THE SIGNIFICANCE OF DOMINANT BALL CARRYING COLLISIONS AS AN INDICATOR OF SUCCESS IN RUGBY UNION AND THE BIOMECHANICAL ANALYSIS THEREOF

by

ASHLEY EVERT

submitted in partial fulfillment of the requirements for the degree DOCTORATE PHILOSOPHIAE

in the

Faculty of Humanities
Department of Biokinetics, Sport and Leisure Sciences
University of Pretoria

February 2006

Pretoria
DEDICATION

This dissertation is dedicated to my very special wife Michelle and our daughter Nicola, as well as my mother Aletta Evert and my grandparents Stan & Sue Evert who have always supported me and been there for me! You have all left an indelible mark on me.
ACKNOWLEDGEMENTS

I would appreciate the opportunity to thank the following people and institutions for their guidance and help in order to successfully complete this study.

**Prof. P.E. Krüger (Promoter):** Department Biokinetics, Sport and Leisure Sciences, University of Pretoria). For your time, guidance and continuous support. I have had many years of contact with you and it has been a privilege. I look forward to working with you in the future.

**To my Family:** Leta Evert, Stan & Sue Evert, John & Trinette Evert, Michelle, Lorraine & Monique Evert, Gerhard & Haricklia Roux, Jacques Roux. Thank you for your support and guidance during my studies.

**Gerrie de Jongh:** Thank you for your help with the statistical input and advice. You have been a wonderful friend and I am grateful that I could share my thoughts and ideas on this study with you knowing that we could together put together the scientific thinking necessary to complete this study.

**The following friends at the Blue Bulls who are an inspiration and who have been the best of friends:** Heyneke Meyer, John MacFarland, Johan van Graan, Dr Tommie Smook, Wynie Strydom, Hennie Kriel, Mike Bayly, Vlok Cilliers, Pote Human, Basil Carzis, Carlin Fullard, Daliah Hurwitz, Stephan Pretorius.

**To my Colleagues who have always supported me and stood by me through many trials and challenges:** Pieter Terblanche, Ian Schwartz, Nico Serfontein, Denzil Frans, Ernst Slabbert, Dean du Rand, Karin Visser, Andries Kabinde and the late Josiah Tshetlo.

**To the following coaches and friends who have impacted on my coaching career:** Neil de Beer, Pieter de Villiers, Dumisani Mhani, Neels Liebel, Dr Jason Suter, Oom Willem Boshoff, Danie du Toit, Arni van Rooyen, Chris Heunis.
To all the players of the following teams that I have been involved with and who have filled my life with the joy of coaching:

Blue Bulls U21 – 2001 (Currie Cup U21 Semi-Finalists);
Blue Bulls U21 – 2002 (Currie Cup U21 Champions);
Blue Bulls U20 – 2003 (Currie Cup U20 Champions);
Bulls Super 12 – 2004
Blue Bulls U20 – 2004 (Currie Cup U20 Champions);
South Africa U21 – 2004 (3rd Place at the IRB World Championship);
Blue Bulls Vodacom – 2005 (Semi-Finalists);
Blue Bulls U21 – 2005 (Currie Cup U21 Champions); and

Riël du Toit: Most of what I know about coaching is due to the time we spent working together as coaches and as friends. Thank you for your support and the coaching path we have taken thus far. Although we might not be coaching together at this stage, I know our paths will meet again on the rugby field. You are the most knowledgeable backline coach I know and I know I will still learn much more about this game from you in the future.

Oom Spiere van Rensburg: Thank you for everything you have done for me in regards to my coaching career since I started coaching in 1997. Your support and input has been greatly appreciated and I owe most of what I know about the “art” of coaching players to you. You are a wonderful man and a great friend.

Michelle Evert: Thank you for all your help with the design of the graphs, the scanning of the pictures for the document and for the detailed final touches of the document. Your support during the whole process of this study has been a wonderful aid and you are greatly appreciated! Without your continued love and support this study would never have been possible.
To my special friends who have always supported Michelle and I: Wessel & Anne-Audette Roux, Anton Ernst, Pieter & Lillian Terblanche, Jackie & Judie van der Westhuizen and Riel du Toit.

