Global positioning system tracking and kinanthropometrical profiling of Zimbabwean National Rugby Sevens players

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It all starts here ™

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

DEDICATION

This thesis is dedicated to my wife,

GAYLE VAN DEN BERG,

Who supported me and my dreams throughout, is a fountain of wisdom to me and whom I love dearly.

Luke 14:11

For whoever exalts himself will be humbled, and he who humbles himself will be exalted.

Pieter van den Berg

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DECLARATION

The co-author of the articles that form part of this thesis, Prof. DDJ Malan (Promoter), Prof. JH De Ridder (Co-promoter) en Dr. S Ellis hereby give permission to the candidate, Mr. PH van den Berg to include the articles as part of the PhD thesis. The contribution (advisory and supportive) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this thesis for examination purposes. This thesis, therefore, serves as fulfilment of the requirements for the degree Philosophiae Doctor in Human Movement Sciences at the Potchefstroom Campus of the North-West University (Potchefstroom Campus).

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SUMMARY

Global positioning system tracking and kinanthropometrical profiling of Zimbabwean National Rugby Sevens players

Rugby sevens has continuously increased in popularity around the world, receiving Olympic status in 2009 to be included as an event at the 2016 Olympic Games. This status will probably motivate international teams participating in this event to pursue performance even more in their quest to win an Olympic medal.

Coaches, sport scientists and selectors are known for placing strong emphasis on certain physiological characteristics of rugby players such as distance covered, speed and work rate, as well as certain morphological characteristics when recruiting, selecting and training rugby players. However, significantly less scientific research studies have been done on the physiological and morphological characteristics of rugby sevens compared to studies done on rugby union. The scarcity of scientific research on rugby sevens is difficult to understand when the evidential status and popularity of this sport code is considered.

The following three objectives of the study were achieved through an ex post facto research design. Firstly, a comparison of the different player position subgroups of elite, national, rugby sevens players with regard to time-motion analyses and kinanthropometric profiles was done. This was followed by an examination of the physiological demands rugby sevens places on its players with regard to different levels of tournaments. Finally, the effect of fatigue on the percentage of time sevens rugby players spend on the movement activities during the two different halves of match-play and the percentage time starter and substitute players spend on high and low-intensity movement activities were compared.

Players were clustered into two positional subgroups, namely forward and backline players. One hundred and eleven sets of time-motion analysis data of elite male, senior, Zimbabwean national rugby sevens players with a mean age of 27.2 years were gathered. Time-motion analysis data sets were acquired by means of a GPS device at 10 Hz (Catapult Innovation, Melbourne, Australia) during match play. Kinanthropometry data such as stature, body mass, skinfolds, girths and breadths were measured following the standard procedures as described by the

International Standard for the Advancement of Kinanthropometry. Body mass and stature were then used to calculate the Body Mass Index, and the different somatotypes were calculated to the nearest 0.1.

Kinanthropometric results indicated that an average Zimbabwean rugby sevens player is 178.4 cm tall and has a body mass of 84.2 kg. The forward players had a practically significantly higher body mass and stature than the backline players. The backline players also differed from the forward players with significantly less muscle mass and percentage muscle mass respectively. Forward players revealed a practically significantly larger forearm girth value compared to that of backline players, as well as a practically significantly bigger femur breadth value. The forward players had a practically significantly higher mesomorphy value compared to the backline players. However, both positional subgroups tend to be dominant mesomorphic in nature with the average somatotype for the total group as endomorphic mesomorph. The kinanthropometry data highlighted that rugby sevens requires players with different types of body composition to adhere to the responsibilities set for the different player position subgroups despite the players exhibiting homogenous somatotype and BMI values.

Time-motion analysis suggested that the elite rugby sevens players travelled an average distance of 1 073 meters (m) at an average work-to-rest ratio of 1:4.7. Forward players spent a moderate, practically significant percentage of time more on walking and less on sprinting than backline players. The work-to-rest ratio of the players indicated that the backline players had moderately practically significantly less rest during a match than forward players. Again, rugby sevens players seem to requires different playing positions to adhere to different responsibilities set for the respective player position. Rugby sevens players spend a practically significant percentage more time standing during international tournaments than during national and district tournaments. The players also spend a practically significant percentage less time on high intensity running during international tournaments than during national and district tournaments. The only practically significant difference (moderate) found between the national and district tournaments were the larger percentage of time players jogged during the district tournament. Finally, players exhibited work-to-rest ratios during international matches inferior to the work-to-rest ratios exhibited during district and national tournaments. Stronger opponents at international tournaments, crowd support and travel fatigue during international tournaments may explain the time-motion analyses differences found.

Rugby sevens players travel an average of 548.1 meters a half and a significantly further distance in the second half compared to distance travelled in the first half. Players spend a

moderately practically significant percentage less time on standing in the second half than in the first half. The players did, however, spend a significantly percentage time more on slow jogging and medium-intensity running in the second half than during the first half. No practically significant differences were found between the percentage of time players had spent on high-intensity running and sprinting between the two halves of rugby sevens match play suggesting that fatigue did not affect the players' movement activities.

Starter players covered a significantly greater distance than substitute players, but substitute players covered a significantly greater relative distance than the starter players. The starter players had spent significantly percentage more time walking than substitute players and the starter players recorded significantly lower work-to-rest ratios than the substitute players. The results therefore suggest that the use of substitute players may support the ability of teams to increase the percentage of time the players spend on high-intensity activities.

To the knowledge of the current research team, no literature could be found that offers such a comprehensive positional kinanthropometric profile of national rugby sevens players. Furthermore, this is the first study that compared the time-motion analyses data between the player positional subgroups and the movement activities of three different levels of rugby sevens tournaments.

Keywords: Rugby Sevens, kinanthropometry, anthropometry, somatotypes, Rugby Union, match-specific training, time-motion analyses, fatigue.

OPSOMMING

Globale posisioneringstelsel-opsporing en kinantropometriese profilering van die Zimbabwiese Nasionale Rugby Sewesspelers

Rugby Sewes word regoor die wêreld toenemend gewild. Dit het in 2009 Olimpiese status verwerf om by die 2016 Olimpiese Spele ingesluit te word as ’n Olimpiese item. Hierdie nuwe status sal internasionale spanne wat hieraan wil deelneem na verwagting motiveer om goeie werksverrigting nog meer na te streef in die najaag van ’n Olimpiese medalje.

Afrigters, sportwetenskaplikes en keurders is bekend daarvoor dat hulle sterk klem lê op sekere fisiologiese eienskappe van die rugbyspelers soos die afstand wat afgelê word, spoed en werkstempo, sowel as sekere morfologiese eienskappe wanneer hulle spelers werf, spanne kies en rugbyspelers afrig. Daar is egter beduidend minder wetenskaplike navorsing oor die fisiologiese en morfologiese eienskappe van rugby sewes spelers vergeleke met studies oor rugby unie. Die skaarste aan wetenskaplike navorsing oor rugby sewes is moeilik om te verstaan wanneer mens die ooglopende status en gewildheid van die sportkode in ag neem.

Die volgende drie doelwitte van die studie is bereik deur 'n *ex post facto* navorsingsontwerp. Eerstens is die verskillende speelposisie subgroepe van elite, nasionale, rugby sewes spelers vergelyk ten opsigte van tyd-beweging-analise en kinantropometriese profiele. Dit is gevolg deur ’n ondersoek na die fisiologiese eise van rugby sewes aan die spelers tydens die verskillende vlakke van toernooie. Laastens is die effek van uitputting op die persentasie tyd wat sewes rugbyspelers gebruik vir die bewegingsaktiwiteite tydens die twee helftes van die wedstryd vergelyk, sowel as die persentasie tyd wat begin- en vervangingspelers wy aan hoë-intensiteit en lae-intensiteit bewegings.

Spelers is in twee posisionele subgroepe verdeel, naamlik voorspelers en agterspelers. Een-honderd-en-elf stelle data vir tyd-beweging-analise is ingesamel van elite, manlike, senior, Zimbabwiese nasionale rugby sewes spelers met ’n gemiddelde ouderdom van 27.2 jaar. Tyd-beweging-analise datastelle is verkry deur middel van ’n GPS-toestel by 10 Hz (Catapult Innovation, Melbourne, Australië) gedurende wedstrydspel. Kinantropometriese data soos statuur, liggaamsmassa, huidplooi, omtrekke en breedtes is gemeet deur die standaardprosedures

te volg soos voorgeskryf deur die Internasionale Standaard vir die Bevordering van Kinantropometrie. Liggaamsmassa en statuur is gebruik om die Liggaamsmassa-indeks (BMI) te bereken, en die verskillende somatotipes is bereken tot die naaste 0.1.

Kinantropometriese resultate het aangedui dat die gemiddelde Zimbabwiese rugby sewes speler 178.4 cm lank is en ’n liggaamsmassa van 84.2 kg het. Die voorspelers het ’n prakties gesproke beduidende hoër liggaamsmassa en statuur gehad as die agterspelers. Die agterlynspelers het van die voorspelers verskil met beduidend minder spiermassa en persentasie spiermassa onderskeidelik. Voorspelers het ’n prakties gesproke beduidend groter voorarm-omtrek gehad vergeleke met die van die agterlynspelers, sowel as 'n prakties gesproke beduidend groter femurbreedte. Die voorspelers het prakties gesproke beduidend hoër mesomorfwaardes as die agterspelers gehad. Beide posisionele subgroepe het egter geneig om dominant mesomorf van aard te wees met die gemiddelde somatotipe vir die algehele groep as endomorf mesomorf. Die kinantropometriese data benadruk dat rugby sewes spelers vereis met verskillende tipes liggaamsamestelling om die verskillende verantwoordelikheide wat die verskillende spelerposisies inhou na te kom, ongeag die feit dat die spelers betreklike homogene somatotipes en liggaamsmassa-indeks waardes toon.

Tyd-beweging-analise toon dat die elite rugby sewes spelers ’n gemiddelde afstand van 1 073 meter (m) aflê teen ’n gemiddelde werk-rus-verhouding van 1:4.7. Voorspelers gebruik ’n gemiddelde, prakties gesproke beduidende persentasie van tyd meer aan loop en minder aan hardloop as agterspelers. Die werk-rus-verhouding van die spelers dui aan dat die agtespelers gemiddeld prakties gesproke beduidend minder rus gedurende ’n wedstryd as voorspelers. Weer eens blyk dit dat rugby sewes spelers vereis dat verskillende spelerposisies verskillende verantwoordelike nakom vir die onderskeie spelerposisies. Rugby sewes spelers spandeer ’n prakties gesproke beduidende persentasie tyd meer aan staan gedurende internasionale toernooie as gedurende nasionale en distriktoernooie. Rugby sewes spelers spandeer ook ’n prakties gesproke beduidende persentasie tyd minder aan intensiewe hardloop gedurende internasionale toernooie as gedurende nasionale en distriktoernooie. Die enigste prakties gesproke beduidende verskil (gemiddeld) wat gevind is tussen die nasionale en distrikstoernooie is die groter persentasie van tyd wat spelers draf gedurende die distriktoernooie. In die laaste plek is die werk-rus-verhouding gedurende internasionale wedstryde laer as die werk-rus-verhouding gedurende distrik- en nasionale toernooie. Sterker opponente by internasionale toernooie, toeskouersteun en reisuitputting gedurende internasionale toernooie kan die tyd-beweging-analise verkille wat gevind is verduidelik.

Rugby sewes spelers lê ’n gemiddeld van 548.1 meter per helfte af en 'n beduidende verder afstand in die tweede helfte vergeleke met die afstand in die eerste helfte. Spelers spandeer ’n gemiddelde prakties gesproke beduidende persentasie van tyd minder aan staan in die tweede helfte as in die eerste helfte. Die spelers het egter ’n beduidende persentasie tyd meer spandeer aan stadig draf en medium-intensiteit hardloop in die tweede helfte as wat die geval was gedurende die eerste helfte. Geen prakties gesproke beduidende verskille is gevind tussen die persentasie tyd wat spelers spandeer het aan hoë-intensiteit hardloop en nael tussen die twee helftes van ’n rugby sewes wedstryd nie, wat blyk te toon dat uitputting nie die spelers se bewegingsaktiwiteite beïnvloed nie.

Beginspelers het ’n beduidende verder afstand afgelê as vervangingspelers, maar vervangingspelers het ’n beduidende verder relatiewe afstand afgelê as die beginspelers. Die beginspelers het ’n beduidende persentasie meer tyd spandeer aan loop as die vervangingspelers en die beginspelers het beduidende laer werk-rus-verhoudings getoon as die vervangingspelers. Die resultate toon dus dat die gebruik van vervangingspelers die vermoë van 'n span om tyd te spandeer aan hoë-intensiteit aktiwiteite kan ondersteun.

Sover die kennis van die huidige navorsingspan strek, kon geen literatuur gevind word wat so ’n omvattende posisionele kinantropometriese profiel van ’n nasionale span sewes rugbyspelers bied nie. Verder is dit die eerste studie wat die tyd-beweging-analise data van die verskillende speelposisie subgroepe vergelyk en wat die bewegingsaktiwiteite van drie verskillende vlakke rugby sewes toernooie vergelyk.

Sleutelwoorde: Sewes Rugby, kinantropometrie, antropometrie, somatotipes, Rugby Union, spel-spesifieke oefeninge, tyd-beweging-analiese, uitputting.

TABLE OF CONTENTS

DEDICATION…… i

ACKNOWLEDGEMENT…….. ii

DECLARATION…… iii

SUMMARY…… iv

OPSOMMING……..... vii

TABLE OF CONTENTS……..... x

LIST OF TABLES…….. xvii

LIST OF FIGURES…… xx

LIST OF ABBREVIATIONS……. xxi

CHAPTER 1

INTRODUCTION…… 1

TITLE PAGE…….. 2

1. INTRODUCTION…….. 2

2. PROBLEM STATEMENT……. 2

3. OBJECTIVES……. 6

4. HYPOTHESIS…… 6

5. PROPOSED ARTICLES…… 6

REFERENCES……... 8

CHAPTER 2

LITERATURE OVERVIEW: TIME-MOTION ANALYSES AND KINANTHROPOMETRY IN RUGBY……. 12

TITLE PAGE…….. 13

2.1. INTRODUCTION……... 15

2.1.1. DIFFERENT RUGBY VARIANTS……. 16

2.1.2. COMPARISONS BETWEEN THE RULES AND NATURE OF RU AND RS…… 16

2.1.3. RELIABILITY AND VALIDITY OF TMA (TIME-MOTION ANALYSES)…… 18

2.2. TMA RESEARCH ON RU……..... 22

2.2.1. HIGH AND LOW-INTENSITY MOVEMENT ACTIVITIES IN RU…... 28

2.2.2. PLAYER POSITIONAL DIFFERENCES WITH REGARD TO TMA OF RU PLAYERS…….. 29

2.2.2.1. PLAYER POSITIONAL DIFFERENCES WITH REGARD TO TOTAL DISTANCE TRAVELLED……... 30

2.2.2.2. PLAYER POSITIONAL DIFFERENCES WITH REGARD TO LOW-INTENSITY MOVEMENT ACTIVITIES……... 32

2.2.2.3. PLAYER POSITIONAL DIFFERENCES WITH REGARD TO HIGH-INTENSITY MOVEMENT ACTIVITIES…….. 33

2.2.2.4. PLAYER POSITIONAL DIFFERENCES WITH REGARD TO ACCELERATIONS…… 35

2.2.3. THE EFFECT OF FATIGUE ON THE MOVEMENT ACTIVITIES OF RU PLAYERS…….. 36

2.2.4. WORK-TO-REST RATIOS OF RU PLAYERS……. 36

2.2.5. ADDITIONAL COMPARISONS DONE ON RU PLAYERS WITH THE AID OF TMA……... 38

2.2.6. CONCLUSION OF TMA ON RU PLAYERS…..... 39

2.3. TMA ON RS…… 39

2.3.1. HIGH- AND LOW-INTENSITY MOVEMENT ACTIVITIES IN RS….. 43

2.3.2. PLAYER POSITIONAL DIFFERENCES IN RS…… 44

2.3.3. THE EFFECT OF FATIGUE ON THE MOVEMENT ACTIVITIES OF RS PLAYERS……... 44

2.3.4. WORK-TO-REST RATIOS OF RS PLAYERS…….. 45

2.4. COMPARISONS BETWEEN RS AND RU PLAYERS WITH REGARD TO TMA RESULTS…….. 46

2.5. KINANTHROPOMETRY IN RU……... 47

2.5.1. PLAYER POSITIONAL DIFFERENCES WITH REGARD TO KINANTHROPOMETRY……... 53

2.5.2. BMI OF RU PLAYERS……... 55

2.5.3. SKINFOLDS OF RU PLAYERS……. 56

2.5.4. BODY FAT OF RU PLAYERS……... 58

2.5.5. MORPHOLOGY OF RU PLAYERS……... 59

2.6. KINANTHROPOMETRY IN RS……... 60

2.7. COMPARISON BETWEEN RS AND RU PLAYERS WITH REGARD TO KINANTHROPOMETRY…….. 64

2.8. CONCLUSION…… 65

2.9. REFERENCES…… 67

CHAPTER 3

A KINANTHROPOMETRIC COMPARISON OF DIFFERENT PLAYER POSITIONS IN ELITE RUGBY UNION SEVENS…… 78

TITLE PAGE…….…. 79

DETAILS OF AUTHORS 80

ABSTRACT……... 82

INTRODUCTION…….. 83

METHODS……. 84

PARTICIPANTS…… 84

PROCEDURES…….. 84

DIRECT MEASUREMENTS…… 84

INDIRECT MEASUREMENTS…… 84

SOMATOTYPING……. 85

STATISTICAL ANALYSES……. 86

RESULTS……... 87

DISCUSSION……. 90

CONCLUSION……... 92

PRACTICAL APPLICATIONS OF THE STUDY……... 92

FUNDING…….. 92

REFERENCES……... 92

CHAPTER 4

TOURNAMENT AND POSITION-SPECIFIC TIME-MOTION ANALYSES OF ELITE ZIMBABWEAN RUGBY SEVENS PLAYERS DURING MATCH PLAY…… 96

TITLE PAGE…….……. 96

DETAILS OF AUTHORS ……..… 98

ABSTRACT……... 100

INTRODUCTION…….. 101

METHODS……. 102

SUBJECTS……. 102

EXPERIMENTAL APPROACH TO THE PROBLEM…… 103

TIME-MOTION ANALYSES……... 103

STATISTICAL ANALYSES……. 104

RESULTS……... 104

DISCUSSION……. 105

PRACTICAL APPLICATIONS……. 107

ACKNOWLEDGEMENT…….. 108

REFERENCES……... 108

CHAPTER 5

EFFECT OF FATIGUE ON THE MOVEMENT ACTIVITIES OF SENIOR MALE ZIMBABWEAN NATIONAL RUGBY SEVENS PLAYERS…… 113

TITLE PAGE…….……. 114

DETAILS OF AUTHORS…….…… 115

ABSTRACT……... 117

1. INTRODUCTION…….. 118

2. METHODS……. 120

3. RESULTS……... 122

4. DISCUSSION……. 123

5. CONCLUSION……... 125

PRACTICAL IMPLICATIONS……. 125

ACKNOWLEDGEMENT…….. 125

REFERENCES……... 126

CHAPTER 6

SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS…… 130

TITLE PAGE……. 131

1. SUMMARY…… 131

2. CONCLUSIONS……..... 135

3. LIMITATIONS AND RECOMMENDATIONS……... 136

APPENDIX…… 137

TITLE PAGE……. 138

APPENDIX A:

LANGUAGE EDITING LETTER A 140

. LANGUAGE EDITING LETTER B 141

APPENDIX B:

INFORMED CONSENT FORM AND PARTICIPANT INFORMATION LEAFLET……... 142

APPENDIX C:

DATA COLLECTION FORMS……. 147

APPENDIX D

REBUTTAL LETTER OF EXAMINARS QUESTIONS THAT COULD NOT BE CHANGED 151

APPENDIX E:

INSTRUCTIONS FOR AUTHORS: JOURNAL OF SCIENCE AND MEDICINE IN SPORT…….. 153

INSTRUCTIONS FOR AUTHORS: THE JOURNAL OF STRENGTH AND CONDITIONING RESEARCH……. 161

INSTRUCTIONS FOR AUTHORS: JOURNAL OF SPORT SCIENCES……... 168

APPENDIX F:

ARTICLE SUBMITTED: JOURNAL OF SCIENCE AND MEDICINE IN SPORT…… 175

LIST OF TABLES

CHAPTER 2:

TABLE 1	THE DIFFERENCES BETWEEN THE NATURE OF THE GAME IN RU AND RS	17
TABLE 2	RESEARCH RELATED TO RELIABILITY AND VALIDITY OF GPS TECHNOLOGY TO DETERMINE HUMAN LOCOMOTION IN SPORT	19
TABLE 3	TMA RESEARCH RELATED TO RU	23
TABLE 4	TOTAL DISTANCE TRAVELLED BY RU PLAYERS DURING A MATCH	31
TABLE 5	WORK-TO-REST RATIOS OF RU PLAYERS	37
TABLE 6	SUMMARY OF TMA RESEARCH CONDUCTED ON RS PLAYERS	40
TABLE 7	SUMMARY OF ARTICLES ON KINANTHROPOMETRY APPLIED IN RU	49
TABLE 8	RESEARCH STUDIES ON BODY MASS AND STATURE OF RU PLAYERS (1995 – 2014)	54

TABLE 9	RESEARCH ARTICLES ON THE KINANTHROPOMETRY OF PLAYERS IN RS	61
TABLE 10a	COMPARISON OF BODY MASS AND STATURE OF THE POSITIONAL GROUPS IN RS	62
TABLE 10b	BODY MASS AND STATURE OF RS PLAYERS (1995 – 2014)	63
TABLE 11	A COMPARISON OF THE BODY MASS AND STATURE VALUES BETWEEN THE FORWARD AND BACKLINE PLAYERS OF RS AND RU	64

CHAPTER 3:

TABLE 1	DESCRIPTIVE STATISTICS OF THE KINANTHROPOMETRIC DATA FOR THE SENIOR ELITE ZIMBABWEAN NATIONAL RS PLAYERS	87
TABLE 2	STATISTICAL ANALYSIS OF THE KINANTHROPOMETRIC DATA FOR THE PLAYER POSITIONAL SUBGROUPS IN THE SENIOR ZIMBABWEAN NATIONAL RS TEAM	88
TABLE 3	SOMATOTYPES OF THE DIFFERENT POSITIONAL SUBGROUPS OF ZIMBABWEAN NATIONAL RS PLAYERS (N=15)	89

CHAPTER 4:

TABLE 1	TMA OF ZIMBABWEAN ELITE RS PLAYERS IN DIFFERENT PLAYING POSITIONAL SUBGROUPS	111
TABLE 2	COMPARATIVE TMA DATA OF THREE DIFFERENT LEVELS OF RS TOURNAMENTS PLAYED BY ELITE ZIMBABWEAN RS PLAYERS	112

CHAPTER 5:

TABLE 1	COMPARATIVE MOVEMENT ACTIVITIES OF ZIMBABWEAN NATIONAL SENIOR RUGBY SEVENS PLAYERS BETWEEN THE TWO DIFFERENT HALVES DURING MATCH PLAY	128
TABLE 2	COMPARISON OF MOVEMENT ACTIVITIES IN ZIMBABWEAN NATIONAL SENIOR STARTER AND SUBSTITUTE RUGBY SEVENS PLAYERS DURING MATCH PLAY	129

LIST OF FIGURES

CHAPTER 3:

FIGURE 1 SOMATOCHART WITH SOMATOTYPES FOR THE TOTAL AND DIFFERENT POSITIONAL SUBGROUPS OF ZIMBABWEAN NATIONAL RS PLAYERS 90

LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
%	Percentage
@	At
∑	Sum of
♀	Females
♂	Males
A	All-rounders
AFL	Australian Football League
ANOVA	Analysis of Variance
ATP-PC	Adenosine Triphosphate Phosphocreatine
B	Backline Players
BD	Body Density
BMI	Body Mass Index
BR	Breadth
CAG	Corrected Arm Girth
CCG	Corrected Calf Girth
cm	Centimeter
C_m	Corrected Muscle Mass Circumference
CTG	Corrected Thigh Girth
CV	Coefficient Of Variation
d	Practical Significance (Cohen)
D	District Tournament
DXA	Dual-energy X-ray Absorptiometry
ES	Effect Size
F	Forward Players

FEMB	Femur Breadth
GR	Girth
HDOP	Horizontal Dilution of Position
HI	High Intensity Activity
HUMB	Humerus Breadth
HWR	Height-weigth ratio
Hz	Hertz
I	International
ISAK	International Standard for the Advancement of Kinanthropometry
ICC	Intraclass correlation coefficient
kg	Kilogram
Km/h	Kilometres per hour
LI	Low Intensity Activity
m	Meter
m/s	Metres per second
MASS	Body mass
mm	millimetre
MSE	Mean Square Error
n	Population
N	National
N/A	Not Applicable
NLDTF	National Lottery Distribution Trust Fund
p	Statistical Significance
PhASRec	Physical Activity, Sport and Recreation Focus Area
r	Practical Significance (Field)
RS	Rugby Union Sevens
RU	Rugby Union
SD	Standard Deviation
s	Seconds
SF	Skinfold
TANITA	TBF-305 Body Fat Analyser
TMA	Time-motion Analysis
U	Under
Vmax	Maximum Velocity

CHAPTER 1

1 INTRODUCTION

1. INTRODUCTION

2. PROBLEM STATEMENT

3. OBJECTIVES

4. HYPOTHESIS

5. PROPOSED CHAPTERS

REFERENCES

1. INTRODUCTION

Rugby Sevens (RS) has shown a steady increase in popularity around the world (Fuller *et al.*, 2010:179; Higham *et al*., 2012:277), hosting a World Cup every four years as well as the annual international HSBC world tour, all of which are regulated by the International Rugby Board (Meir, 2012:76). In addition, RS received Olympic status in 2009 for inclusion as an event at the 2016 Olympic Games in Rio de Janeiro (Higham *et al.*, 2012:277). This status will probably motivate participating international teams to pursue the enhancement of their performance even more in their quest to win an Olympic medal (Carlson *et al.*, 1994:404).

