruik te maak, met *seisoen* (2011 versus 2015) as vasgestelde effek en beide *wenspan* en *verloorspan* as veranderlike effekte. (Die inpas van die veranderlikes van die wenspan en verloorspan as lukrake veranderlike effek, laat korrelasie toe tussen die telling vir 'n gegewe span dwarsdeur verskeie wedstryde). Verder is *GLIMM* met *Poisson*-foutverspreiding en natuurlike logaritmes as skakelfunksie toegerus wat residuele oorverspreiding vir die model toegelaat het. Gebaseer op *GLIMM* is die gemiddeldes vir lynstane, skrums, losskrums, losgemaal ens, per wedstryd vir die 2011 tot 2015 seisoene bepaal. Insgelyks, ten einde die gemiddelde verhoudings tussen die 2011 en 2015 seisoene te vergelyk, is die verhoudings van lynstaankoorse ens tussen die 2011 en 2015 seisoene geskat met 'n 95% VI vir die verhoudingskoers.

Bogenoemde analyses is afsonderlik uitgevoer op data van die wenspanne asook die data van die verloorspanne en ook vir die twee spanne betrokke in elke wedstryd gekombineerd (met ander woorde vir die wedstryd). Analise is uitgevoer deur van die SAS prosedure *GLIMMIX* (SAS, 2013) gebruik te maak.

Doelwit vier gebruik beskrywende statistieke om die getelde en persentasie data vir die 2011 tot 2015 seisoene te bereken. Beskrywende statistieke is per seisoen vir die wenspanne, verloorspanne en die twee spanne betrokke by elke wedstryd bereken (dit is vir die totale telling per wedstryd). Elke syferveranderlike (getal lynstane, skrums, losskrums, losgemale ens.) is geanaliseer deur van die algemene liniêre gemengde model (*GLIMM*) gebruik te maak, waar *seisoen* (2011 vs 2015) as vaste effek en beide *wenspan* en *verloorspan* as lukrake veranderlike effek gebruik is. Die toepassing van die *wenspan* en *verloorspan* as lukrake veranderlike effekte het tot gevolg dat korrelasie tussen die telling ter sake vir 'n gegewe span oor verskeie wedstryde toegelaat kan word. Verder is die *GLIMM* spesifiek met die *Poisson*-foutverspreiding en natuurlike logaritmes as skakelfunksie toegerus, wat residuele oorverspreiding in die model toelaat. Gebaseer op *GLIMM* is gemiddelde waardes vir lynstane, skrums, losskrums, losgemaal ens. per wedstryd vir die 2011 tot 2015 seisoene bepaal. Insgelyks, om die gemiddelde verhoudings tussen die 2011 en 2015 seisoene te vergelyk is verhoudingskoerse tussen die 2015 en 2011 seisoene geskat – met ander woorde die lynstaanverhoudings ens. – met 'n VI van 95%.

Bogenoemde analyses is afsonderlik uitgevoer op data vir die wenspanne, data vir die verloorspanne en data vir die twee spanne betrokke in elke wedstryd gekombineerd (met ander woorde vir die wedstryd). Die persentasie gebiedsvoordeel en balbesit van die wenspan in elke wedstryd is geanaliseer deur die liniêre gemengde model (*GLIMM*) te gebruik met *seisoen* as vaste effek en beide *wenspan* en *verloorspan* as lukrake veranderlike effekte. Gebaseer op die liniêre gemengde model (*GLIMM*) is die vasgestelde persentasie gebiedsvoordeel en balbesit bepaal vir elke seisoen met 95% VI vir die ware persentasie. Insgelyks is die ware persentasie, dit is verskille tussen ware persentasie gebiedsvoordeel en balbesit vergeleke tussen die 2015 en 2011 seisoene bepaal met 'n 95% VI vir die ware verskille. Die analise is uitgevoer deur van die SAS prosedure *MIXED* (sien SAS, 2013) gebruik te maak.

### Resultate

Die resultate van doelwit een onderstreep die belangrikheid van spesifieke vereistes vir die verskeie speelposisies met betrekking tot duikslae en kontak deur Super Rugby-spelers. Dit is duidelik dat losvoorspelers (6 = 16.65 duikslae per 80 minute; 7 = 17.30 duikslae per 80 minute) die hoogste duikslagtempo het, gevolg deur die slotte (4 = 13.74 duikslae per 80 minute; 5 = 14.07 duikslae per 80 minute). In die agterlyn het die binnesenter (12 = 12.89 duikslae per 80 minute) die hoogste duikslagtempo gehad gevolg deur die buitesenter (13 = 9.96 duikslae per 80 minute). Die resultate toon aan dat die oopkantflank (7) die hoogste duikslagtempo van al die speelposisies het (17.30 duikslae per 80 minute). Die oopkantflank (nommer 7) was ook in die meeste kontakspel betrokke, gevolg deur die steelkantflank (nommer 6), loskopslot (nommer 4) en die agsteman (nommer 8) met kontaktempo's van 46.08, 44.81 en 43.03 onderskeidelik per 80 minute kontakting per wedstryd. Die resultate dui op betekenisvolle verskille tussen posisionele groepe vir duikslae, behalwe vir die voorry en die slotte (1,2,3 vs 4,5;  $p = 0.0715$  tot  $p = 0.6324$ ). Binne 'n posisionele groep, naamlik die agterspelers, verskil die duikslae van die binnesenter beduidend van ander agterlynspeleers (9 vs 12,  $p = 0.0029$ ; 10 vs 12,  $p = 0.0045$ ; en 12 vs 13,  $p = 0.0100$ ).

Doelwit twee dui aan dat verloorspanne meer geneig is om die bal uit te gee as wenspanne (127.02 aangeepogings per 80 minute). Die resultate toon 'n beduidende verskil tussen die wenspanne en verloorspanne aan met betrekking tot totale

aangeepogings, swak aangeepogings en goeie aangeepogings ( $p = <0.05$ ). Wenspanne neig om die bal meer te skop (25.77) as verloorspanne (20.23). Resultate toon 'n beduidende verskil tussen wenspanne en verloorspanne met betrekking tot totale skoppe, langskoppe, kortskoppe en meters geskop ( $p = <0.05$ ). Wenspanne het meer langskoppe (18.55) as verloorspanne (14.19) geskop. Wenspanne het ook die kortskop (7.22) meer effektief gebruik en dit was ook meer effektief as dié van die verloorspanne (6.04). Verloorspanne het 'n gemiddelde totaal van 660.01 meter per wedstryd behaal in vergelyking met die wenspanne, met 901.4 meter per wedstryd.

Met die derde doelwit is bevind dat wanneer die twee kompetisies met mekaar vergelyk word, daar slegs twee veranderlikes onderskei kan word. Losskrums en duikslae gemis is die enigste twee veranderlikes wat opvallend verskil het: In die Curriebeker is 3.23 meer losskrums en 8.9 meer duikslae per wedstryd, as in die Super Rugbykompetisie verbou. Die resultate in die studie onderstreep weereens die belangrikheid van meting en ontleding van spesifieke prestasie-aanwysers op 'n gereelde basis, omdat hierdie aanwysers na gelang van die vlak van kompetisie kan verander. Die grootste toename het in die skrums plaasgevind, waar hierdie veranderlike in die Curriebeker van 139.63 tot 143.13 in die SuperRugbyreeks toegeneem het. SuperRugby spanne het minder lynstane verloor, asook minder duikslagpogings gemis, terwyl Curriebekerspanne die losskrum meer as 'n aanvalswapen gebruik het.

Doelwit vier het geïdentifiseer dat speelyd, lynstane verloor, skrums, skrums verloor, duikslae en strafskoppe vanaf 2011 tot 2015 afgeneem het, terwyl lynstane, losskrums en aantal duikslae gemis, toegeneem het. Die studie se resultate bevestig weereens die belangrikheid van meting en analise van spesifieke prestasie-aanwysers op 'n gereelde basis omdat hierdie prestasie-aanwysers in 'n kort tydsverloop kan toeneem of afneem. Vanaf 2011 tot 2015 het die wenspanne konsekwent minder lynstane as die verloorspanne verloor, selfs met 'n algehele toename in die aantal lynstane per wedstryd. Hierdie studie toon 'n minimale afname in die aantal duikslae, maar ondersteun steeds die feit dat wenspanne 'n hoer duikslagtempo as verloorspanne het.

### **Gevolgtrekkings**

Die resultate toon aan dat daar 'n beduidende verskil tussen individuele spelpatrone in dieselfde posisionele groepe is ten opsigte van duikslae en kontaktempo's gehandhaaf tydens wedstrydspel. Verloorspanne gee meer as wenspanne uit en wenspanne skop meer as verloorspanne. Die studie het ook bevind dat wenspanne groter afstand deur skoppe verkry het. Die hoër of laer syfers van die prestasie-aanwysers wat deur die spanne tydens die kompetisies behaal is, beklemtoon die verskillende psigologiese vereistes wat aan spanne gestel word. 'n Gevolgtrekking kan ook gemaak word dat speelyd, lynstane verloor, skrums, skrums verloor, duikslae en strafskoppe vanaf 2011 tot 2015 verminder het.

Die bevindinge mag ook belangrik wees vir verdere navorsing, omdat dit die konstante verskuiwing in die gedrag van spanne oor seisoene binne spesifieke kompetisies aantoon.

### **Sleutelwoorde**

Duikslagtempo, Kontaktempo, Uitgee, Skop, Super Rugby, Curriebeker, Prestasie - aanwyser, Spelaktiwiteite, Gebiedsbesit.

### **Verwysing**

SAS Institute Inc. *SAS/STAT 9.2 User's Guide, 2nd ed.* Cary, NC: SAS Institute Inc.



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## *List of Abbreviations*

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IRB	International Rugby Board
GPS -	Global Positioning Systems
'3D' -	Three Dimensional
TMA -	Time Motion Analysis
RWC -	Rugby World Cup

### Chapter 3

IRB -	International Rugby Board
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### Chapter 4

IRB -	International Rugby Board
CL -	Confidence Levels
CI -	Confidence Intervals
GLIMM -	Generalised Linear Mixed Model

### Chapter 5

SARFU -	South African Rugby Football Union
GLIMM -	Generalised Linear Mixed Model

### Chapter 6

IRB -	International Rugby Board
SARFU -	South African Rugby Football Union
CI -	Confidence Intervals



# *Chapter 1*

## Problem statement and aim of the study

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### 1.1 Introduction

Rugby union is ranked second in participation only to soccer as a football code (Hughes & Fricker, 1994). According to World rugby (2017), rugby is played throughout the world by men and women, boys and girls. Players are attracted to Rugby because of its unique character-building values. Elite athletes are dependent on consistent high level performance for their livelihoods. As a result, athletes and their management will seek any advantage when training and preparing for competition (Gill, Beavan & Cook, 2014). To create this winning edge might be the only advantage a team has, as all teams become physiologically and psychologically similar as the levels of competition and professionalism intensify. Bracewell (2002) stated that statistics are having an increased influence in the rugby-coaching environment and that many of the statistics used are exposed to changeable match constraints and conditions, reducing the practical significance of these data. Statistics is a product of all sport competitions. Statistics can be described as the number of

actions performed by an athlete and team or number of occurrences of match activities during match play. Gabbett, Kelly and Pezet (2007) concluded that an understanding of the skills required of each positional group, and the limitations of specific positions, may assist coaches to deliver appropriate skills training on an individual basis.

Match activities in Rugby Union can be explained as the set phases like scrums and lineouts, and open-play actions such as tackles, passes, kicks, rucks and mauls. Bracewell (2003) argued that from a statistical perspective, rugby brings about a special set of challenges because it is complex and chaotic, and that circumstances change from game to game, and even from phase to phase due to varying conditions.

Coaches apply different game plans and can possibly influence the number of variables not only for the team but for individual playing positions. Other factors that can influence the number of match activities are weather conditions, magnitude of the game and the competition structure. Understanding these match activities also has implications for the training of athletes and can indicate the intensity at which certain variables must be trained. Ideally these statistics aim to identify possible team success and shortcomings.

The recognition of performance analysis as a vital component of the coaching process has led to a significant amount of research being devoted to developing objective systems for gathering information (Hughes, 1996). Bracewell (2003) mentioned that invariably conversation revolves around the perceived performances and relative abilities of individuals and that a method for quantifying individual rugby player performance is explored, emphasising the multi-faceted nature of rugby performance. This quantification has led to the development of a variety of analysis software available on the market today to provide merit to each player. Each software programme has its own unique set of advantages and disadvantages which measures different variables. It is believed that these match activities will differ from winning teams to that of losing teams, and will vary according to the level of competition.

## 1.2 Problem statement

At the completion of the match, the coaches and players are likely to use the match statistics to assess performance. The analysis of game statistics, with regard to individual and collective skills, is one of the tools that can be utilised to describe and monitor behaviour in competition. In spite of the limitations that can arise from the different variables used in research, Hughes and Bartlett (2002) describe this type of data as useful in the attempt to develop greater knowledge of the game. Match statistics present values that can be used as normative data to design and evaluate practices and competitions for peak performances in a collective or individual way. Coaches can use this information to establish goals for players and teams both during practices and matches (Ortega, Villarejo & Palao, 2009).

The current trend in video analysis is the development of performance profiles to describe individual or team patterns created from combinations of key performance indicators (Hughes & Bartlett, 2002). These performance indicators can be seen as all skill activities performed by players during match play. Multivariate statistical techniques allow meaningful statistics to be created that summarise individual performance and negate the variability in match involvement. This increases the power of the statistical tool available to coaches by enabling deficient or superior performances to be identified and put into context (Bracewell, 2002). Bracewell (2002) also stated that an individual's ability cannot be inferred from a single match, but must be monitored over several matches, depending on the level of significance required.

Previous studies suggest that certain factors contribute to successful rugby performances (Hughes & White, 1997; O'Donoghue & Williams, 2005). Research was also conducted on positional demands in rugby (Meir, Newton, Curtis, Fardell, & Butler, 2001; Roberts, Stokes & Trewartha, 2006; Quarrie, Handcock & Toomey, 1996). Continuous studies are required on match statistics because of the fluctuating changes and evolution in the sport of rugby union.

### 1.3 Research questions

The following questions arise:

1. What is the difference in the number of tackles and collisions that different positions sustain during a match of rugby?
2. Will there be a difference in the number of match activities in competitions that are regarded as a higher competitive level?
3. Do the match activities of competitions indicate an increase over the last few years?
4. Will there be differentiating statistics between winning and losing teams?
5. Which variables are more likely to be higher for teams that win or lose?

### 1.4 Aims

The specific aims of the study are to:

1. Investigate the positional tackle and collision rate in the 2013 Super Rugby season.
2. Determine the difference in match activities between Super Rugby and Currie Cup competitions during the 2014 season.
3. Evaluate the evolution of the game of rugby union from 2011 to 2015.
4. Identify possibly significant differences between the match activities of winning and losing teams of Super Rugby during the 2013 season.

### 1.5 Structure of thesis

This thesis is presented in seven parts. Chapter 1 introduces the problem statement, research questions and aims of the study. Chapter 2 focuses on a literature review with regard to the influence of match statistics. Chapters 3 to 6 are presented in article format and the research methods are discussed in each article. Article titles are as follows: Chapter 3: *Positional tackle and collision rates in Super Rugby*. Chapter 4: *Passing and kicking statistics that discriminate between winning and losing teams in the 2013 Super Rugby season*. Chapter 5: *Comparison in match activities between Super Rugby and Currie Cup during the 2014 season*. Chapter 6: *Changes in match activities in Super Rugby from 2011 to 2015*. The final chapter (chapter 7) presents the collective summary, conclusion, and recommendations of the study, followed by

appendices. Referencing is done according to the Harvard method and a list of references is provided at the end of each chapter.

The dissertation is submitted in article format, as approved by the Senate of the University of the Free State (UFS), according to its guidelines for postgraduate studies. Chapters 1, 2 and 7 have been written according to the prescribed standards of the UFS Guidelines for References. The articles have been prepared for publication in accredited peer-reviewed journals. Articles have been written according to the guidelines to authors of the various journals (see the relevant appendices). Articles 1 and 3 were prepared for the *International Journal of Performance Analysis in Sport*. Articles 2 and 4 were prepared for the *South African Journal for Research in Sport, Physical Education and Recreation*. For the purpose of quality and examination, the font and spacing is consistent throughout the thesis. The tables and figures are also placed in the text and not at the end of each article, as prescribed by some journals. The results of the research in Chapters 3 to 6 are presented and interpreted in each chapter respectively. The structure of the thesis is presented in Figure 1.1.



**Figure 1. The structure of the thesis**

#### 1.6 Ethical considerations

Data were supplied by the Cheetahs Super Rugby Franchise using the Verusco *TryMaker Pro* (Verusco Technologies Ltd.; Palmerston North, New Zealand). Verusco has provided Super Rugby teams with *TryMaker Pro* since 2000. This software programme provides a notational analysis of each individual player for each game played (Smart, Hopkins, Quarrie & Gill, 2014). *TryMaker Pro* is an advanced analysis system specifically developed for rugby, and it is the preferred system for professional teams using Verusco. The Verusco coding centre codes all the games for registered

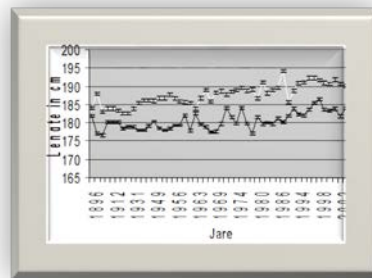
teams and delivers high detail, high-speed analysis within hours of the game being played. There was no personal contact with any players or coaches. Ethical clearance was obtained from the University of the Free State where the study was conducted under ethical clearance number **UFS-HUM-2013-009**.

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#### 2.1 Introduction

The modern game of rugby makes use of professional analysts to provide quantitative reviews of tournaments and matches to coaches and conditioning staff by assessing the relevant data of a match as well as providing feedback relating to each team's

performance. Bracewell (2002) described statistics as a natural by-product of competitive sport, for in many instances this information is used to determine match result (runs, goals, points, time). Bracewell (2001) further described statistics as an addition to the entertainment package provided by the media, but noted that the underlying assumptions must be understood to use statistics effectively so that potential limitations can be identified. In professional team sports, the financial implications associated with success and failure place coaches under pressure to maximise their team's performance (Brooks, Fuller, Kemp & Reddin, 2008). The problem with measuring coach performance was further highlighted by Ford, Coughlan and Williams (2009) who mentioned that the importance of performance is compounded by the fact that numerous skills or components apparently contribute to expert coaching. This has led coaches and conditioning coaches to seek new avenues in the assessment of players over a season, during a match or during training. In the United Kingdom alone there are over a million coaches who work with at least two fifths of players across at least 40 sports codes, with around 30% of coaches being paid for their efforts (Townend & North, 2007). James, Mellalieu and Jones (2005) and O'Donoghue (2006) state that the continued development of professional sport, together with the use of technology and scientific support, is becoming increasingly essential to aid coaches, specialist coaches and trainers in the coaching process and within coaching structures, as it provides them with detailed information on performances of individuals and teams. In addition, it is accessible across all levels of rugby union (hereafter referred to as rugby). This statement was further supported by Ortega, Villarejo and Palao (2009) who state that the analysis of game statistics with regard to individual and collective skills, is one of the tools that can be utilised to describe and monitor behaviour in competition.

The performance of the athlete(s) and win-loss records have been commonly used as a measure of coaching performance, but clearly this measure can be affected by many variables other than the coach (Ford *et al.*, 2009). Gilbert, Coté and Mallett (2006) mention that higher level coaches are successful due to possessing more experience as a coach and greater resources for coaching. Kelly, Coughlan, Green and Caulfield (2012) state that elite rugby union teams currently employ the latest technology to monitor and evaluate the physical demands of training and games on their players.

Franchises invest large sums of money to supply coaches with all possible help in monitoring players, whether with more staff or through the use of analysis systems. Since rugby union became a professional sport in 1995, numerous methods of quantifying constituent elements of competitive play have been investigated (Kelly *et al.*, 2012). Professionalism implies that coaches and their support staff have more time and resources to investigate and examine various aspects of the game in an attempt to obtain a competitive advantage over their opposition. This increases the knowledge base and refines aspects of the game (Hendricks & Lambert, 2010). The game of rugby has seen an increase of match-play demands that should be accurately quantified if it is to provide accurate information to coaches and conditioning staff for the design of training programmes. Increases are predominantly due to law changes and amendments, as well as improved match analysis, equipment technology and player conditioning (Quarrie & Hopkins, 2007). Over the past 15 years the influx of computer based technology has allowed new methods of assessing movement, such as multiple camera methods (Di Salvo, Collins, McNiell & Cardinale, 2006), Global Positioning Systems (GPS) (Coutts & Duffield, 2010) and systems using microprocessor technology (Frencken, Lemmink & Delleman 2010).

The advent of GPS technology for team sports has provided sports practitioners with more detailed information than could previously be obtained through video analysis. Cunniffe, Proctor, Baker and Davies (2009) recommend that the use of GPS accelerometry technology offers valuable insight into physiological demands, information which would not be available through HR-based collection methods or video analysis. Athletes' distance covered in high and low velocity movements, time spent at these speeds, their high-acceleration movements, and work-to-rest ratios can all be collected during competition and training (White & MacFarlane, 2013). Extracting this information can lead to valuable insight into the performance of individuals and their relative capacity or ability (Bracewell, 2002). Hughes and Franks (1997) reported that the observation of individual players and the team's collective behaviour is vitally important for the organisation, design, teaching, and training of team sports.

GPS devices designed specifically for sporting application became commercially available in 2003 (Aughey, 2011). In conjunction with time-motion analysis, a parallel

stream of research within rugby union has been the use of notational analysis to quantify the physical and skill requirements of competition. Notational analysis provides objective feedback of games and players' actions through the frequencies of key performance indicators (Eaves & Hughes, 2003). Hughes (2004) defined notational analysis as "an objective way of recording performance so that key elements of that performance can be quantified in a valid and consistent manner". Notational analysis can identify the key technical factors associated with sporting performance (MacKenzie, Holmyard & Docherty, 1989).

The basic principles for obtaining an individual performance measure from match data are based on four key steps. First, individual performance must be defined and then operationalised by listing all relevant physical tasks such as tackles, passes and kicks. This allows match involvement to be quantified. Quantification of match involvement enables performance measures representing core skill groupings to be calculated. Finally, this allows overall performance to be established (Bracewell, 2003). Performance indicators refer to a selection or combination of action variables that aim to define some or all aspects of a performance (Hughes & Bartlett, 2002). The identification of performance indicators critical for success will allow the development of effective tactical approaches suited to the modern game (Bishop & Barnes, 2013).

More recently the introduction of fully automated tracking systems with no human operator input has allowed live tracking to be demonstrated during games by companies such as TRACAB (Carling, Reilly & Williams, 2009). At present no fully automated 3D system that tracks in real-time and requires no human operator is commercially available to the market. Therefore, the amount of information that is currently analysed in real time within clubs is limited by the method of collecting the data, rather than the way in which the data is used (Redwood-Brown, Cranton & Sunderland, 2012). Kelly *et al.* (2012) state that the physical demand placed on elite rugby union players increases; there is a specific need for objective measurements of player wellbeing. Duffield, Reid, Baker and Spratford (2010) also remark that accurate assessment of the movement profile of athletes during training and match play can assist in the development of specific conditioning activities and recovery strategies. The recovery of athletes is also associated with the time of season and the use of

tapering if the number of match activities is higher than normal. Teams apply this strategy to rest players and also to approach certain games as less important. In a study by Gill *et al.* (2006) it was confirmed that the exercise and collisions involved in rugby can cause a significant increase in creatine kinase. Athletes, coaches and sports scientists throughout the world are increasingly pushing the limits of human adaptation and training loads with the aim of achieving top performance at the major competition of their respective sports (Mujika and Padilla, 2003).

Biomechanical analysis is also an area that coaches and conditioning coaches can utilise to enhance performance of athletes and players. The problem with conducting biomechanical analysis is the need for sound technical experience in the skill which is analysed by the coach. Mellalieu (2008) mention that given the initial work conducted in the field of biomechanics, there is considerable scope to examine the mechanics of rugby, particularly skill execution under fatigue or pressure conditions. Given correct usage, statistics can provide valuable insight into individual performance enabling strengths and weaknesses to be diagnosed (Bracewell, 2002). Good knowledge of rugby in terms of positional differences, factors that influence winning and losing teams, the physiological make-up of players, the difference between levels and seasons can provide valuable information to coaches. Abovementioned influences are discussed as follows:

## 2.2 Description of Rugby Union

Rugby is played throughout the world, with the International Rugby Board encompassing 103 national unions (World Rugby, 2017). Takahashi, Umeda, Mashiko, Chinda, Sugawara and Nakaji (2007) described rugby as one of the most intense contact sports among competitive sports which requires a high degree of physical fitness. Rugby Union football continuously gains popularity in the United States. Both men's and women's clubs have been established at several colleges and universities (Dietzen & Topping, 1999). Two teams engage in a match, each with 15 players on the field at a time, with the exception of players being sent off for misconduct. The game is played over two 40 minute halves separated by a break not exceeding 10 minutes. There are no interruptions, except in the event of an injury (Duthie, Pyne & Hooper, 2003).

### 2.2.1 Positional differences in rugby union

Each player has a designated position and number outlined by the International Rugby Board (IRB), later known as World Rugby (Figure 1). The main objective of rugby is to gain territory by advancing the ball down the field towards the opposition try-line and to score as many points as possible (Hendricks & Lambert, 2010). Kelly *et al.* (2012) state that rugby is a full-body contact game with many injuries resulting from extrinsic forces. Duthie *et al.* (2003) also found that rugby union players have a diverse range of physical attributes. A distinct physique will naturally orientate a player towards a particular position over others. Quarrie *et al.* (1996) and Nicholas (1997) defined the physical requirements of each playing position. The front row positions and loose forwards demand strength and power with loose forwards also being mobile, quick and possessing high levels of endurance; locks are tall, heavy and powerful; inside backs must have good endurance, speed, power and strength; while the outside backs have the same requirements as inside backs, but require more speed.