My Saviour Jesus Christ: My coaching career has been filled with many challenges. The mere fact that I have been able to complete this study is an indication of the wonderful grace that Jesus has bestowed upon me. His continued presence in my life has allowed me to achieve and complete those things so often taken for granted and to Him all the glory. Without His guidance and wisdom it would never have been possible to achieve the success I have been blessed to experience during my coaching career.

“I have strength for all things in Christ who empowers me, I am ready for anything and equal to anything through Him; I am self-sufficient in Christ’s sufficiency.”

Philippians 4:13

“You chart the path ahead of me, and tell me where to stop and rest,
   Every moment you know where I am.
   You know what I am going to say even before I say it, LORD.
   You both precede and follow me.
   You place your hand of blessing on my head.
   Such knowledge is too wonderful for me, too great for me to know.”

Psalm 139 verse 3 - 6
The goal of this study is to gain a better understanding of the factors that play a role in dominant collisions in rugby as well as the relative significance of dominant collisions as an indicator of success. By means of video footage of matches played during the 2003-2005 Super 12 competitions, notational analysis was performed and information was gathered in order to gain the relative data. The hypothesis stands that if a team is aware of the factors that lead to a dominant collision, are able to execute them in a match situation, that team should be more successful.

The following key performance measurements were evaluated in order to indicate how each factor affected the level of success of a team. They are as follows: average total number of collisions for a try to be scored, average total number of forced missed tackles for a try to be scored, ratio of dominant collisions versus passes executed when a try is scored and average positive velocity change of dominant collisions resulting in a try being scored.

In order to prove the hypotheses a $k$-sample case will be used. The samples are related, thus the data used is interval and ratio. Therefore, the test used will be the repeated measures ANOVA test, a special form of n-way analysis of variance.
The statistical evaluation is the critical test value where the d.f values are as following: Key Measurement (3,8), Year Rating (2,8), Year Rating by Key Measurement (3,8). When comparing these with a statistical table for critical values of the F distribution for $\alpha = 0.05$, the critical values are as following: (3,8): 4.07, (2,8): 4.46, and (3,8): 4.07.

Thus, the statistical results are grounds for accepting all three null hypotheses and concluding that there is a statistical significance of at least 95% with an alpha of 0.05 between the means in all three instances. This shows that the data captured for the twelve teams for all tries scored by these teams over a period of three years and for the four key measurements, have a statistical significance of 95% for the readings respectively.

After evaluation of the data and making use of regression analysis and multiple regressions in order to establish the correlation between log position and the four key measurements there can be no doubt that the teams that finished higher on the log did indeed perform better according to the identified key performance measurements.

**KEY WORDS:** rugby, coaching, biomechanics, running lines, defensive lines, dominant collisions, video footage, notational analysis.
SAMEVATTING

TITEL
Die beduidendheid van dominante bal-draende- botsings as 'n indikasie van sukses in rugby en die biomekaniese analise daarvan.

KANDIDAAT
Ashley Evert

PROMOTOR
Prof. P.E. Krüger

GRAAD
DPhil (MBK)

Die doel van hierdie studie is om die faktore wat 'n rol speel in dominante botsings in rugby te identifiseer, sowel as die relevante waarde van hierdie dominante botsings as 'n moontlike indikator van sukses in rugby. Deur middel van video opnames van wedstryde wat gedurende die 2003 – 2005 Super 12 kompetisies gespeel is, is noterende analyses van hierdie wedstryde gemaak en is die relevante inligting uiteengesit om die relatiewe data te verkry. Die hipotese is gestel dat 'n span wat bewus is van die faktore wat lei tot dominante botsings en die vermoë besit om hierdie botsings ook in 'n wedstrydsituasie uit te voer, behoort meer suksesvol te wees in die wedstryde wat hulle speel.

Die volgende sleutelmetinge is geevalueer om 'n indikasie te lever van hoe elk van bogenoemde faktore die vlak van sukses van die spanne sal beïnvloed: die gemiddelde totale hoeveelheid botsings voordat 'n drie gedruk is, die gemiddelde totale hoeveelheid van geforseerde mislukte laagvatte voordat 'n drie gedruk is, die verhouding van dominante botsings teenoor aangeë uitgevoer voordat 'n drie gedruk is, en die gemiddelde positiewe snelheidsverandering van dominante botsing s wanneer 'n drie gedruk is.