2. PROBLEM STATEMENT

Coaches, sport scientists and selectors are known for placing high emphasis on certain physical characteristics of standard 15-a-side rugby players such as speed, work rate, kinanthropometry and body composition when recruiting, selecting and training rugby players (Quarrie *et al*., 1995:263). The tendencies of the coaching staff to value scientific information on the mentioned

physical characteristics are understandable, as their effect on performance is advocated by various researchers (Duthie, 2006:2; Deutsch *et al*., 2007:461; Hartwig *et al.,* 2008:105; Roberts *et al.,* 2008:825; Quarrie *et al*., 2013:353). However, significantly less scientific research studies have been done on RS than on Rugby Union (Martin *et al*., 2013:116). The scarcity of scientific research on RS has also been identified by Elloumi *et al*. (2012:176), Higham *et al*. (2012:278) and Suarez-Arrones *et al*. (2012b:1858), which is difficult to understand when considering the evident status and popularity of this sport code.

The results from scientific research already done in Rugby Union and its effects on players' performance would probably be accentuated in RS due to the drastically reduced number of players in RS despite the fact that the size of the playing field remains the same (Rienzi *et al*., 1999:161). Despite some similarities in the game, it is important to note that RS matches are shorter in duration than Rugby Union matches. Only one Rugby Union match is played daily and never on consecutive days, where several RS (two to six matches) matches take place per day on two to three consecutive days of match play. Rugby Union would allow at least two or more days between matches for recovery of players during tournaments.

Understanding the physiological demands of rugby could lead to sport-specific training sessions (Deutsch *et al*., 1998:561, Duthie *et al*., 2003:987; Smith, 2003:1122), which have been proven to advance performance. Cunniffe *et al*. (2009:1195) and Coughlan *et al*. (2011:602) consider time-motion analysis to be the best method for determining the physical demands of Rugby Union matches via the movement activities of players in such a team sport. Time-motion analysis is used when the duration, type and frequency of the different movement patterns within a sport such as rugby are analysed. Determining movement patterns with time-motion analysis has until recently been a challenge, to say the least. However, new technology such as the 10Hz global positioning system (GPS) has made it possible to conduct valid and objective time-motion analyses of movement activities during matches (Coutts & Duffield, 2010:135; Coughlan *et al.,* 2011:602; Johnston *et al.,* 2013:272).

A decrease in movement activities during match play could be identified as fatigue and is considered detrimental to performance (Granatelli *et al*., 2014:733). Researchers therefore suggest that movement activities be monitored throughout match play to determine the possible effect of fatigue (Duthie *et al*., 2005:524). Van den Berg (2013:925) suggests that the impact of substitute players with regard to movement activities should also be investigated, as starter players are replaced throughout the match by substitute players. Although no significant

differences were found between any movement activities of RS players during the two halves (Rienzi *et al*., 1999:164; Suarez-Arrones *et al*., 2012a:3157), the work rate of players decreased slightly in the second half of match play (Higham *et al*., 2012:281, Carreras *et al*., 2013:845). In comparing the movement activities of starter versus substitute rugby sevens players, Higham *et al*. (2012:281) found that substitute players travelled longer distances on the various movement activities than was the case with the starter players. Apart from the effect of fatigue on the movement activities of rugby players, possible differences that may exist between the movement activities in different levels of tournaments were also identified, as a field of interest, to ensure that match-specific training is in line with the level of tournament (Higham *et al*., 2012:281). Substantial differences were found between the physiological demands placed on the players for all movement activities, except total distance travelled, depending on the tournament level. Players reached a 6% better maximum running velocity during international tournaments, ran less at low intensity velocities during international tournaments and performed more high intensity accelerations when compared to national tournaments (Higham *et al*., 2012:277)

In addition to understanding the challenges related to the effect of tournament level and fatigue on the movement patterns of the players over a period of time, one should understand the complex nature of rugby, especially the fact that different skills and responsibilities are required from different positions of play (Nicholas, 1997:377; Eaton & George, 2006:26; Brooks *et al*., 2008:872; Cupples & O'Connor, 2011:126; Venter *et al*., 2011:1). One can therefore hypothesize that different training sessions might be needed for different positions of play in RS (Rienzi *et al*., 1999:160) and Rugby Union (Scott *et al.,* 2003:173). With regard to position-specific training, literature suggests that Rugby Union players be divided into two positional subgroups, namely forward and backline players (Duthie *et al*., 2003:975; Gamble, 2004:10; Gabbett, 2006:1273).

Cunniffe *et al*, (2009:1197), Coughlan *et al.* (2011:601) and Venter *et al.* (2011:5) compared the movement patterns of the forward and the backline players in Rugby Union during matches by means of GPS time-motion analyses. The velocity of the two groups of players were compared and the results indicated that the backline players covered a significantly larger total distance than any of the forward and spent more time on sprinting than was the case with the forward players.

Other scientific comparisons that have been done in rugby involving position-specific differences include studies in which measurements were done on the morphology of the body and the body build (comprehensively referred to as kinanthropometry) of the positional subgroups (Scott *et al.*, 2003:174; Holway & Garavaglia, 2009:1211). Aspects such as body mass index (BMI),

somatotyping, muscle mass, percentage body fat and skeletal mass are all examples of kinanthropometric measurements.

The importance of kinanthropometry and its relation to performance has been extensively noted in different sport codes by various studies, such as those done in Field Hockey (Gabbett, 2010), Australian Rules Football (Edgecombe & Norton, 2006) and Beach Soccer (Castellano & Casamichana, 2010), to name but a few. The kinanthropometry of players also has direct bearing on the selection processes and performance of players in Rugby Union (Bell, 1979:19; Olds, 2001:260; Holway & Garavaglia, 2009:1211) and Rugby League (Gabbett, 2011:338). Brewer and Davies (1995:132) found that elite Rugby League forward players had a significantly greater body mass than backline players, while the backline players exhibited significantly lower percentage body fat than the forward players. Holway and Garavaglia (2009:1217) did a study on Argentinian Rugby Union players and found that the forward players exhibit more body mass and muscle mass than backline players.

Hence the following research questions: Firstly, how do the different player positional subgroups of the Zimbabwean national RS players compare to one another with regard to kinanthropometric profiles? Secondly, how do the time-motion analyses of the Zimbabwean national RS players compare with one another during the district, national and international tournaments and between the player positional subgroups? Finally, how does fatigue affect the movement activities of the Zimbabwean national RS players?

The results could enable coaches, sport scientists, officials, selectors and players to better understand the movement patterns and kinanthropometric profile of players within Zimbabwean national RS with regard to match play in various tournaments, fatigue management and position-specific training. The knowledge gathered from this study may therefore indirectly lead to position-specific assessment and training programmes that ought to enhance the players' overall performance and development (Coughlan *et al.,* 2011:605) and assist coaches with tactical decision making (Wisbey *et al.,* 2010:531). Understanding the position-specific requirements of RS may also assist in team selection (Du Randt *et al.,* 2006:39) and provide support for the necessity of subdividing the RS players into three instead of two positional subgroups.

3. OBJECTIVES

The objectives of this study are therefore to compare:

1. the different player positional subgroups of the Zimbabwean national RS players with regard to kinanthropometric profiles;
2. the time-motion analyses of the Zimbabwean national RS players with one another during the district, national and international tournaments as well as between the player positional subgroups; and
3. the effect of fatigue on the Zimbabwean national RS players' movement activities.

4. HYPOTHESES

The study is based on the following hypotheses:

1. Practical significant differences in kinanthropometric profiles will be found between the different player-positional subgroups of the Zimbabwean national RS players.
2. Practically significant differences will exist between the time-motion analysis data of the Zimbabwean national RS players with regard to the district, national and international tournaments as well as between the different player positional subgroups.
3. Fatigue will have a practically significant effect on the movement activities of the Zimbabwean national RS players.

5. PROPOSED CHAPTERS

Chapter 1 Introduction: A bibliography will be provided at the end of the chapter in accordance with the guidelines of the North-West University.

Chapter 2 Literature overview: Time-motion analyses and kinanthropometry in rugby. A bibliography will be provided at the end of the chapter in accordance with the guidelines of the North-West University.

Chapter 3 Article 1: A kinanthropometrical comparison of different player positions in elite Rugby Union Sevens: This article has been presented to the *Journal of sports sciences.* The abstract, article and bibliography are presented in line with the guidelines of the journal. However, the tables are included in the text to ensure a better understanding of the results and the line spacing has been kept at 1.5 to create a script that is consistent throughout the thesis.

Chapter 4 Article 2: Tournament and position-specific time-motion analyses of elite Zimbabwean Rugby Sevens players during match play. This article has been presented to the *Journal of strength and conditioning research*. The abstract, article and bibliography are presented in line with the guidelines of the journal. However, the line spacing has been kept at 1.5 to create a script that is consistent throughout the thesis.

Chapter 5 Article 3: Effect of fatigue on the movement activities of senior male Zimbabwean National rugby sevens players. This article has been presented to the *Journal of science and medicine in sport.* The abstract, article and bibliography are presented in line with the guidelines of the journal. However, the line spacing has been kept at 1.5 to create a script that is consistent throughout the thesis.

Chapter 6 Summary, conclusion, limitations and recommendations

Ethical permission was granted by the North-West University (NWU-00122-11-A1)

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CHAPTER 2

2 LITERATURE OVERVIEW: TIME-MOTION ANALYSES AND KINANTHROPOMETRY IN RUGBY

2.1. INTRODUCTION

2.1.1. DIFFERENT RUGBY VARIANTS.

2.1.2. COMPARISONS BETWEEN THE RULES AND NATURE OF RU AND RS.

2.1.3. RELIABILITY AND VALIDITY OF TMA (TIME-MOTION ANALYSES).

2.2. TMA RESEARCH ON RU

2.2.1. HIGH- AND LOW-INTENSITY MOVEMENT ACTIVITIES IN RU.

2.2.2. PLAYER POSITIONAL DIFFERENCES IN RU.

2.2.1.1 PLAYER POSITIONAL DIFFERENCES WITH REGARD TO TOTAL DISTANCE TRAVELLED.

2.2.1.2 PLAYER POSITIONAL DIFFERENCES WITH REGARD TO LOW-INTENSITY MOVEMENT ACTIVITIES.

2.2.1.3 PLAYER POSITIONAL DIFFERENCES WITH REGARD TO HIGH INTENSITY MOVEMENT ACTIVITIES.

2.2.1.4 PLAYER POSITIONAL DIFFERENCES WITH REGARD TO ACCELERATIONS.

2.2.2 THE EFFECT OF FATIGUE ON THE MOVEMENT ACTIVITIES OF RU PLAYERS.

2.2.3 WORK-TO-REST RATIOS OF RU PLAYERS.

2.2.4 ADDITIONAL COMPARISONS DONE ON RU PLAYERS WITH THE AID OF TMA.

2.2.5 CONCLUSION OF TMA ON RU PLAYERS.

2.3 TMA ON RS

2.3.1 HIGH AND LOW-INTENSITY MOVEMENT ACTIVITIES IN RS.

2.3.2 PLAYER POSITIONAL DIFFERENCES IN RS.

2.3.3 THE EFFECT OF FATIGUE ON THE MOVEMENT ACTIVITIES OF RS PLAYERS.

2.3.4 WORK-TO-REST RATIOS OF RS PLAYERS.

2.4 COMPARISONS BETWEEN RS AND RU PLAYERS WITH REGARD TO TMA RESULTS

2.5 KINANTHROPOMETRY AND RU

2.5.1 PLAYER POSITIONAL DIFFERENCES WITH REGARD TO KINANTHROPOMETRY.

2.5.2 BMI OF RU PLAYERS.

2.5.3 SKINFOLDS OF RU PLAYERS.

2.5.4 BODY FAT OF RU PLAYERS.

2.5.5 MORPHOLOGY OF RU PLAYERS.

2.6 KINANTHROPOMETRY IN RS

2.7 COMPARISONS BETWEEN RS AND RU PLAYERS WITH REGARD TO KINANTHROPOMETRY

2.8 CONCLUSION

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2.1 Introduction

Over recent years, rugby as a sport has gained increasing prominence, especially with regard to the expansion of the game and related research. According to Clarke *et al*. (2014:144), a more professional approach, as indicative of the present international rugby arena, means a stronger emphasis on the physical preparation of the players. Research indicates that to improve performance one should understand the physiological and physical demands placed on the participants (Duthie, 2006:2; Deutsch *et al*., 2007:461; Roberts *et al*., 2008:825; Quarrie *et al*., 2013:353). One such a physical demand is kinanthropometrical profiles and they should, according to Quarrie *et al.* (1995:263), be investigated as an important characteristic that may affect the performance of rugby players. In addition to kinanthropometry, physiological components such as endurance, speed, agility (Reid *et al.*, 2013:128) and acceleration (Sayers & Washington-King, 2005:104) are movement activities proposed as being very important components when rugby players strive to achieve success. Deutsch *et al*. (1998:569), Duthie *et al.* (2005:523), Cunniffe *et al*. (2009:1195), Coughlan *et al.* (2011:602) Aughey (2011:305) and Suãrez-Arrones *et al*. (2012b:77) highlight time-motion analysis (TMA) as the best method for determining the physiological demands (movement activities) of rugby matches. Knowledge of the movement activities of the players are considered to be of great value to physiotherapists (Eaton & George 2006:22) to manage their rehabilitation more effectively as well as for sport scientists and coaches to monitor player performance during a match for selection purposes and to enable them to prepare more sport-specific training sessions for the players (Deutsch *et al*., 2007:461; Roberts *et al.*, 2008:825; Austin *et al*., 2011b:1106; Venter *et al*., 2011:1; Suãrez-Arrones *et al*., 2012b:77 & Quarrie *et al*., 2013:353).

The value of sport-specific training sessions for performance enhancement is emphasized by Gamble (2004a:491). To make the training sessions more sport-specific, one also needs to understand the role each of these physiological components play during match play, as well as the quality and contribution they add (Smith, 2003:1122). In addition to the contribution and function of each physiological component, one should understand that different players are allocated different playing positions, each position with its own specific demands and functions during a match (Duthie *et al*., 2003:973; Gamble, 2004b:10). Based on these assumptions and the player positional differences, Eaton and George (2006:22) suggest that the training sessions should be made more position-specific for rugby. However, Duthie *et al.* (2003:974) warn about the complex nature of rugby and suggest that one should try to understand the nature of the sport and the different variants of rugby. In addition to the complexity of rugby, relevant parties must

also understand that there are different variants of rugby, each with its own respective rules and character.

2.1.1 Different rugby variants

Six different variants of rugby are currently played, with vast differences between the respective laws related to each type of variant. Sevens Rugby League differs from Rugby Union Sevens by awarding stoppages for tackled situations (Lopez *et al*., 2012:179) and Touch Rugby refrains from contact. Different variants of rugby that currently exist are Rugby League, Sevens Rugby League, Rugby Tens, Beach Rugby Fives, Touch Rugby, Rugby Union and Rugby Union Sevens. Of the above-mentioned variants, only Rugby League, Rugby Union and Rugby Union Sevens each host its own respective World Cup every four years (Meir *et al*., 2001:450; van Rooyen *et al*., 2008:114 & Fuller *et al*., 2010:179), clearly distinguishing these variants from the rest with regard to popularity and level of competition.

In addition to hosting a World Cup every four years, Rugby Union (RU) also turned professional in 1995 (Eaves *et al*., 2005:58). At the 2007 RU World Cup, over two million spectators were attracted to the event and a television audience of over three billion people watched it (Mellalieu, 2008:791). Sevens Rugby Union (RS) recently received Olympic recognition and will be included as an Olympic Games event from 2016 onwards (Engebretsen & Steffen., 2010:157). Carlson *et al*. (1994:403) point out that when sport codes receive Olympic status their status and popularity increase as national teams pursue a possible Olympic medal. The above-mentioned statements seem to indicate that RU and RS are more popular than their World Cup hosting counterpart, Rugby League. The rules and nature of RU and RS are similar, with Rugby League standing slightly more distinct.

2.1.2 Comparison between the rules and nature of RU and RS

RU and RS are games in which the object for the attacking team is to score points and for the defending team to prevent the attacking team from doing so. Both games are played on the same size grass pitch, which is a hundred meters long and may vary in width of between forty to seventy meters (Meir, 2012:76). A match is officiated by a minimum of one referee on the field of play and two line judges. Rules for both rugby codes are very similar with the same match characteristics present and the same methods required for scoring points (Meir, 2012:76; Higham *et al.,* 2014:111). Starting and substitution players are present in both RU and RS. Substitution players may only substitute another player once, and the substituted player may not return to the game in that specific match. There are two exceptions when a player may return to

the field of play in both rugby variants. Firstly, when the original substituted player left the field for medical staff to clean blood off the player as a health precaution and secondly, when a player had to undergo a concussion test and was subsequently cleared to continue playing. Despite RU and RS both being full-contact sport codes with intermitted bouts of high-intensity activities that demand maximal strength with short periods of low-intensity activity in between (McLean *et al*., 1992:286; Venter *et al*., 2011:1; Suãrez-Arrones *et al*., 2012a:3158 & Meir 2012:78) certain differences do exist between the two codes. These differences are best presented in Table 1.

Table 1: The differences between the nature of the game in RU and RS

Differences	RU	RS
Origin	Rugby (England) 1823	Melrose (Scotland) 1883
Time in play	2 x 40-minute halves	2 halves of 7 minutes Exception is cup final which is 2 halves of 10 minutes
Break at half time	10 minutes	2 minutes
Number of starting players	15 each (8 forward and 7 backline players)	7 each (3 forward and 4 backline players)
Number of reserves	7 to 8	3 to 5
Matches each day	1	3 to 6 average every 3 hours

The contrast in player numbers (30 versus 14), duration of matches (80 minutes versus 14 minutes) and frequency of matches on a given day, can be regarded as the biggest differences between RU and RS. The drastic reduction of player numbers in RS - despite the fact that the size of the playing field remains the same - led Rienzi *et al*. (1999:161) to believe that the findings of the research already done on RU and its effects on the players' performance would probably be accentuated in RS. One such an example is that Duthie *et al*. (2003:987) consider RU an anaerobic-dominant sport and Higham *et al*. (2012:281), Lopez *et al.* (2012:179) and Suarez-Arrones *et al*. (2012a:3157) all indicated that RS should be considered an aerobic energy system-orientated sport. It is, however, important to mention that Marshall (2005:10) did acknowledge the need for an aerobic base as a secondary energy system for RU players to function properly, whilst Carreras *et al*. (2013:844) highlight the importance of the anaerobic energy system for RS players. All these findings are founded on TMA research. Hughes *et al*. (2007:18) warn that the reliability of data from any notation analysis research such as TMA should be proven reliable before the data can be interpreted.

2.1.3 Reliability and validity of TMA

TMA is used when the duration, type and frequency of the different movement patterns within a sport such as rugby are analysed. There are three basic forms of TMA, namely: a) global positioning systems (GPS analyses) in conjunction with computer software packages; b) video material in conjunction with computer software packages (video analyses); and c) semi-automated tracking systems. The expensive nature of the latter and complex nature of rugby did, however, complicate TMA using videos in the analysis of the game (Handcock 1993:7, Duthie *et al*., 2003:974). Since then, several reliability issues related to TMA have been investigated.

Several researchers such as Hughes and Williams (1988:255), Rees (1996:26), Newell (2004:54), Pope (2004:38), Botha (2005:16), Reed and O'Donoghue (2005:12) and Baca, (2006:148) emphasize the importance of video analysis in sport and add objectivity as the biggest advantage. Mallett (2006:122), the international coach of the Italian rugby team from 2006 to 2011, and White (2005:106), coach of the 2007 Rugby World Cup winning team, the South African Springboks, concur with the previous studies and believe that performance in a sport such as rugby could be improved by making use of video analysis. One should understand that all of the above-mentioned research was conducted before 2008 and did indicate that the reliability of TMA via video analyses could be considered acceptable, provided specific guidelines are followed. The mentioned advantages of TMA are in line with those mentioned by Lachapelle *et al*. (2009), who state that the use of technological advances for determining speed, distance and time in sport was an increasingly common phenomenon.

The biggest concerns about video analyses as TMA method are the training qualifications of the operators, the level of complexity of the analyses done and whether inter- and intra-operator tests had been conducted (O'Donoghue, 2007:46). These concerns may have led to the development and use of GPS technology in conjunction with computer software programs. Schutz and Chambaz (1997:339) identify and motivate the use of GPS technology to measure human locomotion by pointing out the following advantages: 1) portability; 2) non-invasive measurement; 3) value of feedback; 4) accessibility; 5) storing and retrieving of data; 6) relative inexpensiveness; and 7) an independent technique to validate velocity. Portas *et al.* (2010:448) point out that GPS technology has addressed the logistical and restrictions of previously mentioned TMA systems and Coutts and Duffield (2010:133) believe GPS methodology to be the norm for sport scientists when quantifying player movements either during training or during a match. Expansive research has been done on the use of GPS technology in rugby. Table 2 presents the applicable studies done on the reliability and validity of GPS technology in TMA.

Table 2: Research related to reliability and validity of GPS technology to determine human locomotion in sport

Authors	Title	Year	Comparison	Sample rate # Make
Edgecomb, S.J. & Norton, K.I.	Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian football.	2006	GPS and computer-based tracking systems	1 Hz # SPI-10
Petersen, C., Pyne, D., Portus, M. & Dawson, B.	Validity and reliability of GPS units to monitor cricket-specific movement patterns.	2009	Different GPS units Data from the same units at different times of the day	1 Hz # SPI-10 5 Hz # SPI-Pro 5 Hz # Mini max
Barbero-Àlvarez, J.C., Coutts, A., Granda, J., Barbero-Àlvarez, V. & Castagna, C.	The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability in athletes.	2010	GPS with time gates	1Hz # SPI-elite
Coutts, A.J. & Duffield, R.	Validity and reliability of GPS devices for measuring movement demands of team sports.	2010	Different devices	1 Hz # SPI SPI-elite and WiSPI
Duffield, R., Reid, M., Baker J. & Spratford, W	Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports.	2010	Units with one another	1Hz # SPI-elite 5 Hz # MinimaxX
Gray, A.J., Jenkins, D., Andrews, M.H., Taaffe,D.R. & Glover, M.L.	Validity and reliability of GPS for measuring distance travelled in field-based team sports.	2010	Linear running, multi directional	1Hz # SP-elite
Jennings, D., Cormack, S., Coutts, A.J., Boyd, L. & Aughey, J.	The validity and reliability of GPS units for measuring distance in team sport-specific running patterns.	2010	Linear running, multi-directional and sport running	1Hz # MinimaxX 5-Hz # MinimaxX

SPI = sport performance indicator, Hz = Hertz

Table 2 (cont.): Research related to reliability and validity of GPS technology to determine human locomotion in sport

Authors	Title	Year	Comparison	Sample rate # Make
Randers, M. B., Mujika, I., Hewitt, A., Santisteban, J., Bischoff, R., Solano, R., Zubillaga, A., Peltola, E., Krustrup, P. & Mohr, M.	Application of four different football match analysis systems: A comparative study.	2010	Video analyses, multi-camera system and two GPS systems	1 Hz # SPI-elite 5 Hz # MinimaxX
Portas, M.D., Harley, J.A., Barnes, C.A. & Rush, C.J.	The validity and reliability of 1-Hz and 5-Hz global positioning systems for linear, multidirectional, and soccer-specific activities.	2010	Linear, multidirectional and soccer-specific activities between devices	1 Hz # MinimaxX 5 Hz # MinimaxX
Castellano, J., Casamichana, D., Calleja-Gonzá, J., Román, J.S. & Ostojic, S.M.	Reliability and accuracy of 10-Hz GPS devices for short-distance exercise.	2011	15 and 30 meter distances	10 Hz # MinimaxX
Waldron, M., Worsfold, P., Twist, C. & Lamb, K.	Predicting 30-m timing gate speed from a 5-Hz GP device.	2011	Time gates and GPS	5 Hz GPSports
Varley, M.C., Fairweather, I.H. & Aughey, R.J.	Validity and reliability of GPS for measuring instantaneous velocity during acceleration, and constant motion.	2012	Acceleration between units	5 Hz # MinimaxX 10 Hz # MinimaxX
Vickery, W, W., Dascombe, B., Duffield, R., Baker, J., Spratford, W & Higham, D.	Accuracy and reliability of GPS devices for measurement of sport-specific movement patterns related to cricket, tennis and field-based team sports.	2014	Devices of different sample rate	5 Hz # MinimaxX 10 Hz # MinimaxX 15-Hz # SPI
Akenhead, R., French, D., Thompson, K.G. & Hayes, P.	The acceleration-dependent validity and reliability of 10-Hz GPS.	2013	Different accelerations	10 Hz # MinimaxX
Johnston, R.J., Watsford, M.L., Pine, M.J., Spurrs, R.W. & Sporri, D.	Assessment of 5-Hz and 10-Hz GPS units for measuring athlete movement demands.	2013	Devices with one another	5 Hz # MinimaxX 10 Hz # MinimaxX

SPI = sport performance indicator, Hz = Hertz

The comprehensive group of studies portrayed in Table 2 clearly reflect the concerns regarding the reliability and validity of GPS analyses. Different models and units with different sample rates were used in the studies. According to Cummins *et al*. (2013:1026) GPS devices function at 1, 5, and 10 Hz rates. Vickery *et al*. (2014) also mention a 15-Hz device in their study.