Figure 1: Different rugby positions

([http://schools.cbe.ab.ca/b857/athletics/Rugby/rugby\\_basics.html](http://schools.cbe.ab.ca/b857/athletics/Rugby/rugby_basics.html))

Since Rugby Union became a professional sports code in 1995, the science examining the sport and its participants has developed rapidly to meet the increased demand for knowledge on the requirements of the game and the characteristics of the players (Reilly, 1997). Professionalism in rugby provides coaches and support staff with more

time and resources to investigate and apply various aspects of the game in an attempt to obtain a competitive advantage over their opposition (Hendricks & Lambert, 2010). The physiological demands of Rugby Union, like other football codes, are complex when compared to individual sports codes (Duthie *et al.*, 2003).

### 2.2.2 Discriminating between winning and losing

Wilson and Kerr (1999) concluded that the general perception of the public, media, spectators, players and coaches alike is that success is judged as winning and failure as losing. It can be assumed that winning and losing teams will have different numbers of match activities even in the same game. Bracewell (2001) concluded that rugby has few outcomes that represent successful contribution in a match context and performance must therefore be measured on successfully completed tasks such as the number of players beaten or the number of metres run on attack. Rugby requires diverse physical attributes and skill sets across 15 playing positions and performance analysts have endeavoured to quantify its physical demands (Duthie *et al.*, 2003). While high physical effort is likely to contribute to a successful match performance, overall performance is also determined by game-specific skills and the abilities of players (Gabbett *et al.*, 2007). Hunter and O'Donoghue (2001) compared the performance of winning and losing teams at the 1999 Rugby World Cup and found that the frequency with which the winner invaded the rival's 22 metre zone and points scored when invading the 22 metre zone were significantly different. Olds (2001) found in the same World Cup that the most successful teams were those who had greater total mass in the forwards. Bennett, Manning, Cook and Kilduff (2010) also reported a strong selection for size (particularly size among forwards) in rugby, and that team success in competitions is predicted by size. Winning and losing sides were found to differ on the number of occasions that a team entered into the opposition's final third of the playing field and the frequency of attacks by which the team went around the opposition (Jones *et al.*, 2008). Stanhope and Hughes (1997) found that successful teams in the 1991 World Cup had better performance in the ruck, recovered a higher number of balls, and had a more effective foot game.

Duthie *et al.* (2003) concluded that the most successful team of the competition had the highest number of contact situations and the greatest ball retention. MacKenzie *et*

*al.* (1989) described rugby as a collision sport, where the contests for the ball in tackle situations was identified as a key determinant of performance. Vaz, Van Rooyen and Sampaio (2010) showed that international competitions that include teams from all nations are unlikely to show statistically significant differences between winning and losing teams. Hughes and White (2001) found that the forwards on winning teams are more effective in the line-out, as they have more variations. Ortega *et al.* (2009) found that winners did not have significantly higher averages in the variables scrums won, lineouts won, and balls won in the attack phases, with significantly higher averages for line breaks, possessions kicked, tackle completion and turnovers won. On the other hand, losing teams had significantly higher averages for the variables scrums lost, lineouts lost, rucks and passes. Kraak and Welman (2014) indicated that the ball is successfully retained by the attacking team in more than 90% of the rucks. Laird and Lorimer (2004) concluded that winning teams favour a “long-ball” style of play in order to maximise scoring success. Bishop and Barnes (2013) noted trends in other indicators which support the notion that winning teams adopted a more territory based strategy rather than a possession based approach to the game. The authors also indicated that discipline in reducing the penalty count when defending in one’s own half was also found to be key in minimising potential scoring opportunities for the attacking team. Hughes *et al.* (2001) argued that the use of an entire season’s matches provides a relatively stable data sample, it also lessens the effect and potentially conceals the current form of the team or individual, thereby illustrating how the issue of sample size can markedly alter the way in which a match performance is perceived.

Vaz *et al.* (2010) noted that the general lack of significant differences between winning and losing teams for the analysed games in their study suggest the existence of different movement patterns, styles of play and performance profiles in rugby teams. The authors also indicated variables from winning and losing teams were very similar, in fact, it was not possible to get a different pattern for winners and losers in close games, which may further suggest that teams use several different ways to win.

### 2.2.3 Differences in levels of competition

In any domain where there is a discrepancy between the recommended level of performance and the level that is commonly accepted and achieved, there is also the opportunity for gaining a competitive advantage for those who can successfully train to reduce the discrepancy (Pavely, Adams, Di Francesco, Larkham & Maher, 2010). In a study conducted by Gabbett (2002), there was a significant effect ( $p < 0.05$ ) of age and playing level on playing experience, body mass, muscular power, speed, agility, and estimated maximal aerobic power, with the physiological capacities of players increasing as the playing level increased. This statement can also be true for skills exhibited by players from different levels of competition, for example the number of rucks, mauls and tackles performed by players due to higher fitness levels and improved capacities of players to perform certain tasks for prolonged periods of time.

Olivier and Du Toit (2007) mentioned that variations of physical characteristics such as mobility, agility, muscular strength and muscular power can occur between positional roles and also between levels of competition. Gabbett (2003) showed that progressive improvements in the physiological capacities of rugby league players as the playing level is increased are evident. Scher (1998) concluded that adult rugby union players could possibly have a 10-12 times higher risk of cervical spinal injuries than juniors. The author further suggested that higher levels of skill and fitness do not always protect players from injury, but could increase its likelihood. Results from a study conducted by Sirotic, Coutts, Knowles and Catterick (2009) showed that differences exist in physical and game-specific skills within a match between two standards of competition; however, overall physical match demands and game-specific skills were similar between the two playing standards. During club and international level games, differences were found in the time spent in running activities with centres of international standard spending more time per game in non-running intense activity (5.4%) than club centres (1.8%) (Docherty, Wenger & Neary, 1988).

Olds (2001) concluded that the body size gradients across competitive standards, and the final rankings of different-sized Rugby Union teams at the recent World Cup, demonstrated that large body size is a significant correlate of success. There was a clear improvement of the game, characterised by an increasing level of competition

and higher quality training programmes, which induced noticeable changes on the players' physical structure and on their levels of performance (Mellalieu, Trewartha & Stokes, 2008). Walsh, Young, Hill, Kittredge and Horn (2007) indicated that experience decreased the extent to which running with the ball slowed the players down during the 10m sprint. Elite players performed more high-intensity activities during the first half, but the total amount of high-intensity activities performed during a match was similar between two standards of competition (Sirotic *et al.*, 2009). Duthie *et al.* (2003) concluded that there appears to be only minor differences in movement patterns of players between international and club level rugby and that the game speed between these levels of competition is not apparent from the time-motion analysis data collected. Gabbett *et al.* (2009) summarised that significant differences can be found in physiological characteristics between junior elite and sub-elite rugby league players, with speed, change of direction speed, vertical jump height, and estimated  $VO_{2\max}$  increasing as the playing level intensified.

#### 2.2.4 Physiological requirements of Rugby Union

##### *High intensity distance covered*

Probably the most important component for rugby players, conditioning coaches and coaches to consider when structuring an exercise programme, is the high intensity distance covered. This component is defined by the distance covered during running, high speed running and sprints. Dwyer & Gabbett (2012) defined a sprint as any movement that is equal to or exceeds the sprint threshold velocity for at least 1 second and any movement with an acceleration that occurs within the highest 5% of accelerations found in the corresponding velocity range. The high intensity distance covered is regarded as actual playing intensity, because most activities are performed during this stage. McLean (1992) determined that when the ball was in open play, the average running pace of players central to the action ranged from 5 to 8m/s. This, together with scrums, lineouts, rucks and mauls were classified as high intensity exercise. According to Austin, Gabbett & Jenkins, (2011) the durations of the most intense repeated high intensity exercise bouts for each position ranged from 53s to 165s and the minimum recovery periods between repeated high intensity exercise bouts ranged from 25s for the back row forwards to 64s for the front row forwards. The

most intense periods of activity are likely to last as long as 120s and as little as 25s recovery time may separate consecutive repeated high intensity exercise bouts.

During a match, outside backs are engaged in more sprints than front row forwards. As a result, outside backs spend significantly more time sprinting than front row forwards. Another difference between forwards and backs is also observed: Mean sprint duration is longer for outside backs than for any other position, contributing to significantly longer mean sprint durations (Deutsch, Maw, Jenkins & Reaburn, 1998). Deutsch, Kearney and Rehrer (2007) revealed an overall difference between forwards and backs (10.2s vs 29.4s). In contrast to this statement, Cahill, Lamb, Worsfold, Headey & Murray (2012) provided new insight into the positional sprint demands of rugby, for instance, that the forwards sprinted greater total distances than the backs. It will therefore be meaningful for conditioning coaches and coaches to be aware of differences and to adapt their programmes to the demands revealed by time-motion analysis.

#### *Distance covered*

The distance covered during a match naturally includes distances covered by walking, jogging, running, high-speed running and sprints. Walking in rugby may be considered as the recovery phase and the non-playing time between set phases, walking back to position after a high-intensity bout or walking to a scrum or lineout. Jogging can be found between scrums and lineouts or when moving back into position after the ball has gone dead or whilst the game is still underway. Running, high-speed running and sprints occur while the game is underway to attend to rucks and mauls or while defending, and can also include running with the ball in hand and chasing the ball. The sum of all these activities amount to the distance covered (Deutsch, Kearney & Rehrer, 2002).

Early estimations of the distance covered during a rugby match indicated that a centre covered 5800 m, of which 2200 m was walking, 1600 m jogging and 2000 m sprinting (Morton, 1978). Deutsch et al. (1998) analysed six players during four under-19 matches at different levels of play. Although backs had a lower overall exertion based on heart rate, they covered the greatest distance, with props and locks covering  $4400 \pm 398$  m, back row  $4080 \pm 363$  m, inside backs  $5530 \pm 337$  m and outside backs 5750

± 405 m. Within elite under-19 colts' rugby, forwards spent a larger percentage of time standing still (46%) compared with the backs (39%), and covered a shorter distance in all gait movements except jogging (Deutsch *et al.*, 1998). Data from Cunniffe, Proctor, Baker & Davies (2009) reveal that players cover on average 6953m during play. A breakdown of this distance showed that 2800m was spent standing and walking, 1900m jogging, 700m cruising, 990m striding, 320m high-intensity running, and 420m sprinting. The distance covered during a game of rugby can be influenced by rule changes over years, but influences like weather, playing conditions, competition structure, team structure or the magnitude of the game can also have an effect.

#### *Percentage work rate/ratio at high-intensity*

The physiological ability of the athlete to cope with high-intensity exercise with very little rest in-between bouts are expressed as a percentage of the work rate at high-intensity and can be related to the overall performance of the team or individual. Christmass, Dawson, Passeretto and Arthur (1999) compared the physiological responses of 90 mins intermittent running and continuous running of similar energy expenditure in physically active individuals. The intermittent exercise, which involved repeated blocks of 12s exercise and 18s passive rest (12:18), demonstrated greater carbohydrate utilisation and lower fat utilisation than the continuous exercise. McLean (1992) concluded that the mean duration of work in a game of rugby was 19s; he further showed that 60% of the duration of work periods were between 11s and 25s and 5% were between 50 s and 60 s. Work-rest ratios on average were 80:106 per game; 20% were 2:1, 18% were 1:4 and higher and 5% were higher than 3:1 (McLean, 1992). In a study conducted by Sykes, Twist, Hall, Nicholas & Lamb (2009) on Rugby League, outside backs had a higher work to rest ratio for ball in play and for defence than all other positional groups ( $p < 0.05$ ). The study of the underlying physiological responses during different work-rest durations and a demonstration of the effects on performance can be used by athletes and coaches alike. Boyle *et al.* (1994) determined that the medium and long work-rest trials were physiologically more demanding.

Deutsch *et al.* (2007) reported mean work-rest ratios of 7.3 for front rows, 7.5 for back rows, 20.9 for inside backs and 22.8 for outside backs. In his study of Super 12 players, front row and back row forwards performed significantly more high-intensity work than inside and outside backs ( $p < 0.01$ ) as a result of performing work more frequently. The mean rest period was significantly longer for inside and outside backs than for front and back row forwards ( $p < 0.01$ ). As a result of a shorter mean rest period, the backs had significantly lower mean work-rest ratios than front and back row forwards ( $p < 0.01$ ). Heart rate data collected by Deutsch *et al.* (1998) indicated that props and locks (58.4%) and back row forwards (56.2%) spent significantly more time in high exertion (85-95% HRmax) than inside backs (40.5%) and outside backs (33.9%). Inside backs (36.5%) and outside backs (38.5%) spent significantly more time in moderate exertion (75-84% HRmax) than props and locks (22.6%) and back row forwards (19.8%). The results add to the understanding of the variety in the positional demands in the game of rugby and can be utilised in the methods for preparing elite rugby players.

#### 2.2.5 Seasonal differences in rugby union

Major changes in international rugby match activities and player size have occurred over the past three decades. Furthermore, developments in match analysis, equipment technology, and player training have contributed to the changes associated with the introduction of professionalism (Quarrie & Hopkins, 2007). Quarrie and Hopkins (2007) also reported that increases in the number of passes, tackles, rucks, tries and ball in play time was associated with the advent of professionalism, whereas the number of lineouts, mauls, kicks in play, and mean participation time per player decreased.

### 2.3 Terminology and definitions

The following table explains the terminology used.

Table 1: Definitions of terminology:

<i>Notational analysis</i>	Hughes (2004) defined notational analysis as “an objective way of recording performance so that key elements of that performance can be quantified in a valid and consistent manner”.
<i>Performance indicators</i>	Performance indicators refer to “a selection, or combination, of action variables that aim to define some or all aspects of a performance” (Hughes & Bartlett, 2002).
<i>Time-motion analysis</i>	Time-motion analysis (TMA) has been defined as “the quantification of movement patterns involved in sporting situations, thus providing speeds, durations, and distances of various locomotor patterns during the course of a game” (Dobson & Keogh, 2007).
<i>GPS</i>	Global Positioning Systems are non-invasive sensing equipment with receivers attached to the players to track movement speeds and distances recorded by players and teams.

### 2.4 Identification of performance indicators

Rugby provides athletes of every shape and size with an opportunity to make an effective contribution to the sport because the various playing positions require widely differing skills and physical attributes (Lee, Myers & Garraway, 1997). Detailed information on the movements in a game provides comprehensive assessment of the

demands of competition and assists in developing specific training regimes (Duthie *et al.*, 2005). The development of performance indicators subsequently leads to the creation of performance profiles, which are suggested to be a description of a pattern of performance from an analysed team or individual (Hughes, Evans & Wells, 2001). Physical performance data related to the activity profile of players has become so sophisticated that performance analysts can now retrieve data corresponding to specific speed zones to evaluate the performance of various players (Redwood-Brown *et al.*, 2012). Variables in rugby include scrums, lineouts, rucks, mauls, tackles, turnovers, tries, kicks, passes, ball carries, etc. The list of variables can be different from one researcher to the next due to the availability of statistics and the programmes used to generate these statistics are sometimes limited.

Table 2: Variables studied in the Six Nations tournament during the 2003-2006 seasons (Ortega *et al.*, 2009)

Group of variables	Variables or game statistics or performance indicators
Points scored	Points scored; tries scored; conversions; penalty goal errors; successful penalty goals; drop errors; successful drops
Phases of play	Scrums won; scrums lost; line-outs won; line-outs lost; balls won in open play; balls won in the opponent's 22mts zone; balls won in the attack phases; mauls won; ruck and drive; errors made; ruck and pass.
Game development	Line breaks; penalty goals conceded; possessions kicked; possessions of kicks to touch; kicks to touch; tackles made; tackles missed; tackle completion; passed completed; turnovers won.

Eaves, Hughes and Lamb (2005) concluded that the introduction of professional playing status in rugby had had a marked effect on game action variables and as a

consequence the playing pattern of the game is significantly different in the era of professional circumstances compared to the era of pre-professional circumstances. It is in light of the above argument that Gamble (2004) stated that the training performed each week by professional rugby union teams is designed to elicit improvement in the strength, power, endurance, skill, and tactical preparedness of its players to maximise both individual and team performance. McKenna, Patrick, Sandstorm and Chennels (1988) argued that the most important variable is the duration of time spent in the different activities. Austin, Gabbett and Jenkins (2011) suggested that the development of modern rugby union has resulted in an increase in high-intensity activity and has become more physically demanding due to the increase in total duration and speed of play. This increase in high-intensity activity will also show more and regular injuries. Tackling is also a key performance indicator in rugby union and coaches closely monitor the number of successful/unsuccessful tackles achieved by each player during competitive play (Kelly *et al.*, 2012). Fuller, Brooks and Cancea (2007) reported the propensity of contact events to cause injury, documenting 221.0 tackle events per game in professional rugby with 6.1 per 1000 tackle events resulting in injury. Results from a study conducted by Cupples and O'Connor (2011) differentiated playing positions and identified a unique sub-set of skills and abilities that are crucial to position-specific performance. However, an objective assessment of skill performance during match play is difficult to achieve and therefore investigation of rugby-specific skills would be most appropriately carried out in controlled conditions (Roberts *et al.*, 2008). Athletes strive for perfection, not the average therefore standard process control techniques must be adjusted to compare performance to perfection, rather than the average (Bracewell, 2002).

There is still much debate about selection policies of coaches and whether skill or physical attributes should carry the most weight during selection. Fuller, Taylor, Brooks and Kemp (2013) argued that the increases observed in body mass and stature amongst elite rugby players indicate that the selection and development of rugby players are likely to be more dependent on coaches' views on which physical parameters enhance the competitive performance of players rather than being a consequence of broader changes amongst the general population.

Match variables will ultimately influence the possession and territory that a losing or winning team can gain. Correia, Araujo, Davids, Fernandes and Fonseca (2011) stated that in field invasion games, it is important to advance upfield when in possession of the ball to score a goal or try. It is for this reason that Greenwood (2003) concluded that opponents contest ball possession, hamper displacement of players with the ball, and attempt to advance upfield to reach a position advantageous for a potential counter attack.

### 2.5 Factors influencing performance indicators

Sport presents many variable conditions which will affect match statistics. Therefore the techniques employed to analyse match statistics must take into consideration the natural variability presented by different matches (Bracewell, 2002). Players are getting taller and heavier, and these trends could have a significant impact on professional rugby in terms of how the game is played, managed and financed (Fuller *et al.*, 2013). The changes in match activities and player characteristics observed are probably due to several factors, including rule changes, developments in match analysis and tactics, modifications to player training and equipment technology. Eaves and Hughes (2003) reported that ball-in-play time increased by a mean of 4 min and 45 s following the introduction of professionalism. They observed a similar pattern, with predicted ball in play time in good conditions increasing by 5 min and 54s between 1995 and 2004.

Although the positional groups cover relatively similar distances throughout the course of a match, the typical distances covered at various speed zones vary considerably. The typical amount of exposure to rugby per match also varies across positions, due to variations in the frequency of substitutions and the time through matches at which they are made (Quarrie *et al.*, 2013). Data presented by White and MacFarlane (2013) showed that using different GPS analysis procedures can significantly influence commonly used measurements of physical performance and work-to-rest ratios. Fluctuations in performance in an invasion game such as rugby union can be dependent upon external factors such as the strength of the opposition, previous performances of the team or individual, the dynamics of the analysed team or

individual, and the changing environmental conditions (Hughes & Bartlett, 2002; James, Mellalieu & Hollely, 2002).

#### *Game structure*

The structure of play has also improved with teams having a set plan and definitive roles for each player. Some teams play much more with their forwards and try to create more rucks and mauls that can continue for 30-60 sec. This will place a bigger demand on the fitness of the forwards than that of the backs.

#### *Weather conditions*

The weather can be a determining factor, especially when playing in the rain. Kicks and handling errors are much more prominent, thus decreasing playing time. Games played in the rain are also low scoring games due the constraints of not being able to run the ball that often.

#### *Magnitude of the game*

In most finals the ball will rather be kicked for touch or to take the penalty for a goal rather than to run the ball. These are all situation specific. Finals are always close affairs.

#### *Competition structure*

The “bonus point” determines the end of the game in many situations. Teams will continue play even after the siren has sounded if there is the possibility of a bonus point. Games can continue well after the 40 or 80 minutes of play.

#### *Referees and law variations*

As team sports descend deeper into the professional era, players are becoming fitter, faster, more powerful, and cynical with regard to the laws of the game (Morrison, 2002). Players and coaches must be knowledgeable of the rules of the game, and referees must strictly enforce these rules (Dietzen & Topping, 1999). The rules of the game and constant amendments to the rules can influence the game of rugby union tremendously. Not only will the rules affect the players, but also the coaches' strategy and conditioning coaches' programme design and the prioritisation of phases to be

trained. Sheridan (2007) stated that rugby consistently changes over time due to either technological advances and/or rule changes. This statement was supported by Kraak and Welman (2014) who argue that rule amendments are fundamental to the development of sports and are introduced for a variety of reasons. Eaves, Lamb and Hughes (2008) reasoned that rule changes are implemented in rugby in response to player performance, to ensure safety, enhance participation and enjoyment, promote game continuity, technological advancement and commercial pressures, as well as to retain game integrity and development. Many of the changes implemented have been to increase the appeal and competitiveness of the game, which have subsequently led to the introduction of several rule changes and amendments, especially between 2007 and 2013 (Eaves *et al.*, 2008). In January 2007 the International Rugby Board (IRB) implemented a new rule for scrum engagement aimed at improving player welfare by reducing impact force and scrum collapses (Gianotti, Hume, Hopkins, Harawira & Truman, 2008). Vahed, Kraak and Venter (2016) concluded that the problem that occurs during the amendment of rules is that the legislators primarily focus on the technical and tactical aspects of the game and very little on the effect of the changes on the physical aspects of the game.

One development in 2008 saw the introduction of the “Experimental Law Variations” or ELS’s which saw significant increases in ball in play time during the Tri-nations tournament (Kraak, Venter & Coetzee, 2016). Duthie *et al.* (2003) showed that there is greater policing of the breakdown by referees in an attempt to ensure that the ball is quickly recycled and play continued. Kraak *et al.* (2016) concluded that coaches, referees and players are responsible for changes in the profile of international rugby, showing that these components cannot work on their own to create changes in the profile.

## 2.6 Types of analysis in rugby union

Recent years have witnessed the introduction of sensing technology during training and competitive play with a view to providing coaches and trainers with real-time feedback relating to objective measures of player performance in the field (Kelly *et al.*, 2012). Companies such as Prozone (Leeds, UK), Amisco (Nice, France), TRACAB (Stockholm, Sweden) and Verusco (Palmerston, New Zealand), have all provided

systems to the commercial market which allow tracking data to be collected and used for post-match analysis (Redwood-Brown *et al.*, 2012). ProZone 3 is a semi-automated match analysis image recognition system used to track players during matches (Sykes, Twist, Hall, Nicolas & Lamb, 2009). Kelly *et al.* (2012) remarked that the primary benefit of these devices is that measurements of physical demands on players can be delivered to coaches and team officials in real-time, allowing for quick evaluation and decision-making processes. Computer based coding systems have also been available for live analysis and half-time reviews such as Focus (Elite Sports Analysis, Fife, Scotland) and Sportscodex (SportsTec, Warriewood, Australia) (Redwood-Brown *et al.*, 2012). Although analysis of positional movement (i.e. intensity and duration of running bouts) can be carried out automatically, analysis of physical loads during specific actions (i.e. tackles and collisions) requires a significant amount of time-consuming manual analysis (Kelly *et al.*, 2012). Biomechanical information can provide systematic bases for modifying existing techniques and assessing the physical capacities necessary to play efficiently and safely. This will both improve performance of game skills and minimise the potential for injury (Milburn, 1993).

### 2.7.1 IRB Match reviews

The International Rugby Board releases match reviews after every major rugby tournament played, such as the IRB Rugby World Cup (RWC), the Six Nations and the Rugby Championship. These match reviews provide valuable feedback to players, coaches and supporters about the state of rugby in general and the changes between teams and seasons. The IRB analysis provided in its RWC report (2011) a brief comparison of the RWC 2011 with RWC 1995. This analysis showed that ball in play increased by 33%, while passes increased from 179 per game to 263 (an increase of almost 50%). Rucks/mauls have more than doubled, increasing by almost one hundred from 69 per game to 162 per game. Kicks decreased from 75 to 41 per game and scrums decreased from 27 to 17, with lineouts down from 37 to 24. The history of RWC has shown that as the tournament progresses into the knock-out stages, so penalty goals increase while tries decrease (IRB analysis RWC report, 2011). Since the RWC 2003 season, the increases have become much more gradual and even decreased in certain areas of play.

Table 3: IRB analysis RWC report (2011) comparison of RWC 2003 to 2011

	<b>RWC 2011</b>	<b>RWC 2007</b>	<b>RWC 2003</b>
<b>Ball in play (% of 80min of play)</b>	<b>44%</b>	44%	42%
<b>Passes</b>	<b>262</b>	224	241
<b>Rucks/ mauls</b>	<b>162</b>	144	136
<b>Kicks</b>	<b>41</b>	56	52
<b>Scrum</b>	<b>17</b>	19	21
<b>Lineouts</b>	<b>24</b>	31	33
<b>Penalties/FKs</b>	<b>21</b>	19	24

Previous IRB game analysis statistical reports have highlighted ongoing scrum issues. In the 2013 Six Nations, for example, the rate of scrum collapses was the highest ever recorded with the majority ending in a penalty or free kick. The Rugby Championship had similar scrum issues, albeit to a lesser extent (IRB analysis Rugby Championship Report, 2013).

IRB analysis of the Six Nations competition (2013) showed an average ball in play time per match as 35mins 35secs (44%). The highest ball in play in any match was 40mins 51secs and the lowest was 31mins 21secs. The average ball in play time per match was 31m 46s or 40%. The highest ball in play in any match was 37m 33s or 47% and the lowest was 28m 41s or 36% (IRB analysis Rugby Championship Report, 2013). These reviews by the IRB indicate marked differences between competitions and even between hemispheres. Differences between the Northern Hemisphere and the Southern Hemisphere have been widely debated. Reviews and consistent analysis of the game of rugby provide background and conclusions to these debates.