Om die hipotese te bewys word 'n $k$-monster gebruik. Die monsters is verwant, dus is die data wat gebruik word is interval en verhouding. Dus, die toets wat gebruik word sal dus die herhalende metings ANOVA toets wees, 'n spesiale vorm van n-rigting analise van variasies.
Die statistiese evalusie is die kritiese toetswaarde waar die d.f waardes as volg is:
Sleutel Meting (3.8), Jaar Meting (2.8), Jaar Meting volgens Sleutel Meting (3.8).
Wanneer die voorgaande vergelyk word met ’n statistiese tabel vir kritiese waardes van
die F verspreiding vir α = 0.05, is die kritiese waardes as volg: (3,8): 4.07, (2,8): 4.46, en
(3,8): 4.07.

Dus, die statistiese resultate onderskryf die aanvaarding van al drie die nul hipoteses en
bevestig dat daar ’n statistiese waarde van ten minste 95% met ’n alfa van 0.05 tussen die
gemiddeldes van al drie gevalle voorkom. Dit bevestig dus dat die data wat versamel is
vir die twaalf spanne en vir al die drieë wat deur hierdie spanne oor ’n tydperk van drie
jaar gedruk is, en vir die vier sleutel metings, besit ’n statistiese waarde van 95% vir die
lesings onderskeidelik.

Na evaluering van die data en die gebruikmaking van regressie analise en veelvoudige
regressies ten einde die korrelasie tussen log posisie en die vier sleutel metings te bepaal,
kan daar onomwonde verklaar word dat die spanne wat hoër op die punteleer geëindig
het, inderdaad ook beter presteer het volgens die geïdentifiseerde prestasie metings.

SLEUTEL WOORDE: rugby, afrigting, biomekanika, hardlooplyne,
verdedigingslyne, dominante botsings, video-opnames, merkbare analise.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td>i</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>SYNOPSIS</td>
<td>vi</td>
</tr>
<tr>
<td>SAMEVATTING</td>
<td>viii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xvii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xxv</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xxviii</td>
</tr>
</tbody>
</table>

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION                                      1
1.2 MOTIVATION AND BACKGROUND                        2
1.3 FORMULATING THE RESEARCH PROBLEM                  3  
  1.3.1 The unit of analysis                          3
1.4 THE RESEARCH GOAL                                 4  
  1.4.1 The research strategy                         5
1.5 METHODS OF RESEARCH                               7  
  1.5.1 Data collection                               7
  1.5.2 Data organisation                             8
  1.5.3 Analysis and interpretation of data           8

CHAPTER 2: THE DEVELOPMENT OF RUGBY FOOTBALL          

2.1 THE DEVELOPMENT OF RUGBY FOOTBALL                 9
2.2 BACKGROUND TO THE SOUTH AFRICAN RUGBY FOOTBALL    
  UNION (SARFU) AND SA RUGBY (PTY) LIMITED            12
CHAPTER 3

3.1 THE NECESSITY OF FEEDBACK FROM NOTATIONAL ANALYSIS 14
3.2 TYPES OF FEEDBACK 15
3.3 THE ROLE OF THE COACH USING FEEDBACK 15
3.4 THE NEED FOR OBJECTIVE INFORMATION 17
3.5 NOTATIONAL ANALYSIS – A REVIEW OF THE LITERATURE 20
3.6 THE DEVELOPMENT OF SPORT - SPECIFIC NOTATION SYSTEMS (HAND NOTATION) 23
3.7 A HISTORICAL REVIEW OF HAND NOTATION SYSTEMS FOR RUGBY UNION 23
3.8 THE USE OF COMPUTERISED NOTATION 27
3.9 THE USE OF COMPUTERISED NOTATION IN RUGBY UNION 29
3.10 THE FUTURE OF NOTATIONAL ANALYSIS IN SPORT 31