Duffield *et al*. (2010:525) found data from a 1-Hz GPS with an intra-class correlation (ICC) of 0.43 for the 5 Hz units, suggesting a more reliable value in comparison to an ICC value of 0.87 for the 1 Hz units when measuring distance. An ICC value of 0.43 for the 5 Hz unit and 0.69 for the 1 Hz unit when measuring high velocities also suggests the latter to be less reliable than data retrieved from a 5-Hz GPS device when velocity and distances in a confined space are measured. In contrast, Vickery *et al*. (2014) believe that the reliability of data does not improve as the sampling rate increases with a coefficient of variance (CV) for the 5 and 15 Hz devices of 3-33% for distance and speed measurements. The low reliability values of the 15 Hz device might have been due to the accelerator that was added to the 10-Hz unit. The reliability results from the accelerator-assisted GPS units are questionable, especially when determining fatigue as identified by Aughey *et al.* (2011:306). According to Johnson *et al*. (2013:272), data from 5-Hz devices were less reliable and valid than data gathered from 10-Hz GPS units. These findings are in line with the research results of Varley *et al*. (2012:125) that found the 10-Hz devices to be three times more accurate than the 5-Hz models when acceleration and velocity were measured (Jennings *et al*., 2010:334). It therefore seems that 10-Hz GPS devices provide more accurate TMA results than those with a smaller sample rate or bigger sample rate due to accelerators being added.

Concerns when gathering data with GPS devices have been raised by, amongst others, Coutts and Duffield (2010:135), Duffield *et al*. (2010:525) and Akenhead *et al*. (2013), who all suggest that GPS devices should not be interchanged by the players due to low inter-unit reliability. Randers *et al.* (2010:181) compared data collected by different TMA systems and cautioned that results gathered from these systems should not be compared with one another either. When players are tracked and analysed via GPS, research teams are advised to measure the signal strength of the satellites (Petersen *et al*., 2009:391). Vickery *et al.* (2014:1701) identify horizontal dilution of position (HDOP) here as the main quality indicator of satellite signal strength. A factor that seems to have no effect on the reliability of the data is the time when the research was performed, as proven by Petersen *et al*. (2009:389).

In conclusion, Castellano *et al*. (2011:234) suggest the 10-Hz MinimaxX 4 to be highly accurate during TMA and Coutts and Duffield (2010:135), Coughlan *et al.* (2011:602) and Johnson *et al.*

(2013:272), all consider the new 10-Hz GPS technology to be a valid and reliable method for performing TMA when adequate HDOP values exist. According to Maddison and Mhurchu (2009:75), the biggest advantages of GPS TMA are a) free access to satellites; b) non-obstructive hardware; c) on-line data availability, and d) easy storage of data. The possibilities of TMA as research tool are therefore palpable when these advantages are taken into consideration.

In view of the above, it is imperative to consider related scientific research since 1995 on RU and RS with regard to TMA. The reason for selecting this period is that literature suggests that the sport codes have changed significantly since RU turned professional in 1995 (Eaves & Hughes, 2003:105; Quarrie & Hopkins, 2007:902).

2.2 TMA research on RU

As indicated earlier, research on the use of TMA on rugby gained momentum over the last two decades. Due to the extent of the application of TMA and the associated elements involved in the related research, the information is presented in a summary in Table 3. The content of the table (19 articles) is briefly discussed to highlight certain elements related to this chapter.

Table 3: TMA research related to RU

Title	Authors	Year & Method	Aim of the study	Population	Match-play activities
Heart rate, blood lactate and kinematic data of elite colts (under 19) rugby union players during competition.	Deutsch, M.U., Maw, G.J., Jenkins, D. & Reaburn, P	1998 (Video)	Determining the physical demands of RU on different player positions.	24 ♂ players from U/19 Brisbane rugby competition; 4 groups of playing positions Scrumhalves excluded Age: mean = 18.4 years	Standing, Walking, Sprinting, Jogging, Cruising, Sprinting, Utility
Time motion analysis of 2001 and 2002 Super 12 rugby.	Duthie, G.M.,; Pyne, D.B. & Hooper, S.L.	2005 (Video)	Quantifying the movement patterns of RU players between halves and player positions.	16 Games 3 Australian-based ♂ rugby teams 4 groups of playing position (Scrumhalves excluded)	Standing Striding Walking Sprinting Jogging Static exertion Tackling Jumping Lifting
Characteristics of effective ball carries in Super 12 rugby.	Sayers, M.G.L & Washington-King, J.	2005 (Video)	Analysing effective ball carries by comparing successful and less successful players and different positional groups.	48 Super 14 rugby matches 90 ♂ players 4 sets of playing positions	Stationary Cruising Walking Sprinting Jogging
Sprinting patterns in rugby union players during competition.	Duthie, G.M., Pyne, D.B,, Marsh, D.J. & Hooper, S.L.	2006a (Video)	Analysing sprint patterns of RU players.	♂ Provincial Australian players. 17 rugby players Age: mean = 23.8 years	Standing Walking Jogging Striding
Position-specific rehabilitation for rugby union players. Part I: Empirical movement analyses data.	Eaton, C. & George, K.	2006 (Video)	Quantifying the positional movement patterns of professional RU players competing in the English Premiership.	35 ♂ players Northampton FRC Age:20-34 years	Standing <0.5 m/s, Walking <2 m/s, Jogging >2 m/s, Runs > 4 m/s, High-speed runs >5.5 m/s Sprints >7 m/s

♂ = Males RU = Rugby Union m/s = meters per second; U =under

Table 3 (cont.): TMA research related to RU

Title	Authors	Year & Method	Aim of the study	Population	Match-play activities
Time-motion analysis of professional rugby union players during match-play.	Deutsch, M.U., Kearney, G.A. & Rehrer, N.J.	2007 (Video)	Determining the physical demands of professional RU in various playing positions to improve training.	8 Super 12 rugby games 29 ♂ Otago Highlanders players	6 speeds of locomotion (e.g. Jumping, Cruising, Scrummaging, Utility Sprinting, Jogging) & other playing activities.
The physical demands of elite English rugby union.	Roberts, S.P., Trewartha, G., Higgitt, R.J., EI-ABD, J & Stokes, K.A.	2008 (Video)	Determining the physical demands of match-play to enhance training.	Premiership ♂ players Tight forwards (n=8), Loose forwards (n=6), Inside backs (n=7), Outside backs (n=8) (Scrumhalves excluded)	Standing, walking, jogging, static exertion, low-intensity running and high-intensity running.
An evaluation of the physiological demands of elite rugby union using global positioning system tracking software.	Cunniffe, B., Proctor, W., Baker, S.J. & Davies, B.	2009 (GPS)	Determining the physiological demands of elite RU on players (case study).	Glenmorgan ♂ University players Forward player (n = 1) Backline player (n = 1) Age: mean = 25 years	% time spend in velocity zones and total distance covered.
Motion analyses of adolescent rugby union players: A comparison of training and game demands	Hartwig, T., Naughton, G. & Searl, J.	2010	Comparing training session intensities with match intensities.	Training: 187.8 hours @161 ♂ players Game: 32.9 hours @ 53 players	0 –1 km/h – stationary, 1–7 km/h – walking, 7–12 km/h – jogging, 12–21 km/h – striding, 21 + km/h - sprinting.
Repeated high-intensity exercise in a professional rugby league.	Austin, D., Gabbett, T. & Jenkins, D.	2011a (Video)	Describing the frequency, duration and nature of repeated high-intensity exercise relative to positional groups.	20 ♂ Queensland Reds players 7 Super 14 matches Frontrow forwards (n = 5) Backrow forwards (n = 5) Inside + outside backs (n = 5)	Standing, forward walking, backward walking, forward jogging, backward jogging, forward striding, forward sprinting, lateral movements.

% = percentage @ = at ♂ = Males RU = Rugby Union km/h = kilometres per hour n = population

Table 3 (cont.): TMA research related to RU

Title	Authors	Year & Method	Aim of the study	Population	Match-play activities
The physical demands of Super 14 Rugby Union	Austin, D., Gabbett, T. & Jenkins, D.	2011a (Video)	Determining the match-play demands of Super 14 RU.	20 ♂ Queensland Reds players 7 Super 14 matches Frontrow forwards (n = 5) Backrow forwards (n = 5) Inside backs (n = 5) Outside backs (n = 5) Age: mean = 23 years	Standing, forward walking, backward walking, forward jogging, backward jogging, forward striding, forward sprinting, lateral movements
Physical game demands in elite rugby union: A global positioning system analysis and possible implications for rehabilitation.	Coughlan, G.F., Green, B.S, Pook, P.T., Toolan, E. & O'Connor, S.P.	2011 (GPS)	Determining the physical demands of an international RU-level game using GPS.	Forward player (n = 1) Backline player (n= 1) Dublin ♂	standing 0–0.5 m/s walking 0.5–1.7 m/s jogging 1.7–3.6 m/s med running 3.6–5 m/s fast running 5–6.7 m/s max running 6.7 > m/s <
The use of global positioning systems (GPS) tracking devices to assess movement demands and impacts in Under-19 Rugby Union match play.	Venter, R.E., Opperman, E. & Opperman, S.	2011 (GPS)	Analysing a selected movement pattern of Elite Under -19 RU forward and backline players.	n =17 ♂ players @ game for 5 games Stellenbosch University Provincial players Age: mean = 18.5 years	Standing 1> km/h Distance travelled at % of individual players' maximum velocity.

% = Percentage ♂ = Males GPS = Global Positioning System RU = Rugby Union m/s = meters per second n = population km/h = kilometres per hour

Table 3 (cont.): TMA research related to RU

Title	Authors	Year & Method	Aim of the study	Population	Match-play activities
Positional demands of international rugby union: Evaluation of player actions and movements.	Quarrie, K.L., Hopkins, W.G., Anthony, M.J. & Gill, N.D.	2013 (Video)	Analysing movements and activities of players in international RU matches, clearly delineating positional roles.	763 players ♂ 27 matches Props, hookers, locks, flankers, eight men, first five eights, midfield centres, wings fullbacks New Zealand elite	0–2 m/s 2–4 m/s 4–6 m/s 6–8 m/s >8 m/s
Return to play in elite Rugby Union: Application of global positioning system technology in return-to-running programmes.	Reid, L.C., Cowman, J.R., Green, B.S. & Coughlan, G.F.	2013 (GPS)	The application of GPS systems in the management of return to play - injured club RU players.	n = 8 ♂; 1 match loose head prop, lock, flanker, scrum half, fly-half, centre, wing and fullback Club players from six nations countries Age: mean = 27.9 years	0–0.5 m/s 0.5–1.7 m/s 1.7–3.6 m/s 3.6–5 m/s 5– 6.7 m/s >6.7
The movement characteristics of English premiership rugby union players.	Cahill, N., Lamb, K., Worsfold, P., Headey, R. & Murray, S.	2013 (GPS)	Quantifying the movement characteristics of English premiership RU players: positional orientated.	n =120 ♂ 44 matches English clubs Age: mean = 17.5 years	Distance travelled at % of individual player's maximum velocity.
Physiological demands of women's rugby union: time-motion analysis and heart rate response.	Virr, J.L., Game, A., Bell, G.J., & Syrotuik, D.	2013 (Video)	Determining the physical demands of women's RU match play using time-motion analysis and heart rate response.	n =38, ♀ 10 matches Age: 18 to 34 years	12 different movement categories: 5 speeds of locomotion Standing Walking Jogging Striding, Sprint, Static high-intensity activities

% = percentage ♂ = Males GPS = Global Positioning System RU = Rugby Union m/s = meters per second n = population
km/h = kilometres per hour

Table 3 (cont.): TMA research related to RU

Title	Authors	Year & Method	Aim of the study	Population	Match-play activities
A new approach to quantify physical demands in rugby union.	Lacome, M., Piscione, J., Hager, J. & Bourdin, M.	2014 (video)	An original approach to assess individual workload during international RU competitions.	n = 30 ♂ 5 matches French RU players	Exercise to recovery

♂ = Males ♀ = Females RU = Rugby Union

When analysing the research depicted in Table 3, is noteworthy that there is a trend of small sample sizes in recent years when using GPS devices. Except for the work done by Cahill *et al*. (2013), who used 120 players in their study, the average sample size of the populations in the studies that made use of GPS devices were very small (7.6). However, several data sets of these populations were analysed. Taking into consideration that researchers prefer to focus on elite sport and the unwillingness of elite sport to allow research teams to make players wear scientific equipment such as GPS devices during tournaments to conduct studies, one may understand the smaller sample sizes. Despite the small sample sizes, valuable information has been gathered by means of TMA conducted as indicated in the research listed in Table 3.

The studies in Table 3 focused on determining the total distances the players travelled and at what velocities these distances were completed. The velocities at which the players moved during play were categorized high and low-intensity movement activities. In addition to movement activities, static exertions were also categorized as high-intensity activities.

2.2.1 High and low-intensity movement activities in RU

From most of the articles reviewed and presented in Table 3, sprinting, high-intensity running and static exertions (tackling, scrumming, jumping and rucking) all are considered high-intensity movement activities. Low-intensity activities included standing, walking, jogging and striding/cruising. The research of Sayers and Washington-King (2005:94), Duthie *et al*. (2005:525) and Virr *et al*. (2013:241) discriminate between the different movement activities through definitions; for example, striding is defined as running with severe arm movement. Other research assigned specific velocities to the different movement activities, but the velocities allocated to the activities differ slightly between research teams. Hartwig *et al*. (2010:968) classify the movement categories as follows: stationary (0–1 km/h), walking (1–7 km/h), jogging (7–12 km/h), striding (12–21 km/h) and sprinting (21 + km/h). Suãrez-Arrones *et al.* (2012b:78) and Cunniffe *et al.* (2009:1197) suggest the following velocities: walking and standing (0–5.9 km/h), jogging (6–11.9 km/h), cruising (12–13.9 km/h), striding (14–17.9 km/h), high-intensity running (18–19.9 km/h) and sprinting to be above 20 km/h.

In contrast Reid *et al*. (2013:123), Coughlan *et al*. (2001:601) and Roberts *et al*. (2008:827) prefer the following velocities to classify the intensity of movement: standing (0–0.5 m/s), walking (0.5–1.7 m/s), jogging (1.7–3.6 m/s), medium-intensity running (3.6–5m/s), high-intensity running (5–6.7m/s), and sprinting to above 6.7m/s. Eaton and George (2006:23) partially agree with the last-mentioned velocities, but classify jogging and medium-intensity running together and regard the activity as sprinting when the player ran faster than 7 m/s.

Quarrie *et al*. (2013:358) used their own scale that reads as follows: zone 1 (≤ 0.1 m/s), zone 2 (0.1–2m/s), zone 3 (2–4m/s), zone 4 (4–6 m/s), zone 5 (6–8m/s) and zone 6 (≥ 8m/s). Cahill *et al*. (2013:233), Duthie, Pyne and Marsh *et al*. (2006:211) and Venter *et al*. (2011:5) all prefer to test each player's maximum velocity in advance and to determine velocity zones that are relative to the percentage expressed for the relevant player's maximum velocity. Standing was considered to be <1 km /h, walking <20% of the relevant player's maximum velocity (Vmax); jogging 20–49% Vmax; Striding 50–79% Vmax; Sprinting 80–95% Vmax; Maximum speed >95% Vmax. One should take note that where the other literature considers sprinting as the maximum velocity, Cahill *et al.* (2013:233) and Venter *et al*. (2011:5) regard the maximum speed category as the maximum velocity. So when Cahill *et al*. and Venter *et al*. refer to sprinting, other literature probably would categorize the same velocity as high-intensity running. It is striking that literature does not always use the same intensity zones for the specific movement velocities, which makes comparison difficult. The lack of standardized velocity protocols for TMA was also found in other sport codes such as soccer, hockey and AFL (Dwyer & Gabbett, 2012:822).

In addition to the movement velocities, research displayed in Table 3 either focused on the time each player spent on the movement intensity or the percentage time the player spent on the movement velocity. In this regard, when TMA is done on football players, McKenna *et al.* (1988:278) are of the opinion that the time spent on each movement activity should be considered the most important variable to address, while Treadwell (1988:284) suggests that the percentage time spent on each activity should give a better indication of the physical demands placed on the football players.

When the movement activities of low and high-intensity activities were interpreted for RU players, the following conclusions were drawn: Austin *et al*. (2011b:262) determined that players spent 75% of their total distance travelled on low-intensity activities and 25% of their total distance travelled on high-intensity activities. Venter *et al.* (2011:6) concur with these findings, indicating that 72.32% of the total distance covered by the players in their research was low-intensity activities. One would therefore expect that match-specific training sessions would adhere to similar percentage time spent on both the high and low-movement activities.

2.2.2 Player positional differences with regard to TMA of RU players

The importance of determining the match- and player-specific demands for RU, as explained earlier, was highlighted by eighteen of the twenty articles in Table 3 addressing player-specific differences during their respective analyses. The importance of understanding the match

demands RU places on the different players' positions was addressed by more than fifty percent of the above-mentioned studies. Eaton and George (2006:24), Quarrie *et al*. (2013:356) and Reid *et al*. (2013:123) analysed each player's position individually. Duthie, Pyne and Marsh *et al.* (2006:209), Cunniffe *et al*. (2009:1196) and Coughlan *et al*. (2011:601) preferred to concentrate their respective studies on the grouping of forward and backline players as suggested by Gamble (2004b:10). Other research teams felt it necessary to divide the two groups further. The reason for the further division might be due to the research teams considering players to perform a higher level of individual duties in the sub-groups. Forward players were subdivided into front row (props, hookers and locks) and backrow forwards (flank and eighth man) while backline players were subdivided into inside backs (scrum half, fly half and centres) and outside backs (wings and full back) (Deutsch *et al.*, 1998:566; Duthie *et al.*, 2005:526; Deutsch *et al*., 2007:465; Roberts *et al.*, 2008:829; Austin *et al.*, 2011a:1898; Austin *et al.*, 2011b:260; Venter *et al.*, 2011:5; Suãrez-Arrones *et al.*, 2012b:1860; Cahill *et al.*, 2013:229).

What distinguished the studies of Deutsch *et al*. (1998:562) and Lacome *et al*. (2014:291) was the exclusion of the data gathered from the scrumhalves due to the unique positional duties of this position. This observation is supported by Eaton and George (2006:25) and Quarrie *et al.* (2013:358), who found scrum halves to discriminate the most in relation to the other positions with regard to the number of sprints they perform. Reid *et al*. (2013:123) also found that scrumhalves covered a greater total distance during a match compared to any other position. When the differences of the movement velocities between the scrumhalves and the rest of the players are considered, one may understand why some research teams decided to exclude the movement data of the scrum halves. From the remarks above it seems that the total distance travelled by the players, and more specifically by the different positions of the various players, are regarded as important.

2.2.2.1 Player positional differences with regard to total distance travelled.

Eight articles reported on the total distance their respective forward and backline players travelled. Due to this volume, these articles are presented and discussed separately.

Table 4: **Total distance travelled by RU players during a match**

Authors	Distance travelled by backline players	Distance travelled by forward players	Significance	Players level
Deutsch *et al.* (1998:467)	5640 meters	4240 meters	$p < 0.01$	Elite u/19
Roberts *et al.* (2008:830)	6217 meters	5581 meters	$p < 0.05$	Elite Senior
Austin *et al.* (2011b:262)	6389 meters	5139 meters	$p < 0.05$	Elite Senior
Venter *et al.* (2011:5)	4452 meters	4487 meters	-	Elite u/19
Coughlan *et al.* (2011:603)	7002 meters	6427 meters	-	Elite Senior
Cahill *et al.* (2013:233)	6545 meters	5850 meters	$p < 0.05$	Elite Senior
Lacome *et al.* (2014:294)	7944 meters	7006 meters	$p < 0.05$	Elite Senior

Significance was indicated by $p < 0.05$ significance

From the data in Table 4 one can infer that senior players are required to cover greater distances during a match than is the case with the under-nineteen age group players. One of the primary reasons why the under-nineteen players covered less distance than the senior players may be that their matches only lasted 70 minutes, as indicated by Venter *et al.* (2011:3) and Deutsch *et al.* (1998:462), while the senior matches lasted 80 minutes. Careful consideration is therefore needed when an under-nineteen player is suddenly selected for a senior side and required to cover longer distances than he was accustomed to. With regard to distance travelled, five of the seven articles cited in Table 4 also indicated that the backline players covered a significantly longer distance than the forward players. When the total distance travelled by the individual positions were compared, Quarrie *et al.* (2013:355) found that the full backs travelled the furthest (6300 m) and flank forwards travelled the shortest distance (5400 m) during a match. It therefore appears that RU players in different positions should concentrate on covering different distances during training to ensure match-specific training.

2.2.2.2 Player positional differences with regard to low-intensity movement activities

Deutsch *et al*. (2007:464) report that forward players stood still more frequently than the backline players. In contrast, Virr *et al.* (2013:242) found that the forward players did not differ significantly from the backline players with regard to standing still during play. Cuniffe *et al*. (2009:1199) concur with Deutsch *et al.* (2007:464) that the forward players (3150) entered the low-intensity activities on more occasions than the backline players (229), but added that when the time these players had spent on the low-intensity activities was analysed, the backline players spent a higher percentage (77.8%) of their time standing and walking than the forward players (66.5%). Roberts *et al*. (2008:828) posit that backline players spent significantly ($p< 0.001$) more time walking (46%) than the forward players (35%). Virr *et al*. (2013:242) confirm that the backline players walked significantly more ($p<0.05$) than forward players. With regard to jogging, significantly ($p<0.05$) greater distances were covered by the forward (2990 meters) players than by the backline players (2470 meters) (Deutsch *et al*., 1998:567). Fourteen years after the study done by Deutsch *et al*., Cahill *et al*. (2012:232) also tested English players with more or less the same age and found that the forward players still jogged more (2616 meters) than the backline players (2559 meters). The above-mentioned results are supported by the findings of Virr *et al*. (2013:242), who tested females and determined that the forward players jogged significantly ($p<0.05$) more than the backline players. When Deutsch *et al*. (2007:464) focused on professional players, they came to the conclusion that the forward players jogged more than the backline players. It seems that despite the gender, age or time period during which the research was done, forward players tend to walk less and jog more than backline players. It therefore seems necessary to address these findings during match-specific training.

When the forward and backline players were divided into positional subcategories, the following was observed from the results: Both inside and outside backline players (analysed separately) covered greater distances on low-intensity activities than forward players (Deutsch *et al*. 1998:567). Eaton and George (2006:26) determined that during matches, backrow forward players spend the least amount of time on low-intensity activities, with outside backline players spending the most time on low-intensity activities. Roberts *et al*. (2008:828) posited no significant differences for front row and backrow forward players with regard to low-intensity activities. Roberts *et al*. (2008:828) indicated that outside backline players walked for longer periods than inside backline players. Deutsch *et al*. (2007:464) agree and reported that the front row forward players walked for significantly ($p < 0.0125$) shorter periods than outside backline players, which is in line with the findings of Venter *et al*. (2011:4), who indicated that outside

backline players spend significantly more time (1 515 s) on walking than front row forward players (2 172 s).

Eaton and George (2006:26) measured distance rather than time, and found that the outside backs covered a longer distance walking, with an average walking distance of 7.5 meters at a time. Eaton and George (2006:26) also reported that the outside backs walked the least number of times and the props jogged the least number (325 times) during a match, but the props covered the longest average distance jogging at a time (8.5 meters). Deutsch *et al*. (2007:464) also stated that front row forwards jogged significantly longer than did players in any other position. Hookers jogged the most (403 times) (Eaton & George, 2006:26) and Cahill *et al.* (2013:233) suggested that the hookers spent 53% of the time jogging compared to all the movement activities, which is the highest percentage of time spent on jogging for any position. Venter *et al.* (2011:4) stated that the props (940 s) and locks (1571 s) spend more time jogging than outside backs (562 s). When the low-intensity activities of the different backline players were compared, the results identified the scrumhalves and fly halves as jogging further and walking less than the wings and full backs (Quarrie *et al.,* 2013:355). From the results presented above it can be concluded that the outside backs may be allowed to experience longer durations of active rest during training in periods of walking, while the front row forwards and specifically the hookers need to be exposed to longer periods of jogging during match-specific training. The back row forwards have to get the least active rest and are therefore expected to spend more time on the high-intensity activities than is expected from players in any other position during training.