### 2.7.2 Time-motion analysis

Time-motion analysis (TMA) involves video recordings of a match and later analysing the video using computerised software to determine the main physical activities of players (Duthie *et al.*, 2003). TMA is an effective method of quantifying the demands of rugby and it provides a conceptual framework for the specific physical preparation of players (Deutsch *et al.*, 2002). TMA can also provide specific information for the

physical and technical preparation of players at each competitive standard (Sirotic *et al.*, 2009). This technique can be used by the researcher to quantify the type, duration, and frequency of discrete movements making up the intermittent activity patterns in team sports (Roberts *et al.*, 2008). Kelly *et al.* (2012) stated that TMA is useful to determine the physical demands of locomotion. The reliability and practical use of these methodologies in determining the physical demands in contact events is limited due to the subjective and time-consuming process of analysing player activity and tasks. Duthie *et al.* (2003) added that TMA can also gather information regarding the movement patterns and energy demands of players. Aughey (2011) questions if it is useful to report the total distance that athletes travel in field sports without reference to the time spent engaged in the actual match play. The methodology of establishing the physiological requirements of rugby competition requires careful consideration because estimating distance covered, assessing blood lactate concentration and monitoring heart rate during competition pose logistical difficulties for investigators. Given these limitations, time-motion analysis remains the most effective tool for quantifying the demands of the game at an elite level (Duthie *et al.*, 2005). TMA systems such as GPS do not measure the demands of competition, but rather the output of players and coaches cannot be certain the players have actually met the demands of competition, and indeed, if players fatigue in games, which is likely, then the true demands of competition have not been met. Thus, activity profile is a more technically correct term to describe the measures regularly reported (Aughey, 2011).

In terms of practical applications, the data derived from TMA are essential in helping to inform fitness assessment and research models (Roberts *et al.*, 2008). An understanding of the limitations of time-motion studies would help to minimise the incorrect use of physical and technical match data in a practical setting (Dobson & Keogh, 2007). Duthie *et al.* (2003) argued that although time-motion analysis directly quantifies the movements of players during competition, its validity is questionable because time-motion analysis simplifies movement patterns into categories, when actual play involves a dynamic combination of tasks, skills and tactics. GPS units are able to measure total distance, maximum speed, and speed within arbitrarily defined speed zones, e.g. walking, jogging, sprinting, etc. (Aughey, 2011). Kelly *et al.* (2012) support these findings and stated that GPS receivers, which are in constant signal

contact with orbital satellites, track player position over time, and have primarily been used to measure player speed and distance travelled during training sessions of competition. Duthie *et al.* (2003) warned that time-motion analysis is a time-consuming process that is inherently prone to measurement error.

## 2.8 Performance analysis software in Rugby Union

Elite rugby teams currently employ the latest technology to monitor and evaluate the physical demands of training and games on their players (Kelly *et al.*, 2012). In addition to using time-motion data to improve training specificity, there is also a need to accurately quantify match demands for the purpose of designing more specific exercise protocols that allow the investigation of issues specific to rugby union (Roberts *et al.*, 2008). This argument resulted in a growing number of analysis systems over the last couple of years. Recent years have witnessed the introduction of sensing technology during training and competitive play with a view to providing coaches and trainers with real-time feedback relating to objective measures of player performance in the field (Kelly *et al.*, 2012).

### *Verusco*

Verusco has provided Super Rugby teams with TryMaker Pro since 2000. This programme provides a notational analysis of each individual player for each game played (Smart *et al.*, 2014). TryMaker Pro is an advanced analysis system specifically developed for rugby and the preferred system for professional teams using Verusco. The Verusco coding centre codes all the games for registered teams and delivers high-detail, high-speed analysis within hours of the game being played. Van Rooyen (2012) used Verusco to investigate tackle performance in Rugby Union and it was also used in this study.

### *ProZone*

Prozone is a new computerised video system that allows the tracking of many individuals performing a sporting activity (Di Salvo *et al.*, 2006). The average velocity recorded by the Prozone system during paced runs of 60m and 50m showed an excellent correlation ( $r=0.999$ ; total error 0.05, limits of agreement 0.12) with the average velocity measured by timing gates (Di Salvo *et al.*, 2006). The results of the

study by Di Salvo *et al.* (2006) indicated that Prozone represents a valid motion analysis system for analysing movement patterns.

### *Catapult*

The development of GPS has provided an accurate, non-invasive alternative technique for quantifying the movement characteristics of team sports (Waldron, Worsfold, Twist & Lamb, 2011). Aughey (2011) argues that modern GPS player tracking systems are able to provide accurate, non-invasive, real-time movement analysis within team sports match play and practice environments. Devices that incorporate global positioning systems and accelerometer sensing capability, typically contained within a special sports vest worn by the player, have been deployed in Rugby to monitor player movement (Kelly *et al.*, 2012). GPS receivers that are in constant signal contact with orbital satellites track player position over time and have primarily been used to measure player speed and distance travelled during training sessions or competition. Sensing devices can contain a tri-axial accelerometer which quantifies body impact by measuring the acceleration and deceleration experienced by the player (Kelly *et al.*, 2012). One such system is the Catapult. Research by Akenhead, French, Thompson and Hayes (2014) examined the acceleration-dependent criterion validity and inter-unit reliability of Catapult s4 10Hz GPS receivers for measuring instantaneous velocity.

The above authors also concluded that the validity and inter-unit reliability of the 10Hz GPS devices tested, appear acceleration-dependent, with greater acceleration reducing the validity and reliability of velocity measurement. Akenhead *et al.* (2014) recommended that those using the Catapult s4 10 Hz model of GPS should be aware that during accelerations of over 4m s<sup>-2</sup> accuracy is compromised. With an increase in the accuracy of GPS, it may be possible in future to detect changes in gait through trunk movement as attempted in early GPS research with cumbersome GPS receivers (Terrier, 2000). The chaotic nature of team sports may make this type of analysis difficult to interpret, but the quest to measure fatigue in competition could be aided by more accurate GPS data (Aughey, 2011).

## 2.9 Reliability and validity

Although validations have been implemented on some of the systems available on the market, no system has undergone systematic validation across a wide range of specific motion. Therefore, no gold standard test has been established (O'Donoghue & Robinson, 2009). Global positioning systems have rapidly advanced in the past 10 years. During this time, extensive validation and reliability testing have been completed, and the devices are applied heavily across many team sports (Aughey, 2011). Sport is unpredictable and there is also no consensus on the speed ranges used to represent classes of movement (Carling *et al.*, 2008). The differences between systems further supports the need for validation data to be available for all systems on the market to allow direct comparisons to take place (Redwood-Brown *et al.*, 2012).

Redwood-Brown *et al.* (2012) recommended that given the number of clubs using GPS systems in training to monitor player movement, it is important that the systems used on match day are able to report data with the same or better accuracy for training and match comparisons. Aughey (2011) determined that human locomotion is influenced by similar factors as outlined for validity. In other words, sample rate, velocity, duration of the task, and the type of task each influences the reliability of GPS. Duffield *et al.* (2010) concluded that the use of GPS technology to measure distance and speed of court-based or confined space movements will likely lead to an underestimation of movement distance and speed. Akenhead *et al.* (2014) argued that due to differences in GPS manufacturer, latitude, the criterion task, utilised methodology, GPS sampling rate and statistical analysis, a generic statement on the validity of GPS for measuring team sports movements is not possible. The authors also concluded that validity was greatest during accelerations of 0-1m s<sup>-2</sup> and decreased in an acceleration-dependent manner. Aughey (2011) stated that the higher the velocity of movement, the lower the reliability of GPS. It was apparent that as the speed of movement increased, the level of GPS error increased for both 5Hz and 10 Hz units (%TEM: 0-14%) (Johnston, Watsford, Pine, Spurrs & Sporri, 2013). The validity and reliability of GPS technology as a measurement tool to assess speed and repeated sprint ability in team sport athletes has previously been reported by Barbero-Alvarez, Coutts, Granda, Barbero-Alvarez and Castagna (2010) and Coutts and Duffield (2010).

### 2.11 Summary

Sport scientists now have a much deeper understanding of the activity profiles of a range of sports owing to the application of GPS technology (Aughey, 2011). Rugby coaches and physical conditioning experts have a keen interest in understanding the physical demands of the sport, in order to develop effective training regimes and enhance on field performance. Information about the requirements of the positions can also assist with the assessment of player performance during matches (Quarrie *et al.*, 2013). Kelly *et al.* (2012) mentioned that while current implementations of this technology can be used to quantify overall physical work and therefore be utilised to build appropriate training programmes to improve physical conditioning, the current technology cannot be effectively used to evaluate injury risk. Brooks *et al.* (2008) argued that balancing the volume of training to maximise players' and teams' performances while minimising the risk of injury in training and matches is a difficult task for coaches. There seems to be three options available, namely to modify the volume, content or intensity of the training performed.

Tee (2015) identified the potential applications of GPS technology within an injury risk management framework:

- Providing match play norms for movement characteristics including extreme values and expected variability;
- Determining whether a player's match exertions exceed the norm and whether additional recovery may be required;
- Monitoring running distances and intensities during training;
- Determining the specificity of training activities to match play demands; and
- Live monitoring of players during matches to determine the onset of fatigue.

White and MacFarlane (2013) emphasised the importance of adapting GPS analysis procedures to the specific circumstances of the game or an individual player's activity within the game. The updates in GPS firmware and increased sampling rates have further improved the validity and inter-unit reliability of GPS. Consequently, practitioners can more confidently rely on the data obtained from current GPS units during training and matches; however, caution is required when measuring high-speed movements (Johnston *et al.*, 2013). Vickery, Dascombe, Baker, Higham, Spratford

and Duffield (2014) recommended that practitioners of GPS devices should be aware that measurements of distance and speed may be consistently underestimated, regardless of the movements performed. Some limitations can occur with regard to the number of observations by researchers. In the final instance, rugby follows no prescribed pattern and each game of rugby is unique in terms of the circumstances created and conditions for play.

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## Chapter 3

### Article 1: Positional tackle and collision rates in Super Rugby

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## Positional tackle and collision rates in Super Rugby

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*The aim of this study was to evaluate differences between playing positions regarding tackle and collision rates in a rugby game, and to determine the collision rates of individual playing positions in professional rugby union. Data from 30 matches (both teams involved) during the 2013 Super Rugby Season were captured and supplied by the Cheetahs Super Rugby Franchise, using the Verusco TryMaker Pro. Significant differences were found between positional groups regarding tackle rates. However, the front row players and second row players did not differ significantly (positions 1, 2, or 3 vs positions 4, or 5;  $p=0.0715$  to  $p=0.6324$ ). Within a positional group, only the difference between the inside centre and the other inside backs was significant (9 vs 12,  $p=0.0029$ ; 10 vs 12,  $p=0.0045$ ; 12 vs 13,  $p=0.0100$ ). No significant differences were observed between second row players and the eighthman (4 vs 8,  $p=0.4183$  and 5 vs 8,  $p=0.6863$ ), although significant differences were found between second row players and the rest of the loose forwards (6 and 7). A significant difference ( $p<0.05$ ) occurred between all forwards and backs when collision rates were compared. The findings revealed significant inter-positional differences in tackling and collision rates within the same positional group.*

**Keywords:** rugby; tackle; collisions; playing positions; rucking

## 3.2 Introduction

### 3.2.1 Tackles and collisions in rugby union

Rugby union players are involved in multiple forms of collisions during match play, including rucking, mauling, ball carries and tackles, with the latter being the predominant form of impacts sustained. Specifically, defensive actions are an important element of rugby union match play, and are perceived by players to be one of the most fatiguing components of the game (Docherty *et al.*, 1988). Overall, the tackle is one of the most frequent type of body contact in rugby union (Kelly *et al.*, 2012). Tackling requires maximal strength and technique to be effective, and should be trained accordingly (Posthumus and Viljoen, 2008). Tackling was defined by McLellan *et al.* (2011) as an event that halted the progress of an opponent in possession of the ball, while van Rooyen (2012) stated that the purpose of a tackle is to stop the attacking team from moving forward and to create opportunities for the defending team to contest for possession of the ball.

Fuller *et al.* (2008) reported that the tackle was the activity/event responsible for the highest incidence of injury (see also Bathgate *et al.*, 2002); however, a much higher proportion of tackle injuries resulted from being tackled rather than from tackling. Previous studies have investigated the injuries sustained (Gabbett, 2005; Garraway *et al.*, 1999), biochemical and endocrine responses to impacts and collisions (McLellan *et al.*, 2011), and physiological correlates of tackling (Gabbett *et al.*, 2010) in rugby union.

Austin *et al.* (2011) indicated that hit-up forwards, adjustable and outside backs in rugby league averaged 166, 89, and 41 tackles, respectively, during a game. Van Rooyen (2012) investigation into the tackle in rugby union has found that professional rugby matches contain over 200 tackle situations (Quarrie *et al.*, 2007), with the forwards making the majority of these contacts (Quarrie *et al.*, 2008). Roberts *et al.* (2008) reported similar results, with tight forwards having the highest tackle count (12), followed by loose forwards (16), while inside backs (13) all performed more tackles than the outside back (8). Tackle count is second only in terms of frequency to the number of passes (over 250) recorded per match that were presented by the International Rugby Board (IRB) in the post-tournament report for the 2011 Rugby World Cup (IRB, 2011). Over the span of two seasons (2009, 2011), a mean tackle count of 138.28 per game was recorded for an international rugby union team over the course of 18 test matches (Kelly *et al.*, 2012). Fuller *et al.* (2007) carried out a study over two full rugby union seasons using 645 players and 13 club teams, and showed that tackles were the most common contact event with an average of 221 events per match. Apart from its importance in injury causation, tackling is also a key performance indicator in rugby union and coaches closely monitor the number of successful and unsuccessful tackles achieved by each player during competitive play (Kelly *et al.*, 2012). According to Quarrie and Hopkins (2007), the number of tackles per match has increased from  $160 \pm 32$  in 1995 to  $270 \pm 25$  in 2004, following the introduction of professionalism.

Gabbett *et al.* (2014) demonstrated that the physical demands of defending are considerably greater than the demands of attacking, with players covering greater total distance per minute, greater distance at low speeds, and a higher frequency of collisions and repeated high-intensity effort bouts. Takarada *et al.* (2003) concluded that rugby matches causes serious structural damage to tissue and the extent of the damage depends on the number and intensity of tackles. Data collected from three players by Kelly *et al.* (2012) were pre-processed to detect impact peak regions and corresponding peak features, and detected a total of 1 179, 619 and 383 impact

peaks for three different positions respectively. McLellan *et al.* (2013) showed that body impacts (G force) experienced by players during high-intensity collisions between opposing players are associated with impact forces greater than 7 Gs, while the total number of impacts experienced by backs ( $582 \pm 162$ ) was significantly less than forwards ( $849 \pm 516$ ) during match play. Detected collisions can be utilised to monitor player wellbeing, develop injury management protocols and return to play criteria for individual players and teams (Kelly *et al.*, 2012).

### 3.2.2 Positional differences

Rugby union players have a diverse range of physical attributes, and each playing position has both responsibilities that are unique, and responsibilities that are common to other positions in the team (Greenwood, 1997, Quarrie *et al.*, 2013). Sirotic *et al.* (2009) showed that two standards of competition have similar game-specific skills and physical demands during a match. However, there is variation within a match according to standard. The physical characteristics of players occupying the different positions in a rugby team typically differ quite markedly because of the demands placed on them by the roles they perform within the team (Lee *et al.*, 1997). This observation raises the question whether there are significant differences between playing positions regarding collision and tackle rates.

In this regard, Sirotic *et al.* (2011) showed that forwards have the highest involvement in defensive skills during match play, because forwards perform the most tackles. Van Rooyen (2012) stated that forwards made more tackles (66%) than backs (34%), and the difference was significant even when group size was accounted for. Similarly, Quarrie and Hopkins (2008) also reported that forwards made more tackles (64%) than backs (36%). However, the open side flanker was identified as the player making more tackles than players in other positions during a match. Vivian *et al.* (2001) concluded that the differences in the number of behaviours completed by players are a function of both playing position and level of competition. Similarly, significant differences between individual playing positions were observed with respect to the incidence of injuries (Gabbett, 2005). Similarly, time-motion studies have shown that rugby players perform different match-play activities during competition depending on playing position (Quarrie *et al.*, 2013), with forwards being involved in significantly more physical collisions and tackles than backs (Gissane *et al.*, 2001). Fuller *et al.* (2010) indicated that centres tend to make more tackles in a match than other backs and are significantly more prone to injury when tackling than players in other positions.

Previous research classified team positions according to subgroups reflecting positional commonality (front row, locks, loose forwards, inside backs and outside backs) (Meir *et al.*, 2001). This classification, however, is not adequately specific for detailed analysis of each position. Results from a study from Cupples and O'Connor (2011) have differentiated playing positions and identified a unique sub-set of skills and abilities that are crucial to position-specific performance. Cognitive indicators have been found to exert the greatest influence over a variety of positions, closely followed by game skills, and to lesser extent physiological indicators.

### 3.2.3 Purpose of the study

Detailed data on the movements in a game provide comprehensive information on the demands of competition and assist in the development of specific training regimes. Research of this nature in rugby is often undertaken within the confines of the team, or an organisation or governing body (Vaz *et al.*, 2010). The purpose of the present study was to provide a somewhat broader perspective, namely to investigate counts of tackles and collisions sustained for

individual playing positions in rugby union matches played in South Africa, Australia and New Zealand during the 2013 Super Rugby season. Since differences between roles of players within positional groups do exist and must be taken into consideration, this research analysed each individual playing position and not only the group. Analyses of the rates of these activities during competition can assist coaches and conditioning staff in the development of position-specific training as well as performance profiles of each position.

### 3.3 Methodology

#### 3.3.1 Subjects and research method

Data were available for both teams involved in 30 games played during the 2013 Super Rugby competition in South Africa, Australia and New Zealand. Therefore, 60 tackle and collision counts were available in total for each playing position. The number of games in our data base varied from fourteen games played by the Cheetahs Super Rugby Franchise, situated in Bloemfontein, South Africa, and between two and five games played by the other fourteen teams during the 2013 Super Rugby season. Tackle and collision counts for fifteen players in the starting line-up for each game were extracted. Data for replacement players were not included in the statistical analysis. The fifteen starting line-up players were individually identified according to playing position as follows (number in brackets): loose-head prop (1), hooker (2), tight-head prop (3), loose-head lock (4), tight-head lock (5), blind-side flanker (6), open-side flanker (7), eighthman (8), scrum-half (9), fly-half (10), left wing (11), inside centre (12), outside centre (13), right wing (14), and full-back (15).

Data collected were statistically analysed to evaluate and compare the number of tackles made and collisions sustained per game during a season of Super Rugby. Data were supplied by the Cheetahs Super Rugby Franchise using the Verusco TryMaker Pro (Verusco Technologies Ltd.; Palmerston North, New Zealand). Verusco has been supplying Super Rugby teams with TryMaker Pro since 2000, and provides a notational analysis of each individual player for each game played (Smart *et al.*, 2014). TryMaker Pro is an advanced analysis system specifically developed exclusively for rugby, and it is the preferred system for professional teams using Verusco. The Verusco coding centre codes all the games for registered teams and delivers high detail, high speed analysis within hours of the game being played. Ethical clearance was obtained from the University of the Free State where the study was conducted under ethical clearance number **UFS-HUM-2013-009**.

#### 3.3.2 Statistical analysis and interpretation of data

All data were captured in Microsoft Excel 2007 and subsequently converted into a SAS data set. Procedure GLIMMIX of the SAS Version 9.22 statistical software package was used for further statistical analysis (SAS, 2009). Means and standard deviations were used for numerical data. The extension to generalized responses, such as binary and count variables, entails generalized mixed models. The most common is the generalized linear mixed model (Ngo & Wand, 2004). Individual tackle counts for each position, team and game were analysed using a generalised linear mixed model (GLIMM) with position and team as fixed effects, the natural logarithm of individual time played in minutes as offset, and position-by-team and game-by-team interaction terms as random effects. Regarding the fitted random effects, it seemed reasonable to allow for correlation between tackle counts for a given individual across several games (modelled by the position-by-team random effect), and for correlation between tackle counts across players in a given team and game (modelled by the team-by-game random effect).

Furthermore, the GLIMM was specified with Poisson error distribution and the natural logarithm as link function. Individual collision counts for each position, team and game were analysed in the same manner. In both cases – tackle counts and collision counts – the model fitted the data well and there was no evidence of residual over-dispersion. Based on the GLIMM, the mean rate of tackles and mean rate of collisions per 80 minutes (that is, normalised to a full-length rugby game) were estimated for each playing position, with 95% confidence intervals (CIs) of the mean rates. Similarly, in order to compare the mean rates of tackles and collisions between different playing positions, rate ratios (that is, ratios of tackle and collision rates between playing positions) were estimated, with 95% CIs for the rate ratios.

### 3.4 Results

#### 3.4.1 Tackle rates

Table 1 presents the mean rates of tackles made by players in the different playing positions (see also Figure 1). Clearly, loose forwards (6: = 16.65 tackles/80 min; 7: = 17.30 tackles/80 min; 8: = 14.68 tackles/80 min) had the highest tackling rates, followed by the locks (4: = 13.74 tackles/80 min; 5: = 14.07 tackles/80 min). Amongst the backs, the inside centre (12: = 12.89 tackles/80 min) was the player with the highest tackling rates, followed by the outside centre (13: = 9.96 tackles/80 min).

Table 1. Mean rates of tackles made (/80 min) by different playing positions and playing time averages over 30 games. (n = 60 per position).

Position	Average minutes played.	Average tackles assisted.	Total tackles in 30 games.	Mean rate (/80 min)	95% confidence interval for mean rate	
					Lower Limit	Upper Limit
1 Loose- head prop	70.3	2.0	568	12.1	10.6	13.9
2 Hooker	64.6	1.6	475	11.1	8.7	14.0
3 Tight- head prop	63.4	2.7	553	13.2	11.3	15.4
4 Loose- head lock	70.7	2.2	666	13.7	11.9	15.8
5 Tight- head lock	71.7	2.1	674	14.1	12.2	16.2
6 Blind-side flank	69.1	3.1	742	16.6	14.3	19.3
7 Open-side flank	71.1	2.9	868	17.3	14.9	20.1
8 8 <sup>th</sup> Man	74.2	2.6	797	14.7	12.7	16.9
9 Scrum-half	68.4	0.9	423	8.9	7.2	11
10 Fly-half	72.9	1.1	505	9.4	7.8	11.3
11 Left wing	75.5	0.6	277	5.2	4.3	6.4
12 Inside centre	73.4	2.0	668	12.9	11.2	14.8
13 Outside centre	76.1	1.4	515	9.9	8.5	11.7
14 Right wing	72.4	0.6	319	6.3	5.1	7.7
15 Full-back	73.3	0.7	301	5.4	4.1	7.1
Tournament Average (Only starting team)	71.1 per player	1.8 per player	157 per team	10.7 per player	10.1 per position	11.3 per position

The results showed that the open-side flanker (7) had the highest tackle rate of all playing positions (17.30 tackles/80 min). Our results, however, were more detailed than those of other authors who only analysed positional groups, and revealed significant differences in tackling

rates among the forwards, which was also clear by comparing the mean rates for positions as shown in Figure 1.

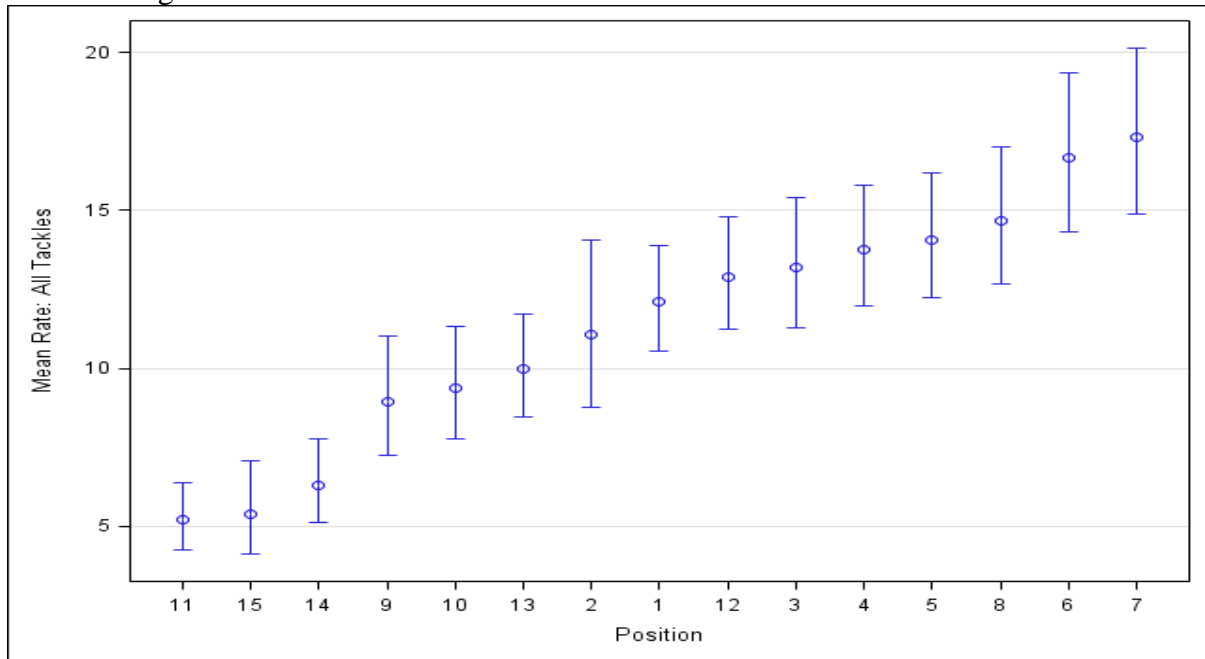


Figure 1. Mean rates of tackles by playing positions (with 95% CI).

### 3.4.2 Collision rates

As shown in Table 2 and Figure 2, the open-side flank (7) was involved in the most collisions (50.91), followed by the blind-side flank (6), loose-head lock (4) and eighthman (8), with collision rates of 46.08, 44.81 and 43.03, respectively, per 80 minutes collision count per game. Amongst the backs, the inside centre had the highest collision rate, namely 32.34/80 min. On average, players in the starting line-up played 71.2 minutes per game.