CHAPTER 4

4.1 DEFENSIVE SYSTEMS 33
4.2 THE PILLARS OF DEFENCE 34
   4.2.1 DEFENSIVE ORGANISATION 34
      4.2.1.1 Man-to-man overlap defence 35
      4.2.1.2 Man-to-man isolation defence 36
      4.2.1.3 One-out defence 38
4.2.2 THE DEFENSIVE SHAPE 40
4.2.3 THE DEFENSIVE ZONES 41
4.2.4 DEFENSIVE SPACING 42
4.2.5 THE EXECUTION LINE 43
4.2.6 ATTITUDE 44
4.2.7 DRIFT DEFENCE AS A CONCEPT 45
4.2.8 SECOND PHASE DEFENCE 46
4.2.9 THIRD AND SUBSEQUENT PHASE DEFENCE 48
4.2.10 RUSH DEFENCE AS A CONCEPT 49
   4.2.10.1 Speed off the line 50
   4.2.10.2 The alignment of each defender 50
   4.2.10.3 Focus on the ball 52
   4.2.10.4 Maintenance of effective width 53

CHAPTER 5

5.1 ATTACKING BACKLINE PLAY 55
   5.1.1 Attacking teams running lines 56
   5.1.2 The aim of backline play 57
   5.1.3 The key factors associated with backline play 57
   5.1.4 Attacking backline play philosophy 58
5.2 THE ATTACKING BACKLINE’S CREATORS 59
5.3 THE ALIGNMENT OF THE ATTACKING BACKLINE FROM THE FACET 60
5.4 THE ATTACKING BACKLINE’S ATTACKING WIDTH 70
5.5 THE ATTACKING BACKLINE’S CHANGE IN INITIAL STARTING POSITION 75
5.6 THE ATTACKING BACKLINE’S ANGLES OF RUNNING 77
5.7 THE ATTACKING BACKLINE’S DECOY RUNNERS 80
5.8 THE ATTACKING BACKLINE’S MANIPULATION OF THE OPPOSITION THROUGH NUMBERS 89
5.9 THE ATTACKING BACKLINE’S MANIPULATION OF THE OPPOSITION THROUGH ADDITION 89
5.10 THE ATTACKING BACKLINE’S MANIPULATION OF THE OPPOSITION THROUGH SUBTRACTION 91
5.11 THE ATTACKING BACKLINE’S STRIKER 92
5.12 THE ATTACKING BACKLINE’S TIMING OF THE MOVEMENT OF THE ATTACK 93
   5.12.1 The initial starting position of the first receiver 94
5.12.2 The alignment of the attacking unit from the facet 94
5.12.3 The timing of the movement of attack 94

5.13 THE ATTACKING BACKLINE’S STRIKE ON THE DEFENSIVE LINE 97

5.14 THE STRIKER’S SPEED VERSUS QUICKNESS 100
5.15 SPEED CONCEPTS SPECIFIC TO RUGBY 100
5.16 THE STRIKER’S RUNNING SPEED 101
5.17 THE ATTACKING BACKLINE’S PASSING SPEED 102
5.18 THE ATTACKING BACKLINE’S THOUGHT SPEED 103
5.19 THE ATTACKING BACKLINE’S STRIKE AREA 104
5.20 THE ATTACKING BACKLINE’S TRAILING SUPPORT RUNNERS 106
5.21 THE ATTACKING BACKLINE’S FIRST WAVE OF SUPPORT RUNNERS 107
5.22 THE ATTACKING BACKLINE’S SECOND WAVE OF SUPPORT RUNNERS 108
5.23 THE STRIKER’S ANGLE OF RUN AFTER A SUCCESSFUL STRIKE HAS BEEN MADE 110
5.24 THE ATTACKING TEAM’S CLEANING UNITS 111
5.25 THE ATTACKING TEAM’S COMMUNICATION 111
5.26 THE ATTACKING TEAM’S DECISION-MAKING 112
5.27.1 PICK AND DRIVE FORWARD BALL CARRIES NEAR THE FRINGES OF THE RUCK 116
5.27.2 “ONE OFF RUNNERS” ONE PASS OFF THE RUCK 116
5.27.3 FORWARDS RUNNING OFF SHORTENED LINEOUTS OR ANY OPEN PHASE PLAY SITUATIONS 117
5.28 CONCLUSION 117