2.2.2.3 Player positional differences with regard to high-intensity movement activities

Based on the analyses of the literature on the high-intensity activities, the following conclusions can be stated: Roberts *et al.* (2008:832) consider high-intensity running such as sprinting and cruising to be of great importance for RU players due to a direct correlation between performance and the effectiveness of high-intensity running. In this regard backline players travelled significantly ($p<0.01$) greater distances sprinting and cruising (mean =207 meters) compared to the forward players (mean =164 meters) (Deutsch *et al*., 1998:567 & Roberts *et al.,* 2008:828). The backline players spent significantly more time on sprinting activities and covered significantly ($p=0.01$) longer distances at higher velocities and for longer periods than the forward players (Duthie *et al.,* 2005:527; Virr *et al*., 2013:242). In a study by Deutsch *et al*. (2007:469), the forwards sprinted 3.3 seconds on average, while backline players sprinted 6.2 seconds on average. Cahill *et al.* (2013:232), Cunniffe *et al.* (2009:1199) and Duthie, Pyne and

Marsh *et al*. (2006:211) concurred that the backline players travelled longer distances at higher velocities and posited that the backline players were also able to maintain a higher average velocity than the forward players. Related to the above-mentioned results, Cuniffe *et al.* (2009:1197) found that the backline players engaged in more sprint activities than was the case with the forward players (34 vs. 19). Duthie, Pyne and Marsh *et al*. (2006:211) had similar results with the backline players engaging in sprints 24 times, while the forward players were only able to sprint 13 times. Coughlan *et al*. (2011:603) concurred with backline players sprinting 16 times while the forward players only sprinted 3 times.

In addition to the results on high-intensity running activities, one should also look at the comparison of the different positions with regard to static exertions and gaining a more comprehensive view of all the high-intensity activities. Deutsch *et al.* (1998:567) established that backline players spend less time on static exertion activities than forward players. These findings are in line with those of Duthie *et al.* (2005:527), who determined that forward players spend more time on each static exertion (mean = 4.7 seconds) compared to backline players (mean =3.3 seconds) and also perform more (mean = 68) actual static exertions than the backline players (mean = 59). In addition, Roberts *et al.* (2008:830) found that the forward players acted more often and for longer periods (89 @ 5.2 seconds) on static exertion activities than did the backline players (24 @ 3.6 seconds). Duthie *et al.* (2005:524) concluded that the forward players spent 14% of their game time on high-intensity static exertions compared to the 6% of backline players. These findings are in line with those of Austin *et al.* (2011a:1900), who also found forward players to spend 14% of their time on high-intensity static exertions compared to the 8% of the backline players. The results indicated above therefore seem to indicate that backline players need to spend more time on longer distances and sprint and cruise greater distances during training than is necessary for forward players. Forward players, on the other hand, need to focus on more training time performing static high-intensity activities. Austin *et al.* (2011b:261) collectively grouped static exertion and sprinting as repeated high-intensity activities and determined that the number of static exertions from the forward players exceeded that of the backline players. With the forward players spending more time on high-intensity static exertions and the backline players running at higher velocities, one should probably focus more on strength training with the forward players and speed and agility training with backline players, as suggested by Duthie *et al.* (2005:524).

When the high-intensity activities of the subdivided positional groupings were compared, the following was found: Austin *et al*. (2011b:261) determined that the outside backs performed sprints longer than 40 meters significantly more ($p < 0.05$) than any of the two forward groups.

Statistically significantly fewer sprints of less than 5 meters were also measured for the outside backline players compared to the two forward groups and the inside backline players. The front row forward players and backrow forward players, on the other hand, had statistically significantly longer durations of static high-intensity activities compared to both backline player groups (Austin *et al*., 2011b:261). According to Deutsch *et al.* (2007:464), the outside backs engaged in statistically significantly ($p<0.0125$) more sprints and for longer durations than the front row forwards. Eaton and George (2006:25) found outside backline players to engage in the most (14) sprints and for the longest distances (15.2 meters). Cahill *et al*. (2013:232) and Quarrie *et al*. (2013:358) agreed that the outside backs covered longer distances than the inside backs and at higher velocities. Venter *et al.* (2011:5) added that it was the outside backs who reached the highest velocities during a match. Reid *et al*. (2013:123) went further and divided the players into individual positions and found that the wings accomplished the highest velocity during a match (Reid *et al*., 2012:123). It therefore seems that the outside backline players need to focus on distances longer than 5 meters during sprint training, while the other positions need to focus on distances less than 5 meters. In addition to high-intensity running, acceleration plays an exceptionally important role towards performance in RU (Austin *et al*., 2011a:1899).

2.2.2.4 Player positional differences with regard to accelerations

Suãrez-Arrones *et al*. (2012b:1860) explain that the term 'accelerations' refers to the frequency with which a player heightens speed as defined in the velocity categories over a 1-second period. Lacome *et al*. (2014:294) found backrow forwards to accelerate at > 3 m.s^{-2} more often than the other three positional groups, with inside backs accelerating significantly more at 1-2 m.s^{-2} than the other three positional groups. The forward players accelerated significantly ($p < 0.05$) more than the backline players, with them accelerating significantly longer and at higher velocities than the forward players. The majority of accelerations (41.2%) occurred between 1 and 2 m.s^{-2} and originated from low-intensity activities (walking - 53.4% and jogging - 31.8%).

Duthie, Pyne and Marsh *et al*. (2006:211) found that the backline players performed more sprints from a striding start and the forwards performed most of their sprints from a low-intensity activity such as walking, jogging or standing. The above statement may suggest that backline players may be more successful during evasive running than forward players. Sayers and Washington-King (2005:99) determined that when players received the ball during high-intensity running, they managed to execute significantly better evasive running outcomes than was the case when they received the ball during low-intensity activities. In addition, Sayers and Washington-King (2005:97) posited that there is a direct correlation between an increase in

velocity and the success rate of evasive running, which might explain why the forward players battled more than the backline players to achieve a successful evasive run, as research has proven that the forward players are running more often at lower velocities. This suggests that the backline players need to train their respective accelerations from an already-moving velocity, while the forward players need to train acceleration from a standing position.

2.2.3 The effect of fatigue on the movement activities of RU players

Duthie *et al.* (2005:524) identified the importance of investigating the movement activities throughout a rugby match as a means to monitor the effect of fatigue. Austin *et al.* (2011a:1898) compared the repeated high-intensity activities during the two halves and found no significant differences. Duthie *et al*. (2005:524) also found no significant differences on the TMA between the two halves in their study. Although not significant, Coughlan *et al.* (2011:602) reported that the players covered longer distances in the second half than in the first half, whilst Cuniffe *et al.* (2009:1200) established that the players travelled at higher velocities in the second half. No statistically significant differences were found between the intensity of the activity, the duration or the work-to-rest ratios in any of the groups of player positions between the two halves (Lacome *et al*., 2014:294). The only significant difference found in the TMA of players between two halves was identified by Roberts *et al.* (2008:830). They found that the players covered a longer distance during the first 10 minutes of the match compared to the last ten minutes. The lack of differences between the movement patterns of the players between the two halves suggest that fatigue has no direct effect on the movement patterns in the latter part of the game (Duthie *et al.*, 2005:530).

Although information in literature on the total distances travelled by the players, the velocity at which the players travelled, the effect of fatigue on the players or the acceleration during play are considered valuable to players for developing match-specific training sessions, Deutsch *et al.* (2007:461) suggests that the calculation of work-to-rest ratios would be even more valuable to the coaching staff for investigating the physiological demands of RU.

2.2.4 Work-to-rest ratios of RU players

Work-to-rest ratios indicate the relation between the lengths of time the player works against the length of time the player is recovering during a match. According to Deutsch *et al.* (1998:563), activities such as sprinting, cruising and static exertions may be defined as work, where standing still was described as rest and walking and jogging both regarded as active rest. The time spent on the different high-intensity activities (considered work) is therefore compared to the time

spent on low-intensity activities to determine the players' work-to-rest ratio. The findings of work-to-rest ratios gathered from the literature are presented in Table 5.

Table 5: Work-to-rest ratios of RU players

Author	P - value	Forward players: work-to-rest ratios	Backline players: work-to-rest ratios
Cuniffe *et al.*, 2009:1200	N/A	1:5.7	
Deutsch *et al.*, 1998:567	$p < 0.05$	1:1.4	1:2.7
Eaton & George 2006:26	$p = 0.894$	1:8.3	1:13
Deutsch *et al.*, 2007:467	$P < 0.0125$	1:7.4	1:21.8
Virr *et al.*, 2013:245	$p < 0.05$	1:4	1:9.1

	Frontrow forwards	Backrow forwards	Inside backs	Outside backs
Deutsch *et al.*, 1998:567	1:1.8	1:1.2	1:3.6	1:2.2
Deutsch *et al.*, 2007:467	1:7.3	1:7.4	1:20.9	1:22.8
Austin *et al.*, 2011b:261	1:4	1:4	1:5	1:6

Significance was indicated by $p < 0.05$ significance

The discrepancy observed between the data from Deutsch *et al.* (1998) and the rest of the literature reported in Table 5 may be due to the early time frame in which the data from the first-mentioned study was captured. Statistically significant differences were found for the work-to-rest ratios between forward and backline players (Deutsch *et al.*, 1998:567; Deutsch *et al*., 2007:467; Virr *et al.*, 2013:245). The smaller rest ratio of the forward players suggest that they need to maintain a higher work load than the backline players. The forward players seemed to work more frequently with high-intensity activities that last longer than eight seconds while the backline players were more involved in high-intensity activities that last for less than 4 seconds (Duthie *et al*. 2005:527). The outside backline players had significantly more recovery time between bouts (109 seconds) compared to the front row forward players (27 seconds) (Austin *et al*., 20011a:1902). Very rarely do the work periods of the players exceed a period of six (Duthie

et al., 2005:529) or ten seconds (Nicholas, 1997:394) with the majority of rest periods being shorter than 20 seconds. Lacome *et al*. (2014:297) concur and added that 60% of the high-intensity activities lasted less than four seconds. In addition to just work-to rest-ratios, Austin *et al.* (2011b:261) decided to investigate the occurrence of repeated high-intensity activities, which are defined as three or more high-intensity activities with less than 21 seconds recovery time in between. The findings suggested that repeated high-intensity activities could be endured for up to two minutes or longer. These short rest periods throughout high-intensity activities have a direct application to the preparation of the players (Duthie *et al.,* 2005:529). When the research presented in Table 5 is analysed, there is a conspicuous difference between the work-to-rest ratios of the forward and backline players. It seems that the forward players have less time to recover than the backline players and the players should be allowed rest accordingly during training.

2.2.5 Additional comparisons done on RU players with the aid of TMA

Except for comparing movement velocities between different positions of players, research also suggests that the differences that may exist between training and match play should be investigated. Hartwig *et al.* (2010:970) compared the movement patterns of training sessions with matches per hour and found that the players sprinted significantly ($p < 0.001$) more and for longer durations during matches than was the case during training. However, the distance and duration of a single sprint between the training session and the match did not differ. Despite the importance of sport-specific training, Hartwig *et al*. (2010:970) report that the training sessions seem to differ significantly from that which is required from players during match play with regard to high-intensity activities. In addition to getting training sessions to be more match-specific, Austin *et al*. (2011b:263) suggest that overall high-intensity activities and higher sprint frequencies have become conspicuous as RU evolved. Another comparison of high-intensity activities was done by Quarrie *et al*. (2013:358), who investigated whether there is a correlation between different levels of competitions with regard to the high-intensity activities. They found that all players covered greater total distances during the high-intensity movement activities during international matches than was the case during lower levels of competition. Coaches should therefore probably allow for players to cover greater distances during training when preparing for a better level of competition.

2.2.6 Conclusion of TMA on RU players

It seems that RU is a sport code in which high-intensity intermittent activities are used during play, suggesting that the anaerobic energy systems play a predominate role, as proven by

Deutsch *et al.* (1998:568) and Cunniffe *et al.* (2009:1202). However, when repeated high-intensity activities during matches are considered, a much stronger aerobic nature emerges as the players do not necessarily have enough time to recover before the next high-intensity activity occurs. This may be the reason why Duthie *et al.* (2005:524) recommend that both the forward and backline players be exposed to some form of endurance training. Virr *et al.* (2013:246) state that training of the players should involve position-specific work activities of a contact nature with work-to-rest ratios simulating match play and focusing on the anaerobic energy pathways with the backline players allowed longer rest recovery time to ensure that their Adenosine Triphosphate Phosphocreatine (ATP-PC) sources are recovered. Due to the fact that no statistically significant differences were found for the work-to-rest ratios between the two backline and the two forward player subgroups (Duthie *et al*., 2005:524), one may argue that it is not necessary to subdivide the backline and forward players further. It seems that further subdivisions among the players when training will have no effect on the physiological abilities of the players. However, Nicholas (1997:394) suggests that existing position-specific differences may increase gradually as the level of play increases.

The above-mentioned literature reflects the research that has been done with TMA with a specific focus on RU due to its popularity and status. In the introduction of this chapter RS is also identified as a very popular and professional variant of rugby, especially with RS recently obtaining Olympic status. With the popularity of both rugby variants well established, it is necessary also to report on the research done on RS via TMA. Finally the results from the RU studies are compared to findings from RS to evaluate the hypothesis of Rienzi *et al*. (1999:161), who believe that the results from research already done on RU and its effects on the players' performance would be accentuated in RS.

2.3 TMA on RS

A total of six scientific articles focusing on TMA of RS were considered for inclusion in the section. A summary of the relevant information is presented in Table 6. Where applicable, a brief discussion follows to highlight some of the findings.

Table 6: Summary of TMA research conducted on RS

Title	Authors	Year & Method	Aim of the study:	Population	Match-play activities, Velocities
Investigation of anthropometric and work-rate profiles of Rugby Sevens.	Rienzi, E., Reilly, T. & Malkin, C.	1999 (video)	Determining and describing anthropometric and match performance profiles of RS players.	30 matches	Static pose, walking, jogging, movement sideways, high-intensity running, jogging backwards and walking backwards
Running demands and heart rate responses in men rugby sevens.	Suarez-Arrones, L., Nunez, F.J., Portillo, J. & Mendez-Villanueva, A.	2012a (GPS)	Analysing match running performance and exercise intensity in male RS players.	n = 7 5 matches	Walking (0-6 km/h); jogging (6.1-12 km/h); cruising (12.1- 14 km/h); striding (14.1 -18 km/h); high-intensity running 18.1-20 km/h); sprinting (>20 km/h)
Match running performance and exercise intensity in elite female rugby Sevens.	Suarez-Arrones, L., Nunez, F.J., Portillo, J. & Mendez-Villanueva, A.	2012b (GPS)	Analysing match running performance and exercise intensity in female RS players.	n = 12 5 matches	Standing & walking (0-6 km/h); jogging (6.1-12 km/h); cruising (12.1- 14 km/h); striding (14.1 -18 km/h); high-intensity running (18.1-20 km/h); sprinting (>20 km/h)
Movement patterns in rugby sevens: Effects of tournament level, fatigue and substitute players.	Higham, D.G., Payne, D.B., Anson, J.M. & Eddy, A.	2012 (GPS)	Determining and understanding the physical demands that RS place on the players.	n = 19 16 matches	**Velocities:** 0-2 m $s^{-1;}$ 2-3.5 m s^{-1}; 3.5-5 m s^{-1};5-6 ms^{-1}; 0 > 6 m s^{-1} **Accelerations:** 2-4 ms^{-2} (Moderate),>4 m s^{2} (High)

GPS = Global Positioning System n = population km/h = kilometres per hour m/s = metres per second RS = Rugby Sevens % = Percentage

Table 6 (cont.): Summary of TMA research conducted on RS

Title	Authors	Year & Method	Aim of the study:	Population	Match-play activities, Velocities
Comparison of activity profiles and physiological demands between international rugby sevens matches and training.	Higham D.G., Pyne, D.B., Anson, J.M., Hopkins W.G. & Eddy A.	2013 (GPS)	Quantifying position-specific activity profiles	n =42	Total distance, Maximum velocity, accelerations, decelerations, Distance in velocity zones: 0-2 m s^{-1}; 2-3.5m s^{-1}; 3.5 – 5 m s^{-1}; 5-6 m s-1; ≥6 m s^{-1}
Time-motion analyses via global positioning systems that discriminate between successful and less-successful South African, U/18 provincial rugby teams.	Van den Berg, P.H.	2013 (GPS)	Determining if the movement patterns of the South African, U/18 provincial rugby teams differ between the successful and less-successful rugby players.	16 matches n = 160 8 successful teams 8 less-successful teams	% time and distance for all categories; standing 0-0.5 m/s; walking 0.5-1.7 m/s; jogging 1.7-3.6 m/s; med running 3.6-5 m/s; fast running 5-6.7 m/s; max running 6.7 m/s <
Match analysis and temporal patterns of fatigue in rugby sevens	Granatelli, G., Gabbett, T.J., Briotti, G., Padulo, J., Buglione, A., D'Ottavio, S. & Ruscello, B.M.	2014 (GPS)	Investigating the physical and physiological demands of elite men's rugby sevens	n=9	% distance - 0.1<14km^{-1} & >14km-1 % time - 0.1<14km^{-1} & >14km^{-1}

GPS = Global Positioning System n = population km/h = kilometres per hour m/s = metres per second RS = Rugby Sevens % = Percentage

Table 6 (cont.): Summary of TMA research conducted on RS

Positional differences in match running performance and physical collisions in men rugby sevens.	Suarez-Arrones, L., Arenas, C., Ló pez, G., Requena, B., Terrill, O. & Mendez-Villanueva, A.	2014 (GPS)	Determining the positional differences that exist in a match with regard to running performance and physical collisions in men RS.	n = 10 23 matches	Walking (0.1-6 km/h); jogging (6.1-12 km/h); cruising (12.1-14 km/h); striding (14.1 -18 km/h); high-intensity running 18.1-20 km/h); sprinting (>20 km/h)
The demands of international rugby sevens.	Ross, A., Gill, N & Cronin	2015 (GPS)	Quantifying the global match demands of international rugby sevens	n =27	Total distance 0-5m s^{-1}(m) >5m s^{-1} (m)

GPS = Global Positioning System n = population km/h = kilometres per hour m/s = metres per second RS = Rugby Sevens % = Percentage

Except for the study conducted by Rienzi *et al*. in 1999, all the other studies were conducted after RS received Olympic status, and all but one research team chose to use GPS to do their TMA. Different objectives from the relevant research were achieved by means of TMA determining the movement activities by various groups of players. The results from the TMA were used to a) compare successful with less successful players, b) to determine positional differences between players, c) to establish the effect of fatigue on the players and d) to determine the work-to-rest ratios of the players all via the different movement activity intensities.

2.3.1 High- and low-intensity movement activities in RS

Before the availability of GPS analysis, Rienzi *et al*. (1999) categorized the movement activities of their players with the aid of movement definitions. The rest of the literature uses very similar velocities to categorize their players' movement activities. Due to these similarities, comparing the results of the movement intensities from different studies may be easier. When the studies that focused on the movement activities of RS players as mentioned in Table 6 were analysed, the following aspects were concluded:

Suarez-Arrones *et al*. (2012a:3157) determined that low-intensity activities represented 61% of all movement activities for the male and 62.9% for the female RS players (Suarez-Arrones *et al.,* 2012b:1860). Despite the previous remarks, Meir (2012:77) considers the high-intensity movement activities of RS players to be of great value, as he believes that the RS players are required to produce numerous repeated bursts of high intensity efforts separated by brief periods of recovery. The highest-intensity movement activity is considered to be sprinting. Suarez-Arrones *et al*. (2012a:3158) measured the longest sprint of male RS players to be 67.1 meters and the maximum speed reached was 29.9 km/h. The females' longest sprint was 54.6 meters and their respective maximum speed was 28.3 km/h (Suarez-Arrones *et al.,* 2012b:1861). Another comparison between the movement activities of the different genders was done by Suarez-Arrones *et al*. (2012a:3157), who determined that, on average, the total distance covered by male RS players was 1 580.8 m while female RS players covered 1 556 m (Suarez-Arrones *et al.,* 2012b:1861) on average during each game. The similar distances covered by both genders might indicate that RS demands the same physiological attributes from both genders. Except for comparing the movement activities of the different genders, some research described in Table 6 also compared the movement activity results of successful and less successful teams with one another. Rienzi *et al.* (1999:164) found no significant differences between the movement activities of the two groups, but van den Berg (2013:925) determined that players from less

successful teams walked more and for longer periods than players from successful teams. Lastly, studies indicated in Table 6 compared the movement intensities from the different players' positional groups.

2.3.2 Player positional differences in RS

When the low-intensity movement patterns of the forward and backline players were compared, Rienzi *et al.* (1999:162) found forward players to be more static and jogging significantly more ($p<0.01$) than backline players. Forward players covered a total distance of 599 m in the first half, compared to the 677 m backline players covered in the first half. Forward players also covered 540 m in the second half, compared to the 615 m of backline players, indicating that backline players cover a significantly greater total distance when compared to forward players (Granatelli *et al*., 2014:732). Higham *et al*. (2013) also found that backline players travelled a significant greater total distance in all the movement velocity zones. According to Suarez-Arrones *et al.* (2014:320), forward players covered a substantially shorter distance at velocities above 14 km/h than was the case for backline players. When the total distance covered by RS players was compared between the forward (1507.6 meters) and backline players (1713.3 meters) no significant difference was found (Suarez-Arrones *et al*., 2014:318). In contrast, Ross *et al.* (2015:1037) found forward players to travel a greater total distance than backline players and greater distances at higher velocities. Further comparisons between the positional player groups went on to determine maximum distance and speed of RS players and determined that they reached a maximal sprint distance of 37.5 meters for the forward and 44.5 meters for the backline players (Suarez-Arrones *et al.*, 2014:319), which is in line with the findings of Ross *et al*. (2015:1037) who also determined that backline players travelled at a greater maximum velocity than forward players. The backline players therefore tend to sprint for longer distances at a time than the forward players. The maximum distance sprinted by the players in the study by Suarez-Arrones *et al.* (2014) differs slightly from the distance reported in an earlier study done by Suarez-Arrones *et al.* in 2012 (2012a). Possible reasons for these differences might be the much higher number of matches (23) reported on in the more recent study compared to the earlier study in which only two to three matches for each player were analysed. In addition to player positional differences, one should value that fatigue may also influence movement activities as indicated in the next section.

2.3.3 The effect of fatigue on the movement activities of RS players

When the results from the movement activities of RS players over the duration of a match are compared to determine the effect of fatigue, the following aspects were reported:

a) No significant differences were found between any movement activities of RS players over the two halves (Rienzi *et al*., 1999:162; Suarez-Arrones *et al.*, 2012a:3157; Suarez-Arrones *et al*., 2012b:1860; Granatelli *et al*., 2014:732).

b) The frequency of velocity changes in the second half was significantly less (Rienzi *et al.*, 1999:164).

c) Suarez-Arrones *et al.* (2014:318) observed that the players ran significantly less ($p < 0.01$) at slow to medium running velocities during the second half than was the case for the first half.

It therefore seems that the players might walk and cruise (slow to medium running velocities) more in the second half than in the first half. Carreras *et al*. (2013:843) suggest that fatigue is not only experienced by the players throughout a match, but may also occur over the duration of the tournament as the matches are played in quick succession on the same day. Higham *et al.* (2012:281) found no significant differences in the match activities between different matches of the same tournament. What Higham *et al*. (2012:277) did find was that there is a substantial differences between the physiological demands placed on the players for all movement activities, except total distance travelled, depending on the tournament level. Players reached a 6% better maximum running velocity during international tournaments and covered 16% as well as 27% greater distances during 5-6 $m.s^{-1}$ and > 6 $m.s^{-1}$ running velocities respectively during international tournaments. Players also ran less at low intensity velocities during international tournaments and performed more high-intensity accelerations when compared to national tournaments. Higham *et al*. (2012:280) also found a small (non-significant) decrease in the work-to-rest rate of the RS players from the first to the second half. The importance and value of understanding the work-to-rest ratios as explained earlier necessitates a similar discussion for RS players.

2.3.4 Work-to-rest ratios of RS players

When the work-to-rest ratios of the South African U/18 provincial rugby teams were analysed, van den Berg (2013:925) found a value of 1:17.6. This is considerably more than the result from a study (1:0.5) done by Suarez-Arrones *et al*. (2012a:3158) on males and a study (1:0.4) by Suarez-Arrones *et al.* (2012b:1862) on female RS players. The discrepancy between the results from van den Berg (2013:925 and Suarez-Arrones *et al*. (2012a:3158) might be ascribed to the fact that low-intensity activities such as jogging were considered to be active rest by van den Berg, but to be high-intensity activities by Suarez-Arrones *et al*. Substitution players expressed a

higher work-to-rest ratio during their respective time on the field than could be achieved by the starting players (Higham *et al*., 2012:280). Higham *et al.* (2012:280) hypothesize that the starting players managed themselves with regard to energy consumption, as they did not know how long they were still going to be expected to play. Excellent communication between the coach and the players concerning the time the players will be expected to play seems to be required to ensure maximum effort.

Considering the differences between RS and RU with regard to the TMA literature above and their practical applications, a brief discussion follows in section 2.5.

2.4 Comparisons between RS and RU players with regard to TMA results

When the movement activities are compared between RS and RU, the following findings emerged. Suarez-Arrones *et al*. (2012a:3157) determined that low-intensity activities represented 61% of all movement activities for the male and 62.9% for the female RS players (Suarez-Arrones *et al.*, 2012b:1860). These results are considerably less than the 75% found by Austin *et al*. (2011b:262) and the 72.3% determined by Venter *et al*. (2011:6) for the total time RU players spend on low-intensity activities. It seems that RS players should spend more time on high-intensity activities than RU players during match-specific training sessions. Lopez *et al*. (2012:179) stated that RS displayed more sudden stops and open field sprints than RU. Suarez-Arrones *et al*. (2012b:1862) found that stoppages of play are less frequent in RS than in RU and the game is played at a much faster tempo than RU. When the maximum distance sprinted was measured for RS and RU, distinct differences were found.