Table 2. Mean rates of collisions sustained (/80 min) by different positions over 30 games. (n = 60 per position).

Position	Rate (/80 min)	95% confidence interval for mean rate	
		Lower Limit	Upper Limit
1 Loose- head prop	39.3	36.4	42.6
2 Hooker	38.5	34.3	43.2
3 Tight- head prop	42.1	39	45.4
4 Loose- head lock	44.8	41.2	48.7
5 Tight- head lock	41.2	37.4	45.4
6 Blind-side flank	46.1	41.9	50.6
7 Open-side flank	50.9	47.1	55.1
8 8 <sup>th</sup> Man	43.1	39.2	47.3
9 Scrum-half	16.3	13.9	19.1
10 Fly-half	19.5	17	22.4
11 Left wing	19.4	17.1	21.9
12 Inside centre	32.3	28.9	36.1
13 Outside centre	25.7	23.3	28.4
14 Right wing	19.9	17	23.2
15 Full-back	20.5	17.8	23.6

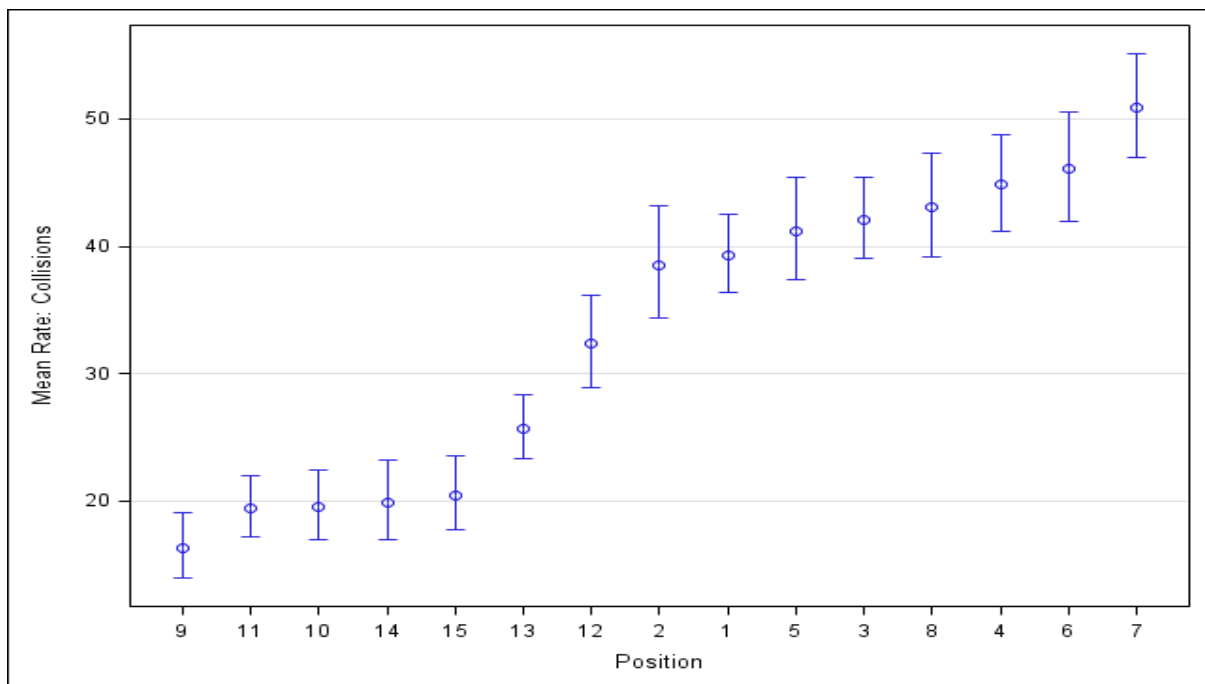


Figure 2. Means for positional collisions.

### 3.4.3 Positional differences between playing positions

The question was asked whether statistically significant differences ( $p \leq 0.05$ ) between the playing positions were observed regarding the mean rates of tackles made and collisions sustained. To answer this question, pairwise rate ratios – that is, the pairwise ratios of tackle (and collision) rates between playing positions – were estimated, with 95% CIs for the rate

ratios. All pairwise comparisons between the fifteen playing positions were performed. As expected, statistically significant differences were recorded between the forwards and backs.

Therefore, the inter-positional differences between players from the same positional group were determined. The results showed significant differences between positional groups for tackles, except for the front row players and the second row (1, 2, 3 vs 4, 5;  $p=0.0715$  to  $p=0.6324$ ). Within a positional group, namely the backline players, the tackling rate of the inside centre differed significantly from the tackling rate of the other backline players (9 vs 12,  $p=0.0029$ ; 10 vs 12,  $p=0.0045$ ; and 12 vs 13,  $p=0.0100$ ). There was no significant differences between second row players and the eighthman (4 vs 8,  $p=0.4183$ ; and 5 vs 8,  $p=0.6863$ ), although significant differences were found between second row players and the rest of the loose forwards (6 and 7).

Table 3 presents the ratios of tackling rates for 16 selected pairs of playing positions. As reflected by the data in Table 3, there were no statistically significant differences in tackling rates among the front row players (1, 2, 3), between the two locks (4, 5), among the loose forwards (6, 7, 8) or among the outside backs (11, 14, 15), but load differences between these positions have practical implications. Inside backs were grouped as scrum-half (9), fly-half (10), and centres (12, 13). It is shown in Table 3, however, that significant differences occurred between players from the group of inside backs. Specifically, the scrum-half (9) made significantly less tackles than the inside centre (12) (rate ratio 0.69; 95% CI 0.54 – 0.88,  $p=0.0029$ ). Similarly, the fly-half (10) made significantly less tackles than the inside centre (12) (rate ratio 0.73; 95% CI 0.58 – 0.91,  $p=0.0045$ ). In other words, the scrum- and fly-halves performed approximately 30% less tackles than the inside centre. Furthermore, the inside centre made significantly more tackles than the outside centre (13) (rate ratio 1.29; 95% CI 1.06 – 1.57,  $p = 0.0100$ ).

Table 3. Positional ratios of tackling rates difference between playing positions.

Comparison (Pair of playing positions)	Rate ratio	95% CI for rate ratio		P-value
		Lower	Upper	
1 vs 2	1.09	0.85	1.4	0.4874
1 vs 3	0.92	0.75	1.12	0.4126
2 vs 3	0.84	0.62	1.13	0.2512
4 vs 5	0.97	0.81	1.17	0.8013
6 vs 7	0.96	0.78	1.18	0.7116
6 vs 8	1.13	0.93	1.38	0.2078
7 vs 8	1.18	0.96	1.44	0.1151
9 vs 10	0.95	0.74	1.22	0.6981
9 vs 12	0.69	0.54	0.88	0.0029*
9 vs 13	0.89	0.69	1.16	0.4042
10 vs 12	0.72	0.58	0.9	0.0045*
10 vs 13	0.94	0.72	1.22	0.6504
12 vs 13	1.29	1.06	1.57	0.01*
11 vs 14	0.83	0.63	1.09	0.1804
11 vs 15	0.96	0.7	1.32	0.8332
14 vs 15	1.16	0.81	1.67	0.3997

Note: \* $P = <0.05$

Similar to Table 3, Table 4 presents the ratios of collision rates for 16 selected pairs of playing positions. There were no significant differences in the collision rates sustained among front row players (1, 2, 3), between the locks (4, 5) and among the outside backs (11, 14, and 15). However, the collision rates of the open side flank (7) and eighthman (8) in the loose forward group differed significantly (rate ratio 1.18; 95% CI 1.06 – 1.32,  $p=0.0036$ ), with the open side flank (7) sustaining approximately 18% more collisions on average than the eighthman (8). No significant difference was recorded when the eighthman was compared to the blind side flank.

The inside back group of players exhibited significant differences in collision rates between playing positions, where both centres had significantly higher rates of collisions than either the scrumhalf (9) or fly-half (10), and the inside centre (12) had a significantly higher rate of collisions than the outside centre (13).

Table 4. Positional Ratios of collision rates difference between playing positions.

Comparison (Pair of playing positions)	Rate ratio	95% CI for rate ratio		P-value > t
		Lower	Upper	
1 vs 2	1.02	0.9	1.15	0.7495
1 vs 3	0.93	0.83	1.04	0.2207
2 vs 3	0.91	0.8	1.04	0.1984
4 vs 5	1.08	0.95	1.23	0.1968
6 vs 7	0.9	0.8	1.02	0.1137
6 vs 8	1.07	0.92	1.23	0.3464
7 vs 8	1.18	1.05	1.32	0.0036*
9 vs 10	0.83	0.69	1	0.0614
9 vs 12	0.5	0.42	0.6	<.0001*
9 vs 13	0.63	0.53	0.75	<.0001*
10 vs 12	0.6	0.5	0.72	<.0001*
10 vs 13	0.75	0.63	0.91	0.0036*
12 vs 13	1.25	1.1	1.43	0.0008*
11 vs 14	0.97	0.79	1.2	0.822
11 vs 15	0.94	0.79	1.12	0.5328
14 vs 15	0.97	0.77	1.21	0.7893

Note: \*Statistical significant difference \*P = <0.05

### 3.5 Discussion

The results of this study underline the importance of specific demands on the various playing positions regarding the tackles and collisions sustained by Super Rugby players. Previous research only reported data for positional groups, but not for the individual playing positions (References). Furthermore, previous research was based on data from Rugby League games. This was the first study of its kind conducted on Rugby union.

Our findings support Cupples and O'Connor (2011) who identified a unique sub-set of skills and abilities crucial to position-specific performance. A significant difference was noted between all forwards and the backs regarding the number of collisions sustained. Our study agrees with that of Quarrie and Hopkins (2008), who found that forwards made the most tackles (64%) compared to backs (36%). This result is mainly due to the fact that forwards is part of the set piece (scrums and lineouts). According to Sirotic *et al.* (2011), the forwards have the highest involvement in defensive skills during match play, because forwards perform the most tackles.

Differentiating between the different playing positions, our study found that among the forwards, the blind side (6) and open side (7) flanks bear the greatest load. Among the backs, the inside centre (12) has the highest load, which is significantly higher than either that of the fly-half (10) or scrum-half (9), and significantly higher than the load of the outside centre (13).

Averages for tackles per team were not consistent with other studies, at 157 per team. Our data, which stem from 2013, suggest that there was an increase in the number of tackles when compared to 2011, reported as 138.28 per game by Kelly *et al.* (2012). Therefore, our data

suggest that match averages have increased to 314 tackles per game. The increase in tackles can be due to the more intensive and expanding game plan incorporated by Super Rugby teams. Eaves and Hughes (2003) also concluded that the professional approach to rugby resulted in an increase in match activities such as tackles and rucks. It must be kept in mind that weather conditions, game plan and the competition structure can also affect the average tackles and collisions during match play.

For the purpose of this study, the number of collisions sustained by a player was defined as the sum of assisted tackles, total tackles, ball carries, clean outs, other ruck actions, ruck actions, and total rucks. As with tackles, forwards sustained the highest number of collisions, followed closely by the centres. The higher number of collisions by the centres among the backs is likely due to the specific collision area on the field. Coaches see this as a fragile area in defence and use centres and loose forwards as ball carriers in the mid-field, which increases the number of collisions sustained by centres as ball carriers and as tacklers. The scrum-half is involved in the lowest number of collisions (16.32/80 min), probably because the scrum-half only has to pass the ball and serve as the link between the forwards and backs. Coaches urge scrum-halves to avoid contact. It is clear that loose-head locks (4), and loose forwards (6, 7 and 8) are the most active forwards in contact, with centres (12 and 13) the most active backline players. These positions can be seen as the players that will sustain the most collisions, and are also associated with the highest tackle count during a game of rugby union. Ultimately, players in high collision positions are more prone to injury and will need more time to recover.

### 3.6 Conclusions and Recommendations

The present paper reports rates of tackling and collisions for individual playing positions in rugby union matches played during the 2013 Super Rugby season in South Africa, not exclusively for positional groups. Our results show that there are significant differences between individual playing positions within the same positional group with regard to tackling and collision rates sustained during match play.

This finding may be important for future research as previous studies only focused on positional groups rather than individual positions. It is important to note that forwards generally have the highest rates of tackles and collisions, which implies a higher demand for recovery and conditioning. It would also be unfair to compare the scrum-half (16.32 collisions per game) with a centre (32.34 collisions per game) as the norm, although conventionally they are grouped as inside backs. External factors such as game plan and weather conditions still influence positional roles, and therefore, the tackle count and collisions sustained.

### 3.7 Practical application

The high numbers of tackles performed by forwards emphasise the different physiological demands for this positional group, and it is recommended that conditioning programmes be designed to improve performance in the forwards by including a substantial amount of tackling, collisions, and wrestling. Furthermore, certain positions will have to train less due to the higher number of collisions and tackles sustained during previous games. The load differences between playing positions also indicate practical implications for training and recovery purposes through means of monitoring. Coaches need to be aware of these differences when planning training programs.

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Chapter 4  
Article 2: Passing and kicking statistics that discriminate between winning and losing teams in the 2013 Super rugby season.

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## **Abstract**

Passing and kicking are the two fundamental ways to move the ball in rugby union, and the successful completion of these tasks may contribute to team success. Performance indicators measured during a rugby match, such as number of kicks, rucks, mauls and passes, can provide insight into team performance. This study determined the number of passes and kicks discriminating between winning and losing teams. Data from 30 matches played by 15 teams involved in two matches each during the 2013 Super Rugby season were captured and supplied by the Cheetahs Super Rugby Franchise in Bloemfontein, South Africa, using the Verusco TryMaker Pro. Results showed that losing teams tended to pass more frequently (157.4 per match) than winning teams (127.0 per match). Borderline significance between winning and losing teams was observed with respect to total number of passes ( $p=0.0598$ ) and good passes ( $p=0.0607$ ). In contrast, winning teams had higher counts of kicks per match. Winning teams had a mean of 25.8 total kicks per game, as compared to 20.2 of losing teams, and a mean of 901.4 m vs 660.0 m in kicking meters gained. Significant differences between winning and losing teams were found for the rates of total kicks ( $p=0.0088$ ) and long kicks ( $p=0.0239$ ), and also with regard to kicking meters ( $p=0.017$ ). The results of the study suggest that losing teams pass more than winning teams and that winning teams kick more than losing teams. The study also found that a greater distance was gained through kicks by winning teams, although these teams had less attacking minutes. Tactics and strategies used by teams and weather conditions can influence the number of passes and kicks per match and therefore the outcome of the game.

**Keywords:** Super Rugby, Passes, Kicking, Performance indicators

## **Introduction**

Passing and kicking are the two fundamental ways to move the ball in rugby union, and the successful completion of these tasks may contribute to team success. A team in possession of the ball strives to maintain continuity of possession (Greenwood, 2003), which can be achieved with good passing skills and the ability to pass in the run. Passing has been described as a common performance indicator in rugby as this action is executed by all players (James, Mellalieu & Jones, 2005). In rugby union, a major constraint on decision making and actions of players is the backward pass (IRB, 2013). Recent studies included data on changes in player characteristics and match activities in Bledisloe Cup Rugby from 1972 to 2004 (Quarrie & Hopkins, 2007), differences in game statistics between winning and losing rugby teams in the Six Nations tournament and rugby game-related statistics in IRB and Super Twelve close games from 2003 to 2006 (Ortega, Villarejo & Palao, 2009; Vaz, Van Rooyen & Sampaio, 2010) and match analysis of the Super 14 rugby tournament in 2006 (Van den Berg & Malan, 2010).

The influence of passing and kicking has however not been quantified and research on the effect on winning and losing is scarce. Ortega et al. (2009) and Vaz et al. (2010) focused on a wide variety of statistical differences between winning and losing rugby union teams. Ortega et al. (2009) concluded that losing teams had slightly higher averages than winning teams of passes completed. Winning teams prefer to kick for territorial advances rather than to play a "ball in hand" possession-dominated style that requires more passes, rucks and mauls. It was also noted that winning teams made fewer passes and won fewer turnovers on the opposition's possession Vaz et al. (2010). Laird and Lorimer (2004) reported that 48% of tries were scored using three or less passes, and concluded that the higher the number of passes in a given move, the less likely a try will be scored. The ability of a team to control the ball with accurate passing would seem an obvious prerequisite for success, but no research on the actual effects of passing and kicking have been conducted. Therefore, the aim of this study was to calculate the frequency and rates of the two most common methods of advancing in territory, namely passes and kicks, made by Super Rugby teams during the 2013

season. Furthermore the study aimed to differentiate between winning and losing teams by examining variables such as the quality of passing, meters gained and type of kicks used.

Calculating the frequency or rate of an activity during play is possible by dividing the number of activities with the time in attack. This will provide a frequency of activities per minute or per second. Attacking minutes are defined as the time that a team is in possession of the ball or the time a team spends in attack. Within this attack, different activity cycles such as passing, rucking, mauling and kicks are apparent. The IRB analysis of the 2013 Six Nations (IRB, 2013) and Rugby Championship (IRB, 2013b) revealed the rate of passes for the time of possession, which was a pass every 8.8 seconds for Six Nations rugby and one pass every 8 seconds during the Rugby Championship. Furthermore, the analysis showed inter-positional differences in the frequency of passes to the time of possession. The IRB analysis calculated the total number of passes per game for both teams combined, where the 2013 Six Nations (IRB, 2013) indicated an average of 242 passes per match and an average of 235 passes per match for the Rugby Championship (IRB, 2013b). One of the more influential variables in terms of number of passes completed is the bonus points on offer to teams who score more than four tries per match or losing with seven or less points. The bonus-point system was rationalised as a way to encourage and reward positive and offensive play, as well as try scoring. It was also constructed as an incentive, or even benefit, for teams that fail to win or tie close matches (Torres & Hager, 2005). Therefore, more time is spent on skill acquisition and improvement of passes and offloads. Good weather conditions have been associated with increases in tries and points scored and with reductions in the number of kicks in play and participation time per player (Quarrie & Hopkins, 2007).

James et al. (2005) defined kicking as a position-specific performance indicator for the positions of the backs, as flyhalves display significantly greater successful kicks at the expense of successful tackles. The role played by a team's kicker in determining the outcome of a rugby union match is becoming increasingly important (Holmes, Jones, Harland & Pitzing, 2006). According to Tainton (2000), tactical kicking can influence a team's performance directly, while Hynard (2000) considered a good tactical kick as a major weapon in a team's ability to perform. The reason for this may be that teams can easily gain territory

with minimum effort by using tactical kicking, while the possibility of a turnover in the opposition's half exists. (Van den Berg & Malan, 2010).

Kicking is an area where a noticeable change in rugby evolution has occurred. From the Rugby World Cup in 1995, there has been a 45% reduction in kicks up to the Rugby World Cup in 2011, while passes increased by 47% (IRB, 2011). Ortega et al. (2009) reported that winning teams had a higher number of kicked possessions and kicks to touch, which indicated that the foot game was used more by the winning teams. This finding contradicts that of the IRB (2011) as kicks decreased, although it still was a more favourable option for winning teams. Vaz et al. (2010) confirmed these results with data that showed that winning teams of international and regional matches during 2003 and 2006 consistently kicked more often than losing teams. Quarrie and Hopkins (2007) associated poor conditions with 24% more kicks in play per match than matches played in good conditions, although there was a large decrease (30%) in the number of kicks in play per match following the introduction of professionalism. Vaz et al. (2010) suggested that a kicking-based game plan is a more effective style of play during the Super 12 competition than an open running possession-dominated game. The IRB also revealed the frequency or rates of kicks for the 2013 Six Nations (IRB, 2013a) and Rugby Championship (IRB, 2013b) and showed a rate of kicking for time of possession as 1 kick for every 40 seconds during the Rugby Championship and 1 kick every 40.5 seconds during the Six Nations.

Van den Berg and Malan (2010) found that meters gained, kicks from hand, line breaks and percentage tackles made were the match profile variables that discriminated accurately (92.86%) between successful and less successful Super 14 rugby union teams. Vaz et al. (2010) showed that winning teams made fewer rucks and pass movements, won more mauls and turnovers, completed fewer passes and made fewer errors ( $p \leq 0.05$ ). They also kicked a greater amount of their possession (including kicks to touch) and made more tackles ( $p \leq 0.05$ ). They concluded that kicking the ball and making more tackles than the opposition were the two most influential factors in determining a winning outcome (Vaz et al. 2010).

Therefore this study also aimed to evaluate variables such as the quality of passing, meters gained and the type of kicks used between winning and losing teams.

Pavely, Adams, Di Francesco, Larkham and Maher (2010) indicated that out of the 95 passes to the preferred side made during their study, 81 were legal passes (backwards and to own teammate), whereas only 41 of the 95 passes to the non-preferred side were legal. The difference between these ratios was statistically significant ( $p=0.001$ ). Rugby is based on running forwards and passing the ball backwards or behind the player, to either side of the body. Despite exhortation to train so that rugby skills can be executed equally well on both sides of the body, there is evidence of preferential use of one side (Grouios, 2004). Pavely et al. (2010) found that among 20 first-grade rugby union players, most of the passes to the non-preferred side were forward passes, namely 57% vs 15% forward passes on the preferred side. Non-preferred side passes also travelled less distance than passes to the preferred side (13.5 m vs 15.4 m) (Sirotic, Coutts, Knowles & Catterick, 2009). Players with a strong preference for passing to the left, adapt their passing skill by compensating for their non-preferred side deficiency, and will not be able to fully capitalise on the ball-passing requirements and side to side movements of the game (McMorris, 2006). Positional differences can also be observed between players. These positional differences will be directly related to the skill set demanded for each position. James et al. (2005) reported that player 10's profile indicated significantly greater successful passes (median 20,  $\pm$  CLs of 28 and 14.15, respectively) and successful kicks (median 15.5,  $\pm$  CLs of 17 and 11.97, respectively) at the expense of successful tackles. Sirotic et al. (2009) showed that two standards of competition have similar game-specific skills and physical demands during a match, but there is variation within a match according to standard. During the 2013 Six Nations, 16% of passes were made by forwards, 51% by the scrumhalf and 33% by the backs (IRB, 2013a), while 18% of passes were made by forwards in the Rugby Championship, 47% by the scrumhalf and 35% by the backs (IRB, 2013b).

Laird and Lorimer (2004) determined that 75% of tries scored in international matches during the 2003 rugby season came from ball possession gained in the opponents' half, thus

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emphasising the importance for a team to gain territory. Glogg (2000) reported that gaining territory can be done with good tactical kicking. The highest values for meters gained likely were a result of players who had received the kick from the opposition replying by immediately kicking the ball back, either into touch or to the opposition, both scenarios resulting in relatively large meters (Agnew, 2006).

Table 1: Performance indicators defined (Vahed *et al.*, 2016).

<b>Performance indicators</b>	<b>Definitions</b>
Playing time	The time that the ball was in play out of the original 80 minutes and without stoppages
Kicking	Kicking in rugby union is defined as any kick in general play, including kick to touch, chip-kick, punt and field-goal (King, Jenkins & Gabbett, 2009). Kicking also includes kick out of hand and is regarded as a tactical use in rugby
Passing	This is the transfer of the ball from one player to the next by use of their hands in a backward motion
Good pass	These are passes that were completed and reached the intended receiver
Bad passes	This is a pass that went forward, or to ground or did not reach intended receiver
Territory	The percentage of field advantage enjoyed by teams during playing time

For the purpose of this study only kicks out of hand were calculated. Long kicks are kicks made to gain territory and not with the purpose of regaining ball possession. These kicks are most often performed from within own half of the field to drive the opposition back, such as punt kicks. Traditionally, teams kick for territory when they gain possession in their own half, and attack when possession is gained within opposition territory. Clearance kicking for distance is a prerequisite skill in first-grade rugby union (Pavely *et al.* 2010). Short kicks are used to regain possession after it has been kicked such as up and unders, chip kicks and cross kicks. The idea is not to gain territory and is seen as an attacking kick from which points can be scored.

## **Methodology**

### *Sample*

This study used a stratified, cross-sectional sample of 30 games played during the 2013 Super Rugby competition. The number of games in our database included two games each for the 15 participating franchises from South Africa, New Zealand and Australia. The 2013 database was used, because 2014 and 2015 only recorded the number of kicks and passes but not kicking meters as measured during 2013. Games were observed and data recorded using Verusco video analysis. Performance indicators recorded were number of kicks out of hand, distance of kicks, passes made, match time, and the result of the contest. Rates of kicks and passes were determined by dividing the time in possession of the ball with the number of occurrences of each variable. Data were obtained from the Cheetahs Super Rugby Franchise in Bloemfontein, South Africa, using the Verusco TryMaker Pro (Verusco Technologies Ltd.; Palmerston North, New Zealand). Verusco has been supplying Super Rugby teams with TryMaker Pro since 2000, and provides a notational analysis of each individual player for each game played (Smart, Hopkins, Quarrie & Gill, 2014). The Verusco coding centre oversees reliability with more than twenty analysts and the head of coding before data is sent to the franchises. The reliability of the coding was determined by the re-analysis method (test-retest reliability) for inter-rater reliability (James, Mackenzie & Capra, 2013). This method entails that a different analyst do a re-analysis of the video material after the original analysis. Twenty-five percent of matches were re-analysed by a different experienced performance analyst at the Cheetahs Super Rugby Franchise to avoid bias. Inter-rater agreement was interpreted as follows: Poor (0–0.20), fair (0.30–0.40), moderate (0.50–0.60), strong (0.70–0.80) and almost perfect (>0.80) (Liporace *et al.*, 2012). Analysis showed that the strength of the agreement between all variables was strong to almost perfect (Table 2).

Table 2. Intra-rater reliability correlations coefficient (ICC) of the coding test-retest

	ICC
Playing time	1.00
Kicks made	0.83
Passes	0.75
Good passes	0.79
Bad passes	0.81
Long kicks	0.85
Short kicks	0.90

Ethical clearance was obtained from the University of the Free State in Bloemfontein, South Africa, where the study was conducted under ethical clearance number UFS-HUM-2013-009.