CHAPTER 6

6.1 INTRODUCTION TO BIOMECHANICAL ASPECTS 118
6.2 KINEMATICS 118
6.3 SCALARS AND VECTORS 119
6.4 DISTANCE AND DISPLACEMENT 119
6.5 NEWTON’S LAWS OF UNIFORM MOTION IN A RUGBY CONTEXT 121
  6.5.1 NEWTON’S FIRST LAW 121
  6.5.2 NEWTON’S SECOND LAW 122
    6.5.2.1 Acceleration, Speed, and Position: Kinematics 123
    6.5.2.2 Figuring out the force of a “Big Hit” 123
    6.5.2.3 A Force to be reckoned with! 125
  6.5.3 NEWTON’S THIRD LAW 126
    6.5.3.1 Momentum and Impulse 126
6.6 BASIC TERMS ASSOCIATED WITH BIOMECHANICAL ANALYSIS OF RUGBY SITUATIONS 128
  6.6.1 Principle 1 – STABILITY 130
  6.6.2 Principle 2 – GROUND REACTION FORCES 131
  6.6.3 Principle 3 – DIRECTION OF THE GROUND REACTION FORCES 132
  6.6.4 Principle 4 – EFFICIENT USE OF GROUND REACTION FORCES 135
6.7 THE ANALYSIS AND INTERPRETATION OF THE OBSERVED COLLISIONS 136
  6.7.1 The science of ball carrying collisions 136
  6.7.2 Principle 5 – COLLISION STABILITY 136
  6.7.3 The effective body positioning required for entering the collision site 137
  6.7.4 Principle 6 – EFFECTIVE MOMENTUM GENERATION 137
  6.7.5 Principle 7 – EFFECTIVE BODY TECHNIQUE USAGE 138
CHAPTER 7: METHODS, THE EXPERIMENTAL DESIGN AND THE RELEVANT PROCEDURES

7.1 METHOD
7.2 PRE-CONTACT SITUATIONS BEFORE THE COLLISION TOOK PLACE – BALL CARRIER/S
7.3 PRE-CONTACT SITUATIONS BEFORE THE COLLISION TOOK PLACE – THE DEFENDER/S
7.4 KEY FACTORS PRESENT AT THE IN-CONTACT SITUATIONS AS THE COLLISION TAKES PLACE
7.6 THE POST-CONTACT EVALUATION OF THE TRY SCORED

CHAPTER 8: ANALYSIS AND INTERPRETATION

8.1 ANALYSIS AND INTERPRETATION
8.1.1 Average total number of collisions for a try to be scored
8.1.2 Average total number of forced missed tackles for a try to be scored
8.1.3 Ratio of dominant collisions versus passes executed when a try is scored
8.1.4 Average positive velocity change of dominant collisions resulting in a try being scored
8.2 THE STATISTICAL SIGNIFICANCE OF THE DATA
8.3 THE STATISTICAL TESTING PROCEDURE
8.4 THE TEST OF SIGNIFICANCE
8.5 THE SELECTION OF A STATISTICAL TEST
8.6 \( k \) – SAMPLE RELATED CASE FOR INTERVAL / RATIO DATA
CHAPTER 9

9.1 INTERPRETATION OF THE DATA 187
9.2 PHYSICS VS ABILITY: WHAT IS THE LINK? 191
9.3 WHERE COACHING COMES IN: THE EFFECTIVE USE OF CENTER OF MASS AND TORQUE 191
9.4 SPEED, AGILITY, QUICKNESS AND THE ABILITY TO BEAT THE DEFENDER WITH FOOTWORK 198
9.5 THE ABILITY TO RUN OVER THE DEFENDER 201
  9.5.1 A FULL-ON DEFENDER BEATING COLLISION 201
    9.5.1.1 Attacking from quick or slow ball 202
    9.5.1.2 The ball carriers ability to hit the collision line at maximum speed when running onto the ball 203
    9.5.1.3 The level of effective footwork ahead of the collision so that the ball carrier dominates the collision site 205
    9.5.1.4 Manipulation of the defender so that he is flat footed 208
    9.5.1.5 The defender is forced to tackle making use of his weaker shoulder 209
    9.5.1.6 The defender has been manipulated into over tracking by the probe used by the attacking backline and the ball carrier hits the line using the effective running line 216
    9.5.1.7 The ball carrier enters the collision site with his full mass moving through the line of application of the defender 216
    9.5.1.8 The ball carrier is physically bigger and more powerful than the defender 217
    9.5.1.9 The ball carrier has a player/s leached to him thus doubling the mass of the ball carrier into the
THE REPEATED EXECUTION OF COLLISIONS THAT IN EFFECT SOFTEN UP THE OPPOSITION BEFORE THE FINAL KNOCK-OUT BLOW IS ISSUED