Suarez-Arrones *et al.* (2012a:3158) measured the longest sprint of male RS players to be 67.1 meters and Eaton and George (2006:25) found the maximum sprint distance of RU players to be only 15.2 meters. In addition to maximum distance, maximum velocity can also be compared. Cahill *et al.* (2013:232) measured the maximum velocity of RU players to be 31.7 km/h which is very similar to the 29.9 km/h for RS as measured by Suarez-Arrones *et al*. (2012a:3158). Higham *et al.* (2012:278) determined that the RS players covered a 45% longer distance than RU players per minute and at higher velocities. Meir (2012:77) agreed that the RS players ran at higher velocities than players in RU. Suarez-Arrones *et al*. (2012a:3156) concurred that RS players ran greater distances in a similar time frame than players in RU. The fewer stoppages and higher tempo of play may be the reason why Lopez *et al*. (2012:179), Higham *et al.* (2012:281) and Suarez-Arrones *et al.* (2012a:3157) all suggested that RS displays an appreciable aerobic demand on the energy systems and Carreras *et al.* (2013:844) believe that RS players require a better developed aerobic and anaerobic energy system than RU players.

When RU and RS are compared with regard to TMA on positional differences, the following results came to light. According to Austin *et al.* (2011b262); Cahill *et al*. (2012:233) and Lacome *et al.* (2014:294), RU forward players cover significantly less distance than RU backline players. These findings differ from those of Suarez-Arrones *et al*. (2014:318) who measured the total distance covered by RS forward (1507.6 meters) and backline players (1 713.3 meters) and determined that there are no significant differences in RS.

Rienzi *et al.* (1999:162) found forward players to be more static and jogged significantly more ($p<0.01$) than backline players. Research on RU provided similar results with Deutsch *et al*. (1998:567) determining that the forward players jogged significantly longer distances (2 990 meters) than the backline players (2 470 meters) during a match. With regard to positional differences on high-intensity activities, Suarez-Arrones *et al.* (2014:320) found that forward RS players covered a substantially shorter distances sprinting and cruising than the backline players, which is similar to the findings of Deutsch *et al*. (1998:567) and Roberts *et al.* (2008:828) who stated that RU backline players travelled significantly ($p<0.01$) longer distances sprinting and cruising (mean =207 meters) compared to the forward players (mean =164 meters).

When the comparison of the effect of fatigue on RS and RU was done, results indicated that no significant differences were found between any movement activities during the two halves for either RU (Rienzi *et al*. 1999:162; Suarez-Arrones *et al.* 2012a:3157; Suarez-Arrones *et al*. 2012b:1860) or RS (Duthie *et al*., 2005:524).

In addition to TMA, Quarrie *et al*. (1995:263) suggested kinanthropometry profiles to be investigated as another important determinant of physical characteristic of rugby players that may affect performance.

2.5. Kinanthropometry in RU

The inclusion of kinanthropometry as an investigating instrument was directly derived from its importance and relation to performance in sport, which has been extensively noted in different sport codes by various studies such as those done in Australian Rules Football (Edgecomb & Norton, 2006), Soccer (Barros *et al*., 2007) and Field Hockey (Gabbett, 2010), to name but a few. The kinanthropometry of players also has a direct bearing on the performance and selection processes of players in RU (Bell, 1979:19; Olds, 2001:260 & Holway & Garavaglia, 2009:1211; Coughlan *et al*., 2011:600) and RS (Higham *et al.*, 2012:278; Suarez-Arrones *et al*., 2012a:3156).

Kinanthropometry can be defined as ‘‘The academic discipline that involves the use of anthropometric measures in relation to other scientific parameters and/or thematic areas such as human movement, physiology or applied health sciences” (Stewart, 2010:455). Aspects such as body mass index (BMI), somatotyping, muscle mass; percentage body fat and skeletal mass are therefore all such examples of kinanthropometric measurements (Stewart, 2010:455). To give a summary of the related literature that focused on identifying the demands placed on the kinanthropometrical profile of RU players, a total of twenty one scientific (21) articles are presented in Table 7.

Table 7: Summary of articles on Kinanthropometry applied in RU.

Title	Authors	Year	Aim	Population	Type of body composition
The estimation of body density in rugby union football players.	Bell, W.	1995	Determining whether the body density in RU football players could be effectively determined by the Durnin and Womersley equation.	n =45 ♂	Stature Body Mass Density
The New Zealand rugby injury and performance project. IV. Anthropometric and physical performance comparisons between positional categories of senior A rugby players.	Quarrie, K.L., Handcock, P., Toomey, M.J. & Waller, A.E.	1996	Determining the anthropometric and physical performance characteristics of a sample of senior players and whether the data from the forward players discriminate with those of the backline players.	n =356 ♂	Stature Body Mass Somatotyping
The evolution of physique in male rugby union players in the twentieth century.	Olds, T.	2001	Analysing the evolution of the physique of RU players and comparing rates in change.	n =1420 ♂	BMI, Stature Somatotypes Body Mass
Die relatiewe liggaamsgroottes van adolessente en volwasse Suid-Afrikaanse rugbyspelers.	Wilders, C. & De Ridder, J.H.	2001	Determining whether the available kinanthropometry models for adult rugby players are suitable for youth rugby players.	n = 718 ♂	Skinfolds Circumferences
Aerobic exercise physiology in a professional rugby union team.	Scott, A.C., Roe, N., Coats, A.J.S. & Piepoli, M.F.	2003	Determining the similarities/differences between backs and forwards with regard to body mass.	n = 28 ♂	% Body fat (TANITA) % Body fat (skinfolds) Stature, Body mass
Comparison of positional groups in terms of anthropometric, rugby-specific skills, physical and motor components among u 13, u 16, u 18 and u 19 elite rugby players.	Van Gent, M. & Spamer, E.J.	2005	Comparing playing groups among u 13, u 16, u 18 and u 19 elite rugby players with regard to anthropometric values.	n = 80 ♂	% Body fat, Stature Body mass ∑ 7 skinfolds Circumferences

♂ = Males; n = Population; u = under; ∑ = Sum of; TANITA = (TBF-305 – Body fat analyser); % = Percentage.

Table 7 (cont.): Summary of articles on Kinanthropometry applied in RU.

Title	Authors	Year	Aim	Population	Type of body composition
Fitness and body composition profiling of elite junior South African rugby players.	Du Randt, J., du Toit, S., Boressen, J., Hew Butler, T., Masimla, H., Jakoet, I. & Lambert, M.	2006	Determining the body composition of elite junior South African rugby players.	n = 174 ♂	% Body fat Stature Body mass ∑ 7 skinfolds
Anthropometry profiles of elite rugby players: quantifying changes in lean mass.	Duthie, G.M., Pyne, D.B., Hopkins, W.G. Livingston, S. & Hooper, S.L.	2006b	Determining the utility of a practical measure of lean mass for monitoring changes in body composition.	n = 74 ♂	Body mass ∑ 7 skinfolds
A comparison of talented South African and English youth rugby players with reference to game-specific anthropometric-, physical and motor variables.	Plotz, A.F. & Spamer, M.J.	2006	Determining and comparing the anthropometric variables of the talented South African and English youth rugby players.	n = 64 ♂	Stature Body mass Skinfolds Girths
Anthropometric, physical, motor and game-specific profiles of elite u 16 and u 18 year old South African schoolboy rugby players.	Spamer, E.J. & de la Port, Y.	2006	Determining the characteristics of elite u 16 and u 18 year old South African schoolboy rugby player.	n = 146 ♂	Body and muscle mass, ∑ 7 skinfolds, Stature % Body fat, Somatotypes, % Body fat
Veranderinge ten opsigte van Antropometriese en motoriese komponente vanaf die 2000- tot 2001 seisoen by o/19, o/21 en senior elite-klubrugbyspelers.	Hanekom, A., De Ridder, J.H. & Malan, D.D.J.	2008	Determining which anthropometric differences occur over a period of two years in RU following a scientific conditioning programme.	n = 180 ♂	% Body fat
Kinanthropometry of group 1 rugby players in Buenos Aires, Argentina.	Holway, F.E. & Garavaglia, R.	2009	Determining position-specific descriptive information on anthropometric characteristics.	n = 133 ♂	Somatotyping, Muscle and skeletal mass, Muscle bone ratio, BMI, ∑ 7 skinfolds, Stature.

BMI = Body Mass Index; ♂ = Males; n = Population; u = under; ∑ = Sum of; % = Percentage.

Table 7 (cont.): Summary of articles on Kinanthropometry applied in RU

Title	Authors	Year	Aim	Population	Type of body composition
Comparative characteristics of elite New Zealand and South African u/16 rugby players with reference to game-specific skills, physical abilities and anthropometric data.	Spamer, E.J., du Plessies, D.J. & Kruger, E.	2009	Determining and comparing the anthropometric profiles of elite u/16 New Zealand and South African groups.	n = 89	% body fat Body mass, stature, skinfolds, girths
Effects of a short-term pre-season training program on the body composition and anaerobic performance of professional rugby union players.	Argus, C.K., Gill, N., Keogh, J., Hopkins, W.G. & Beaven, C.M.	2010	Determining the effects of a short-term pre-season training programme on the body composition and anaerobic performance of professional RU players.	n = 33 ♂	Body mass Fat mass Fat free mass ∑ 8 skinfolds Stretched stature
Digit ratio (2D:4D) and performance in elite rugby players.	Bennett, M., Manning, J.T., Cook, C.J. & Kilduff, L.P.	2010	Determining whether a longer four-digit than two-digit finger indicates performance in RU.	N = 44 ♂	Stature Body mass BMI
Physical fitness profiles of elite women's rugby union players.	Hene, N.M., Bassett, S.H. & Andrews, B.S.	2011	Determining the physical fitness of elite women's RU players.	n =32 ♀	% Body fat Stature Body mass
Scaling strength and power for body mass differences in rugby union players.	Crewther, B.T., Kilduff, L.P., Cook, C.J., Cunningham, D.J., Bunce, P.J., Bracken, R.M. & Gaviglio, C.M.	2012	Determining the relationship between body mass and peak force, as well as peak power.	n = 79 ♂	Body mass

BMI = Body Mass Index; ♂ = Males; ♀ = Females; n = Population; u = under; ∑ = Sum of; % = Percentage.

Table 7 (cont.): Summary of articles on Kinanthropometry applied in RU

Title	Authors	Year	Aim	Population	Type of body composition
How they won Rugby World Cup through height, mass and collective experience.	Sedeaud, A., Marc, A., Schipman, J., Tafflet, M., Hager, J. & Toussaint, J.	2012	Determining the evolution of anthropometric characteristics in World Cup rugby players.	n =2692 ♂	Mass Stature BMI
Changes in the stature, body mass and age of English professional rugby players: A 10-year review.	Fuller, C.W., Taylor, A. E., Brooks, J.H.M. & Kemp, P.T.	2013	Determining changes in the stature and body mass of players by positional differences from 2002 to 2012.	n = 4852 ♂	BMI
Anthropometric profile and body composition of Irish adolescent rugby union players aged 16-18.	Delahunt, E., Byrne, R.B., Doolin, R.K., McInerney, R.G., Ruddock, C.T.J. & Green, B.S.	2013	Determining the anthropometric profile and body composition of Irish adolescent RU players throughout the long-term player development model.	n = 136 ♂	% Body fat Stature Body mass Fat mass Lean mass Fat free mass
A new approach to quantify physical demands in rugby union.	Lacome, M., Piscione, J. & Hager, J.	2014	Determining an original approach to assess individual workload during international RU competitions.	n = 30 ♂	% Body fat Stature Body mass

BMI = Body Mass Index; ♂ = Males n = Population u = under; % = Percentage.

All but three studies used a balance beam, stadiometer, skinfold callipers and a measuring tape to determine the body composition of the RU players. Bell (1995:47) added hydrostatic weighing to assess body density, while Lacome *et al.* (2014:292) and Delahunt *et al.* (2013:3255) made use of the DXA to X-ray the players. The kinanthropometry studies listed in the table above are in line with the suggestions by Olds (2001:253) to investigate the evolution of the players' body composition over a time period with or without intervention training, and secondly by Nicholas (1997:377) to study comparisons between different player positions.

2.5.1 Player positional differences with regard to kinanthropometry

When the literature presented in Table 7 compared the RU player positional groups (forward and backline players) with regard to kinanthropometry, the biggest differences that emerged were found in body mass and stature (Duthie *et al.,* 2003:987). These results are interesting when taking into consideration that Olds (2001:257), Bennett *et al.* (2010:1419) and Sedeaud *et al.* (2012:582) state that bigger values of stature and body mass in RU have a direct positive relation to performance. A study by Crewther *et al.* (2012:30) supports the previous statement by indicating a direct correlation between body mass and the ability of the player to produce peak force and peak power. Differences between forward and backline RU players with regard to body mass and stature may therefore be important to discuss and it was thought appropriate to present a summary of the results from the above-mentioned literature in Table format.

Table 8: Research studies on body mass and stature of RU players (1995 – 2014)

Authors	Year	Mean Stature		Significant differences	Mean Body mass		Significant differences	Age
Bell, W	1995	182 cm			89.95 kg			19-27 years
		Forward players	**Backline players**		**Forward players**	**Back players**		
Scott *et al.*	2003	190.2 cm	179.5 cm	$p < 0.001$	104 kg	86.3 kg	$p < 0.001$	22.4 years
Van Gent & Spamer	2005	187.9 cm	180 cm	insignificant	90 kg	76 kg	insignificant	18 years
Van Gent & Spamer	2005	185 cm	182.1 cm	insignificant	93.76 kg	81.9 kg	insignificant	19 years
Duthie *et al.*	2006	Not measured	Not measured		107.6 kg	89 kg	insignificant	Seniors
Holway & Garavaglia	2009	181.2 cm	175.7 cm	$p < 0.001$	94.4 kg	79.5 kg	$p < 0.001$	24.3 years
Bennett *et al.*	2010	189 cm	184 cm	$p = 0.02$	108.8 kg	91.8 kg	$p < 0.001$	25.1 years
Hene *et al.*	2011	165 cm	160.9 cm	$p = 0.04$	78.9 kg	62.97 kg	$p < 0.001$	♀
Fuller *et al.*	2013	188.7 cm	181.9 cm	N/A	109.9 kg	91.2 kg	N/A	25.6 years
Delahunt *et al.*	2013	182 cm	178 cm	$p = 0.00$	83.63 kg	73.62 kg	$p = 0.00$	16.93 years
Lacome *et al.*	2014	188 cm	183 cm	insignificant	108.3 kg	94 kg	$p < 0.001$	27.9 years
		Season 2003	**Season 2004**		**Season 2003**	**Season 2004**		
Spamer & Dela Port	2006	175.4 cm	178 2 cm	insignificant	76 kg	79.5 kg	insignificant	16 years
Spamer & Dela Port	2006	180.3 cm	180.4 cm	insignificant	85 kg	86.8 kg	insignificant	18 years
		U/16	**U/18**		**U/16**	**U/18**		
Du Randt *et al.*	2006	175.6 cm	179.2 cm	$p < 0.001$	76.5 kg	84.9 kg	$p < 0.001$	16 - 18 years

Significance was indicated by $p < 0.05$ significance

Hene *et al*. (2011:5) and Lacome *et al*. (2014:293) established that the forward players tend to be significantly heavier than the backline players. Quarrie *et al*. (1996:54); Scott *et al*. (2003:175); Holway and Garavaglia (2009:1217); Bennett *et al*. (2010:1417); Sedeaud *et al*. (2012:581) and Delahunt *et al.* (2013:3257) also found that the forward players are heavier than the backline players and added that forward players were also significantly taller than the backline players. The following results emerged when the stature and body mass of the individual player positions were compared. Locks were taller than loose-forward players and back-row forwards were taller than front-row forwards, but no player differs significantly with regard to body mass (Quarrie *et al*., 1996:54). In contrast, van Gent and Spamer (2005:57) indicate a significant difference between the body mass (d = 1.89) of u/19 front-row and back-row forward players. Van Gent and Spamer (2005:56) also found a practically significant difference between body mass of the u/18 front (d = 1.67) and backrow forward players and added that there is a practically significant difference (d = 1.13) between body mass of the u/18 scrumhalves and the rest of the backline. Du Randt *et al*. (2006:40) posit that in general the props are the heaviest and the scrumhalves the lightest players in a team. Related to this, Du Randt *et al*. (2006:40) determined that when the stature and body mass of the u/18 players were compared with u/19 players, significantly smaller values were observed for the u/18 group. It therefore seems that forward players are heavier and taller than backline players and older players seem to be heavier and taller than younger players.

Another comparison between kinanthropometric profiles was done by Spamer and Dela Port (2006:178), who compared the body mass and stature of two different u/16 and u/18 player age groups over the 2003 and 2004 seasons, but no significant differences were found. In a comparative study that focused on anthropometric differences over a time period (485.2 players per season for 9 seasons), Fuller *et al*. (2013:796) found that fly halves ($p < 0.001$) and props ($p = 0.003$) have increased in stature while fly half and backrow forwards ($p = 0.006$) have increased in body mass. However, Fuller *et al*. (2013:801) convey a warning that the changes in either body mass or stature does not necessarily relate to a difference in body composition. This may be why kinanthropometrists are known to use body mass and stature together in an equation, [by dividing the weight in kilograms via the square of height in meters] to determine body mass index (BMI) (Eston *et al*., 2009:35)].

2.5.2 BMI of RU players

BMI evaluates the human body by providing a value that pinpoints whether an individual's body mass is in proportion to their height or stature (Walsh *et al*., 2011:38). Sedeaud *et al.* (2012:583)

state that from the 1987 World Cup (WC) to the 2007 WC, the BMI has increased steadily. An average BMI value of 27.9 for RU players was posited by Holway and Garavaglia (2009:1215). Bennett *et al*. (2010:1417) and Fuller *et al*. (2013:799) found similar results for the BMI values of the backline (27 & 27.6) and forward players (30.6 & 30.9) respectively. When the BMI values of the forward and backline players as mentioned in the studies above are compared, no significant differences between the two groups seem to be present. Due to BMI not being able to distinguish between fat mass and lean muscle mass, the value has been debated and the use of other kinanthropometric measurements to determine the percentage body fat, muscle mass, lean mass and somatotyping have been argued to be more effective. One such a kinanthropometry measurement is the use of skinfold measurement.

2.5.3 Skinfolds of RU players

According to Slater *et al.* (2006:208), skinfold measurement would give an indication of the proportionality of total body mass with regard to lean body mass and total body fat. Argus *et al*. (2010:685) used skinfolds and girths/circumferences to determine body composition of rugby players before and after a 4-week intense training week. A small decrease in the sum (∑) of eight skinfolds (-11mm) and a small increase in the upper-arm girth (0.6 cm) and mid-thigh girth (1.9 cm) were found. When Plotz and Spamer (2006:102) compared the skinfolds and girths of the eighteen-year-old Leopards, Bulls and English RU players, no significant differences were found between the anthropometric variables of the three groups. Noteworthy differences that were visible was that the South African teams differed slightly from the English team with regard to the pectoral skinfold (Leopards = 7.71) (Bulls =8.27) (English team = 13.07), calf skinfold (Leopards = 8.71) (English team = 15.28) and ankle girth (English team= 27.2) (Bulls = 23.82). Holway and Garavaglia (2009:1213) measured the ∑ 6 skinfolds and found the props to show a much higher value (114.2mm) than the average value of the team (79 mm). Van Gent and Spamer (2005:56) found a practically significant difference for the triceps skinfold (tight five = 12.71) (loose forwards = 8.25), subscapular skinfold (tight five = 15.36) (loose forwards = 11.03), ∑ 7skinfolds (tight five = 82.07) (loose forwards = 65.53) and calf girth (tight five = 37.09) (loose forwards = 39.88) between the u/18 forward players. Practically significant differences for the triceps (tight five = 13.36) (loose forwards = 9), supraspinal (tight five = 14) (loose forwards = 9.75), subscapular (tight five = 17.71) (loose forwards = 10.63), abdominal (tight five = 22) (loose forwards = 14.38), and calf skinfolds (tight five = 11.86) (loose forwards = 8.88), as well as the ∑ 7 skinfolds (tight five = 95.21) (loose forwards = 66.25), were found between the u/19 front row and backrow forward players.

A significant difference was also determined between the scrumhalf and other backline players for ankle girth (scrum half = 23.07) (backline players = 25.3), and humerus breadth (scrum half = 6.63) (backline players = 7.4), on the u/18 age group as well as for forearm (scrum half = 29.5) (backline players = 30.94), and ankle girth (scrum half = 23.17) (backline players = 25), for the u/19 group (van Gent & Spamer, 2005:57). Spamer and Dela Port (2006:178) found no significant differences between the 2003 and 2004 season of the u/16 and u/18 player age group with regard to the ∑ 7 skinfolds. Hanekom *et al*. (2008:46) compared the ∑ 6 skinfolds where 5 measurements of the same players were taken over a two-year period and also found no significant differences. Duthie, Pyne and Hopkins *et al*. (2006:203) monitored the fluctuation of the ∑ 7 skinfolds of Super Rugby players over a period of 6 years and found a slight decrease (5.3%) in the value of the forward players from the pre-season to the competition phase and a 7.8% increase of the value when the club league started. When ∑ 7 skinfolds in female rugby players were measured, the results indicated that the forward players had statistically significantly ($p = 0.003$) higher values (137.7 mm) than the backline players (106.66 mm) (Hene *et al*., 2011:4).

Spamer *et al*. (2009:54) did a study in which they compared the results of New Zealand u/16 players (group 1) and two u/16 South African groups of players (groups 2 and 3) with regard to skinfolds amongst others. The study found the New Zealand group to have greater values than the first South African group for supraspinal (SA^1 = 11.91) (NZ = 20.69) and pectoral (SA^1 = 6.8) (NZ = 9.73) skinfolds. The New Zealand group also had higher practically significant values than the South African second group for the triceps (SA^2 = 8.02) (NZ = 12.96), pectoral (SA^2 = 5.73) (NZ = 9.73), abdominal (SA^2 = 12.64) (NZ = 20.73), thigh (SA^2 = 10.77) (NZ = 17.15) and calf (SA^2 = 7.11) (NZ = 11.75) skinfold values. Du Randt *et al*. (2006:40) found no significant differences of the ∑ 7 skinfolds between the u/16 and u/18 age groups. The above-mentioned findings seem to indicate that although the ∑ of skinfolds did not differ between groups, a conspicuous difference existed between the different player positions with regard to kinanthropometric measurements. Whithers *et al*. (1987:197) suggested that the sum of skinfolds should be used in conjunction with body density so that percentage fat could be determined as a component of the body composition with the following formula: [Body density = 1.10326 - 0.00031 (Age) - 0.0036 (∑ 6 skinfolds)]. The body density value necessary for determining fat percentage was calculated by Bell (1995:48) as 1.0695 for a RU-specific population.

2.5.4 Body fat of RU players

The disadvantages of body fat for RU players, such as reducing acceleration and increasing energy expenditure have been highlighted by Duthie (2006:4). Scott *et al*. (2003:175) posit that forward RU players exhibit 16.1% and back line players 12.1% body fat. Van Gent and Spamer (2005:57) found that in the u/18 players, body fat of the front row forward players (23.58%) differed practically significantly (d = 0.1.92) from that of backrow forward players (16.69%). Delahunt *et al.* (2013:3257) also found forward players to present significantly higher (p = 0.00) % body fat (18. 46%) than the backline players (14.34%). In contrast, no statistically significant differences were observed for the % body fat of forward (15.5%) and backline players (13.5%) by Lacome *et al.* (2014:292). When the positional groups of female rugby players were compared, values of 30.81% body fat for forward and 26.11% body fat for backline players were found (Hene *et al*., 2011:4). Except for the results found by Lacome *et al*. (2014:292) there seems to be a tendency for the forward players to exhibit a higher value of fat percentage than the backline players among both genders of RU players. The reason for the findings of Lacome *et al*. indicating that no significant differences existed among the forward and backline players with regard to % body fat might be the small sample size of players used (n=30) in their study. The literature listed in Table 7 also examined the differences of fat percentages that may exist between different age groups. In a study by du Randt *et al.* (2006:41) the % body fat of the two age groups (u/16 and u/18) were compared and no significant differences were found.

Studies listed in Table 7 also focused on measuring the kinanthropometry of players over time to determine whether any changes were experienced. Hanekom *et al.* (2008:46) took five measurements over two years of the same players and posited no significant differences in percentage body fat over that period. Spamer and Dela Port (2006:178) compared the percentage body fat and percentage muscle mass of a u/16 and a u/18 rugby player age group over the 2003 and 2004 seasons and also found no practically significant differences between groups over the two-season time frame. When the actual fat-free (lean) mass of the same players was compared over a period of time, Argus *et al*. (2010:685) found a slight increase (2.2kg) after a four-week high-intensity training period and Duthie, Pyne and Hopkins *et al*. (2006:205) found trivial differences in the same players' fat-free mass over a six-year period. It seems from the findings of the above paragraph that despite the time frame between tests, the percentage body fat and lean mass does not change over time, especially if no intervention had taken place. When the percentage muscle mass, percentage skeletal mass and percentage fat mass are compared in proportionality, a much better indication of the rugby players' body composition and profile can

be obtained. The previous statement might be the reason why Olds (2001:254), as well as Wilders and de Ridder (2001:100) express the importance of identifying the different morphological profiles of the different positions in RU players.