#### *Statistical analysis*

Each count variable (number of kicks and number of passes) was analysed using a generalised linear mixed model (GLIMM) with winning indicator (won versus lost) as fixed effects, and team and opposing team as random effect. The extension to generalized responses, such as binary and count variables, entails generalized mixed models. The most common is the generalized linear mixed model (Ngo & Wand, 2004). The fitting of the variables Team and Opposing team as random effects allowed for correlation between the counts in question for a given team across several games. Furthermore, the GLIMM was specified with Poisson error distribution and the natural logarithm as link function; residual over-dispersion was allowed for in the model. Based on the GLIMM, the mean rates of kicks and passes per game were estimated for the winning and losing teams. In order to compare the mean rates between winning and losing teams, rate ratios of kicks and passes between the winning and losing teams were estimated, together with 95% confidence intervals (CIs) for the rate ratios. The analysis was carried out using the SAS procedure GLIMMIX (SAS, 2008). Similarly, the continuous variables attacking minutes and kicking meters were analysed using a linear mixed model with winning indicator (won versus lost) as fixed effects,

and team and opposing team as random effects. Based on the mixed model, the mean attacking minutes and kicking meters were estimated for the winning and losing teams. In order to compare the winning and losing teams, the mean differences between the winning and losing teams were estimated, together with 95% CIs for the mean differences. The analysis was carried out using the SAS procedure MIXED (SAS, 2008).

## **Results**

Table 3 presents the mean total passes, bad passes, good passes, total kicks, long kicks and short kicks in the 2013 Super Rugby season. Furthermore, the passing and kicking rates per minute for the losing and winning teams are presented, as well as the "losing team/winning team" ratio of passing and kicking rates (namely the rate ratio), together with a 95% confidence interval (CI) for the rate ratio and the associated p-value comparing losing and winning teams.

### *Passing*

Losing teams tended to pass the ball more frequently (mean of 157.4 passes per game) per match than winning teams (mean of 127.0 passes per game); the corresponding rates per min of total passes for losing teams was 3.86 (1 pass every 15.7 sec) compared to 3.42 passes per minute (1 pass every 17.6 sec) for winning teams. The rate ratio is 1.129 which means that the rate of passing for losing teams was about 13% higher than for winning teams. The difference between losing and winning teams was borderline statistically significant ( $p=0.0598$ ). Similar results were obtained for good passes, where losing teams had more good passes on average (mean of 145.8) than winning teams (mean of 117.6), with a rate ratio of 1.131, again indicating that the rate of good passes of losing teams was about 13% higher than the rate of good passes of winning teams ( $p=0.0607$ ). In contrast, the passing rates of bad passes for winning and losing team were similar, at around 0.25 per minute.

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**Table 3.** Mean number and rate per minute of passes and kicks during the 2013 Super Rugby season.

	Total passes		Good passes		Bad passes		Total kicks		Long kicks		Short kicks	
	Won	Lost	Won	Lost	Won	Lost	Won	Lost	Won	Lost	Won	Lost
Mean	127.0	157.4	117.6	145.8	9.5	11.1	25.8	20.2	18.6	14.2	7.2	6.0
Rate (per minute)	3.41	3.85	3.14	3.55	0.25	0.26	0.693	0.486	0.499	0.341	0.194	0.145
Rate ratio "won/lost"	1.129		1.131		1.043		0.7		0.682		0.747	
95% CI for rate ratio	0.935 to 1.363		0.942 to 1.359		0.728 to 1.495		0.540 to 0.908		0.491 to 0.947		0.472 to 1.182	
p-value	0.0598		0.0607		0.389		0.0088		0.0239		0.2031	

Winning teams completed 117.6 good passes and only 9.5 bad passes per game. This resulted in a pass completion rate of 92% for winning teams and 92.5% completion rate for losing teams.

### *Kicking*

In contrast to passing, winning teams tended to kick the ball more (25.8 kicks per game) than losing teams (20.2 kicks per game). The kicking rate for winning teams was 0.693 kicks per minute vs 0.486 kicks per minute for losing teams. Both winning and losing teams made use of the long kick (0.49 and 0.34, respectively) more often than the short kick (0.19 and 0.14, respectively). The "losing team/winning team" rate ratio for total kicks is 0.700 which means that the rate of total kicks for the losing team was 30% lower than for the winning team. The difference between winning and losing teams was statistically significant ( $p=0.0088$ ).

Similarly, the rate ratio of long kicks was 0.682, so that the rate of long kicks for the winning team was also about 30% lower than for the losing team; this difference was also statistically significant ( $p=0.0239$ ). The rate of short kicks was about 25% lower for the losing team compared to the winning team, but this difference was not statistically significant ( $p=0.2031$ ).

### *Attacking minutes and kicking meters*

Table 4 presents the mean attacking minutes (ball in play time) and total kicking meters during the 2013 Super Rugby season. Furthermore, the "losing team/winning team" difference of attacking minutes and kicking meters are presented, together with a 95% confidence interval (CI) for the difference and the associated p-value comparing losing and winning teams. Table 4 also indicate that losing teams (41.6 minutes) spent more time on attack than winning teams (37.5 minutes), with a difference of 4.1 minutes, which was statistically significant ( $p=0.0328$ ). Furthermore, Table 4 shows that losing teams gained a mean total of 660.0 m per game through kicking, in comparison to 901.4 m per game for winning teams; the difference in kicking meters between losing and winning teams was also statistically significant ( $p=0.017$ ).

**Table 4.** Mean attacking minutes and kicking meters for losing and winning teams in the 2013 Super Rugby season.

	Attacking minutes		Kicking meters	
	Won	Lost	Won	Lost
Mean	37.5	41.6	37.5	41.6
Difference "won/lost"	4.1		-241.1	
95% CI for difference	0.4 to 7.8		-436.3 to -46.5	
p-value	0.0328		0.017	

### Discussion

Results from our study indicated that losing teams tended to pass the ball more frequently (mean of 157.4 passes per game) than winning teams (mean of 127.0 passes per game) and that the number of passes showed borderline significance between winning and losing teams ( $p=0.0598$ ). Losing teams tend to keep the ball for longer periods to try and win the game by scoring tries but also to receive a bonus point for losing with less than seven points. These results compare well with data from the 2013 Six Nations, where a similar analysis showed that England completed on average 134 passes per match, and both France and Wales 132 passes per match (IRB, 2013a). The results of this also agree with the findings Vaz et al. (2010) who showed that winning teams made fewer pass movements and completed fewer passes, indicating that losing teams might play a more running and ball-in-hand game due to the need to score tries. Table 1 shows that losing teams had more good passes ( $n=145.7$ ) and bad passes ( $n=11.0$ ) than winning teams, which is largely, but not exclusively, due to longer attacking time and the higher number of total passes by these teams (the passing rates were also higher for losing teams compared to winning teams).

Weather conditions can also affect the outcome of number of passes and the passing rate. Wet weather is mostly associated with a close game by keeping the ball closer to the ruck or forwards. Therefore, the number of passes will greatly decrease. Pavely et al. (2010) concluded that there was considerable unilateral bias during passing. The completion rate indicates that winning and losing teams both have good passing ability and that the change in the number of passes is due to the game plan employed by losing teams and is mostly caused by the match situation. Teams do not employ a different game plan automatically, but is forced on them by the situation of being behind on the scoreboard. This study calculated passing rate, in addition to the total number (count) of passes, since a team can only pass when in possession of the ball.

This study contradicts that of the International Rugby Board (2013a) and IRB (2013b) as they concluded that an average of one pass every 8.8 seconds (6.8 passes per minute) is recorded for the 2013 Six Nations (IRB, 2013a) and one pass every 8 seconds (7.5 passes per minute) during the 2013 Rugby Championship (IRB, 2013b). Our study found a rate of total passes for losing teams to be 3.8 passes per minute (1 pass every 15.7 sec) vs 3.4 passes per minute (1 pass every 17.6 sec) for winning teams.

The higher numbers from the Six Nations and Rugby Championship could be explained by the fact that this study used only a team's attacking minutes to calculate the rate, while the IRB (2013a) had used the total match time and data from both teams involved in a match. Both winning and losing teams had small error margins with very few bad passes (0.25 and 0.26 bad passes per game, respectively). This emphasises the fact that these players are all professional and train in a professional environment. Winning teams also placed greater emphasis on defence, as it prevented points from being scored during the prolonged attacking phase by the losing teams. These prolonged attacking phases of losing teams were associated with a greater count of passes.

The current study agrees with Ortega et al. (2009) who also reported that winning teams had a higher number of kicked possessions and kicks to touch, indicating the willingness of winning teams to use a more territory-orientated game plan. The IRB (2013b) reported that the Rugby Championship of 2013 had an average of 47 kicks per match, which compares well with this study recording an average of 46 kicks per match. Data presented in Table 2 suggest that both winning and losing teams preferred the long kick over short kicks, and emphasise the importance of territory for teams. Further studies could also be initiated as to the difference in number of kicks between the first and second half, the origin of kicks and differences in kicks made by different players. It can be argued that long kicks is used more often in a team's own half and short kicks in the opponents half of the field due to the attacking nature of the short kick.

The possibility of winning back possession from short kicks might be the reason for a higher rate of short kicks by winning teams. "Up and unders" or high kicks is an attacking weapon for many teams. These kicks gain relatively little territory, but the possibility of regaining possession is relatively high, especially if players are adequately skilled to chase and contest

the ball. These differences between kicks within the same sport highlight the need to evaluate different kick types separately within a sport (Ball, 2010). Players in the modern era are improving the technique of contesting a kick. Vaz et al. (2010) also found that winning teams kicked more than losing teams ( $p \leq 0.05$ ). Winning teams tended to gain more territory through better placed kicks and higher kicking ability of players. Results of our study agrees with Van den Berg and Malan (2010) who identified meters gained (46%) as the variable which had the greatest practical significance of ranking among Super 14 rugby union teams with our study indicating a significant difference between winning and losing teams for meters gained ( $p=0.017$ ). This Losing teams gained a mean total of 660.0 m per game in comparison to winning teams, with 901.4 m per game. Winning teams used the kick to push opposition back into their own half and used the lineout to compete for the ball rather than the short kick. Due to the pressure exerted by winning teams with long kicks, and pressure from good defensive skill, losing teams will try to kick to touch for relieve and therefore carry less distance.

### **Practical application**

This study determined the frequency and rate of passes and kicks made by Super Rugby teams during the 2013 season, and further investigated the differences between winning and losing teams in this regard. Our results suggest that, firstly, losing teams pass more than winning teams and, secondly, that winning teams kick more than losing teams. The study also found that a greater distance was gained through kicks by winning teams, although these teams had less attacking minutes. Therefore, winning teams had a greater kicking ratio than losing teams. Winning teams use the long kick more effectively than losing teams because of greater distance gained through these kicks. Losing teams will use the short kick less than winning teams because possession will be the overwhelming factor. It will be suggested that teams employ good tactical kicking and place greater emphasis on the regaining of possession after a ball have been kicked.

Secondly, this study found that both teams had sufficient passing ability and that the greater number of passes made by losing teams was due to the match situation, game plan and weather conditions. It will be recommended to coaches to spend more time on improving tactical kicking by providing kicking coaches for players and improve the distance of kicks. This is sometimes more affordable to unions with greater financial backing. Proper passing

skills must be coached and players taught to pass and offload under pressure situations due to high pace and good defensive structures associated with Super rugby. Passing skills in wet weather is also neglected and should be trained regularly by coaches as conditions will change from one match to the next. More time should also be spent by kick receivers like the wings and fullbacks to catch high balls to retain ball possession from kicks.

### **Limitations of the study**

Further studies are recommended with regard to the effectiveness concerning regaining possession and positional kick differences of players. Data received from Verusco for this study did not measure the number of kicks and passes for 1<sup>st</sup> and 2<sup>nd</sup> halves separately, which could also lead to more research. What about definitions used for the difference performance indicators?

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and Currie Cup during the 2014 season

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## **ABSTRACT**

*Previous studies on differences in level of competition in rugby focused on physiological and psychological components, yet little research is available on comparing performance indicators between different levels of play. Therefore, this study attempted to compare performance indicators of Currie Cup and Super Rugby, and to differentiate between the winning and losing teams of both competitions. A total of 30 games played during the 2014 Super Rugby competition and 30 games played during the 2014 Currie Cup were observed. The numbers of most match activities were similar for two competitions, with the average numbers of lineouts, scrums, rucks, tackles and penalties differing by 3% or less between competitions. Statistically and practically significant differences between competitions were for mauls and missed tackles. The average of 6.4 mauls in Super Rugby was significantly lower than the average of 9.6 in the Currie Cup, with a rate ratio of 0.69, implying a difference in the average number of mauls of about 30% ( $p=0.0071$ ). Similarly, the average number of missed tackles was about 20% lower in the Super Rugby competition compared to the Currie Cup (rate ratio of 0.80;  $p=0.0014$ ). Average numbers of activities were also generally similar for winning and losing teams in the two competitions.*

**Key words:** Levels of competition; Performance indicators; Currie Cup Rugby; Super Rugby.

## INTRODUCTION

In any domain with a discrepancy between the recommended level of performance and the level that is commonly achieved, there is the opportunity for gaining a competitive advantage for players who can successfully train to reduce the discrepancy (Pavely *et al.*, 2010). The increasingly business-like environment of professional sport has resulted in greater scrutiny and analysis of players' performance (Colby & Sheard, 2004). There is however still a large knowledge gap that shows the difference in performance indicators as players move from one competitive level of play to the next. As a result, Hendricks and Lambert (2010) concluded that the game of rugby, from amateur to professional, has become more physical and quicker, which involves more frequent and forceful contact events as determined by in-depth game analysis. Quarrie and Hopkins (2007) determined that professionalism was associated with increases in passes, tackles, rucks, tries, ball-in play time, and body mass, while large reductions in participation time per player and kicks during play, and moderate reductions in lineouts and mauls were recorded.

Increases and decreases associated with performance indicators is also true with regard to skills exhibited by players from different levels of competition. The number of rucks and tackles performed by players are just some of the indicators that can be increased due to higher fitness levels and improved capacity of players to perform certain tasks for prolonged periods of time. Vivian *et al.* (2001) reported that differences were evident in the number of behaviours completed by individuals as a function of both playing position and level of competition. Eaves *et al.* (2005), reported significant increases in the

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frequency of rucks and lineouts and a significant decrease in the frequency of mauls, scrums, total game kicks, kicks out of play, kicks in play, and set possessions over the years which can also be true for different levels. Sirotic *et al.* (2009) provided evidence in rugby league that two standards of competition have similar game-specific skills and physical demands during a match, but there can be variation within a match according to standard. Variations in match standard are also mentioned by the International Rugby Board (IRB, 2003), who stated that the competitive level of play will dictate such match activities as "ball in play" time. For example, at the 2003 Rugby World Cup, the ball was in play 42% of the time, compared to 40% during the 2006 under-21 Rugby World Cup.

It has been suggested by Van Rooyen (2012) that the higher the standard of play, the better the tackle technique, although this technique was not related to the outcome of matches played by teams that were composed of players with a similar quality of tackle execution. Changes in match activities are also reflected in the match outcome. Vaz *et al.* (2010) showed that winning teams in international and regional matches during 2003 and 2006 were consistently more effective at retaining the ball on their own lineout than losing teams. Teams that are not able to protect the ball during rucks will lose their ball possession to the opposing team and may concede points against them due to the turnover ball (Rugby Football Union, 2004).

Another area of concern as playing levels increase is the changes in territory and possession. Van den Berg and Malan (2010) stated that for a team to score

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points and be successful, teams need ball possession and to gain territory. Ball possession includes passes made, rucks and turnovers (Groenewald & SARFU Technical Committee, 2001). Although meters gained are not a match activity of play as such, it is a unit to measure performance such as the percentage of territory gained (Agnew, 2006). Van den Berg and Malan (2010) concluded that the match profile variables which emerged as the biggest predictors of ranking among the Super 14 rugby union teams were in order of contribution: meters gained (46%), kicks from hand (28%) and line breaks (8%). The importance of meters gained as the major discriminator and contributor to rugby performance was highlighted by O'Shea (2002). Hunter and O'Donoghue (2001) suggested distinct differences in terms of changes in possession and methods used by the teams to gain territory.

Referees and the interpretation of rules, such as the length of advantage time played, can also impact on level of competition. Quarrie and Hopkins (2007) reported that the variability in match activities that acts over longer periods can arise from modifications to laws and the interpretation of laws that exist at a given time. More experienced referees will officiate at a higher level. Referees are key sport personnel who have important responsibilities both on and off the field. From a service perspective, they ensure that competitions are conducted safely and in accordance with sanctioned rules and regulations (Warner *et al.*, 2013). The decisions by referees can impact on the number of match activities performed by teams and players, and can therefore be seen as a possible influence on changes in match activities.

## **PURPOSE OF THE RESEARCH**

Due to the various influences on performance indicators associated with the changes in the level of play, this study set out to compare the incidence of performance indicators between Super Rugby and Currie Cup rugby, to report any significance between levels of competition, and to differentiate between winning and losing teams from both competitions.

## **METHODOLOGY**

### **Sample**

A total of 30 games played during the 2014 Super Rugby competition and 30 games played during the 2014 Currie Cup were observed, resulting in 60 observations per competition. Super Rugby games were played in South Africa, New Zealand and Australia, while all Currie Cup games were played in South Africa. Data were statistically analysed to evaluate and compare the number of lineouts, lineouts lost, scrums, scrums lost, mauls, rucks, tackles, missed tackles and penalties conceded by losing and winning teams on these two levels of rugby to provide a sufficient body of data for coaches to determine the importance of variables to focus on during training.

### **Research method and techniques**

Time-motion analysis was conducted on all games played. Data was supplied by the Cheetahs Super Rugby Franchise in Bloemfontein, South Africa, using the Verusco TryMaker Pro (Verusco Technologies Ltd.; Palmerston North,

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New Zealand). Only data from 2014 could be used due to changing variables being used by team management during a season. The 2014 season was the only season available where both Currie Cup and Super Rugby measured similar variables. The Currie Cup is the local provincial rugby competition of South Africa involving between 6 to 8 teams and usually do not include any international players, while the Super Rugby competition involves teams from South Africa, Australia and New Zealand and have evolved from 15 to 18 teams. Super Rugby teams include international players from all three countries and is rated as an international tournament. Verusco has been supplying Super Rugby teams with TryMaker Pro since 2000, and provides a notational analysis of each individual player for each game played (Smart *et al.*, 2014). TryMaker Pro is an advanced analysis system developed exclusively for rugby, and it is the preferred system for professional teams using Verusco. The Verusco coding centre codes all the games for registered teams and delivers high detail, high speed analysis within hours of the game being played. The Verusco coding centre oversees reliability with more than twenty analysts and the head of coding before data is sent to the franchises. The reliability of the coding was determined by the re-analysis method (test-retest reliability) for inter-rater reliability. This method entails that a different analyst do a re-analysis of the video material after the original analysis. Twenty-five percent of matches were re-analysed by a different experienced performance analyst at the Cheetahs Super Rugby Franchise to avoid bias (James, Mackenzie & Capra, 2013). Ethics clearance was obtained from the University of the Free State where the study was conducted under ethical clearance number UFS-HUM-2013-009.

### **Statistical analysis and interpretation of data**

All data were captured in a Microsoft Excel 2007 spreadsheet and subsequently converted into a SAS data set (SAS, 2009). Descriptive statistics for the count and percentage data were calculated for the 2014 Super Rugby and Currie Cup competitions. Descriptive statistics were calculated per competition for the winning and losing teams separately, and for the two teams involved in each game combined (that is, for the total count per game). The extension to generalized responses, such as binary and count variables, entails generalized mixed models. The most common is the generalized linear mixed model (Ngo & Wand, 2004). Each count variable (such as number of lineouts, scrums, rucks, mauls) was analysed using a generalised linear mixed model (GLIMM) with competition (Super versus Currie Cup) as fixed effect, and both winning team and losing team as random effect. The fitting of the variables winning team and losing team as random effects allowed for correlation between the counts in question for a given team across several games.

Furthermore, the GLIMM was specified with Poisson error distribution and the natural logarithm as link function. Residual over-dispersion was allowed for in the model. Based on the GLIMM, the mean rates of variables, such as lineouts, scrums, rucks, mauls, per game were estimated for the 2014 Super Rugby and Currie Cup competitions. Similarly, in order to compare the mean rates between the 2014 Super Rugby and Currie Cup competitions, rate ratios of the different variables between the 2014 Super Rugby and Currie Cup competitions were estimated, together with 95% confidence intervals (CIs) for the rate ratios. Confidence Intervals can also use information to calculate boundaries within

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which researchers believe a population will fall (Field, 2013). Procedure GLIMMIX of the SAS Version 9.22 statistical software package was used for this analysis (SAS, 2009).

The analyses were carried out separately for the data of the winning teams, for the data of the losing teams, and for the data of two teams involved in each game combined (that is, for the game). Percentage territory and percentage possession of the *winning team* in each game were analysed using a linear mixed model with competition as fixed effect, and both winning team and losing team as random effects. Based on the linear mixed model, the mean percentage territory (and possession) was estimated for each competition, with a 95% CI for the mean percentage. Similarly, in order to compare the mean percentage between the 2014 Super Rugby and Currie Cup competitions, mean differences – that is, differences of mean percentage territory and possession – between the 2014 Super Rugby and Currie Cup competitions were estimated, with 95% CIs for the mean differences. The analysis was carried out using SAS procedure MIXED (SAS, 2013).

### **RESULTS**

Table 1 presents the mean number (and standard deviation) of match activities for Currie Cup and Super Rugby competitions during the 2014 rugby season. Differences in match activities between the Currie Cup and Super Rugby competitions are expressed as rate ratios and 95% CIs for the rate ratios, which allow one to judge the reported differences on a meaningful scale, namely the percentage scale.

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The numbers of most match activities were similar for the two competitions: the rate ratios for lineouts, scrums, rucks, tackles and penalties all fell between 0.97 to 1.03, which implies that the corresponding average numbers of activities did differ by 3% or less between competitions. The “Super Rugby/Currie Cup” rate ratio for lineouts lost was 0.90, and for scrums lost 1.15, meaning 10% fewer lineouts lost but 15% more scrums lost on average in Super Rugby compared to the Currie Cup; however, these are percentages of low mean counts, so that the differences between the competitions – namely fractions of a line out or scrum, are practically of no importance. Furthermore, all the above mentioned differences in activities were not statistically significant.

The only statistically significant differences between competitions were for mauls and missed tackles. The average of 6.4 mauls in Super Rugby was significantly lower than the average of 9.6 in the Currie Cup, with a rate ratio of 0.69, implying a difference in the average number of mauls of about 30% ( $p=0.0071$ ). Similarly, the average number of missed tackles was about 20% lower in the Super Rugby competition compared to the Currie Cup (rate ratio of 0.80;  $p=0.0014$ ).

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**TABLE 1. MATCH ACTIVITIES (PER GAME) FOR BOTH COMPETITIONS DURING THE 2014 RUGBY SEASON**

<b>Variable</b>	<b>Currie Cup Mean (SD)</b>	<b>Super Rugby Mean (SD)</b>	<b>Rate Ratio Super/Currie</b>	<b>95% CI for Rate Ratio</b>	<b>p-value</b>
Lineouts	21.8 (5.44)	21.9 (4.63)	1.033	0.903 to 1.184	0.6314
Lineouts lost	4.5 (2.08)	4.3 (2.07)	0.901	0.684 to 1.187	0.4479
Scrum	15.7 (4.70)	16.4 (4.27)	1.005	0.856 to 1.179	0.9544
Scrum lost	2.1 (1.68)	2.4 (1.73)	1.148	0.746 to 1.767	0.5219
Rucks	139.6 (26.86)	143.1 (22.80)	1.015	0.917 to 1.123	0.7697
Mauls	9.6 (4.16)	6.4 (3.25)	0.692	0.532 to 0.900	0.0071*
Tackles	275.1 (45.58)	270.8 (38.32)	0.991	0.900 to 1.090	0.8434
Tackles missed	45.3 (10.68)	36.4 (9.84)	0.804	0.705 to 0.916	0.0014*
Penalties	24.1 (4.54)	23.4 (4.12)	0.972	0.885 to 1.069	0.5532

\*Statistically significant difference  $p < 0.05$

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Table 2 presents the data in a stratified manner, namely by winning and losing team. The results indicate that the average numbers of match activities were generally similar for winning and losing teams in both types of competition, and were similar for the two competitions within each stratum, with the following exceptions: For winning teams, the average of 2.6 mauls in Super Rugby was significantly lower than the average of 5.4 mauls in the Currie Cup, with a rate ratio of 0.57, implying a difference in the average number of mauls of about 40% ( $p=0.0074$ ). Similarly, among winning teams, the average number of missed tackles was about 25% lower in the Super Rugby competition compared to the Currie Cup (rate ratio of 0.73;  $p=0.0009$ ). In contrast, among losing teams the average number of mauls and missed tackles were similar for the two competitions, and no statistically significant differences were found between either the two competitions in either stratum.