9.5.2.1 Dominating ball carrying collisions that lead to a ruck being formed

9.5.2.2 Dominating ball carrying collisions that lead to the defender being bumped off

9.5.2.3 Dominating ball carrying collisions where the ball carrier is able to give an effective off-load to a support player

9.6 CONCLUSION
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1:</td>
<td>Graph showing the relative percentages of teams winning matches by scoring more tries than the opposition</td>
</tr>
<tr>
<td>Figure 3.1:</td>
<td>A schematic diagram representing how the coaching process can be improved by means of feedback</td>
</tr>
<tr>
<td>Figure 3.2:</td>
<td>A schematic diagram representing the coaching process</td>
</tr>
<tr>
<td>Figure 3.3:</td>
<td>A schematic diagram representing the coaching process, utilising some of the computer-aided analysis and feedback technology</td>
</tr>
<tr>
<td>Figure 3.4:</td>
<td>A schematic diagram representing a hand notation system used during the 1995 Rugby World Cup</td>
</tr>
<tr>
<td>Figure 4.1:</td>
<td>Man-to-man overlap defence from a scrum</td>
</tr>
<tr>
<td>Figure 4.2:</td>
<td>Man-to-man isolation defence</td>
</tr>
<tr>
<td>Figure 4.3:</td>
<td>One-out defence</td>
</tr>
<tr>
<td>Figure 4.4:</td>
<td>Defensive shape</td>
</tr>
<tr>
<td>Figure 4.5:</td>
<td>Key for Rush defence diagrams</td>
</tr>
<tr>
<td>Figure 4.6:</td>
<td>Basic annotation of the “Rush” defensive system</td>
</tr>
<tr>
<td>Figure 4.7:</td>
<td>Basic annotation of the “Rush” defensive system focussing on the effective alignment of each defender</td>
</tr>
</tbody>
</table>
Figure 4.8: Basic annotation of the “Rush” defensive system focussing on the ball

Figure 4.9: Basic annotation of the “Rush” defensive system indicating effective width

Figure 5.1: Alignment, angle, speed and penetration in attack

Figure 5.2: Attacker pulling the first defender out of alignment while the second defender marks his opposite attacker running at him

Figure 5.3: Attacker being pulled away from his defensive channel

Figure 5.4: Outside attackers hold their line but adjust their rate of Advance

Figure 5.5: “Deep” and “Flat” alignment versus “Shallow” and “Steep” Alignment

Figure 5.6: Working space in attacking play

Figure 5.7: The way to hit a space in attacking play

Figure 5.8: Pass to an extra player too early and too far back

Figure 5.9: (a) Necessary accuracy for a wide pass, (b) poor accuracy of a wide pass

Figure 5.10: Channel running in attacking play

Figure 5.11: Channel running in attacking play
Figure 5.12: (a) Tacklers everywhere and (b) tacklers contained

Figure 5.13: The 90° passing rule

Figure 5.14: Stair passing showing the full peripheral vision for all the attackers

Figure 5.15: Indicating the use of an “O,I” decoy line and the support lines created through its use after a clean break has been achieved

Figure 5.16: Indicating the use of an “O,I” decoy line where the striker offloads to a trailer coming in, and the support lines created after the line break has been achieved

Figure 5.17: Indicating an “O,I” decoy line where the trailer becomes the primary cleaner with the previous ball carrier on the inside after an attempted line break has been unsuccessful

Figure 5.18: Indicating the concept of a “One-out” decoy line ending in a score

Figure 5.19: Indicating a decoy runner on the inside accompanied by a “One-out” decoy on the outside with resultant trailing lines that are created

Figure 5.20: (a) Addition through a circle ball, (b) Addition through an extra player entering the line

Figure 5.21: Subtraction through committing two tacklers

Figure 5.22: A front on tackle
Figure 5.23: From the side tackle situation 105

Figure 5.24: Inside and outside first wave supporting running lines 107

Figure 5.25: Concentration on inside supporting lines 109

Figure 5.26: Second wave supporting running lines after a line break 110

Figure 6.1: Diagram indicating the distance covered by a player moving from A to B 118