2.5.5 Morphology of RU players

Quarrie *et al.* (1996:54) determined that the front row forwards were more mesomorphic and less ectomorphic than the backrow forwards with a practical significant value of d = 1.4. Holway and Garavaglia (2009:1217) posited that forward and backline players differed significantly ($p < 0.001$) with regard to mesomorphy. Quarrie *et al*. (1996:54) partially agree by finding forward and backline players to differ significantly with regard to mesomorphy and ectomorphy. With regard to individual positions Holway and Garavaglia (2009:1217) state that centres are more mesomorphic than any other position, with wings being the leanest, with the least % muscle mass. Spamer and Dela Port (2006:178) established that both u/16 and u/17 players were mesomorphic by nature during both the 2003 and 2004 seasons. The above literature thus suggested that RU players tend to be mesomorphic by nature even though morphological differences do exist between different player positions.

The warning of de Ridder (1993:3-32) that morphological profiles of adults should not be accepted as normal for adolescents led to the study of Wilders and de Ridder (2001:100), who compared the body composition profiles of the two groups. Skeletal size differences were statistically significantly larger amongst adults due to adolescents still being in their growth years. De Ridder (2001:100) concludes that kinanthropometric data from adolescents differ from those of adults regarding their respective morphological profiles. Despite the morphological differences that exist between adults and adolescents as identified by Wilders and de Ridder (2001:100), Duthie *et al*. (2003:975) suggest that the level of competition might also require different kinanthropometry profiles, as players in better competitions indicated higher values concerning stature and mass. Quarrie *et al*. (1995:267) add neck circumference as an additional kinanthropometric variable that tends to increase in value as the level of competition increases.

The above-mentioned literature overview discussed kinanthropometric research that focused on RU populations. The importance of RS, as already explained, led to the next section that will aim to explain the currently existing kinanthropometric research that focuses on RS.

2.6. Kinanthropometry in RS

Although some kinanthropometric results were provided by literature, only four articles, to the knowledge of the research team, recognized the kinanthropometric results from their respective study as part of the aim of the study. These results will be easier to explain via a table, followed by a brief discussion.

Table 9: Research articles on kinanthropometry of players in RS

Title	Authors	Year	Aim	Population	Measurement
Investigation of anthropometric and work-rate profiles of Rugby Sevens.	Reinzi, E., Reilly, T. & Malkin, C.	1999	Determining and describing anthropometric and match performance profiles of Sevens Rugby players.	n = 30	Mass, stature, muscle mass, morphology
Epidemiological study of injuries in international rugby sevens.	Fuller, C.W., Taylor, A. & Molloy, M.	2010	Assessing incidence nature and causes of injuries sustained in international RS	n = 290	Mass, Stature
Monitoring training load and fatigue in rugby sevens players.	Elloumi, M., Makni, E., Moalla, W., Bouaziz, T., Tabka, Z., Lac, G. & Chamari, K.	2012	Training load and fatigue in rugby sevens players.	n = 16	Mass, Stature, % Fat mass
Physiological, anthropometric and performance characteristics of rugby sevens players.	Higham, D.G., Pyne, D.B., Anson, J.M. & Eddy, A.	2013	Determining physiological, anthropometric and performance profiles of elite rugby sevens players.	n = 18	Mass, Stature, ∑ 7 skinfolds

∑ = sum of; % = percentage

The following results emerged from the above-mentioned kinanthropometric studies. When the kinanthropometric data of less successful and successful players were compared, Rienzi *et al*. (1999:162) found no significant differences between the anthropometric values of the successful and less successful RS players. When the kinanthropometric data was compared of RS players before and after a six-week high-intensity and two-week tapering training week, the RS players' body mass, fat mass percentage and BMI decreased significantly (Elloumi *et al.*, 2012:179). It

seems therefore that differences in kinanthropometric data of RS players may vary extensively over a relatively brief intervention period. Lastly, comparisons between the body mass and stature of the two different player positional groups were drawn in two studies listed in Table 10a. The results from these two studies were thought to be presented best in table format.

Table 10a: Comparison of body mass and stature of the positional groups in RS

Authors	Rienzi *et al.*	Fuller *et al.*
Year	1999	2010
Stature backline players cm	175.6 cm	180.1 cm
Stature forward players cm	184.6 cm	187.5 cm
Significance of stature differences	$p < 0.001$	$p < 0.001$
Body mass backline players kg	78.6 kg	86 kg
Body mass forward players kg	93.5 kg	97.7 kg
Significance of body mass differences	$p < 0.001$	$p < 0.001$

Significance was indicated by $p < 0.05$ significance

From Table 10a Rienzi *et al*. (1999:162) and Fuller *et al.* (2010:181) found the forward players to be significantly heavier and taller than the backline players. Rienzi *et al*. (1999:162) add that the forward players also portrayed significantly more muscle mass than the backline players. Other research studies not mentioned in Table 10a also acknowledged the important role mass and stature play as physical performance indicators and therefore reported their results even though it was not part of the aim of their respective studies. Hence an illustration follows of the results from the literature on body mass and stature amongst RS players in Table format.

Table 10b: Body mass and stature of RS players (1995 – 2014)

Authors	Year	Mean Stature (cm)	Mean body mass	Age in years
Elloumi, M., Makni, E., Moalla,W., Bouaziz, T., Tabka, Z., Lac, G. & Chamari, K.	2012	183.1	86.4 kg	23.8
Higham, D.G., Payne, D.B., Anson, J.M. & Eddy, A.	2012	182	89.7 kg	21.2
Suarez-Arrones, L., Nunez, F.J., Portillo, J. & Mendez-Villanueva, A.	2012a	180.4	87.9 kg	27.4
Suarez-Arrones, L., Nunez, F.J., Portillo, J. & Mendez-Villanueva, A.	2012b	165.5 ♀	63.7 kg	27.8
Higham, D.G., Pyne, D.B., Anson, J.M. & Eddy, A.	2013	183	89.7 kg	21.9
Clarke, A.C., Presland, J., Rattray, B. & Pyne, D.B.	2014	168 ♀	69 kg	25

♀ = female; kg = kilogram

The results from Table 10b seem to indicate that when the body mass and stature of International RS players from different countries are compared, grouping the different genders together, similar results emerge. Except for the direct measurements listed above, Carter and Heath (1990:345) suggest that somatotyping of players could provide more insight into the players' kinanthropometric profiles. RS players portray, according to Rienzi *et al*. (1999:163), a mesomorphic predominant somatotype profile. Taking into consideration that there is a negative correlation between mesomorphy, muscle mass and high-intensity activities (Rienzi *et al*., 1999:162) and RS expecting players to perform more high-intensity activities than RU, the existing mesomorph profile is unexpected. Meir (2012:77) believes that the negative correlation between mesomorphy and high-intensity activities is due to the fact that less mass (muscles is heavy) require proportionally less energy to maintain high-intensity activities. It therefore seems that RS players portray a mesomorphic somatotype, but needs to function with a strong aerobic capacity.

2.7 Comparison between RS and RU players with regard to kinanthropometry

When the studies of RS and RU with regard to kinanthropometry were done the following results emerged. Higham *et al.* (2013:21) found the ∑ 7 skinfolds of male RS players to be 52.2 mm on average, while Duthie *et al*. (2006b:203) monitored the ∑ 7 skinfolds for male RU players to be 84 mm and 60 mm for forward and backline players respectively. Van Gent and Spamer (2005:53) also measured the ∑ 7 skinfolds for male RU players and determined a value of 74.7mm. When the female players were measured, Clarke *et al*. (2014:145) found the ∑ 7 skinfolds for RS players to be 85 mm. When the ∑ 7 skinfolds in female RU players were measured, the results indicated values of 137.7 mm for forward players and 106.66 mm value for the backline players (Hene *et al*., 2011:4). Results for both genders seem to indicate that RU players present much higher ∑ 7 skinfold values than RS players. Previous kinanthropometric research on both RU and RS players also compared the stature and body mass among forward and backline players and the results were thought to be best presented in Table format.

Table 11: A comparison of the body mass and stature values between the forward and backline players of RS and RU

	RS		**RU**	
	Rienzi *et al*. (1999:162)	Fuller *et al.* (2010:181)	Lacome *et al*. (2014:293)	Bennett *et al.* (2010:1417)
Body mass forward players	93.5 kg	97.7 kg	108.3 kg	108.8 kg
Body mass backline players	78.6 kg	86 kg	94 kg	91.8 kg
Stature forward players	184.6 cm	187.5 cm	188 cm	189 cm
Stature backline players	175.6 cm	180.1 cm	183 cm	184 cm

The results in Table 11 seem to indicate that although RU players seem to be heavier than RS players, there are no differences with regard to stature.

Literature seems to have preferred studying the evolution of the rugby players' body composition over a time period with or without intervention training, and compared kinanthropometric measurements among different player positions.

2.8 Conclusion

When the movement activities of rugby players positional groups were compared clear differences were determined. Forward players in both rugby variants spend more time on low movement velocities when compared to the backline players. It seems that rugby players spend more than half of match-time on low intensity movement activities. However, RS players spend more time on high-intensity activities than RU players. RS players also displayed more open field sprints than RU players. Stoppages of play are less frequent in RS than in RU and the game is played at a much faster tempo than RU. RS players sprint greater distances at a time when compared to RU players. In addition to maximum distance, when maximum velocities are compared, one can assume that players reach the same maximum velocity. However, RS players covered a 45% longer distance per minute and at higher velocities than RU players. The fewer stoppages and higher tempo of play may suggest that RS require better aerobic energy systems when compared to RU players. When the effect of fatigue on the performance on RS and RU players was investigated, results indicated that no significant differences were found between any movement activities during the two halves.

When the kinanthropometry of rugby players was compared, clear differences among player positional groups were determined. Forward rugby players are significantly heavier than the backline players in both RU and RS. Although no significant differences were found between the stature of RS forward and backline players, RU forward players were found to be significantly taller than RU backline players. RS forward players portray significantly more muscle mass than the backline players which is exceptionally interesting as Crewther *et al*. (2012:30) stated that a direct correlation between body mass and the ability of the player to produce peak force and peak power existed. Fat mass, however, is considered disadvantageous to rugby players, as it leads to reduced acceleration and an increase in energy expenditure (Duthie, 2006:4). It was therefore interesting to notice that forward RU players exhibit a higher fat percentage than the backline players. When the BMI values of the forward and backline RU players were compared, no significant differences between the two groups were present. Finally, when player positional comparisons were drawn with regard to kinanthropometric data, Quarrie *et al.* (1996:54) determined that the front row forwards were more mesomorphic and less ectomorphic than the backrow RU forwards. Holway and Garavaglia (2009:1217) agreed that RU forward and backline players differed significantly ($p< 0.001$) with regard to mesomorphy. However, both RS and RU players tend to be mesomorphic by nature.

According to literature, the body mass and stature of International RS players from different countries seem to be homogenous. RS players do, however, seem to change in kinanthropometric profile more drastic over intervention time periods than was the case with RU players. Another huge difference between RS and RU players seems to be that RU players present much higher $\sum 7$ skinfold values than RS players.

Literature also suggested that the level of competition might have an impact on kinanthropometry profiles, as players in better competitions indicated higher values of stature, mass and neck circumference. Male rugby players also indicated significantly bigger values for stature and mass in higher levels of competition and Wilders and de Ridder (2001:100) identify morphological differences between adults and adolescents.

One should therefore understand that different competition levels, different player positions, gender, rugby variant and age may all affect the kinanthropometric profile of successful rugby players.

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CHAPTER 3

3 A KINANTHROPOMETRIC COMPARISON OF DIFFERENT PLAYER POSITIONS IN ELITE RUGBY UNION SEVENS

TITLE PAGE

ABSTRACT

INTRODUCTION

METHODS

Participants

Procedures

Statistical Analyses

RESULTS

DISCUSSIONS

CONCLUSION

PRACTICAL APPLICATIONS OF THE STUDY

FUNDING

REFERENCES

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A kinanthropometric comparison of different player positions in elite Rugby Union Sevens

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Abstract

A kinanthropometry profile acts as an important physical characteristic that affects the performance of each rugby player. It is important to understand that different players are allocated different positions with different responsibilities, consequently leading to different kinanthropometry profiles from the player positional subgroups. The aim of this study was to compare the different player position subgroups of elite, national, Rugby Union Sevens (RS) players with regard to kinanthropometric profiles. Positional subgroups were divided into forward and backline players. All (n=15) the national, male, elite RS players of Zimbabwe participated in the study. Stature, body mass, skinfolds, girths and breadths were measured through the standard procedures as described by the international standard for the advancement of Kinanthropometry. Body mass and stature were used to calculate the Body Mass Index (BMI) and the different somatotypes were calculated to the nearest 0.1. Significant differences were found between the forward and backline players with regard to stature, body mass, forearm girth, femur breadth and mesomorphy. In addition, backline players had significantly less muscle mass (kg) and percentage muscle mass when compared to the forward players. The forward players in the current study had a practical significantly higher mesomorphy value compared to the backline players. The study highlighted that RS requires players with different types of body compositions to adhere to the responsibilities set for the different player positional subgroups despite the players exhibiting a homogenous somatotype and BMI values.

Keywords: Sevens Rugby, kinanthropometry, anthropometry, somatotypes, Rugby Union.

Introduction

Rugby Union Sevens (RS) host their own World Cup every four years (Fuller, Taylor & Molloy, 2010) and recently received Olympic status to be included as an event from 2016 in Rio de Janeiro (Engebretsen & Steffen, 2010). Achieving Olympic status will, according to Carlson et al. (1994), motivate international teams to pursue performance even more in the quest to win an Olympic medal. Research suggests that in order to improve performance, one has to understand the physiological and physical demands placed on the participants (Nicholas, 1997, Cunniffe, Proctor, Baker & Davies, 2009). Quarrie et al. (1995) suggest that the kinanthropometric profiles of sport participants should be investigated since it is regarded as an important physical characteristic that may affect the performance of rugby players. It has been proven that such kinanthropometric evaluation has a direct bearing on the selection processes and performance of players in rugby (Bell, 1979; Carlson et al., 1994; Olds, 2001, Holway & Garavaglia, 2009). Stewart, Marfell-Jones, Olds and De Ridder (2011) define kinanthropometry as *[t]he academic discipline that involves the use of anthropometric measures in relation to other scientific parameters and/or thematic areas such as human movement, physiology or applied health sciences*".

When kinanthropometric measurements are conducted, one should bear in mind that different players are allocated to different player positions, each position with its own specific functions and responsibilities during a match, and this is can be related to their kinanthropometry (Duthie, Pyne & Hooper, 2003; Gamble, 2004; Eaton & George, 2006). Literature on Rugby Union suggests that when position-specific differences are investigated, the players should be subdivided into forward and backline players (Duthie *et al.* 2003; Gamble, 2004). Given the above information, the following research question arises: How do the different player positional subgroups of the Zimbabwean National RS players compare to one another with regard to kinanthropometric profiles?

The results of the current study could enable coaches, sport scientists, officials, selectors and players to better understand the possible influence the position-specific kinanthropometric profiles of players in a senior national RS team may have on their playing performance. The knowledge gathered from this study may therefore indirectly lead to position-specific physical assessment and training programmes for the players which should enhance their overall performance and development (Coughlan, Green, Pook, Toolan & O'Connor, 2011) and assist coaches with team selection (Quarrie, Handcock, Toomey & Waller, 1996; Du Randt et al., 2006).

Methods

Participants

All the senior male players of the Zimbabwean national RS team (n=15) with a mean age of 27.2 years were tested. Players were divided into forward (n=6) and backline players (n = 9). Before commencement of the project, all the players completed an informed consent form once the study protocol had been explained to them. The team management also granted their approval for the project. It was explained to the players that participation was voluntary and any player could withdraw at any time if they so wished. The study received ethical approval from the Ethics Committee in the Faculty of Health Sciences of the North-West University [NWU-00122-11-A1].

Procedures

Seventeen kinanthropometric measurements were taken on the players of the Zimbabwean National RS team by two internationally accredited level II Kinanthropometrists by means of data recorders. All measurements (stature, body mass, girths, skinfolds and breadths) were taken in accordance with the standard procedures as described by the International Standard for the Advancement of Kinanthropometry (ISAK) (Stewart et al., 2011). All kinanthropometric data were collected in the mornings prior to any physical activity.

Direct measurements: Body mass was measured with a calibrated electronic scale (Precision, A&D Company, Saitama, Japan) to the nearest 0.1 kg (Stewart et al., 2011). Stature was measured with a stadiometer to the nearest 0.1 cm (Stewart et al., 2011). Six skinfold sites (triceps, subscapular, supraspinal, abdominal, thigh and calf) were measured to the nearest 0.2 mm by using a Harpenden skinfold calliper (Stewart et al., 2011). Breadths (cm) (femur, humerus, wrist and ankle) were measured with bone callipers and girths (forearm, mid-thigh and calf) by using a flexible steel tape (Lufkin, Cooper Tools, Apex, NC) to the nearest 0.1 cm respectively. All measurements were taken twice with a third measurement when any of the 2 measurements were outside the allowed limits. In the case of two measurements, the mean was taken as the official reading, whereas the median was used in the case of three measurements.

Indirect measurements: Body mass and stature were used to calculate the Body Mass Index (BMI) as suggested by Eston, Hawes, Martin and Reilly (2009).

$$\textbf{BMI = MASS (kg)/STAT}^{2}\textbf{ (m)}.$$

The fat percentage was determined by means of the equation of Whithers, Craig, Bourdon and Norton (1987). **Body density (BD) = 1.10326 - 0.00031 (Age) - 0.0036 (∑ 6 skinfolds).**

∑ 6 skinfolds = (triceps + subscapular + supraspinal + abdominal + front thigh + medial calf)

Skeletal mass (kg) was calculated with the equation of Martin (1991).

[0.00006 x STAT x (femur breadth + humerus breadth + wrist breadth + ankle breadth)^2].

Lee et al. (2000) suggest that muscle mass (kg) and percentage muscle mass should be calculated as follows.

STAT (0.00744 x CAG^2 + 0.00088 x CTG^2 + 0.0044 x CCG^2) + 2.4 x (gender) – 0.048 x (Age) + race + 7.8

Where: CAG = corrected arm girth (relaxed);

CTG = corrected thigh girth (mid-thigh);

CCG = corrected calf girth;

STAT = stature;

MASS = Body mass;

Race = -2 for Asians, 1.1 for African Americans and 0 for Whites and Hispanics;

Corrected muscle circumferences = C_m; C_m = Climb – 3.1416 x (skinfold/10).

Somatotyping: The different somatotypes were calculated to the nearest 0.1 by using the equations as suggested by Carter and Heath (1990). The somatotypes for the individuals and for the mean total of all the players in each positional subgroup were calculated as follows:

Endomorphy = -0.7182 + 0.1451(∑ of skinfolds x 170.18/Stature) - 0.00068 (∑ of skinfolds x 170.18/stature)^2 + 0.0000014(∑ of skinfolds x 170.18/stature)^3

Where the ∑ of skinfolds = triceps, subscapular and supraspinal skinfolds.

Mesomorphy = 0.858(HUMB) + 0.601(FEMB) + (CAG) + 0.161 (CCG) – 0.131 (STAT) + 4.5

Where HUMB = humerus breadth (cm);

FEMB = femur breadth (cm);

CAG = corrected arm girth (flexed arm girth [cm] – triceps skinfold [mm]/10);

CCG = corrected calf girth (calf girth [cm] – calf skinfold [mm]/10);

HWR = Height-weight ratio;

Endomorphy = (HWR x 0.732) – 28.58;

Where (HWR) = STAT/3√MASS;

Note: if HWR < 40.75, but > 38.25 then Ectomorphy = HWR x 0.463 – 17.63 and if HWR ≤ 38.25 then Ectomorphy = 0.1

Somatotype plotting = A three-number somatotype rating was plotted on a two-dimensional somatochart using X and Y coordinates.

The coordinates were calculated as follows:

X = ectomorphy - endomorphy
Y = 2 x mesomorphy - (endomorphy + ectomorphy) (Carter & Heath, 1990)

Statistical analyses

The statistical software packages from SPSS Inc. (2013) and Statsoft Inc. (2013) were used to analyse the data. Descriptive statistics were initially determined to give an indication of the kinanthropometric profile of all the players. Secondly, parametric data analysis was performed via a t-test to compare the data between the player's positional groups. Thirdly, due to the small population size, non-parametric data analysis was performed with the Mann-Whitney test to confirm the results of the parametric data analysis. During the exploration of the data, Q-Q plots were drawn to determine normality by eyeballing the plots. From this, all the variables seemed to be normally distributed. As this study does not consist of a random sample**,** statistical significance (p-values) is not relevant and will only be reported for completeness. The interpretation of the non-parametric effect size (r) will therefore be applied to determine whether these differences were important in practice. Emphasis will be placed on differences with a large practical significant value. Guidelines for the interpretation of r is r=0.1 is small; 0.3 is medium and 0.5 is large (Field, 2009).

Results

The results of the descriptive statistics from the kinanthropometric data for the total group of senior elite Zimbabwean national RS players are presented in Table 1.

Table 1: Descriptive statistics of the kinanthropometric data for the senior elite Zimbabwean national RS players

Variables	Mean n =15	SD	Variables	mean	SD
Stature (cm)	178.44	4.79	**Medial calf SF**	6.87	2.10
Body mass (kg)	84.16	8.31	**∑ 6 skinfolds (mm)**	50.30	17.16
% Body fat	9.46	2.77	**Bone density**	1.08	0.01
% Muscle mass	41.62	2.18	**Arm GR flexed**	38.47	2.04
% Skeletal mass	11.47	0.80	**Arm GR relax**	34.24	3.24
Muscle mass (kg)	37.29	2.15	**Calf GR**	37.73	2.21
Skeletal mass (kg)	9.65	1.14	**Forearm GR**	29.98	2.02
Triceps SF	9.21	11.22	**Mid-thigh GR**	58.10	2.39
Subscapular SF	10.41	3.80	**Humerus BR**	7.45	0.45
Supraspinal SF	6.55	2.46	**Femur BR**	9.61	0.62
Abdominal SF	11.63	5.31	**Wrist BR**	5.79	0.34
Front thigh SF	8.77	3.30	**Ankle BR**	7.14	0.31

SF = Skinfold (mm); GR = Girth (cm); BR = Breadth (cm)

The descriptive data indicated that on average the Zimbabwean RS player is 178.4 cm tall and has a body mass of 84.2 kg. Except for stature and body mass, to the knowledge of this research team, no scientific literature exists in which a full kinanthropometric profile of RS players has been published to date. The scarcity of kinanthropometric data on RS will therefore be partially addressed by the data in Table 2.

Table 2: Statistical analyses of the kinanthropometric data for the player positional subgroups in the senior Zimbabwean national RS team

	Backline players (n = 9)		Forward players (n = 6)		t-test	Mann-Whitney	Effect size
Variable	mean	SD	mean	SD	p-values	p-value	r-value
Stature (cm)	174.31	4.9	183.01	6.7	0.04	0.67	0.47
Body mass (kg)	81.13	8.5	88.7	7	0.07	0.67	0.49
% Body fat	9.47	3.4	9.45	1.7	0.99	0.53	0.18
% Muscle mass	40.93	2.6	42.66	0.7	0.09	0.11	0.43
% Skeletal mass	11.54	0.6	11.38	1.1	0.75	0.78	0.09
Muscle mass (kg)	36.55	2.4	38.39	1.3	0.07	0.18	0.61
Skeletal mass (kg)	9.36	1	10.09	1.2	0.26	0.33	0.27
Triceps SF	6.53	2.8	5.87	0.8	0.52	1	0.00
Subscapular SF	10.81	4.8	9.82	0.3	0.58	0.69	0.11
Supraspinal SF	6.38	3	6.82	1.24	0.71	0.18	0.35
Abdominal SF	11.49	6.4	11.83	3.8	0.90	0.53	0.18
Front thigh SF	8.36	3.2	9.38	3.6	0.59	0.69	0.12
Medial calf SF	6.63	2.47	7.23	1.51	0.57	0.61	0.14
∑ 6 skinfolds	50.2	21.2	50.45	10.3	0.98	0.53	0.18
Bone density	1.08	0.0	1.08	0.0	0.61	1	0.15
Arm GR flexed	38.26	2.3	38.8	1.71	0.61	0.69	0.12
Arm GR relax	33.62	3.9	35.17	1.7	0.32	0.33	0.26
Calf GR	37.84	2.2	37.55	2.4	0.82	0.86	0.05
Forearm GR	29.43	2.5	30.8	0.5	0.14	0.05	0.52
Mid-thigh GR	57.83	2.4	58.5	2.6	0.62	0.46	0.21
Humerus BR	7.42	0.4	7.48	0.5	0.81	0.61	0.15
Femur BR	9.47	0.76	10.1	0.56	0.61	0.60	0.44
Wrist BR	5.77	0.4	5.82	0.3	0.79	0.78	0.09
Ankle BR	7.03	0.3	7.30	0.3	0.15	0.14	0.39
BMI	26.36	2.0	26.47	1.5	0.9	0.77	0.09

SF = Skinfold (mm); GR = Girth (cm); BR = Breadth (cm) r = 0.1 (Small); r = 0.3 (Medium)*; r ≥ 0.5 (Large)**; r = 0.5 practical significance;

From the analysis presented in Table 2, the following was observed. Although several medium practically significant differences emerged between the different player positional groups, only

the variables that pose large practically significant differences are discussed. The forward players had a practically significantly higher body mass (r = 0.49) and stature (r=0.47) than the backline players. The backline players also differed from the forward players with practically significantly less muscle mass (r = 0.61) and percentage muscle mass (r = 0.63) respectively. Forward players revealed a practically significant (r= 0.52) larger forearm girth value compared to that of backline players, as well as a practically significantly (r= 0.44) bigger femur breadth value.