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**TABLE 2. MATCH ACTIVITIES (PER GAME) STRATIFIED BY MATCH OUTCOME (WINNING VERSUS LOSING TEAM) FOR BOTH COMPETITIONS**

Variable	Winning team					Losing team				
	Super Rugby Mean (SD)	Currie Cup Mean (SD)	Rate Ratio Super/ Currie	95% CI for Rate Ratio	p-value	Super Rugby Mean (SD)	Currie Cup Mean (SD)	Rate Ratio Super/ Currie	95% CI for Rate Ratio	p-value
Line outs	10.3 (2.5)	10.4 (3.2)	0.992	0.849 to 1.159	0.9153	11.6 (3.7)	11.4 (3.9)	1.039	0.856 to 1.261	0.6912
Line outs lost	2.1 (2.1)	1.8 (1.0)	0.883	0.537 to 1.451	0.6158	2.2 (1.6)	2.7 (1.7)	0.817	0.574 to 1.163	0.2573
Scrum	8.4 (2.7)	8.1 (3.3)	1.032	0.847 to 1.258	0.7502	8.2 (3.2)	7.5 (3.4)	1.083	0.855 to 1.371	0.4992
Scrum lost	1.2 (1.1)	0.9 (0.8)	1.385	0.830 to 2.312	0.2069	1.2 (1.2)	1.2 (1.3)	0.960	0.542 to 1.703	0.8865
Rucks	71.4 (21.7)	64.8 (20.8)	1.102	0.936 to 1.297	0.2374	71.7 (19.8)	74.8 (23.9)	0.959	0.821 to 1.122	0.5975
Mauls	2.6 (2.1)	5.4 (3.3)	0.570	0.380 to 0.854	0.0074*	3.6 (3.1)	4.2 (2.1)	0.921	0.636 to 1.334	0.6575
Tackles	139.1 (36.3)	143.7 (39.1)	0.996	0.857 to 1.158	0.9611	131.5 (39.7)	131.3 (40.7)	1.034	0.864 to 1.251	0.6707
Tackles missed	17.7 (4.8)	24.6 (8.9)	0.726	0.604 to 0.871	0.0009*	18.3 (8.5)	20.7 (6.7)	0.886	0.721 to 1.089	0.2456
Penalties	12.0 (3.1)	11.3 (3.3)	1.054	0.902 to 1.233	0.4993	11.2 (3.1)	12.6 (3.6)	0.901	0.761 to 1.067	0.2169

\*Statistically significant difference  $p < 0.05$

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Table 3 shows that the percentages possession and territory of losing teams in the two competitions were practically identical. Furthermore, the percentages possession and territory of losing teams in both competitions were very close to 50%, which means that the percentages possession and territory of winning teams and losing teams were practically identical, namely about 50%..

**TABLE 3. POSSESSION AND TERRITORY FOR LOSING TEAMS IN SUPER RUGBY AND CURRY CUP RUGBY<sup>1</sup>**

Variable	Currie Cup	Super Rugby	Difference Super Currie	95% CI for Difference	p-value
Possession	51.9	50.6	-1.3	-5.7 to 3.2	0.5690
Territory	50.5	50.7	0.2	-4.7 to 4.4	0.9353

<sup>1</sup>Possession and territory of winning team are the complement to sum to 100%

## DISCUSSION

The results of this study emphasize the importance of specific demands on the various levels of play regarding match activities such as the lineout, scrum, ruck, maul and tackle counts by Super Rugby and Currie Cup players. Our study showed that a significant difference exists between the winning teams of the different competitions with regard to mauls ( $p=0.0074$ ) and missed tackles ( $p=0.0009$ ). The same variables (mauls,  $p=0.0071$  and tackles missed,  $p=0.0014$ ) also differed significantly when both winning and losing teams from the two competitions were compared.

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Our research support that of Sirotic *et al.* (2009) who showed that while two standards of competition have similar game-specific skills during a match, there is variation within a match according to standard. Our study agrees with that of Vivian *et al.* (2001) who reported that differences were evident in the number of match activities completed by individuals as a function of both playing position and level of competition. Our study found that in Super Rugby, the number of lineouts, scrums, scrums lost and rucks were higher than in the Currie Cup, although there were no significant differences ( $p=0.6314$ ,  $p=0.7697$ ,  $p=0.5291$  and  $p=0.9544$ , respectively). In Super Rugby, teams lost fewer lineouts even though the number of lineouts increased, thus differentiating between the different levels of competition. This indicates that higher levels of competition show improved performance in lineouts and that higher level team's place greater emphasis on the execution of set pieces. Increases in scrums can be due to a more open and running game by the higher level teams.

Our findings also show that the Currie Cup competition had higher means for missed tackles and mauls. Both these activities showed significant differences between competitions with  $p=0.0014$  for tackles missed and  $p=0.0071$  for mauls. These findings support Van Rooyen (2012) who stated that the higher the standard of play, the better the tackle technique. Super Rugby players spend more time improving tackle technique and are bigger and more physical and can therefore handle the higher collision impacts from the ball carrier. Consequently, it is noteworthy that in our study winning teams had a higher missed tackle count (24.6) than losing teams (20.7) in Currie Cup, while the

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contrary was observed in Super Rugby, with 18.3 missed tackles by losing teams and 17.7 missed tackles by winning teams. It is apparent that in the Currie Cup, which is a local South African competition, teams make use of the maul significantly more than Super Rugby teams ( $p=0.0071$ ). This might indicate the more physical style of play associated with South African teams.

Results from this study show that average numbers of activities for winning teams were not greater than losing teams in all variables, but rather indicate that winning teams place greater emphasis on the set phases such as lineouts and scrums, by losing fewer of these set phases as losing teams. This is supported by Vaz *et al.* (2010) who found that winning teams in international and regional matches were consistently more effective at their own lineout than losing teams. Winning teams also have a higher number of tackles performed due to the continuous offense and pressure applied by the losing teams, and show better tackle completion than losing teams in all competitions. For this reason, there is a significant difference in the number of missed tackles by winning teams at all levels of play. Higher level teams spend more time on perfecting their defensive structure and handle the collision situation better than lower level teams. The possession is higher for losing teams in both competitions. Our data, which stem from 2014, suggest that there was a slight increase in the number of tackles for winning teams when compared to losing teams, but both winning and losing teams missed fewer tackles in Super Rugby than in Currie Cup Rugby. This suggests the more physical nature of Super Rugby with players being better conditioned, heavier and better skilled. The increase in tackles can be due to the more intensive and expanding game plan applied by

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Super Rugby teams. Winning teams have better defensive structures and can sustain pressure over longer periods or phases of attack by losing teams with higher tackle completion, which can be due to better physical improvement in players from the higher level of competition.

Eaves and Hughes (2003) also concluded that the professional approach to rugby resulted in an increase in match activities. It must be kept in mind that weather conditions, game plan and the competition structure can also affect the match activities during match play.

### **CONCLUSION AND PRACTICAL IMPLICATIONS**

This paper reports the number of tackles, rucks, mauls, scrums, lineouts, percentage possession and territory for Super Rugby and Currie Cup rugby, and also changes observed between winning and losing teams from both competitions. The differences in match activities performed by teams over different competitions emphasise the different physiological demands on and preparation of teams. It is recommended that coaching and conditioning be designed to improve these performance indicators by including a substantial amount of tackling, rucking and lineouts, as these are the prominent activities that increase to higher levels of play. Ultimately, players in higher level rugby receive more and better coaching and conditioning, increasing the skill level of each player, physique and fitness levels.

Coaches need to be aware of the differences in the number of scrums and lineouts when planning training programs. Players are getting bigger and more

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conditioned to perform higher number of mauls and to break tackles. Teams seeking improvement need to increase tackle completion, improve lineout contesting and emphasise the maul as an attacking measure.

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## Chapter 6

### Article 4: Analysis of Super rugby from 2011 to 2015.

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## Analysis of Super Rugby from 2011 to 2015

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### Abstract

*Rugby shows proof of evolution within the professional era due to large contributions from technology and improved training. Evidence of evolution in rugby can be traced through statistics. Therefore, the aim of this study was to compare match activities over five seasons (2011–2015) of Super Rugby union matches played in South Africa, Australia and New Zealand, and to investigate performance indicators that allow discrimination between winning and losing teams. Data from 30 matches per season (4 matches from each of the 15 participating teams) were captured and supplied by the Cheetahs Super Rugby Franchise (Bloemfontein, South Africa), using the Verusco TryMaker Pro. Differences in mean rates were found between seasons and between winning and losing teams. Losing teams showed an increase in rucks and mauls, they lost more scrums and missed more tackles than winning teams. Playing time, scrums lost, and penalties decreased from 2011 to 2015, while scrums (1.76%), rucks (0.80%), mauls (4.42%), and tackles (1.07%) showed a slight increase. However, no significant differences were observed for scrums, rucks, mauls or tackles. Significant differences were found for lineouts (mean of 3.5% per year; 95% confidence interval (CI) 0.7% to 6.5%;  $p=0.0156$ ) and tackles missed (5.7%; 95% CI 3.0% to 8.4%;  $p<0.001$ ). Although the mean annual increase in tackles was not statistically significant (1.1%; 95% CI -0.1% to 2.2%;  $p=0.0673$ ), it might be of some practical importance. The findings agree with the results of previous research, namely that most changes in data over five seasons can be contributed to the physiological improvement of players and the increased emphasis on perfecting set phases (scrums and lineouts) during training.*

**Keywords:** performance indicators; scrums; lineouts; rucks; mauls; tackling

## 1. Introduction

As the profile of rugby is constantly changing, the need for data concerning changes over seasons as rugby evolves is of greater importance to coaches to stay up to date with the trends over time as identified within this study. Major changes in international rugby match activities and player size have occurred over the past three decades. Furthermore, developments in match analysis, equipment technology, and player training have contributed to the changes associated with the introduction of professionalism (Quarrie & Hopkins, 2007). Performance indicators might change as the competition and season changes as Duthie *et al.* (2003) indicated that factors such as the referee, weather conditions, ground conditions, the tactics employed by the teams, and the time of the match (night vs day matches) play a role in the variability of certain performance indicators. Quarrie and Hopkins, (2007) reported that increases in performance indicators such as the number of passes, tackles, rucks, tries and ball-in-play time was associated with the advent of professionalism, whereas the number of line outs, mauls, kicks in play, and mean participation time per player decreased, while Fuller *et al.* (2007) reported that professional rugby matches contain over 200 tackle situations. With regard to scrums, Quarrie and Hopkins (2007) noted that time trends revealed an increase in the number of rucks and a decrease in the number of scrums. Vahed *et al.* (2016) indicated that rucks and mauls increased significantly from 2007 to 2013.

The problem is whether it can be expected that there are differences in the performance indicators between winning and losing teams as rugby evolved over the last couple of years. Vaz *et al.* (2010) showed that winning teams in international and regional matches during 2003 and 2006 were consistently more effective at retaining the ball on their own lineout than losing teams. In the phases of obtaining the ball, and more specifically in scrums, winning teams lose fewer balls than losing teams (winning teams have an efficacy of 90% in these actions) (Ortega *et al.*, 2009). The performance indicators analysed by Vaz *et al.* (2010) were scrums, lineouts, penalties, free kicks, rucks, mauls, turnovers, passes, tackles, kicks, and methods of scoring. Van den Berg and Malan (2010) concluded that metres gained, kicks out of hand, line-breaks, and percentage tackles made were the most important discriminators between successful and less successful rugby teams, but was conducted in 2006 which makes this study timely. Van den Berg and Malan (2010) also identified possession, territory and discipline as the most important factors for teams to be successful and score points.

According to Correia *et al.* (2011), distance gained is a variable that can be used to distinguish between successful and unsuccessful attacks. The statement referred to above indicates the willingness of winning teams to use the foot game and will result in higher kicking values (Ortega *et al.*, 2009). Ortega *et al.* (2009) also found that losing teams had insignificantly higher averages than winning teams of tackles missed and passes completed. Vaz *et al.* (2010) showed that winning teams made fewer rucks and pass movements, won more mauls and turnovers, completed fewer passes and made fewer errors than losing teams ( $p < 0.05$ ). Winning teams also kicked a greater amount of their possession (including kicks to touch) and made more tackles ( $p < 0.05$ ) (Vaz *et al.*, 2010). Winning teams have better defensive capabilities (Hunter & O'Donoghue, 2001) and miss fewer tackles than losing teams (Prim *et al.*, 2007). With regard to possession, the time that teams are involved in defence and attack can influence the frequency of activities such as passing and tackling, since a team can pass the ball only if it has possession of it, and it can tackle only if it is on the defensive and the opposing team has possession. Therefore, studies must be conducted with

playing time in mind, rather than merely reporting frequencies of performance indicators. More time spent on defence is closely associated with a higher number of tackles made by the particular team. Traditionally, teams kick for territory when they gain possession in their own half, and attack when possession is gained in the opposition's territory (Agnew, 2006). Groenewald and the South African Rugby Football Union (SARFU) Technical Committee (2001) identified the number of passes made, rucks and turnovers as performance indicators that will influence a team's number of ball possessions. Another indicator is the penalties conceded by teams. When a team concedes penalties due to bad discipline, the opposition may gain an opportunity to kick a goal, which in turn can lead directly to points for the opposition (IRB, 2006). During the 1999 Rugby World Cup, 572 kicks were taken of which 334 kicks were penalties and the remaining 238 kicks were conversion attempts (Jackson, 2003). When expressed per individual tournament, data showed that the points conceded by the winning teams were significantly lower than those conceded by the losing teams ( $p < 0.04$ ). Ortega *et al.* (2009) also indicated that winning teams carried out more penalty goal attempts and drop kicks than losing teams.

### **1.1. Purpose of the study**

Data on match activities provide valuable information on the changes of match demands of a competition such as the Super Rugby competition, and assist in the development of specific training regimes, game plan and even contracting of players with certain abilities. Vaz *et al.* (2010) stated that research of this nature in rugby is often undertaken within the confines of the team, or an organisation or governing body. Therefore, this study aimed to analyse possible changes to the performance indicators over five seasons of Super Rugby union matches played in South Africa, Australia and New Zealand during the 2011–2015 Super Rugby seasons, and to compare the performance indicators that might discriminate between winning and losing teams. Changes to the performance indicators during competition might assist coaches and conditioning staff in the development of a more specific and accommodating game plan and position-specific training according to team strengths and weaknesses.

## **2. Methodology**

### **2.1. Subjects and research method**

Data were collected over five seasons from 2011 to 2015 for South African, Australian and New Zealand teams. The data of 30 Super Rugby games per season was recorded and resulted in 2 records per match (winning and losing team), resulting in 60 records per season and 300 records over the 5 seasons. Therefore, each of the fifteen participating teams contributed to 4 records per season. No play-off matches were used during the study, that made use of round robin matches only. Counts of the number of line outs, scrums, rucks, mauls, tackles, tackles missed and penalties were extracted for each season, team and game, as well as percentage possession and percentage territory. Data were analysed statistically to evaluate, compare and show the regression in the total number of match activities made by losing and winning teams from the 2011 to 2015 Super Rugby season.

Data were provided by the Cheetahs Super Rugby Franchise in Bloemfontein, South Africa, using the Verusco TryMaker Pro (Verusco Technologies Ltd.; Palmerston North, New Zealand). Verusco has been supplying Super Rugby teams with TryMaker Pro since 2000, and provides a notational analysis of each individual player for each game played (Smart *et al.*, 2014).

TryMaker Pro is an advanced analysis system developed exclusively for rugby, and it is the preferred system for professional teams using Verusco. The Verusco coding centre codes all the games for registered teams and delivers high-detail, high-speed analysis within hours of the game being played. The Verusco coding centre oversees reliability with more than twenty analysts and the head of coding before data is sent to the franchises. The reliability of the coding was determined by the re-analysis method (test-retest reliability) for inter-rater reliability (James *et al.*, 2005). This method entails that a different analyst do a re-analysis of the video material after the original analysis. Twenty-five percent of matches were re-analysed by a different experienced performance analyst at the Cheetahs Super Rugby Franchise to avoid bias. The researchers made use of the Intraclass Correlation Coefficient (ICC) to determine the reliability of all variables (Gratton & Jones, 2004). Inter-rater agreement was interpreted as follows: Poor (0–0.20), fair (0.30–0.40), moderate (0.50–0.60), strong (0.70–0.80) and almost perfect (>0.80) (Liporace *et al.*, 2012). Analysis showed that the strength of the agreement between all variables was almost perfect (Table 1).

Table 1. Intra-rater reliability correlations coefficient (ICC) of the coding test-retest

	ICC
Playing time	1.00
Lineouts	1.00
Lineouts lost	0.95
Scrum	1.00
Scrum lost	0.98
Rucks	1.00
Mauls	1.00
Tackles	0.84
Tackles missed	0.80
Penalties	1.00

Ethical clearance was obtained from the University of the Free State where the study was conducted under ethical clearance number **UFS-HUM-2013-009**.

## 2.2. Statistical analysis and interpretation of data

All data were captured in Microsoft Excel 2007 and subsequently converted into a SAS data set. Procedures GLIMMIX and MIXED of the SAS Version 9.22 statistical software package was used for further statistical analysis (SAS, 2013). Descriptive statistics for the count and percentage data were calculated for the 2011–2015 seasons. Descriptive statistics were calculated per season for winning teams and losing teams, and for the two teams involved in each game combined.

Table 2: Performance indicators defined (Vahed *et al.*, 2016).

<b>Performance indicators</b>	<b>Definitions</b>
Playing time	The time that the ball was in play out of the original 80 minutes and without stoppages
Lineouts	Number of times the teams had to throw the ball into the lineout to restart the game after the ball went into touch
Lineouts lost	When the team that threw the ball into the lineout lost it in the contest
Scrum	Number of times the teams had to put the ball into the scrum after minor infringements such as a knock-on or forward pass
Scrum lost	When the team that put the ball into the scrum lost it in the contest
Rucks	A ruck was when the ball was on the ground and two players made contact over the ball.
Mauls	When a player with the ball was held up, without being tackled, by an opposing player and a player from his own team
Tackles	When one or more opposing players made contact with the ball carrier and successfully brought him to ground
Tackles missed	When one or more opposing players made contact with the ball carrier and failed to bring him to ground
Penalties	Number of major infringements committed by teams such as offside, foul play and scrum collapses
Possession	The percentage of possession of the ball enjoyed by teams during playing time
Territory	The percentage of field advantage enjoyed by teams during playing time

Each count variable (such as number of line outs, scrums, rucks, mauls) was analysed using a generalised linear mixed model (GLIMM) with season as fixed covariate effect, and season, winning team, losing team, season by winning team and season by losing team interactions as random effects. When variance components were zero they were dropped from the model. Random effects were also dropped from the model when the model fitting algorithm did not converge. Furthermore, the GLIMM was specified with Poisson error distribution and the natural logarithm as link function. Residual over-dispersion was allowed for in the model. Based on the GLIMM, the regression slope over time (season) for the count variables was estimated. The model was set up in such a way that the value of the regression slope can be interpreted as follows: if the value of the slope is  $\beta$ , then the average count (per minute playing time) in question changed on the log-scale by the amount of  $\beta$  per year. This implies that the average count on the original changed by a multiple of  $\exp(\beta)$  per year. The above analyses were carried out separately for the data of the winning teams, the losing teams, and for the data of two teams involved in each game combined

(that is, for the game). Percentage territory and percentage possession of the *winning team* in each game were analysed using a linear mixed model with season as fixed covariate effect, and season, winning team, losing team, season winning team and season losing team as random effects. Based on the linear mixed model, the regression slope over time (season) for percentage territory (and possession) was estimated. The model was set up in such a way that the value of the regression slope can be interpreted as follows: if the value of the slope is  $\beta$ , then territory (possession) change  $\beta$  percent points per year; similarly, playing time changes  $\beta$  minutes per year.

All estimates of regression slopes, and therefore all estimates of changes in mean counts or mean percent per year, were reported to together with 95% confidence intervals (CI) – in addition to P-values – as recommended by Hopkins *et al.* (2008).

### 3. Results

#### 3.1. Performance indicators measured from 2011 to 2015

Table 3 presents the means and standard deviations (SD) for all indicators from the 2011 to 2015 Super Rugby seasons (winning and losing teams combined). Playing time (34.12 vs 31.95), scrums lost (0.03 vs 0.02) and penalties (0.35 vs 0.34) decreased from 2011 to 2015 per minute of playing time, while scrums (0.27 vs 0.28), rucks (2.08 vs 2.16), mauls (0.07 vs 0.10), and tackles (3.96 vs 4.20) showed a slight increase per minute of playing time but showed no significance. The number of missed tackles per minute of playing time (0.46 vs 0.60) from 2011 to 2015 showed a significant increase ( $p = <0.001$ ; Table 4) and so too did lineouts ( $p = 0.0156$ ; Table 4) by increasing from 0.31 per minute in 2011 to 0.34 per minute for 2015. The number of lost scrums decreased slightly from 0.03 in 2011 to 0.02 in 2015, even though the number of scrums showed a decrease.

Table 3. Means ( $\pm$  SD) of all teams for all variables in the 2011–2015 Super Rugby seasons.

Variable	Season				
	2011	2012	2013	2014	2015
Playing time*	34.12 (3.422)	33.83 (3.187)	33.16 (2.867)	33.13 (2.459)	31.95 (2.856)
Lineouts <sup>#</sup>	0.31 (0.063)	0.29 (0.059)	0.33 (0.068)	0.33 (0.081)	0.34 (0.096)
Lineouts lost	0.06 (0.038)	0.06 (0.026)	0.05 (0.029)	0.06 (0.032)	0.06 (0.022)
Scrum	0.27 (0.095)	0.24 (0.074)	0.26 (0.076)	0.25 (0.070)	0.28 (0.082)
Scrums lost	0.03 (0.024)	0.02 (0.019)	0.02 (0.019)	0.03 (0.028)	0.02 (0.026)
Rucks	2.08 (0.232)	2.17 (0.203)	2.28 (0.208)	2.15 (0.276)	2.16 (0.305)
Mauls	0.07 (0.040)	0.09 (0.057)	0.10 (0.039)	0.09 (0.048)	0.10 (0.065)
Tackles	3.96 (0.407)	4.12 (0.394)	4.31 (0.327)	4.08 (0.434)	4.20 (0.475)
Tackles missed	0.46 (0.122)	0.51 (0.112)	0.53 (0.111)	0.54 (0.137)	0.60 (0.107)
Penalties	0.35 (0.081)	0.37 (0.097)	0.31 (0.074)	0.35 (0.064)	0.34 (0.086)

\*Unit for playing time = minutes; <sup>#</sup>unit for all other performance indicators = count/minute

Mauls also showed a slight increase from 0.07 per minute of playing time in 2011 to 0.10 every minute of playing time in 2015 with no significance. Lineouts lost did not increase, while lineouts increased and remained at 0.06 lost lineouts per minute of playing time.

Table 4 confirms that average increases per year were noted for all count variables. Missed tackles, mauls and lineouts showed the greatest increase over the five seasons of Super Rugby. Of these three variables, missed tackles (mean of 5.7% per year; 95% CI 3.0% to 8.4%;  $p \leq 0.001$ ) and lineouts (mean of 3.5% per year; 95% CI 0.7% to 6.5%;  $p = 0.0156$ ) showed statistically significant increases. The small increases in mauls (mean of 4.4% per year; 95% CI -1.2% to 10.4%;  $p = 0.1270$ ), scrums (mean of 1.8% per year; 95% CI -5.0% to 9.0%;  $p = 0.4795$ ), rucks (mean of 0.8% per year; 95% CI -0.5% to 2.1%;  $p = 0.2349$ ) and tackles (mean of 1.1% per year; 95% CI -0.1% to 2.2%;  $p = 0.0673$ ) were not statistically significant.

Table 4. Percentage change (increase) per year for count variables.

Variable	Change per year (%)		
	Mean	95% confidence interval	P-value
Lineouts*	3.5	0.7 to 6.5	0.0156
Scrums	1.8	-5.0 to 9.0	0.4795
Rucks	0.8	-0.5 to 2.1	0.2349
Mauls	4.4	-1.2 to 10.4	0.1270
Tackles	1.1	-0.1 to 2.2	0.0673
Missed tackles*	5.7	3.0 to 8.4	<0.001

\*Statistically significant difference

The increase in missed tackles and tackles shows that tackle completion percentages of players and teams in 2015 has decreased from 2011. The tackle completion rate for 2011 is 88.2% while in 2015 the completion rate was only 85.7%. Penalties conceded by teams indicated no consistent change. Penalties increased from 2011 to 2012, then decreased to 2013 and then showed an increase up to 2015. Figure 1 illustrates that there was a decrease in the actual playing time from 2011 to 2015. The decrease was consistent from 2011 (34.12 min) to 2014 (33.13 min), with the greatest decrease occurring from 2014 to 2015 with a 1 minute and 18 second decrease. The average decrease in playing time per year (slope of the regression shown in Figure 1) was 0.53 min (95% CI 0.13 to 0.94 min;  $P = 0.0107$ ).

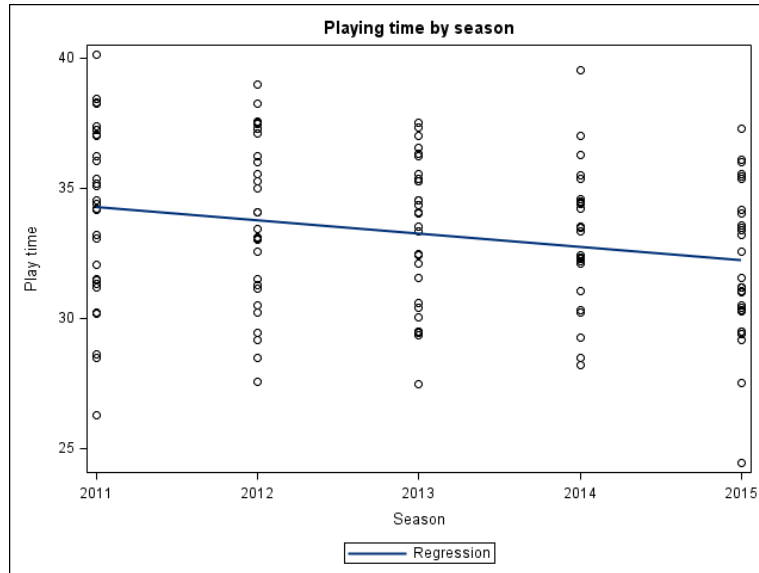


Figure 1. Playing time from 2011 to 2015.

### 3.2 Winning and losing

Table 5 provides means and standard deviations of all variables separately for the winning and losing teams from 2011 to 2015. Losing teams consistently lost more lineouts than winning teams.

As shown in Table 5, losing teams had fewer scrums (0.25, 0.22, 0.24, 0.25, 0.27) per minute of playing time than winning teams (0.29, 0.26, 0.28, 0.25, 0.30) from 2011 to 2015. Losing teams lost more scrums than the winning teams, while losing teams showed a higher number of rucks (2.16, 2.18, 2.39, 2.17, 2.30) than winning teams (2.00, 2.17, 2.16, 2.14, 2.02) for all seasons. This difference increased even more in 2015 (2.30 for losing teams vs 2.02 for winning teams). The use of the maul increased for losing teams from 0.05 per minute of playing time in 2011 to 0.09 per minute of playing time in 2015, although it was still less than the number of mauls executed by winning teams. Losing teams consistently had less tackles than winning teams for all seasons, but winning teams showed less missed tackles than losing teams even though they had more tackles to make in three of the five seasons.