Figure 6.2: Diagram indicating a player moving forwards from position A towards position B, then being tackled backwards to the initial starting position 118

Figure 6.3: The effect of force 122

Figure 6.4: The effect of a torque 122

Figure 6.5: The velocities of both players are indicated for before and after the collision. Momentum is conserved in the collision 126

Figure 6.6: Indication of centre of mass in various positions 127

Figure 6.7: Stable and unstable positions when the ball carrier and defender meet 129

Figure 6.8: Relationship of stride rate, stride length and running velocity 130

Figure 6.9: Use of ground reaction forces to cause lateral motion 132
Figure 8.1: Data table for the key performance measurements 161

Figure 8.2: Average number of forced missed tackles vs total average number of collisions 163

Figure 8.3: Average number of forced missed tackles vs average positive velocity change of dominant collisions 165

Figure 8.4: Average number of forced missed tackles vs ratio of dominant collisions versus passes executed 167

Figure 8.5: Average number of collisions vs average positive velocity change of dominant collisions 169

Figure 8.6: Average number of collisions vs ratio of dominant collisions versus passes executed 171

Figure 8.7: Ratio of dominant collisions versus passes executed vs average positive velocity change of dominant collisions 173

Figure 8.8: Average total number of collisions for a try to be scored (2003, 2004 and 2005) 175

Figure 8.9: Average total number of forced missed tackles for the Try to be scored (2003, 2004 and 2005) 177

Figure 8.10: Ratio of dominant collisions versus passes executed when a try is scored (2003, 2004 and 2005) 179

Figure 8.11: Average positive velocity change of dominant collisions resulting in a try being scored (2003, 2004 and 2005) 181
Figure 9.1: Distribution of tries scored – 2003

Figure 9.2: Distribution of tries scored – 2004

Figure 9.3: Distribution of tries scored – 2005

Figure 9.4: Comparison between dominant and non-dominant collisions when placed according to log position – 2003, 2004 and 2005

Figure 9.5: Player on the left lowers his centre of mass and drives up and through the ball carrier on the right

Figure 9.6: Lateral forces are less effective at destabilising a player whose stance is low to the ground

Figure 9.7: Percentage of tries scored where footwork was used when scoring the try

Figure 9.8: Velocity vectors before ($V_1 \rightarrow$) and after ($V_2 \rightarrow$) the player moves

Figure 9.9: Average momentum of ball carriers in the collision when the try is scored – 2003, 2004 and 2005

Figure 9.10: Side-step as a percentage of total footwork when a try is scored – 2003, 2004 and 2005

Figure 9.11: Distribution of tries scored for 2003 – scrum

Figure 9.12: Distribution of tries scored for 2004 – scrum

Figure 9.13: Distribution of tries scored for 2005 – scrum
Figure 9.14: Distribution of tries scored for 2003 – lineouts