BMI is a kinanthropometric measurement that is calculated indirectly. It is extensively used for the assessment of body composition and provides some insight into the morphology of the player's build. BMI provides a value that pinpoints whether an individual's body mass is in proportion to their height or stature (Walsh et al., 2011). The average BMI for the total group of Zimbabwean RS players was 26.41, but again no large practically significant differences were found between the BMI of the players in the different player positional subgroups. Except for the kinanthropometric measurements as listed in Table 2, Carter and Heath (1990) suggest that somatotyping of players (related to body build) could provide more insight into the players' kinanthropometric profile. The comparisons of the somatotypes of the players in the different positional subgroups are presented in Table 3 with a plotting of the mean somatotypes for each subgroup presented in Figure 1.

Table 3: Somatotypes of the different positional subgroups of Zimbabwean national RS players (n=15)

	Forward players (n = 6)		**Backline players (n = 9)**		**t-test**	**Mann-Whitney**	**Effect sizes**
Variable	mean	SD	mean	SD	p-values	p-value	r-value
Endomorphy	2.22	1.07	2.03	0.36	0.64	0.86	0.06
Mesomorphy	6.66	0.89	5.95	0.49	0.07	0.11	0.43
Ectomorphy	1.26	0.6	1.56	0.67	0.40	0.33	0.26

r = 0.1 (Small); r = 0.3 (Medium); r = 0.5 (Large); r ≥ 0.5 practical significance

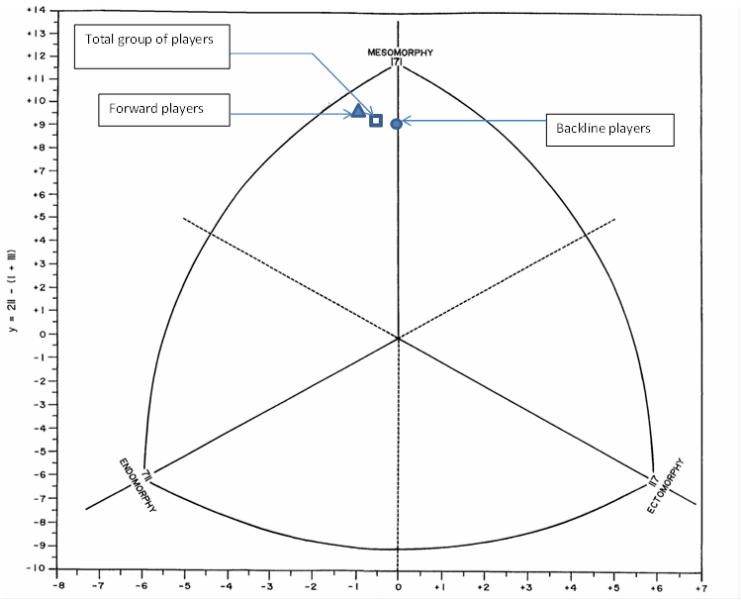

Figure 1: Somatochart with somatotypes for the total and different positional subgroups of Zimbabwean national RS players

The forward players in the current study had a practically significantly (r = 0.49) higher mesomorphy value compared to the backline players. However, both positional subgroups tend to be dominant mesomorphic in nature, with the average somatotype for the total group as endomorphic mesomorph.

Discussions

The average height (178.44cm) of the Zimbabwean RS player is comparable to the research conducted by Elloumi et al. (2012) (183cm); Suarez-Arrones et al. (2014) (180.4cm) and Higham, Pyne, Anson and Eddy (2013) (180.4cm) respectively, all focusing on sevens rugby. The average body mass (84.1kg) of the Zimbabwean RS players is also in the proximity of the body mass values reported by Elloumi et al. (2012) (86.4 kg); Suãrez-Arrones et al. (2012) (87.9 kg) and Higham et al. (2013) (89.7 kg). Backline players in the current study exhibited a fat percentage of 9.46, which is comparable to the 9.2% found amongst the national RS backline players of the United States of America as measured by Carlson et al. (1994).

Taking into consideration that the previously mentioned studies focused on elite teams from different nationalities, one can assume that all elite international RS players presented an almost similar body mass and stature irrespective of nationality. The similarity in body mass and stature of the different international RS players may be accredited to the regular basis the teams play against one another, causing the management teams to select players that may adapt to the physique of the opponents. Coaches and selectors may have developed a similar philosophy of

the ideal build or morphology for RS players to enable them to perform optimally on the field and may have applied the philosophy during their respective selection processes.

The large practically significant differences between the stature values of the different players' positional subgroups in RS are similar to the findings of Rienzi, Reilly and Malkin (1999) and Fuller et al. (2010). The practically significant differences found between the body mass of Zimbabwean forward and backline RS players also correspond with the findings of Rienzi et al. (1999) and Fuller et al. (2010), who found the forward players to exhibit higher values of body mass when compared to the backline players. The practically significant smaller backline players in the present study (as indicated by the smaller muscle mass and % muscle mass) are in line with the results of Rienzi et al. (1999), who found forward RS players to have more muscle mass than backline players. The practically significantly less mass of the Zimbabwean backline RS players in the current study may be linked to a higher degree of work output for lighter players when compared to the heavier players as stated by Meir (2012). The additional body and muscle mass of the forward players may be explained by the different responsibilities of the respective players, such as scrumming and lifting other players at line-outs and at kick-offs. The backline players on the other hand may be able to continue for longer periods on high-intensity running activities due to their lower body mass compared to that of the forward players.

The practically significant difference found between the forearm girth of forward and backline players may be attributed to the necessity of the forward players to bind during scrums, line-out and kick-off support, where a bigger forearm could lead to increased grip strength. The bigger femur breadth values of the forward players may be attributed to the forward players being superior in stature and mass when compared to the backline players. Bigger players require proportionally bigger femurs. No practically significant differences were found for any of the other kinanthropometrical measurements. As far as body composition is concerned, the forward players in the current study had a practically significant ($r = 0.49$) higher mesomorphy value than the backline players, which is similar to the findings of Quarrie et al. (1996), as well as Holway and Garavaglia (2009), who determined that forward players in Rugby Union presented significantly ($p< 0.001$) superior mesomorphy values in comparison to the backline players. However, both player subgroups in the current study are dominant mesomorphic in nature as expected, with the average somatotype of the whole group as endomorphic mesomorph. In general, Rugby Union players are also endomorphic mesomorphs.

No significant differences were found in the BMI of the Zimbabwean RS players amongst the different player positional subgroups. An interesting observation was that the average BMI value

(26.4) for the total group of Zimbabwean RS players in the present study is very similar to the 26.1 reported by Elloumi et al. (2012) for Tunisian RS players.

Conclusion

The different RS player positional subgroups did not differ with regard to BMI. However, when the kinanthropometric measurements of the Zimbabwean RS players in the positional subgroups were compared, forward players were significantly heavier and presented bigger stature, forearm girth, femur breadth and mesomorphy values than backline players. In addition backline players had less muscle mass (kg) and percentage muscle mass than forward players. These kinanthropometric differences between the player positions could be attributed to the different responsibilities of each player's positional group.

In addition to the objective of the present study, a comparison of results between previous research and results from the current study suggests that RS players seem to be a homogenous group of players, despite their respective nationalities.

Practical Applications of the study

The study highlighted that RS requires players with different types of body compositions to adhere to the responsibilities as set for the different player position subgroups despite the players exhibiting homogenous somatotypes and BMI values.

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CHAPTER 4

4 TOURNAMENT AND POSITION-SPECIFIC TIME-MOTION ANALYSES OF ELITE ZIMBABWEAN RUGBY SEVENS PLAYERS DURING MATCH PLAY.

TITLE PAGE

ABSTRACT

INTRODUCTION

METHODS

- **Subjects**
- **Experimental Approach to the problem**
- **Time-motion Analyses**
- **Statistical Analyses**

RESULTS

DISCUSSION

PRACTICAL APPLICATIONS

ACKNOWLEDGEMENTS

REFERENCES

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TOURNAMENT AND POSITION-SPECIFIC TIME-MOTION ANALYSES OF ELITE ZIMBABWEAN RUGBY SEVENS PLAYERS DURING MATCH PLAY

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ABSTRACT

Van den Berg, PH, Malan, DDJ & De Ridder, JH. Tournament and position-specific time-motion analyses of elite Zimbabwean Rugby Sevens players during match play. J Strength & Cond Res 2015 – The purpose of this study was to examine the physiological demands Rugby Union Sevens (RS) places on its players with regard to time-motion analyses (TMA), focusing on possible player positional differences and differences that may exist among different levels of tournaments. Players were clustered into two groups, namely forward and backline players. One hundred and eleven data sets of the elite male, senior RS players with a mean age of 27.2 years participated in the study. Data sets were gathered at matches from three tournaments held in the same month. TMA data were captured with a GPS device at 10 Hz (Catapult Innovation, Melbourne, Australia). Players travelled an average distance of 1 073 meters (m) at an average work-to-rest ratio of 1:5.1. Forward players spent a significant (d=0.53) percentage of time more on walking (d= 0.56) and less on sprinting (d=0.56) than backline players. The work-to-rest ratio of the players indicated that the backline players had significantly (d=0.67) less rest during a match than forward players. The differences found with regard to TMA of the different players positions might be related to the different responsibilities and physiological demands associated with each player position. RS players spend a practically significant percentage of time more on standing and less on high intensity running during international tournaments than during national (d= 0.98) and district (d = 0.82) tournaments. Players also exhibited lower work-to-rest ratios during international

matches than during the district and national tournaments. Stronger opponents at international tournaments, crowd support and travel fatigue during international tournament may explain the TMA differences that were found.

Keywords: Sevens Rugby, match-specific training, time-motion analyses, rugby union

INTRODUCTION

Rugby Union Sevens (RS) recently obtained Olympic status to be included as an event in Rio de Janeiro as part of the 2016 Olympic Games (14, 21). This status will probably motivate international teams participating in this event to pursue the enhancement of their performance even more in their quest to win an Olympic medal (5). Researchers suggest that more effective training sessions could lead to improved performance (19). Therefore understanding the movement activities of rugby players would contribute to improved game-related training sessions (10) (even more so for RS). The knowledge and testing of the movement activities of rugby players during match-play are therefore considered to be of great value to coaches and sport scientists to monitor player performance during a match and to enable them to prepare more sport-specific training sessions for the players (3, 23, 28).

The value of sport-specific training sessions for enhancing the performance of Rugby players was clearly emphasized (8, 13, 30). This can be linked to the physical demands being placed on the players by the various movement activities as reflected by the percentage time spent by each player on the different movement activities during match-play (34). In an effort to make the training sessions more sport specific, it is necessary to understand the qualities, role and contribution the involved physiological components associated with the different movement activities have on match-play (30). According to the literature, time-motion analysis (TMA) is considered the most reliable, valid and objective method available for determining the contribution of each movement activity towards sport performance (2, 6, 7, 32).

In addition to the contribution of each movement activity towards performance, different playing positions in a team sport also pose specific physical demands and responsibilities on players during a match (10, 16, 26, 35). Literature suggests that both Rugby Union (10, 16) and RS (15, 33) players be subdivided into forward and backline players when position-specific differences are investigated. Based on these findings and the associated player-

positional differences, it is suggested that the training sessions be made more position specific for Rugby Union players (4, 6, 23,). Due to the lower number of players in RS (seven[7] vs. fifteen [15]) and the fact that the size of the playing field remains the same for both RS and standard Rugby Union, research on player performance on the latter indicated that it would probably be accentuated in RS (27). Differences in the movement activities of the various player positions in Rugby Union has been identified (11). Research on position-specific training and the total distance travelled by players in the different positions of Rugby Union (as part of TMA) found that the backline players covered a significantly greater total distance than was the case with the forward players (20). In another study it was reported that forward players stood still more frequently than the backline players (9) and that forward players jogged significantly more than the backline players (4, 8). There is little research that reported TMA's in relation to RS (7).

Apart from player-positional differences in movement activities, substantial differences were found among movement activities of RS players at different levels of tournaments (18), suggesting that one should also analyse the movement activities of the specific tournament level to prepare accurate match-specific training sessions for the players. The purpose of this study was therefore to examine the physiological demands RS places on its players with regard to TMA, focusing on possible player positional differences as well as differences that may exist among different levels of tournaments.

The results of this study could enable coaches, sport scientists and players to better understand the intensity and duration of the movement activities found in an elite RS team during different levels of competition and for different positional subgroups. It may indirectly also lead to position-specific assessment and training programmes, which may assist in the enhancement of the players' overall performance and development (6). The results from the current study may also assist coaches to better assess the performance-related requirements associated with the level of tournament on the preparation of teams for such RS tournament.

METHODS

Subjects

Nineteen elite male, senior RS players of the Zimbabwean national team, with a mean age of 27.2 years were used in the study. All the players had at least two years' experience of

playing RS. Players were clustered into forward and backline players with the assumption that each group were required to perform match-play responsibilities for that relevant group during a match. Before the commencement of the study, all the players completed an informed consent form after the study protocol had been explained to them. It was also explained to the players that their participation in the study was done on a voluntary basis and that any player could withdraw at any time during the study. The team management also gave their approval for the study to be conducted. The study was approved by the Ethics Committee of the North-West University [NWU-00122-11-A1].

Experimental Approach to the Problem

One hundred and eleven (111) data sets of the Zimbabwean, RS players were gathered at RS matches from three different levels of tournaments held one week apart. Each data set consisted of the TMA elements (distance travelled, percentage time spent in the five velocity categories and work-to-rest ratios) for each player during a match. The first two tournaments (district and provincial) were held in Harare, Zimbabwe (35 data sets from each tournament), and the last tournament (international) was held in Hong Kong (41 sets of data). All matches were played on a standard rugby field with a natural grass surface.

Time-motion analyses

Time-motion analysis data were captured with players wearing a safe, stretchable harness under their playing attire with a small pouch between the shoulder blades in which a minimaxX GPS device (Team Sport v 2.5, Catapult Innovation, Melbourne, Australia) was fitted. The devices were activated five minutes before play started and switched off just after each of the matches to record data at 10 Hz when switched on. The recorded data were downloaded and analysed using Logan Plus 4.4.0 software developed for this system (Catapult Innovation, Melbourne, Australia). Movement velocities were categorized as suggested by Reid *et al*. in 2013, which was at the time of data retrieving the most recent published guideline, namely: low-intensity activities/standing (0 – 0.5 m/s), walking (0.6 – 1.7 m/s), jogging (1.8 – 3.6 m/s), high-intensity activities/medium-intensity running (3.7 – 5 m/s), high-intensity running (5.1 – 6.7 m/s), and sprinting (above 6.7 m/s), indicating velocity zones that represent the range of locomotor activity profiles typical of intermittent team sports and are routinely used during GPS monitoring in Rugby Union (6) and RS (34). To ensure inter-device validity, each player was allocated the same GPS device throughout all three tournaments (1). Another reliability concern as indicated by the literature was addressed

by ensuring that the horizontal dilution of position never went above 1, which is an acceptable value for good GPS signal strength throughout (24). Finally, neither the time players were off the playing field nor the half-time interval was included in the analyses.

The analyses of the data are expressed as suggested by the respective literature:

- Movement activity data were expressed in percentage of time spent in each movement activity compared to the total time spent on all the movement activities (7).
- Total distance travelled during the match was calculated with data presented as total distance travelled per minute to account for variations in game time (18).
- Work-to-rest ratios were determined by comparing the time players had spent on low-intensity activities with the time players had spent on high-intensity activities. Low-intensity activities included standing, walking and jogging. The rest of the movement activities were considered high-intensity activities (22).

Statistical analyses

The Statistical Consultation Services of the North-West University was consulted to determine the statistical methods and procedures for the analysis of the research data. The Statistical Data Processing package (31) was used to process the data. A hierarchical linear model (mixed models) was used to firstly compare the TMA data of the different positional subgroups and secondly to compare the TMA data that exist between the different levels of tournaments to take into account the dependency of more than one measurement per player. During the exploration of the data, Q-Q plots were drawn to determine normality by eyeballing the plots. From this, all the variables can be assumed to be normally distributed. The study population was not randomly selected and all the players from the described population took part in the study, making it an descriptive study. Due to the descriptive nature of the study, practical significance was determined by means of Cohen's effect sizes (12). Practical significance was set as follows: a small effect ≥ 0.2; a moderate effect ≥ 0.5 and a large effect as ≥ 0.8.

RESULTS

The following results were found when the TMA of the different player positions were analysed.

*Insert Table 1 please

Results from Table 1 indicate that the elite RS players travelled an average distance of 1 073 meters (m) at an average work-to-rest ratio of 1:4.7. Forward players spent a moderate, practically significant percentage of time more on walking (d=0.53) and less on sprinting (d= 0.56) than backline players. The work-to-rest ratio of the players indicated that the backline players had moderate practically significantly (d=0.67) less rest during a match than forward players. The rest of the TMA only indicated small or no significant differences between the two groups of players. As indicated in one of the objectives, the comparative TMA data of the RS players for the three different levels of tournaments were also analysed. The results are presented in Table 2.

*Insert Table 2 please

Table 2 indicates that elite Zimbabwean RS players spend a practically significant percentage time more standing during international tournaments than during national (d=0.98) and district (d=0.82) tournaments. The players also spend a practically significant percentage of time less on high intensity running during international tournaments than during national (d=0.74) and district tournaments (d=0.51). The only practically significant difference (moderate) found between the national and district tournaments was the larger percentage of time players jogged during the district tournament (d=0.56). Finally, moderately practically significant differences were found when the work-to-rest ratios of the three tournaments were compared with players working harder during district and national tournaments than during the international tournament.

DISCUSSION

The importance of match-specific training to enhance performance and of understanding the physiological requirements RS places on the movement activities of the players directed the current study to gather reliable and valid TMA data of elite RS players through GPS technology. It was also important to investigate the possible movement activity differences in the two player positional subgroups, as well as during the different levels of tournament.

The results of the current study that indicates that players travelled an average distance of 1 073 meters (m) are slightly less than the 1221 m found by Granatelli et al. The 1031.68 m

travelled by backline players and 1129.4 meters travelled by forward players in the current study are also less than the 1452 travelled by forward and 1420 m travelled by backline players in the study determined by Ross et al. The variances in distance travelled by various studies might be due to technical and tactical profiles of different teams (29). However, the practically significant differences found between the player positions are in line with previous studies reporting that forward RS players walked significantly more ($p<0.01$) (28), travelled significantly greater distances (29) (even though only small significance in current study) and spent less time on sprinting than RS backline players (33). The current study also found that the backline players had moderately practically significantly ($d=0.67$) less rest during a match than forward players. To the knowledge of the research team, no other study could be found that compared the work-to-rest ratios of the different player positions for RS players. The differences found with regard to TMA of the different players positions might be related to the different responsibilities and physiological demands associated with each player position (27).

TMA data that compared the movement activities of RS players at different levels of domestic tournaments indicated that players slowly jogged for a significant percentage of time more during the district tournament than during the national tournament. No research could be found where the movement activities of domestic competitions were compared, which makes it impossible to compare the relevant results from the current study with previous work. A possible explanation for these findings may lie in the fact that the district tournament is hosted first. Players therefore may have anticipated their respective positional play on the field better (17) and were therefore able to position themselves more effectively with less jogging during the second (national) tournament. The lack of differences in the movement activities between the two domestic tournaments suggests that the movement activities of RS players seem similar during lower levels of competition. The reason for these similar results may be due to the familiarities the players experienced during the two tournaments (25) and the fact that the opposition players at the district and national tournament were constructed from the same player pool.

The comparison of TMA data between movement activities of RS players during international and domestic tournaments relate to similar observations made in rugby union where it was found that players in international matches sprinted significantly more and further than in lower level matches (23). Finally, the practically significant differences found between the percentage time spent on the movement activities and work-to-rest ratios of the

players during the three tournaments contradict the findings of a previous study (18), which suggested that players played with greater physical load during international than during domestic tournaments. The latter study drew the conclusion with regard to work load from the number of velocities that occurred during the two types of tournaments and not the work-to-rest ratio's. Their results may therefore indicate higher intensities, but not necessarily a higher work load, as rest was never taken into consideration in the previous study. The reason players seem to work harder during district and national tournaments than during international tournaments might be substantiated by their familiarity with conditions when playing at home, by crowd support and by the absence of the negative effect of travel fatigue on the international tournament as suggested by literature (25).

This study is the first to analyse the different movement activities of RS players during three different levels of competition and between three different positional groups. Results from the current study provide relevant and objective information that will assist sport scientists and coaches to develop better match-specific training sessions which can account for player positional differences as well as differences between levels of tournament.

PRACTICAL APPLICATIONS

- Practically significant differences observed in some of the movement activities support the application of position-specific training for certain movement activities associated with the enhancement of player performance in RS.
- The practically significant differences found among some of the movement activities during different levels of RS competitions suggest that coaches and sport scientists need to ensure that their respective preparations are in line with the level of tournament.
- Movement activities of RS players seem to be similar during lower levels of competition such as national and district tournaments.

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Table 1: TMA of Zimbabwean elite RS players in different playing positional subgroups

Variables	Mean Team	Mean B n=60	Mean F n=51	MSE	p -value	ES
Total distance (m)	1073	1031.68	1129.4	9196	0.275	0.33
% time standing	51.30	52.69	50.61	41.77	0.19	0.23
% time walking	16.19	14.98	17.2	25.07	0.39	0.53*
% time jogging	15.13	14.25	15.84	12.01	0.122	0.47
% time medium-intensity running	9.21	9.37	8.89	6.9	0.46	0.29
% time high-intensity running	6.31	6.42	6.11	9.4	0.178	0.36
% time sprinting	1.91	2.29	1.5	3.43	0.14	0.56*
Work-to-Rest ratio	1:4.7	1:4.5	1:5.1	1.9	0.048	0.67*

B – Backline players; F – Forward players; ES – Effect Sizes; ES large ≥ 0.8**; moderate ≥ 0.5 *; small ≥ 0.2; MSE - Mean square error

Table 2: Comparative TMA data of three different levels of RS tournaments played by elite Zimbabwean RS players

Variables	Mean D n=35	Mean N n=35	Mean I n =41	MSE	p -value	ES N vs I	ES N vs D	ES D vs I
Total distance (m)	1078	1112	1131	94717	0.750	0.06	0.11	0.17
% time standing	49.6	48.8	55.4	67.6	0.000	0.98**	0.16	0.82**
% time walking	16.99	18.63	14.91	35.7	0.250	0.37	0.06	0.31
% time jogging	16.13	15.3	15.9	17.66	0.045	0.43	0.56*	0.14
% time medium-intensity running	8.92	8.34	8.57	32.5	0.185	0.15	0.42	0.27
% time high-intensity running	6.4	6.65	3.58	10.86	0.070	0.74*	0.24	0.51*
% time sprinting	2.07	2.28	1.8	9.58	0.220	0.40	0.30	0.10
Work-to-Rest ratio	1:4.8	1:4.8	1:6.2	3	0.007	0.75*	0.21	0.54*

I – International; N – National; D – District tournament; ES – Effect Sizes; ES large ≥ 0.8**; moderate ≥ 0.5 *; small ≥ 0.2; MSE Mean square error

CHAPTER 5

5 EFFECT OF FATIGUE ON THE ZIMBABWEAN NATIONAL RUGBY SEVENS PLAYERS MOVEMENT ACTIVITIES.

TITLE PAGE

ABSTRACT

1. **INTRODUCTION**
2. **METHODS**
3. **RESULTS**
4. **DISCUSSION**
5. **CONCLUSION**

PRACTICAL IMPLICATIONS

ACKNOWLEDGEMENTS

REFERENCES

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Effect of fatigue on the movement activities of senior male Zimbabwean National rugby sevens players

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Abstract

Objectives

To determine the effect of fatigue on the percentage of time sevens rugby players spend on the movement activities during the two different halves of match play and to compare the percentage of time starter and substitute players spend on high and low-intensity movement activities.

Design

Observational ex post facto design.

Methods

Sixty-one time-motion analyses data sets of twelve (12) senior male elite Zimbabwean rugby sevens players with a mean age of 27.8 years were gathered at two International Sevens tournaments. Time-motion analysis data were captured at 10Hz with a minimaxX GPS device.

Results

Results indicated that no practically significant differences were found between the percentages of time players had spent on high-intensity movement activities between the two halves of match play. Starter players covered a significantly greater distance (r=0.26) than

substitute players, but substitute players covered a significantly greater relative distance (distance per minute) (r=0.33) than the starter players. The starter players had spent significantly percentage more time (r = 0.33) walking than substitute players and recorded significantly (r = 0,35) lower work-to-rest ratios than the substitute players. Hence the substitute players had less rest during match play and therefore a higher work-to-rest ratio than the starter players.

Conclusions

The current study showed no large practically significant differences between the high intensity movement activities of the players during the two halves of match play, suggesting that fatigue did not affect the players' movement activities. An increase in work-to-rest-ratios was found for substitute players compared to the starter players. The results therefore suggest that the use of substitute players may support the ability of teams to increase the percentage of time the players spent on high-intensity activities.

Keywords: rugby, tournament level, time-motion analyses, fatigue

1. Introduction

Rugby sevens is played across the globe in tournaments that stretch across two to three days where teams are expected to play three to six matches a day (14) with rest periods between matches on the same day that may vary from 20 to 180 minutes. Match play lasts 14 minutes (two seven-minute halves with a two-minute break in between), except for the cup final which lasts 20 minutes (two halves of 10 minutes each) (16). Each team consists of 12 players with seven starter and five substitute players (3). The popularity of rugby sevens as well as its Olympic status has increased the need for scientific research which can contribute to the improvement of players' performance (10).