Table 5. Means ( $\pm$  SD) of count variables for winning and losing teams in the 2011–2015 Super Rugby seasons.

Variable	Season									
	2011		2012		2013		2014		2015	
	Win	Lose	Win	Lose	Win	Lose	Win	Lose	Win	Lose
Lineouts	0.29 (0.114)	0.32 (0.079)	0.28 (0.089)	0.31 (0.100)	0.32 (0.107)	0.33 (0.089)	0.31 (0.090)	0.35 (0.118)	0.33 (0.129)	0.35 (0.116)
Lineouts lost	0.05 (0.042)	0.07 (0.063)	0.05 (0.038)	0.06 (0.041)	0.04 (0.042)	0.05 (0.046)	0.06 (0.062)	0.06 (0.048)	0.05 (0.040)	0.06 (0.047)
Scrums	0.29 (0.107)	0.25 (0.130)	0.26 (0.106)	0.22 (0.099)	0.28 (0.090)	0.24 (0.092)	0.25 (0.087)	0.25 (0.101)	0.30 (0.114)	0.27 (0.126)
Scrums lost	0.02 (0.032)	0.03 (0.036)	0.02 (0.031)	0.02 (0.023)	0.02 (0.024)	0.02 (0.024)	0.03 (0.035)	0.03 (0.036)	0.03 (0.037)	0.02 (0.040)
Rucks	2.00 (0.480)	2.16 (0.526)	2.17 (0.670)	2.18 (0.566)	2.16 (0.519)	2.39 (0.549)	2.14 (0.576)	2.17 (0.612)	2.02 (0.687)	2.30 (0.705)
Mauls	0.10 (0.075)	0.05 (0.048)	0.10 (0.107)	0.08 (0.072)	0.13 (0.083)	0.07 (0.057)	0.08 (0.063)	0.10 (0.090)	0.10 (0.090)	0.09 (0.069)
Tackles	4.09 (1.020)	3.84 (0.813)	4.16 (0.959)	4.08 (1.157)	4.58 (1.009)	4.05 (1.003)	4.21 (1.104)	3.94 (1.064)	4.49 (1.276)	3.90 (1.187)
Tackles missed	0.45 (0.184)	0.48 (0.189)	0.47 (0.158)	0.56 (0.183)	0.59 (0.189)	0.48 (0.209)	0.53 (0.141)	0.55 (0.244)	0.64 (0.224)	0.56 (0.214)
Penalties	0.36 (0.101)	0.33 (0.118)	0.38 (0.106)	0.35 (0.165)	0.30 (0.095)	0.32 (0.098)	0.36 (0.096)	0.34 (0.094)	0.33 (0.096)	0.35 (0.135)

### 3.3. Territory and possession

It is apparent from Figure 2 and Figure 3 that the percentage territory and possession for winning teams decreased only slightly from 2011 to 2015. The average decrease in percent territory for the winning team per year (slope of the regression line in Figure 2) was 1.0 (95% CI 0.1 to 1.9;  $P=0.0233$ ). Similarly, the average decrease in percent possession for the winning team per year (slope of the regression line in Figure 3) was 0.36 (95% CI -0.64 to 1.37;  $P=0.4730$ ).

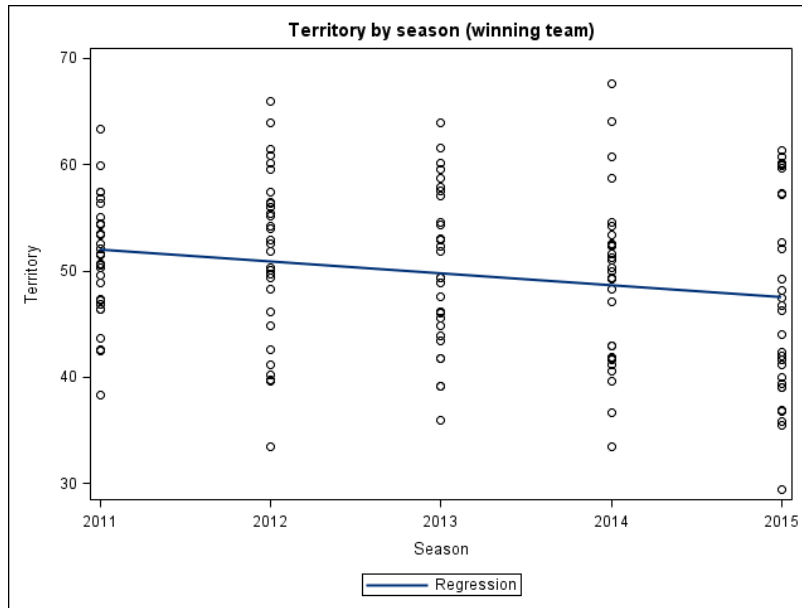


Figure 2. Percent territory of winning teams for 2011 to 2015.

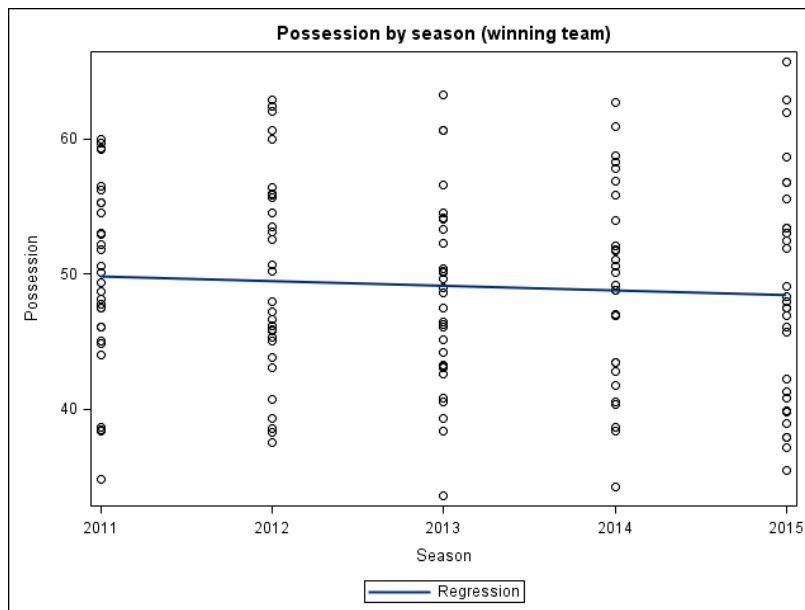


Figure 3. Percent possession of winning teams for 2011 to 2015.

#### 4. Discussion

The results of this study emphasise the importance of measuring and analysing specific performance indicators on a regular basis, as these performance indicators can change in a short time frame.

##### **Performance indicators measured from 2011 to 2015**

Findings from the current study saw both increases and decreases in the various performance indicators across the five years of Super Rugby. Possible reasons for the decrease in scrums could have been the willingness of teams to play the advantage provided by the referee for minor offenses. Greater emphasis is also placed on the demand of having a good scrum, as this will provide good possession to the backline during attacking play. Lineouts are more often used to create an attacking base and set up the maul. Due to the increase in kicks in modern rugby, it is obvious that lineouts would increase. Lineouts showed a significant increase ( $p=0.0156$ ) over the five seasons. Quarrie and Hopkins (2007) noted that time trends revealed an increase in the number of rucks. On the contrary, our data revealed an increase in the number of rucks from 2011 to 2013 and then a slight decrease to 2015. In three of the five seasons, losing teams had less penalties awarded to them, or the opposite could be true regarding winning teams conceding less penalties than losing teams but showed no significance. These results contradict previous research.

Williams *et al.* (2005) analysed the effects of the January 2000 rule changes on the match and ball in play time across five years during major international and national competitions, and found a significant increase between 1999 and 2003. Changes in playing time will also be noted in different levels of play and different competitions. Playing time can be influenced by the game plan of a team and weather conditions. Close games with small winning margins have higher playing times, as the losing teams try to keep the ball in hand to score a try and therefore will go well into injury time. The decrease of overall playing time is surprising as previous research showed this as an area where increases are most likely to occur. Quarrie and Hopkins (2007) reported that increases in performance indicators such as the number of passes, tackles, rucks, tries and ball-in-play time were associated with the advent of professionalism.

##### **Winning and losing**

Previous research reported that the phases of obtaining the ball, and more specifically in scrums, winning teams lose fewer balls than losing teams (Ortega *et al.*, 2009), supporting our results with regard to the 2011–2015 Super Rugby seasons. Our findings support Vaz *et al.* (2010) who showed that winning teams in international and regional matches during 2003 and 2006 were consistently more effective at retaining the ball on their own lineout than losing teams. From 2011 to 2015, winning teams consistently lost fewer lineouts than losing teams, even with an overall increase in the number of lineouts per game. Our study indicates an increase in the number of tackles, especially by the winning teams, and supports the fact that winning teams have higher tackle rates than losing teams. Winning teams have shown that they have better defensive capabilities (Hunter & O'Donoghue, 2001) and missed fewer tackles than losing teams (Prim *et al.*, 2007). Our results showed that winning teams missed 11.2% and 14.3% of tackles in 2011 and 2015, respectively, while losing teams missed 12.5% and 14.4% of tackles in these two seasons, respectively. These numbers are more noteworthy when considering that winning teams had to make more tackles. It should be kept in mind that player size and physical attributes have also increased over the last

number of years. This means that attacking players are running harder at the defence and create higher speeds and power that can break tackles. It is understandable that the tackles by winning teams remain higher than losing teams, because of the higher possession by losing teams. Winning teams tend to have better defensive structures and higher tackle completion rates than losing teams, although the missed tackles were higher for winning teams in 2015. The increased in missed tackles showed statistical significance ( $p < 0.001$ ), while tackles made ( $p = 0.0673$ ) were not statistically significant, but did show an important trend. Winning teams can withstand long periods of defence due to better tackle percentages and structure.

### **Territory and possession**

The current findings also contradict Van den Berg and Malan (2010) who identified possession, territory and discipline as the most important factors for teams to be successful and score points. Our data revealed that winning teams had less possession and less territory than the losing teams from 2011 to 2015. It is not the higher possession or territory of losing teams that will secure wins, but rather the quality and use of possession.

## **5. Conclusions and recommendations**

This article reports combined counts for performance indicators for the winning and losing teams involved in 30 matches per season, in matches played from the 2011 to 2015 Super Rugby seasons in South Africa, New Zealand and Australia. Our results show that there is an evolution of the game of rugby within only five seasons, which emphasises the importance to regularly analyse available match data.

It can be concluded that playing time and scrums lost decreased, while lineouts, scrums, rucks, mauls, tackles and tackles missed increased from 2011 to 2015, with no notable change in lineouts lost or penalties. From 2011 to 2015, losing teams had more lineouts and may suggest that winning teams were able to clear the ball better after sustained periods of pressure. This improvement in lineouts between winning and losing teams becomes more apparent when the lineouts lost were evaluated. Losing teams tend to lose more lineouts than winning teams, which is an indication of good lineout contesting by winning teams. The maul is a very effective attacking tool for teams with strong forwards to score tries and also compliments good lineout play. Limitations of the study may include the fact that quality of possession needs to be argued and determined to ensure the true effects of territory and possession of teams.

The findings may be important for future research as they indicate a shift in the behaviour of teams over seasons within a particular competition and how they differ between teams from various countries. Previous studies have been conducted over larger time spans. Future studies may include the examination of external factors such as game plan and weather conditions which still influences the game of rugby, and therefore, all performance indicators.

## **6. Practical application**

Performance indicators measured for teams over seasons emphasise the different physiological demands for and preparation of teams. It is recommended that coaching and conditioning be designed to improve these performance indicators by including a substantial amount of tackling,

rucking, and mauling. Coaches need to be aware of the differences in the number of scrums and lineouts when planning training programs. Players are getting bigger and more conditioned to perform higher numbers of mauls and break tackles. Teams seeking improvement need to increase tackle completion, improve lineout contesting and focus on the maul as an attacking weapon.

### **7. Acknowledgements**

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## Chapter 7 Summary, conclusions and recommendations

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## 7.1 Summary

Professional coaches including conditioning and specialist coaches, players and teams are on an endless quest for perfection in their sport. Through continuous research of topics similar to this study, researchers will be able to provide some answers to questions that arise from participation at different levels of play, demands of various positions and seasonal changes in the sport. With professional status, rugby has evolved into a faster, more dynamic sport with greater emphasis on the physical elements of matches, which means players are involved in more frequent and powerful contact situations (Eaves & Hughes, 2003). Liebermann, Katz, Hughes, Bartlett and McClements (2002) also concluded that as the game changed, so did the use of science and technology increase in the game of rugby, allowing for more practical and accurate methods of describing the demands of the sport. More accurate statistics can contribute greatly to the success of players and teams. It must be understood that many variables can influence the outcome of a match, such as weather conditions, competition structure and opponents. Statistics alone and by perfecting these statistical variables do not guarantee success, but can certainly contribute to the improvement of game plans that teams follow, finding weaknesses and strengths, and motivate players to improve their performance.

The game of rugby union underwent numerous changes over the past few years and is also seen in the different levels of play as attention is moved from Currie Cup to Super Rugby. This is evident in the changes of playing time, differences in number of open play kicks, the number of passes by winning and losing teams, and the increase in phases such as rucks and mauls. The general match profile of Super Rugby has moved to a game with fewer scrums and kicks and more ball carries and tackles (Kraak *et al.*, 2016). All these changes can be influenced by improved coaching and training techniques and regimes used. Coaches spend hours to find new and innovative training methods to enhance player technique. Improved skills have decreased the number of scrums, because of less knocks and forward passes. Hendricks *et al.* (2013) indicated that success in rugby is dependant partly on the defensive strategies of teams. With this in mind, players are bigger and stronger than ever. More tackles are broken and there is an increase in line breaks. This is evident in the levels of play from amateur to professional. The better the defence means fewer metres can be

gained by the opposition on attack. Teams also employ a variety of team tactics to gain metres on attack, which can include higher number of ball carries. Higher numbers in ball carries means more tackles, rucks and passes. This indicates that increases in one phase of rugby statistics can influence multiple other phases of rugby statistics. Players are also getting more skilful with the apparent increase in off loads and increase in passing. Abilities of players are getting more and better. Passing distance, speed and accuracy is improving, while kicks out of hand show greater distances.

It can be concluded that rugby have improved dramatically over the last couple of years. Winning teams tend to kicks more, have improved tackle completion rates and are more effective in phases such as lineouts and scrums. Losing teams tend to pass more, set up more rucks and show a decreased distance gained through kicks in play. Over seasons of Super Rugby, the maul is shown to be a very effective tool for try scoring, while tackles and the number of missed tackles have increased. Playing time decreased over the last 5 years within the Super Rugby competition. Differences between levels of play are also evident in the number of mauls, rucks, tackles, lineouts and scrums. Positional differences have been noted in terms of collision and tackle rates of players as loose forwards receive the most contact of all the players. The study also identified that forwards are involved in many more game events versus backline players.

The final conclusions for each research question follow this summary.

## 7.2 Conclusions

### 7.2.1 Research question 1

In comparison to other global team sports, the demand of the game is significantly increased by the frequency of physical collisions that occur during match play (Gabbett, 2015). Quarrie *et al.* (2012) identified that players are typically involved in 10-22 tackles per game, while Austin *et al.* (2011) concluded that the involvement in physical collisions, rugby union players are regularly exposed to 7-17 repeated high-intensity effort bouts (three or more sprints, scrums/rucks/mauls or tackle efforts with less than twenty-one seconds between efforts) per game. The presence of contact contributes significantly to the physical exertions experienced by rugby union players

(Johnston *et al.*, 2014). This study concluded that there are significant differences between individual playing positions within the same positional group with regard to tackling and collision rates sustained during match play. It is important to note that forwards generally have the highest rates of tackles and collisions, which implies a higher demand for recovery and conditioning. It would also be unfair to compare the scrum-half (16.32 collisions per game) with a centre (32.34 collisions per game) as the norm, although conventionally they are grouped as inside backs. Therefore it is suggested to monitor player recovery from one position to the next

### 7.2.2 Research question 2

The results of this study suggests that, firstly, losing teams pass more than winning teams and agrees with Vahed *et al.* (2016) that reported an increase in the number of passes completed from 2007 to 2013 ( $104.8 \pm 19.6$  vs.  $113.6 \pm 24.7$ ,  $p = 0.04$ ), and secondly, that winning teams kick more than losing teams. The study also found that a greater distance was gained through kicks by winning teams, although these teams had less attacking minutes. Therefore, winning teams had a greater kicking ratio than losing teams. Losing teams also have a greater passing ratio than winning teams. Winning teams had greater success with kicks in play and metres gained with kicks. Kraak *et al.* (2016) concluded that the decrease in 22m kick restarts can be due to the accuracy of goal kickers and is an area that is very important to the success of a team, which has also led to the appointment of specialist kicking coaches. It would be suggested that teams employ the help of professional kicking coaches to improve the tactical kicking abilities of players.

### 7.2.3 Research question 3

This study showed that a significant difference exist between the winning teams of the different competitions for the variables of mauls ( $p = 0.0074$ ) and missed tackles ( $p = 0.0009$ ). The same variables (mauls,  $p = 0.0071$  and tackles missed,  $p = 0.0014$ ) also show significance when both winning and losing teams from the two competitions (Currie Cup and Super Rugby) are compared. The amount of tackling, rucking, and lineouts are the stand out activities that increase to higher levels of play. Kraak *et al.* (2016) showed that a trend is evident that defending teams were conceded more penalties and free kicks. It would be advisable that teams improve physicality and skills

of players as they move from one level of rugby to the next as players are stronger with higher skill levels as professionalism increase.

#### 7.2.4 Research question 4

The results show that there is an evolution of the game of rugby within only 5 seasons of Super Rugby and emphasize the importance to regularly analyse available match data. Losing teams tend to lose more lineouts than winning teams. It can be concluded that playing time and scrums lost decreased, while lineouts, scrums, rucks, mauls, tackles and tackles missed increased from 2011 to 2015, with no notable change in lineouts lost or penalties. Vahed *et al.* (2016) concluded that rucks/mauls increased significantly from 2007 to 2013 ( $68.9 \pm 12.9$  vs  $84.3 \pm 16.1$ ,  $p < 0.01$ ), while the number of scrums decreased significantly from 2007 to 2013 ( $9.3 \pm 3$  vs  $6.9 \pm 2.4$ ,  $p < 0.01$ ), while the number of lineouts showed a significant decrease ( $15.6 \pm 3.3$  vs  $12.3 \pm 3.1$ ,  $p < 0.01$ ) as the lineouts won and lost both decreased. Kraak *et al.* (2016) also reported significant differences in the number of tries ( $p < 0.01$ ), conversion kicks ( $p = 0.04$ ), penalty kicks ( $p < 0.01$ ) and drop goals ( $p < 0.01$ ) between the 2008 and 2012 Super Rugby seasons. It would be suggested that coaches consistently monitor performance indicators from one season to the next as this can either increase or decrease on a yearly basis. It is advised that coaches stay up to date with latest articles

### 7.3 Recommendations and limitations

A major challenge for practitioners in rugby union is the broad differences in the physical attributes and abilities of players in different positions (Tee, 2015). With the development of GPS technology for use in sport, researchers can now create more profiles for different levels of play, positions, and teams to provide more accurate profiles for the players and conditioning coaches. This was highlighted by a study by Cunniffe *et al.* (2009) who also recommended the evaluation of training loads and activity profiles for players. As a result, coaches are under continual pressure to produce high-quality conditioning and skills training programmes. The relationship between training and physical performance is clearly established, with increases in training load leading to improved performance (Foster, Daines, Hector, Snyder & Welsh, 1996). Therefore, there must be a balance in the training intensities to accommodate needed rest after and before matches.

Research question 1 emphasized the differences between positions and can assist coaches in program design by identifying more strenuous positions that might need more recovery time due to their higher involvement in the match. A possible amendment to the current study may be to evaluate and analyse the effect and impact of substitutions as players do not always finish a match, which can be due to injury or tactical changes to a team.

In answering Research Question 2 the problem that arise from the evaluation of Super Rugby is the possible differences between the playing styles of New Zealand, Australian and South African teams, and is statistics will be able to differentiate between these participating teams. Kraak *et al.* (2016) recommended that performance profiles be developed for tournaments and opponents to help understand what players experience technically, tactically, and physically.

This above mentioned recommendation can also be applied to Research question 3 involving the different levels of play and positions. This will ensure continuous knowledge for coaches to stay up to date with the latest information. Future studies can also include the Varsity Cup as another level in competition as many players evolve from university rugby to Currie Cup to Super Rugby.

It is also important to note that changes in match activities were evident in Research question 4 over only four years of Super Rugby. This highlight the importance of continuous evaluation of the game as rules change or competition structure changes. Evaluating the impact of law changes and patterns of play is essential for conditioning and determining the influence on performance indicators.

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## Chapter 8 Reflections on the Research

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*“I have no special talents. I am only passionately curious.”* – Albert  
Einstein

## 8.1 Introduction

The Webster Dictionary define research as “the diligent inquiry or examination in seeking facts or principles; laborious or continued search after truth; investigation”. For me, research is the end product of curiosity that provides answers to the many questions we have as professionals and scholars in our field of practice. This journey of curiosity, as any other, needs preparation and planning, an enquiring mind, an adventurous spirit, knowing what your final destination should be, and most of all perseverance. Some students are very careful for research and sometimes scared. Yes, it can be infuriating and frustrating, but knowing that you have written something new, proven something right (or wrong) and explored new ways of thinking, research has a way of bringing you back to even bigger ideas and increases the curiosity even more. It provides new insight into the ways we see and experience daily occurrences. It gives us an in depth look at what it takes to be an athlete, a player, a referee or a coach so that we can show the world the intense competition and scientific approach of sports. Ultimately, it improves our knowledge and make us all better coaches, players and fans.

Research provides us with assurance that our way of thinking is not always wrong and no matter who you are, you can change the mind set of even the greatest academic minds. This research process showed me a lot about myself and taught me that we will always need the help of others. This can include a last review from someone else, a helping hand in statistics, and guidance in our academic writing. I will always be thankful for the help of others and it encouraged me to be that mentor for other research students, because I know that you will always need someone to help you. This is sometimes needed in life too. After all the hard work, rewriting, changing of ideas and long hours of reading article after article, this research process is at an end. I am thankful to be finished, but will look back at this process as one of not just obtaining a degree, but one where I developed as a person, lecturer and researcher. I gained friends, new colleagues and family that are also just a little bit more curious. Below are some lessons I have learned.

## 8.2 The research topic

Through my years as researcher, conditioning coach and lecturer, I realised that training a sports team is much harder than originally expected. I always motivate my students to be specific in the prescription of exercise programs by implementing the SAID (Specific Adaptation to Imposed Demands) principle and to do proper assessments of player and team needs. This led me to reading more on profiling of different sports and to determine if these studies focused on positional needs. It never made sense to let the props sprint the same distances as wings or loose forwards. Most research conducted was only performed on positional groups and did not differentiate between players from the same group. For example the wing versus the fullback is classified as outside backs. In research these players is always grouped together, but in reality they are individuals. As a supporter and student of rugby, above mentioned drove me to seek answers to these unknown grouping of players. Furthermore, I decided to compare the losing and winning teams. Rassie Erasmus, coach of the Free State Cheetahs in 2005, compared players' statistics to indicate whether a player had beaten his direct opponent. This led me to believe that individuals can have marked effects on the outcome of the game and motivate players to perform better in the next match.

Another fascination was how match profiling would change from one level of competition to the next. Players comment on how different Super Rugby is when compared to Currie Cup, but will statistics be able to back these comments. My dad always said: "*The players of today are not as strong or hard as players from yester years, and those guys were much tougher*". Again, this statement is not based on fact. The answer will lie in how the game evolved. Therefore, the topic of changes in match demands over seasons of Super Rugby concluded my questions about the game. There are still a lot of questions within the game of rugby union and through research and staying curious; we can hopefully provide answers to all coaches, players, conditioning coaches and fans alike.

### 8.3 Pearls of experience

I was somewhat naïve when I started out on this research journey. I was full of enthusiasm, thinking this was an opportunity for not only gathering research information, but also to increase the knowledge of coaches and conditioning coaches. I thought that coaches and conditioning coaches would share this passion, but was left disappointed. Coaches believed differently and sometimes I had the idea that they did not really grasp the concept of what was being delivered to them. I also had the sense that coaches hold their plans, ideas, training methods very close. Instead they should widen their horizons and implement new information to improve on existing training methods. Conditioning coaches were much more open to new ideas and were willing to learn more, after all it is for them that we are doing all this research. They understood the meaning and effect the study had on training and fitness. They wanted to learn more and even helped with new research ideas.

A couple of things you might need before attempting a research process would be to:

- Learn to type
- Save your work on a regular basis
- Do not use multiple computers or memory sticks
- Backup your work.
- Save the file with the date you last worked on it.
- Understand statistics

#### 8.4 Personal remarks

For me this journey was not a solitary one. My family were my biggest supporters and helped me to work through this process and I am truly thankful. My wife Nadine was also neglected sometimes as a result of this, but her support and love encouraged me to finish even quicker. I also had the best research supervisor anyone can ask for. Prof Derik Coetzee was invaluable and added so much knowledge and experience. He was also the one that made sure I was on track and that everything gets done in time. I am privileged to have him as a supervisor but also a mentor.

When it comes to statistics, I needed someone who understood my needs and what the statistics should say from all that data. Prof Robert Schall was that person. His explanations and statistics are from the top drawer. The data gathering procedure can be lengthy and a real struggle, but thanks to Charl Strydom from the Cheetahs, I might be the one researcher who experienced this as the easiest. Always willing to help and assist, he was just a phone call away. He attended to my problems while he was busy winning a Currie Cup

After this research process I am full of new ideas and new research possibilities. This will see me return, because of all the curiosity.