Figure 9.15: Distribution of tries scored for 2004 – lineouts

Figure 9.16: Distribution of tries scored for 2005 – lineouts

Figure 9.17: Missed tackles as a percentage of defensive errors committed 2003, 2004 and 2005
<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1:</td>
<td>6</td>
</tr>
<tr>
<td>Criteria for relevant hypotheses testing</td>
<td>154</td>
</tr>
<tr>
<td>Table 8.2:</td>
<td>156</td>
</tr>
<tr>
<td>Data table for the key performance measurements</td>
<td>157</td>
</tr>
<tr>
<td>Table 8.3:</td>
<td>158</td>
</tr>
<tr>
<td>Data table summary for the key performance measurements</td>
<td>158</td>
</tr>
<tr>
<td>Table 8.4:</td>
<td>158</td>
</tr>
<tr>
<td>Model summary</td>
<td>158</td>
</tr>
<tr>
<td>Table 8.5:</td>
<td>160</td>
</tr>
<tr>
<td>Total number of forced missed tackles vs total average number of collisions</td>
<td>162</td>
</tr>
<tr>
<td>Table 8.6:</td>
<td>166</td>
</tr>
<tr>
<td>Average number of forced missed tackles vs ratio of dominant collision versus passes executed</td>
<td>166</td>
</tr>
<tr>
<td>Table 8.7:</td>
<td>168</td>
</tr>
<tr>
<td>Total average number of collisions vs ratio of dominant collisions versus passes executed</td>
<td>168</td>
</tr>
<tr>
<td>Table 8.9:</td>
<td>170</td>
</tr>
<tr>
<td>Ratio of dominant collisions versus passes executed vs average positive velocity change</td>
<td>170</td>
</tr>
<tr>
<td>Table 8.11: Average total number of collisions for a try to be scored</td>
<td>172</td>
</tr>
<tr>
<td>Table 8.12: Average number of forced missed tackles for the try to be scored</td>
<td>174</td>
</tr>
<tr>
<td>Table 8.13: Ratio of dominant collisions versus passes executed when a try is scored</td>
<td>176</td>
</tr>
<tr>
<td>Table 8.14: Average positive velocity change of dominant collisions resulting in a try being scored</td>
<td>178</td>
</tr>
<tr>
<td>Table 8.15(a): Rate of change in collisions between teams ranked from position 1 through to 6; 2003-2005</td>
<td>181</td>
</tr>
<tr>
<td>Table 8.15(b): Rate of change in collisions between teams ranked from position 7 through to 12; 2003-2005</td>
<td>182</td>
</tr>
<tr>
<td>Table 8.16: Changes in collisions 2003 – 2005 between nations</td>
<td>183</td>
</tr>
<tr>
<td>Table 9.1: Distribution of tries scored as a percentage – 2003</td>
<td>188</td>
</tr>
<tr>
<td>Table 9.2: Distribution of tries scored as a percentage – 2004</td>
<td>189</td>
</tr>
<tr>
<td>Table 9.3: Distribution of tries scored as a percentage – 2005</td>
<td>190</td>
</tr>
<tr>
<td>Table 9.4: Comparison between dominant and non-dominant collisions when placed according to log positions</td>
<td>192</td>
</tr>
<tr>
<td>Table 9.5: Percentage of tries when footwork was used when scoring a try</td>
<td>198</td>
</tr>
<tr>
<td>Table 9.6: Average momentum of ball carriers in the collision when a try is scored</td>
<td>203</td>
</tr>
</tbody>
</table>
Table 9.7: Side-step as a percentage of total footwork when a try is scored

Table 9.8: Distribution of tries scored as a percentage: 2003 – scrums

Table 9.9: Distribution of tries scored as a percentage: 2004 – scrums

Table 9.10: Distribution of tries scored as a percentage: 2005 – scrums

Table 9.11: Tries scored as a percentage: 2003 – lineouts

Table 9.12: Tries scored as a percentage: 2004 – lineouts

Table 9.13: Tries scored as a percentage: 2005 – lineouts

Table 9.14: Missed tackles as a percentage of defensive errors committed
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPENDIX 1:</td>
<td>Super 12 log – 2003</td>
</tr>
<tr>
<td>APPENDIX 2:</td>
<td>Super 12 log – 2004</td>
</tr>
<tr>
<td>APPENDIX 3:</td>
<td>Super 12 log – 2005</td>
</tr>
<tr>
<td>APPENDIX 4:</td>
<td>Coaching staff (2003 – 2005)</td>
</tr>
<tr>
<td>APPENDIX 5:</td>
<td>Clean break vs Collision tries scored (2003, 2004 and 2005)</td>
</tr>
<tr>
<td>APPENDIX 6:</td>
<td>Clean break vs Collision tries scored according to nations, Clean break vs Collision tries scored – Australia, Clean break vs Collision tries scored – New Zealand, Clean break vs Collision tries scored – South Africa</td>
</tr>
<tr>
<td>APPENDIX 7:</td>
<td>Average mass of ball carriers during the collision (2003, 2004 and 2005)</td>
</tr>
<tr>
<td>APPENDIX 8:</td>
<td>Average mass of ball carriers during the collision according to nations</td>
</tr>
</tbody>
</table>
APPENDIX 11: Distribution of tries scored according to log position 2003 – 2005 (Position 1 – 12 and average) 256

CD APPENDIX: Notational Analysis Sheet S12 – 2003
Notational Analysis Sheet S12 – 2004
Notational Analysis Sheet S12 – 2005 CD