## Appendices

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*International Journal for performance analysis in sport.*

## **Instructions for Authors**

### **1. Scope**

The International Journal of Performance Analysis in Sport is published on behalf of the Centre for Performance Analysis, Cardiff School of Sport at Cardiff Metropolitan University and in association with the International Society of Performance Analysis in Sport. The emphasis is on the analysis of actual performance in sport and exercise. Studies using observational methods, biomechanical analysis, self-report emanating from actual sports performance, qualitative observation and measurements such as heart rate response during actual sports performance are all within the scope of the journal. Laboratory studies of key techniques within sports are also of interest where such techniques are clearly important and cannot be analysed in detail during actual competition. Such techniques include tennis serves and golf swings. There may be other contributions that do not analyse sports performance at all that are within the scope of the journal. For example, interview studies or meta-analyses may lead to theoretical contributions explaining the nature of sports performance, tactics used and factors influencing performance. Review articles relevant to sports performance are also welcome. Other topics covered include technologies such as design of analysis systems, sports equipment, research into training, and modelling and predicting performance. Contributors wishing to clarify whether papers they are writing are within the scope of the journal are welcome to contact the general editor.

The volume of papers published by the journal has increased from 40 in 2008 to 68 in 2013 and as a consequence the quality of accepted papers has also increased. Authors should use the most recent issues of the journal to understand the required quality. Authors should ask themselves the following questions when preparing a paper.

(a) Does the paper report on a substantive research exercise? If the data could be gathered and analysed over a single weekend, the authors should consider submitting the work for poster presentation at a conference.

(b) Is the research sufficiently original? Will the paper have impact? Does the paper make a contribution to our knowledge of something important about sports performance?

(c) Does the research warrant the number of authors listed on the paper? This has become a problem with a lot of recent submissions where the nature and volume of the work certainly does not warrant the number of authors included. In cases like this, the paper has not been sent for review and has been rejected by the editor.

(d) Is the analysis sufficiently rigorous? Authors should consider the reliability of methods used, the units of analysis used, the choice of independent and dependent variables and the assumptions of any statistical tests used. In saying this, there is nothing wrong with original descriptive research and authors should avoid complex predictive modelling designs where these are not appropriate.

(e) Does the paper fit within the scope of the journal? Sports performance analysis does involve a more expanded array of methods and types of study these days. However, there have been papers submitted to the journal that are clearly not performance analysis papers. Some of these papers are of a very high quality in all other respects, but they are simply not within the scope of the journal.

## **2. Submission**

Authors must submit an original article in electronic form, (preferably by e-mail) in Microsoft Word, to the General Editor (podonoghue@cardiffmet.ac.uk). Papers submitted to the Journal will be refereed blind by acknowledged experts in the subject. The General Editor has the final decision on publication. No word limits are specified for papers, but discursive treatments of the subject matter are discouraged. The Journal does not normally publish letters to the editor. Due to the volume of papers submitted, we now require authors to provide the names of three potential expert independent reviewers for their paper.

## **3. Originality**

All material submitted for publication in the journal must be accompanied by a statement by the lead author, with the authority of all of the authors, that: the material submitted is original and unpublished, and is not under consideration for publication elsewhere and that the material will not be submitted for publication elsewhere while it is under consideration by the journal.

## **4. Format**

Papers consist of a title page, blind title page and the main text of the paper. Figures and tables should be included in the text rather than following the text. Typical sections of the text are Introduction, Methods, Results, Discussion, Conclusions, any acknowledgements, References and author correspondence details. However, it is acceptable to have a conclusions paragraph at the end of the discussion. Further variation is possible for review articles or where papers report on a series of studies which are best reported in a study by study order.

### *Page Layout*

Pages must be A4 using margins of 3cm at the top, bottom, left and right. Portrait orientation is used except where landscaped orientation clearly assists the presentation of tables and / or figures. Paragraph text should be single spaced.

### *Title Page*

The title page should contain the title (Times Roman, size 18, bold), author names using first names, other initials and surnames and affiliations of authors, the abstract and key words. All text other than the abstract should use Times Roman size 12 font. The abstract should be bold and in italics not exceeding 200 words. It should be inserted in the article after the authors' affiliations and indented by 1 cm at the left and right. The abstract should not contain figures or tables.

### *Blind Title Page*

This should include all of the information on the title page except the author names and affiliations. Where acknowledgements or information in the methods about ethical clearance may compromise the blind reviewing process, the General Editor will temporarily remove this information while the paper is being reviewed.

### *Headings*

Headings and subheadings should all be in Times Roman font, bold and size 12. Headings should be numbered 1., 2., 3., etc with any subheadings being 1.1., 1.2., for example.

### *Tables*

Tables should normally only include horizontal lines to mark the top and bottom and separate column headings from the main body of tables. Tables must be created in word to facilitate any necessary editing by the journal. There are occasions, where correlation tables, for example, require vertical lines and this is acceptable. Table captions should appear above the table.

### *Figures*

Illustrations, photographs, screen dumps, charts, plates and any other artwork should be included in the electronic submission. Authors must have permission to use any photographs within the paper and copyrighted material from published sources must not be included as Figures in the paper. Figure headings should be placed below figures.

### *Symbols, units and abbreviations*

Symbols, units and abbreviations in papers must conform to the *Système International d'Unités* (SI Units). Authors are advised to consult the National Physical Laboratory publication (R.J. Bell (ed. ), 1993, *SI: The International System of Units*. London: HMSO). For all abbreviations other than units, write the word or words to be abbreviated in full on the first mention followed by the abbreviation in parentheses. If at all possible, group these definitions together near the beginning of the article. As indicated earlier, avoid use of nonstandard abbreviations, especially fabricated ones, within the text; words are much easier to read and follow than abbreviations.

### *References*

References in the text are cited as follows: Smith (1985) ... or (Brown and Green, 1996) ... or, if there are more than two authors, as Jones *et al.* (1993) ... or (Jones *et al.*, 1993). Citations of different publications by the same author(s) in the same year are differentiated as Green (1993a) ... (Brown *et al.*, 1995b); the a, b, c, etc. , are normally in order of citation in the text. Multiple citations are listed in ascending chronological order. Multiple publications by the same authors are treated in lists: Smith (1991, 1995), Brown and Green (1992, 1993), Jones *et al.* (1993, 1996a,b); or (Smith, 1991, 1995; Brown and Green, 1992, 1993; Jones *et al.*, 1993, 1996a,b). A list of all cited references should be collected at the end of the paper in alphabetical order by, in the first instant, the first author's surname. Where the name of the first author appears more than once, the order is determined by: first, the number of co-authors (zero, one, or more than one); secondly, for one co-author, the first co-author's surname then the year; for two or more co-authors, year then order as dictated by the use of 1990a,b,c (for example) in the citations. The following is an example of how references would be ordered in the reference list: Brown (1980), Brown (1990), Brown and Jones (1977), Brown and Smith (1973), Brown and Smith (1975), Brown *et al.* (1990a), Brown *et al.* (1990b), Brown *et al.* (1990c). Note that the last three examples would all have been cited as Brown *et al.* in the text, with the a, b and c relating to the order of citation. The names and initials of all authors should be given in the list of references. The style should follow the examples below:

#### Journal Papers

Newton, P.K. and Keller, J.B. (2005), The probability of winning at tennis, *Theory and Data, Studies in Applied Mathematics*, 114, 214-269.

#### Books

Ashe, A. (1981), **Arthur Ashe's Tennis Clinic**. London: Heinemann.

Chapters of Edited Books (including conference proceedings published as books)

Hughes, M. and Clarke, S. (1995), Surface effect on elite tennis strategy. In Reilly, T., Hughes, M. and Lees, A. (Eds.) **Science and Racket Sports** (pp. 272-277). London: E & FN Spon.

Conference abstracts published in journals

O'Donoghue, P.G. (2003), The effect of scoreline on elite tennis strategy: a cluster analysis. **Journal of Sports Sciences**, 21, 284-285.

### **5. Proofs**

Once accepted papers have been edited, the PDF versions will be sent to the authors for final checking and final editing.

### **6. Copyright**

Submission of a paper to the International Journal of Performance Analysis in Sport is taken to imply that it represents original, unpublished research and that authors agree that the International Journal of Performance Analysis will have copyright to the material.

### **INFORMATION FOR AUTHORS**

The *South African Journal for Research in Sport, Physical Education and Recreation* is published by Stellenbosch University. Contributions from the fields of Sport Science, Physical Education, Recreation/Leisure Studies, Exercise Science and Dance Studies will be considered for publication. The articles submitted will be administered by the appropriate Subject Review Editor and evaluated by two or more referees. The decision as to whether a particular article is to be published or not, rests with the Editorial Board.

### **SUBMISSION**

Manuscripts that do not comply with the following requirements regarding process, style and format will not be handled. Manuscripts should be typed with **one and a half spacing** in 12-point Times New Roman letter size. The original manuscript can be submitted by e-mail. The length may not exceed 20 pages (tables, figures, references, etc. included). The **page setup** (cm) must be in the following format:

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*Top:* 3.56 cm *Width:* 17.5 cm

*Bottom:* 1.78 cm *Height:* 24.5 cm

*Left:* 2.11 cm

*Right:* 2.11 cm

*Gutter:* 0.00 cm

*Header:* 2.03 cm

*Footer:* 0.89 cm

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Each manuscript must be accompanied by a cover letter in which the following is declared:

(1) that the manuscript contains original research; (2) that the manuscript or parts of the manuscript has not been published elsewhere previously; (3) that the manuscript is not currently being presented elsewhere for publication; and (4) that all the authors have read and approved the manuscript. This signed declaration regarding the originality must accompany each manuscript.

Authors are also requested to name three (3) potential referees, of which one (1) **must** be an international referee (the journal is not bound to use these referees). Complete information regarding the referees (name, surname, e-mail address and telephone numbers) must be *South African Journal for Research in Sport, Physical Education and Recreation* provided in the cover letter.

We discourage the practice of parts of one study in different journals. Authors who submit a manuscript from a study of which some data has been or will be published elsewhere, must provide a strong justification in an accompanying letter to the Editor. The justification for not publishing all the data together in one paper must also be motivated in the covering letter. Should the article be taken from a master's thesis or doctoral dissertation, academic ethic requires that the student will be the first author.

The author should also ensure that the **LANGUAGE** of the manuscript has been thoroughly edited at the time of submission (English [UK]). The name, address and telephone number of the person who has done the language editing must be provided. Any expenses incurred by the journal dealing with language editing will be added to the author's page fees.

The manuscript must have an **ETHICAL CLEARANCE NUMBER** that was supplied by authentic ethical committee of a specific institution. The process that was followed to obtain ethical clearance must be described in the manuscript under the heading **Ethical clearance**. No manuscript can be published without this declaration.

Any uncertainty regarding the **STATISTICAL PROCEDURES** that arise during the assessment of the manuscript will be referred to a local statistician. Any expenses incurred by the journal dealing with statistical procedures will be added to the author's page fees.

## **PREPARATION OF MANUSCRIPT**

Manuscripts must be presented in a format that is compatible with *Microsoft Word for Windows* (PC). Tables, all figures (illustrations, diagrams, etc.) and graphs are also regarded as text and must be presented in a format that is compatible with *Word*. Photographs must be presented in *jpg* format.

Original manuscripts must contain the following sections in the following sequence: Title page, Abstract, Introduction, Methodology, Results, Discussion, Practical application, Conclusions, Acknowledgements and References.

### **Title page**

The first page of each manuscript should indicate the *title* in English and Afrikaans (will be translated for foreign authors), the *names* (**title, first name in full and other initials, surname**) of the author(s), the *telephone* numbers (work & home [Mobile – for local authors]), *facsimile* number, *e-mail* address (if available) and the *field of study*. The **complet mailing address** of the first named author and the institution where the work was conducted should be provided in full. When more than one author and/or authors from various departments are involved the **1author(s)** must be numbered according to their **1department(s)**. If any of the above-mentioned information should change during the review process, please inform the subject editor. A **short title**, of not more than **45 characters** including the spaces, should be provided for use as a running head.

### **Abstract**

Each manuscript must be accompanied by an abstract of approximately 150-200 words in *English* and should be set on a *separate page* as a **SINGLE** paragraph (one and a half *South African Journal for Research in Sport, Physical Education and Recreation* spacing). A list of three to seven **key words** in *English* is required for indexing purposes and should be typed below the abstract. Articles in Afrikaans must include an **additional** extended summary

(500-1000 words) in English. This summary must start on a new page (just before the reference list) and also provide the English title of the article at the beginning.

### **Text**

Start the text on a new page with the title of the article (centred and *without* the names of the authors). Follow the style of the most recent issue of the journal regarding the use of headings and subheadings. Use only **one space** after a paragraph. Only make use of *section breaks* and not *page breaks*. The text, as well as the tables and figures, may under **no circumstances** be in any other format than **normal**. Thus, no *style sheets* may be used.

### **Tables and figures**

Tables and figures should be numbered in *Arabic* numerals (1, 2, etc.). Tables require the heading at the *top* while figures a legend *below* and both separate from the table/figure. **Note:** Use the decimal POINT (**not** the decimal comma). The site where the table or figure must be placed in the text must be indicated clearly in the manuscript. ***Tables and figures are placed after the reference list with each on a separate page.***

### **References**

In the *text* the Harvard method must be adopted by providing the author's surname and the date placed in parentheses. *For example:* Daly (1970); King and Loathes (1985); (Botha & Sonn, 2002); McGuines *et al.* (1986) or (Daly, 1970:80) when Daly is not part of the sentence. More than one reference must be arranged **chronologically** (Daly, 1970; King & Loathes, 1985). Note that *et al.* (italics) is used in the body of the text when there are **more than two authors**, but never in the list of references.

### **List of references**

Only the references cited in the text should be listed alphabetically according to surname (last name) of authors (capitals) after the body of text under the heading, **References** (capitals) starting on a new page. In the case where the TITLE of an article, book, etc., is in any other language than English, the author must also provide an English translation of the title in parentheses.

In the case of articles published in **JOURNALS**, references listed should include the surnames and initials (capitals) of all authors, the date of the publication in parentheses, the full title of the article, the full title of the journal (italics), the volume number, the serial number in parentheses (omitted **only** if the said journal does not use issue numbers), followed by a colon and a space with the first and last page numbers separated by a hyphen.

#### *Example:*

VAN WYK, G.J. & AMOORE, J.N. (1995). A practical solution for calculating instantaneous values of tension in the extensor muscles of the knee joint during extension and flexion. *South African Journal for Research in Sport, Physical Education and Recreation*, 18(1): 77-97.

If the reference is a **BOOK**, the surname (last name) and initials of the author or editor (Ed.) must be given, followed by the date of publication in parentheses, the title of the book (italics) as given on the title page, the number of the edition (ed.) in parentheses, the city (and abbreviation for the state in the case of the USA OR the country [in curved parentheses]) where published, followed by a colon, a space and the name of the publisher.

*South African Journal for Research in Sport, Physical Education and Recreation*

*Example:*

JEWETT, A.E.; BAIN, L.L. & ENNIS, C.E. (1995). *The curriculum process in Physical Education* (2nded.). Madison, WI: WCB Brown & Benchmark.

For a **CHAPTER** from a book, the page numbers of the chapter cited must be provided in parentheses (not italics) after the title of the book. For further details, authors should consult the most recent publication of this Journal for other examples.

*Example:*

DE RIDDER, J.H. (1999). Kinanthropometry in exercise and sport. In L.O. Amusa, A.L. Toriola, I.U. Onyewadume (Eds.), *Physical Education and sport in Africa* (pp.235-263). Ibadan (Nigeria): LAP Publications.

If the reference is a THESIS (master's level) or DISSERTATION (doctoral level), italics is **not** used in the title as it is an unpublished work.

*Example:*

CRAVEN, D.H. (1978). The evolution of major games. Unpublished PhD-dissertation. Stellenbosch: Stellenbosch University.

For **ELECTRONIC SOURCES**, all references start with the same information that would be provided for a printed source (if available). The web page information follows the reference. It will usually contain the name of the author(s) (if known), year of publication or last revision, title of complete work in inverted commas, title of web page in italics, Uniform Resource Locator (URL) or access path in text brackets (do not end the path statement with a full stop) and date of access. See "*How to cite information from the Internet and the Worldwide Web*" at <http://www.apa.org/journals/webref.html> for specific examples. When citing a web site in the text, merely give the author and date (in this case: Ackermann, 1996).

*Example of Web Page:*

ACKERMANN, E. (1996). "Writing your own Web Pages." *Creating Web Pages*. Hyperlink: [<http://www.mwc.edu/ernie/writeweb/writeweb.html>]. Retrieved on 22 October 1999.

When referencing an article in a **NEWSPAPER** the key word of the newspaper is typed in capitals, as this is how **it will appear in the alphabetical references**, namely *The CAPE ARGUS* will appear under "C" or *Die BURGER* will appear under "B".

*Example:*

*CAPE ARGUS (The)* (1980). 10 January, p.4.

**INTERVIEWS**

*Example:*

POTGIETER, J.R. (2003). Personal interview with the Chairperson of the Department of Sport Science. 31 January.

Stellenbosch: Stellenbosch University.

**CORRESPONDENCE**

*Example:*

POTGIETER, J.J.J. (2003). Personal correspondence of the Director of the Sport Bureau, 5 February. Stellenbosch:

Stellenbosch University.

### **CONGRESS PROCEEDINGS**

*Example:*

RENSON, R. (Ed.) (1976). *The history, the evolution and diffusion of sport and games in different cultures.*

Proceedings of the 4th International HISPA Congress, Leuven, Belgium, 1-5 April 1975. Brussels (Belgium):

B.L.O.S.O.

*South African Journal for Research in Sport, Physical Education and Recreation*

When referring to a paper presented in the above-mentioned proceedings, it must be presented as follows:

REES, R. (1976). Organisation of sport in nineteenth century Liverpool. In R. Renson (Ed.), *The history, the evolution and diffusion of sport and games in different cultures* (pp.237-247).

Proceedings of the 4th

International HISPA Congress, Leuven, Belgium, 1-5 April 1975. Brussels (Belgium):

B.L.O.S.O.

### **ADMINISTRATION**

If authors honour the rules and specifications for the submission of manuscripts, unnecessary delays would be avoided. A manuscript that does not meet the requirements, as set out above, will be returned to the author without being evaluated. Requesting copying right concerning figures or photographs is the responsibility of the authors and should be indicated.

The corresponding author will receive a complimentary copy of the journal and five reprints of the article. The original manuscripts and illustrations will be discarded one month after publication unless a request is received to return the original to the first-named author. A page fee of **R300** per page is payable on receipt of an account issued by the Editor.

### *The African Journal for Physical Activity and Health Sciences (AJPHEs)*

#### **AIM**

The African Journal for Physical Activity and Health Sciences (AJPHEs) is a peer-reviewed journal established to:

- i) Provide a forum for health specialists, researchers in physical activity, professionals in human movement studies as well as other sport-related professionals in Africa, the opportunity to report their research findings based on African settings and experiences, and also to exchange ideas among themselves. Research-related contributions by specialists in physical activity and health sciences from other continents are also welcome.
- ii) Afford the professionals and other interested individuals in these disciplines the opportunity to learn more about the practice of the disciplines in different parts of the continent.
- iii) Create an awareness in the rest of the world about the professional practice in the disciplines in Africa.

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AJPHEs publishes research papers that contribute to knowledge and practice, and also develops theory either as new information, reviews, confirmation of previous findings, application of new teaching/coaching techniques and research notes. Letters to the editor relating to the materials previously published in AJPHEs could be submitted within 3 months after publication of the article in question. Such letter will be referred to the corresponding author and both the letter and response will be published concurrently in a subsequent issue of the journal. Manuscripts are considered for publication in AJPHEs based on the understanding that they have not been published or submitted for publication in any other journal. In submitting papers for publication, corresponding authors should make such declarations. Where part of a paper has been published or presented at congresses, seminars or symposia, reference to that publication should be made in the acknowledgement section of the manuscript. AJPHEs is published quarterly, i.e. in March, June, September and December. Supplements/Special editions are also published periodically.

#### **SUBMISSION OF MANUSCRIPT**

Original manuscript and all correspondence should be addressed to the Editor-In-Chief:

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Thohoyandou 0950

Republic of South Africa

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#### **PREPARATION OF MANUSCRIPT**

Manuscripts should be type written in fluent English (using 12-point Times New Roman font and 1½ line-spacing) on one side of white A4-sized paper justified fully with 3cm margin on all sides. In preparing manuscripts, MS-Word, Office 2007 for Windows should be used. Length of manuscripts should not normally exceed 12 printed pages (including tables, figures, references, etc.). For articles exceeding 12 typed pages US\$ 10.0 is charged per every extra page. Authors will be requested to pay a publication fee to defray the very high cost of publication. The pages of manuscripts must be numbered sequentially beginning with the title page. The presentation format should be consistent with the guidelines in the publication format of the American Psychological Association (APA) (6<sup>th</sup> edition).

#### **Title page**

The title page of the manuscript should contain the following information:

Concise and informative title.

Author(s) name(s) with first and middle initials. Authors' highest qualifications and main area of research specialisation should be provided.

Author(s) institutional addresses, including telephone and fax numbers.

Corresponding author's contact details, including e-mail address.

A short running title of not more than 6 words.

### **Abstract**

An abstract of 200-250 words is required with up to a maximum of 5 keywords provided below the abstract. Abstract must be typed on a separate page using single line spacing, with the purpose of the study, methods, major results and conclusions concisely presented. Abbreviations should either be defined or excluded.

### **Text**

Text should carry the following designated headings also using single line spacing: Introduction, materials and methods, results, discussion, acknowledgement, references and appendices (if appropriate).

### **Introduction**

The introduction should start on a new page and in addition to comprehensively giving the background of the study it should clearly state the problem and purpose of the study. Authors should cite relevant references to support the basis of the study. A concise but informative and critical literature review is required.

### **Methodology**

This section should provide sufficient and relevant information regarding study participants, ethics/informed consent, instrumentation, research design, validity and reliability estimates, data collection procedures, statistical methods and data analysis techniques used. Qualitative research techniques are also acceptable.

### **Results**

Findings should be presented precisely and clearly. Tables and figures must be presented separately or at the end of the manuscript and their appropriate locations in the text indicated. The results section should not contain materials that are appropriate for presentation under the discussion section. Formulas, units and quantities should be expressed in the *systeme internationale (SI)* units. Colour printing of figures and tables is expensive and could be done upon request at authors' expense.

### **Discussion**

The discussion section should reflect only important aspects of the study and its major conclusions. Information presented in the results section should not be repeated under the discussion. Relevant references should be cited in order to justify the findings of the study. Overall, the discussion should be critical and tactfully written.

### **References**

The American Psychological Association (APA) format should be used for referencing. Only references cited in the text should be alphabetically listed in the reference section at the end of the article. References should not be numbered either in the text or in the reference list. Authors are advised to consider the following examples in referencing:

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In compiling the reference list at the end of the text the following examples for journal references, chapter from a book, book publication and electronic citations should be considered:

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Journal references should include the surname and initials of the author(s), year of publication, title of paper, name of the journal in which the paper has been published, volume and number of journal issue and page numbers.

For one author: McDonald, A.K. (1999). Youth sports in Africa: A review of programmes in selected countries. *International Journal of Youth Sports*, 1(4), 102-117. For two authors: Johnson, A.G. & O'Kefee, L.M. (2003). Analysis of performance factors in provincial table tennis players. *Journal of Sport Performance*, 2(3), 12-31.

For multiple authors: Kemper, G.A., McPherson, A.B., Toledo, I. & Abdullah, I.I. (1996). Kinematic analysis of forehand smash in badminton. *Science of Racket Sports*, 24(2), 99-112.

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For edited references: Amusa, L.O. & Toriola, A.L. (Eds.) (2003). *Contemporary Issues in Physical Education and Sports* (2<sup>nd</sup> ed.) (pp. 20-24). Makhado, South Africa: Leach Printers.

For chapter references in a book: Adams, L.L. & Neveling, I.A. (2004). Body fat characteristics of sumo wrestlers. In J.K. Manny & F.O. Boyd (Eds.), *Advances in Kinanthropometry* (pp. 21-29). Johannesburg, South Africa: The Publishers Company Ltd.

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Electronic sources should be easily accessible. Details of Internet website links should also be provided fully. Consider the following example:

Wilson, G.A. (1997). Does sport sponsorship have a direct effect on product sales? *The Cyber- Journal of Sport Marketing (online)*, October, 1(4), at <http://www.cad.gu.au/cjism/wilson.html>. February 1997.

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28 October 2013

Mr R. Schoeman  
Department of Exercise and Sport Sciences  
UFS

**Ethical Clearance Application: Time motion analysis of international rugby AND  
Guidelines for positional specific coaching, conditioning and rehabilitation of rugby union  
players**

Dear Mr Schoeman

With reference to your application for ethical clearance with the Faculty of the Humanities, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence, is:

**UFS-HUM-2013-009**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension in writing.

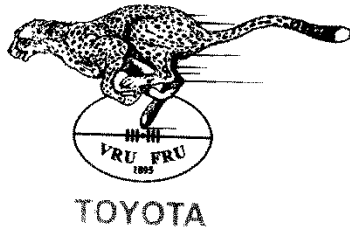
We request that any changes that may take place during the course of your research project be submitted in writing to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours sincerely,

Katinka de Wet  
Ethics Committee (Faculty of the Humanities)  
Copy: Ms Charné van der Walt (Research Co-ordinator)





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**12 September 2013**

**To Whom It May Concern,**

**I, Michael Horak, hereby authorises Mr Riaan Schoeman to use the data gathered by myself in my work for the Toyota Free State Cheetahs for his academic research.**

**I hope that there will be feedback on his findings and look forward to receiving a copy.**

**Kind regards**

**Michael Horak**  
**Assistant Coach**



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Rugby statistics that discriminate between rugby teams,  
levels of play and changes through seasons

Author: Riaan Schoeman

Nature of document: PhD Thesis (Article-style), Dept of Exercise and Sports Sciences, Faculty of Health Sciences, UFS

Date of this statement: 14 November 2016

AM Grobler