As rugby teams strive towards performance, the physiological impact of the game/s as depicted by movement activities have to be determined through time-motion analyses (TMA) of the respective players (21). Global positioning system (GPS) units are considered to be the most valid and reliable TMA method to measure the movement activities of rugby players during matches (4, 5, 12). Movement activities within the game are divided into high-

intensity (fast jogging, running and sprinting) and low-intensity (slow jogging, walking and standing) activities.

The knowledge and testing of the movement activities of rugby players during match-play are considered to be of great value to coaches and sport scientists for determining work rate and monitoring player performance during a match (2, 18).

A decrease in movement activities during the match could be identified as fatigue and considered detrimental to performance (9). Research argues that the inability of rugby sevens players to continue high-intensity movement activities for the complete duration of a match is related to the onset of fatigue (11). It was therefore suggested that movement activities be monitored throughout match play to determine the possible effect of fatigue during match play (7).

Due to the relatively high intensity of match play during sevens rugby, coaches also regard it as necessary to determine whether a difference occurs in the movement activities between the two halves of matches. Although, no significant differences were found between any movement activities of rugby sevens players during the two halves (20, 23), results indicated that the work rate of players decreased slightly, in the second half of match-play (3, 11).

In addition to comparing the effect of fatigue on the movement activities of the players during the two halves, literature suggests that the impact of movement activities of substitute players should also be investigated (25) due to the fact that starter players are replaced throughout the match by substitute players. The reason for the substitutions may be either to replace an injured player, to enhance a tactical concern of the coach or to try and prevent a decrease in the team's work rate. When comparing the movement activities of starter versus substitute rugby sevens players, research found that substitute players travelled longer distances on the various movement activities than was the case with the starter players (11).

The resulting aims of this study were to determine the effect of fatigue on the percentage of time sevens rugby players spend on the movement activities during the two different halves of match play and to compare the percentage of time starter and substitute players spend on high- and low-intensity movement activities.

Results of the present study may provide additional insight into the movement activities of rugby sevens players which may assist coaches, sport scientists and players to better understand the impact of the intensities and durations of the movement activities throughout

the different halves of match-play. It may also guide coaches with regard to when and how often to use their respective substitute players during the game to minimize the influence of fatigue on the team's and/or individual's performance.

2. Methods

Twelve (12) senior male elite Zimbabwean rugby sevens players with a mean age of 27.8 years were used in the study. All the players had at least two years' experience of playing rugby sevens. Before the start of the study, all the players completed an informed consent form after the study protocol had been explained to them. It was also explained to the players that their participation in the study was done on a voluntary basis and that any player may withdraw at any time during the study without reprisal. The team management also gave their approval for the study. The study was approved by the Ethics Committee of the North-West University [NWU-00122-11-A1].

Sixty one TMA data sets were gathered from the Zimbabwean rugby sevens matches played at two International Sevens tournaments which were held one week apart. TMA elements such as work-to-rest ratios, distance travelled and percentage of time spent by the players in five different velocity categories during each half of match play, were included in the analyses. The data sets were divided into TMA of players who completed the first and second half. When the TMA data sets of the two halves were compared, only data sets that represented a player's TMA of a full half were used.

TMA data were also divided for starter and substitute players with the hypothesis that substitute players are expected to play for shorter durations which might influence their respective TMA. When the data of the substitute and starter players were analysed, only data sets of substitute players that were introduce in the second half (less than 7 minutes) were compared with data sets of starter players who completed the match. Data of players who left the field during match time was discarded. All matches were played on a dry, standard rugby field with a natural grass surface.

Time-motion analysis data were captured with players wearing a safe, stretchable harness under their playing attire with a small pouch between the shoulder blades in which a minimaxX GPS device (Team Sport v 2.5, Catapult Innovation, Melbourne, Australia) was

fitted. The devices were activated five minutes before play started and switched off just after each of the matches to record data at 10 Hz when switched on. Recorded data were downloaded and analysed using Logan Plus 4.4.0 software, developed for this system (Catapult Innovation, Melbourne, Australia). Movement velocities were categorized as suggested by literature in 2013 (19), which was at the time of data retrieving the most recent published guideline, namely: low-intensity activities/standing (0 – 0.5 m/s), walking (0.6 – 1.7 m/s), jogging (1.8 – 3.6 m/s), high-intensity activities/medium-intensity running (3.7 – 5 m/s), high-intensity running (5.1 – 6.7 m/s), and sprinting (above 6.7 m/s) indicating velocity zones that represent the range of locomotor activity profiles typical of intermittent team sports and are routinely used during GPS monitoring of players' movement patterns in Rugby Union and Rugby Sevens. To ensure inter-device validity, each player was allocated the same GPS device throughout both tournaments (1).

Another reliability concern as indicated by the literature was addressed by ensuring the horizontal dilution of position were never above 1, which is an acceptable value for good GPS signal strength throughout the recording (17). The movement activity data captured from the GPS recordings was expressed as follows: the percentage of time spent in each movement activity and the total distance travelled (24). Total distance travelled during the match was also calculated as total distance travelled per minute (relative distance) to account for variations in game time (6; 11). Work-to-rest ratios were determined by comparing the time players had spent on low-intensity activities with the time players had spent on high-intensity activities. Low-intensity activities included standing, walking and jogging. The rest of the movement activities were considered to be high-intensity activities (15). Finally, the time players were off the playing field and the time for the half-time interval were not included in the analyses.

The Statistical Consultation Services of the North-West University was consulted to determine the statistical methods and procedures for the analysis of the research data. The Statsoft Statistical Data Processing package (22) was used to process the data. A hierarchical linear model (mixed models) was used to compare the TMA data of the two halves and that between the substitute and starter players. During the exploration of the data, Q-Q plots were drawn to determine normality by eyeballing the plots. From this, all the variables can be assumed to be normally distributed. Due to the fact that this was not a randomly selected sample, statistical significance alone was not used to determine differences between the groups, but more emphasis was placed on practical significance through Cohen's effect sizes

(8). Practical significance was set as follows: small effect ≥ 0.2; moderate effect ≥ 0.5 and a large effect as ≥ 0.8. For the comparison between the starter and substitute data sets a non-parametric Mann-Whitney test was additionally done to address the discrepancy that exist between the number of players of the two groups. However, this analysis does not take the dependence of repeated measures into consideration as was the case for hierarchical linear models.

3. Results

The TMA data of the national senior Zimbabwean rugby sevens players between the two different halves during match play are displayed in Table 1.

*Insert table 1

Table 1 indicates that players travel an average of 548.1 meters per match half and a significantly (d = 0.53) bigger distance in the second half compared to distance travelled in the first half. Players spend a moderately practically significant percentage of time standing less (d = 0.47) in the second half than in the first half. The players did, however, spend a significantly (moderate size) percentage time more on slow jogging (d = 0.58) and medium-intensity running (d = 0.45) in the second half than what the case was during the first half. No practically significant differences were found between the percentage of time players had spent on high-intensity running and sprinting between the two halves of rugby sevens match play. In addition to comparing the TMA data of the sevens rugby players between the two different halves, the current study also aimed at investigating the possible differences that may exist between the TMA data of the starter and substitute rugby sevens players. The results for this comparison are presented in Table 2.

*Insert table 2

All TMA variables discriminated practically significantly (d value) between starter and substitute players. Substitute players had spent a higher percentage of time on all high-intensity activities, as well as on medium-intensity running. The starter players also spent significantly more percentage time on the lower-intensity activities. However, only four variables indicated a practically significant difference between starter and substitute rugby sevens players, which was confirmed by a moderate practical effect size of the Mann-

Whitney test. Starter players covered a significantly greater distance (d =0.8) (r=0.26) than substitute players, but substitute players covered a significantly greater relative distance (distance per minute) (d = 1.33) (r=0.33) than the starter players. The starter players had spent significantly percentage more time (d = 0.67) (r = 0.33) walking than substitute players and lastly, the starter players recorded significantly (d = 0.81) (r = 0,35) lower work-to-rest ratios than the substitute players. When the work-to-rest ratios are considered, one should understand that the second value in the ratio expresses the seconds during which the player or group rested. Hence the substitute players had less rest during match play and therefore a higher work-to-rest ratio than the starter players.

4. Discussion

The important effect of fatigue on players and teams' ability to perform has been proven (11). Understanding the effect of fatigue on the movement activities of elite senior Zimbabwean rugby sevens players led the current study to collect valid and reliable TMA data via GPS technology to compare the movement activities of rugby sevens players between the two halves, as well as between starter and substitute players during match play.

The findings of the current study indicated rugby sevens players travel an average of 548.1 meters a half at 78.8 m min^{-1} which are less than the 745 meters travelled in the first half at 97.7 m min^{-1} for forward and 895.5 meters travelled in the first half for backline players at 112.2 m min^{-1} as determined by Suarez-Aronnes et al. (2014). However, the findings from the current study seems in line with research that found that players travelled a total distance of 643 meters in the first half and 578 meters in the second half (9) are more similar to findings of the current study. A tendency of some rugby sevens teams to play more direct with less continuity while other teams try to prevent contact and keep continuity might be the reason why different observations with regard to total distance travelled by rugby sevens players during a match occur in literature (26).

Although rugby sevens players covered a significantly (d = 0.53) bigger distance in the first half compared to distance travelled in the second half, one can see that no difference existed between the relative total distances (m min^{-1}) travelled between the two halves. The reason for the significantly longer distances travelled in the first half might have been due to the fact that the second halves were all shorter in duration when compared to the first half. The

second halves were presumably cut short by match officials who were under pressure to get the next match started on time as scheduled for television.

The finding that rugby sevens players had spent a significant percentage of time more on slow and medium-intensity running movement activities in the second half of match play and a higher percentage of time standing still in the first half are in line with the available literature which found rugby sevens players, although not significantly, to be more stationary in the first half (20). These findings may be explained by the fact that rugby sevens players try to preserve as much energy as possible (11) by trying to remain stationary when they have the opportunity to do so in the first half. As the match progresses and time of match play becomes less, players may venture more towards jogging and medium-intensity running activities instead of being stationary, especially if they are behind on the score board. Similar to previous research, no practically significant differences were found between the percentage of time players had spent on high-intensity running and sprinting movement categories between the two halves of rugby sevens match play (20, 23). In addition to the lack of practically significant differences between the movement activities of the two different halves during match play, comparisons were also drawn between the TMA data of the starter and substitute players.

The practically significant greater relevant distance travelled by the substitute players in a specific allocated game time is similar to that reported by previous literature (11). It therefore seems that the substitute players travel at greater velocities as they travelled greater distances over the same time period of time than starter players. The starter players spend a significant greater percentage of time walking, when compared to the substitute players. The current study also found that substitute rugby sevens players displayed a significantly better work-to-rest ratio than the starter players. These results are in line with previous research who stated that substitute rugby sevens players presented a better work rate than the starter players (11). The reason for the lower work rate by the starter players may be due to them trying to preserve some energy for later in the match to try to counter the effect of fatigue, while the substitute players are aware that they will probably have a shorter duration of game time in the match; thus encouraging them to work at a higher rate (11).

5. Conclusion

The current study showed no large practically significant differences between the movement activities of the Zimbabwean national rugby sevens players during the two halves of match play, suggesting that fatigue did not affect the players' movement activities. However, a decrease in percentage time spent on walking and an increase in work-to-rest ratios were found for substitute players compared to the starter players. The results therefore suggest that the use of substitute players may support the ability of teams to counter the stagnation of the work rate put on a display by the teams towards the end of a match by introducing substitute players which should increase the teams work rate. Good communication with players if they were going to be substituted may also encourage them to increase their work rate as they would not need to reserve energy for alter stage in the game.

Practical implications

- The data of the study may assist sport scientists in preparing their training sessions more sport specifically, taking into consideration that players should try, during training sessions, to adhere to work-to-rest ratios that occur throughout both halves of match play;
- No significant differences between the work-to-rest ratios of the two halves, but an increase between the work-to-rest ratios of the starter and substitute players suggest that the latter could be arrayed to counter the lack of significant increased high-intensity movement activities during match play and coaches should be encouraged to do so;

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Table 1: Comparative movement activities of Zimbabwean national senior rugby sevens players between the two different halves during match play

		1St Half (*n*=57)	2nd Half (*n*=44)			
Variables	**Mean for Total Group**	**Mean for First half**	**Mean for Second half**	**MSE**	**p -value**	**ES**
Total distance (m)	548.1	596.8	504	30724	0.043	0.53*
Relative distance (m min^{-1})	78.8	78	79.7	28255.9	0.780	0.07
% time standing^{LI}	56.92	59.77	54.07	131.5	0.061	0.47*
% time walking^{LI}	13.75	13.15	14.35	30.1	0.395	0.22
% time jogging^{LI}	13.18	11.73	14.63	20.0	0.016	0.58*
% time medium-intensity running^{HI}	8.07	7.35	8.79	8.9	0.069	0.45*
% time high-intensity running^{HI}	5.91	5.74	6.08	9.6	0.670	0.11
% time sprinting^{HI}	1.48	1.24	1.71	2.5	0.260	0.25
Work-to-Rest ratio	1:6.86	1:7.33	1:6.38	18.4	0.399	0.20

ES – Effect Sizes; ES large ≥ 0.8**; moderate ≥ 0.5*; small ≥ 0.2; MSE - Mean square error; LI = low intensity activity; HI = high intensity activity

Table 2: Comparison of movement activities in Zimbabwean national senior starter and substitute rugby sevens players during match play

	Team	Starter (*n*=54)	Substitute (*n*= 7)				Mann-Whitney	
Variables	**Mean**	**Mean**	**Mean**	**MSE**	**p–value**	**ES = d**	**p-value**	**ES = r**
Total distance (m)	550.8	564.2	424	30878	0.052	0.80 **	0.041	0.26
Relative distance (m min^{-1})	91.2.	74.89	107.39	23238.7	0.001	1.33**	0.000	0.33
% time standing^{LI}	53.92	57.80	50.04	141.2	0.121	0.64*	0.643	0.04
% time walking^{LI}	12.38	14.20	10.56	29.1	0.098	0.67*	0.001	0.33
% time jogging^{LI}	14.17	12.90	15.44	22.0	0.220	0.50*	0.686	0.04
% time medium-intensity running ^{HI}	9.10	7.79	10.32	9.1	0.053	0.8**	0.222	0.12
% time high-intensity running^{HI}	6.78	5.66	7.90	9.1	0.070	0.74*	0.080	0.17
% time sprinting^{HI}	1.72	1.39	2.04	2.6	0.374	0.34*	0.024	0.21
Work-to-Rest ratio	1:5.71	1:5.30	1:3.86	18.4	0.117	0.81**	0.000	0.35

Guidelines for d – ES: large = 0.8**; moderate ≥ 0.5*; small ≥0.2; Guidelines for r – ES: large ≥ 0.5**; moderate ≥ 0.2*; small ≥ 0.1; ES – Effect Sizes; MSE - Mean square error; LI = low intensity activity; HI = high intensity activity

CHAPTER 6

6 SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

1. SUMMARY
2. CONCLUSIONS
3. LIMITATIONS AND RECOMMENDATIONS

1 Summary

The purpose of this study was firstly to compare the different player positional subgroups of the Zimbabwean national sevens rugby players with regard to kinanthropometric profiles; secondly to compare the time-motion analyses of the Zimbabwean national rugby sevens players with one another during the district, national and international tournaments, as well as between the player positional subgroups; and lastly to determine the effect of fatigue on the Zimbabwean national rugby sevens players' movement activities.

Chapter 1 provided a brief summary of the problem that underlies the research questions of the study and the research questions as such, the objectives and the related hypotheses of the study, as well as the structure of the thesis.

Chapter 2 consisted of a literature overview titled: "Kinanthropometry and time-motion analyses in rugby." The aims of the review were firstly to name the different rugby variants and to explain how rugby union differs from rugby sevens with regard to structure; secondly to examine the existing scientific literature which have addressed the reliability and validity concerns of global

positioning system (GPS), time-motion analyses; thirdly to provide an overview on the scientific literature that exist where time-motion analyses were done on rugby union and rugby sevens followed by a discussion of the comparative time-motion analyses results found between the two rugby variants; and lastly to provide a review of the kinanthropometric research that has been done on rugby union and sevens rugby players, followed by a comparative discussion of the results found between the players of the two rugby variants.

There are several different rugby variants, but rugby union and rugby sevens seem to be the most popular variants with the most similar structure. When the structure of rugby union and rugby sevens are compared, the contrast in player numbers (30 versus 14), duration of matches (80 minutes versus 14 minutes) and frequency of matches on a given day seems to be the biggest differences between the two rugby variants. The drastic reduction of player numbers in rugby sevens despite the fact that the size of the playing field remains the same led research teams to believe that the work already done on rugby union and the effects thereof on the players' performance would be accentuated in rugby sevens.

Analysing movement activities via GPS time-motion analysis will allow the coaching staff to make training more match specific, which would lead to improved performance. Research suggests that the new 10-Hz GPS technology should be considered the golden standard, and is considered a valid and reliable method for performing time-motion analyses when adequate satellite strength values exist. The possibilities of TMA as research tool are therefore significant when these advantages are taken into consideration.

When the movement activities of rugby sevens and rugby union are compared, research determined that low-intensity activities represented 61% of all movement activities for the rugby sevens players, which is considerably less than the 75% and 72.3% determined for rugby union players. Rugby sevens displayed more sudden stops, open field sprints and is played at a much faster tempo than rugby union. Rugby sevens players maximum sprint distance is also significantly longer and they run at higher average velocities than for rugby union players. Research is in agreement that rugby sevens players display an appreciable aerobic demand on the energy systems, where rugby union requires a more anaerobic orientated energy system.

The player positional differences between rugby union and rugby sevens with regard to time-motion analysis show that rugby union forward players cover significantly less distance than backline players, while no differences were determined between the total distance travelled between rugby sevens forward and backline players.

Forward players seem to be more static and jogged significantly more ($p<0.01$) than backline players in both rugby union and rugby sevens. When the comparison of the effect of fatigue on movement activities of rugby sevens and rugby union was done, results indicated that no significant differences were found between any movement activities during the two halves for either. In addition to time-motion analyses, kinanthropometry profiles were also identified as another important determinant of physiological characteristic of rugby players that may affect performance.

Clear kinanthropometric differences among player positional groups were determined. Forward rugby players were found to be significantly heavier than the backline players in both rugby variants. Both rugby sevens and rugby union players tend to be mesomorphic by nature. According to literature, the body mass and stature of international rugby sevens players from different countries also seem to be homogenous. Rugby sevens players seem to change in kinanthropometric profile more drastic over intervention time periods than was the case with rugby union players. Another huge difference between rugby union and rugby sevens players seems to be that rugby union players present much higher $\sum 7$ skinfold values than rugby sevens players. Literature also suggests that the level of competition might have an impact on kinanthropometry profiles, as players in better competitions indicated higher values of stature, mass and neck circumference. One should therefore understand that different competition levels, different player positions, gender, rugby variant, age and fatigue may all affect the physiological components of successful rugby players.

Chapter 3 consisted of the first article, which was compiled in accordance with the guidelines of the *Journal of Sports Sciences* and titled: "A kinanthropometric comparison of different player positions in elite rugby union sevens." The purpose of the study was to compare the different player position subgroups of elite, national, rugby union sevens players with regard to kinanthropometric profiles. The article succeeded in determining that on average the Zimbabwean RS player is 178.4 cm tall and has a body mass of 84.2 kg. Forward players had a practically significantly higher body mass ($r = 0.49$) and stature ($r=0.47$) than the backline players. The backline players also differed from the forward players with practically significantly less muscle mass ($r = 0.61$) and percentage muscle mass ($r = 0.63$) respectively. Forward players revealed a practically significantly ($r= 0.52$) larger forearm girth value compared to that of backline players, as well as a practically significantly ($r= 0.44$) bigger femur breadth value. The forward players in the current study also had a practically significantly ($r = 0.49$) higher mesomorphy value compared to the backline players. However, both positional subgroups tend to be dominant mesomorphic in nature with the average somatotype for the total

group as endomorphic mesomorph. The chapter highlighted that rugby sevens requires players with different types of body compositions to adhere to the responsibilities as set for the different player position subgroups despite the players exhibiting homogenous somatotype values.

Chapter 4 consisted of the second article, which was compiled in accordance with the guidelines of the *Journal of Strength and Conditioning Research* and titled: "Tournament and position-specific time-motion analyses of elite Zimbabwean rugby sevens players during match play". The purpose of the study was to examine the physiological demands rugby sevens places on its players with regard to time-motion analyses, focusing on possible player positional differences and differences that may exist among different levels of tournaments. Players travelled an average distance of 1 073 meters (m) at an average work-to-rest ratio of 1:5.1. Forward players spent a significant (d=0.53) percentage time more on walking (d= 0.56) and less on sprinting (d=0.56) than backline players. The work-to-rest ratio of the players indicated that the backline players had significantly (d=0.67) less rest during a match than forward players. The differences found with regard to TMA of the different players positions might be related to the different responsibilities and physiological demands associated with each player position. RS players spent a practically significant percentage of time more standing and less on high intensity running during international tournaments than during national (d= 0.98) and district (d = 0.82) tournaments. Players also exhibited a lower work-to-rest ratios during international matches than during the district and national tournaments. Stronger opponents at international tournaments, crowd support and travel fatigue during international tournament may explain the TMA differences found.

Chapter 5 consisted of the third article, which was compiled in accordance with the guidelines of the *Journal of Science and Medicine in Sport* and titled: "The effect of fatigue on the movement activities of senior male Zimbabwean National rugby sevens players". The purpose of the study was to determine the effect of fatigue on the percentage of time sevens rugby players spent on the movement activities during the two different halves of match play and to compare the percentage of time starter and substitute players spend on high and low-intensity movement activities. The current study showed no practically significant differences were found between the percentages of time players had spent on high-intensity movement activities between the two halves of match play. It seems therefore that fatigue did not affect the players' movement activities. Starter players covered a significantly greater distance (r=0.26) than substitute players, but substitute players covered a significantly greater relative distance (distance per minute)

(r=0.33) than the starter players. The starter players spent significantly percentage more time (r = 0.33) walking than substitute players and recorded significantly (r = 0,35) lower work-to-rest ratios than the substitute players. This implies that the substitute players had less rest during match play and therefore a higher work-to-rest ratio than the starter players, suggesting that the use of substitute players may support the ability of teams to increase the percentage of time the players spend on high-intensity activities.

2 Conclusions

The conclusions drawn from this research are presented in accordance with the set hypotheses from Chapter 1.

Hypothesis 1: Practically significant differences in kinanthropometric profiles will be found between the different player-positional subgroups of the Zimbabwean national rugby sevens players.

Hypothesis 1 is accepted, as forward players presented significantly greater stature, body mass, forearm girth, femur breadth, muscle mass, percentage muscle mass and mesomorphy values when compared to backline players.

Hypothesis 2: Practically significant differences will exist between the time-motion analysis data of the Zimbabwean national RS players with regard to the district, national and international tournaments as well as between the different player positional subgroups.

Hypothesis 2 is accepted, because RS players because significant differences such as percentage time standing, high intensity running and work to rest ratios did emerge between the movement activity time-motion analyses data of the three different levels of tournaments which was consistent with the first part of the hypothesized and practical significant differences between the player positional subgroups for work-to-rest ratios, percentage time walking and sprinting was established which was in agreement with the second part of the hypothesis.

Hypothesis 3: Fatigue will have a practically significant effect on the movement activities of the Zimbabwean National RS players.

Hypothesis 3 is partially rejected as no significantly practically significant differences between the high and low intensity movement activities of the players during the two halves of match play occurred, suggesting that fatigue did not affect the players' movement activities. However,

an increase in work-to-rest-ratios was found for substitute players compared to the starter players suggesting that the use of substitute players may support the ability of teams to increase the percentage of time the players spend on high-intensity activities.

To the knowledge of the current research team, no literature could be found where such a comprehensive positional kinanthropometric profile of national sevens rugby players were determined. Although Higam *et al.* (2012) compared the movement activities of RS players during two different types of tournaments, this is the first study that compared the time-motion analyses data between three different levels of rugby sevens' tournaments.

3 Limitations and recommendations

The population in the current study was relatively small due to the expensive nature of GPS devices and the reluctance of elite players to participate in research. The results from the thesis can therefore not be seen as representative of elite sevens rugby players internationally. Future studies should therefore try to include more players from different nationalities to increase their population size and make the findings representative of a bigger general population. Another suggestion for future research is to compare the movement activities of the different players during training and match play via GPS time-motion analyses.

APPENDIX

APPENDIX A, B, C, D E & F

APPENDIX A	**LANGUAGE EDITING LETTER A & B**
APPENDIX B	**INFORMED CONSENT FORM AND PARTICIPANT INFORMATION LEAFLET**
	GENERAL DEMOGRAPHIC AND INFORMATION QUESTIONNAIRE
APPENDIX C	**DATA COLLECTION FORMS**
APPENDIX D	**REBUTTEL LETTER OF EXAMINARS QUESTIONS THAT COULD NOT BE CHANGED**
APPENDIX E	**INSTRUCTIONS TO AUTHORS**
APPENDIX F	**ARTICLE SUBMITTED: JOURNAL OF SCIENCE AND MEDICINE IN SPORT**

APPENDIX A LANGUAGE EDITING LETTERS

31 March 2015

I, **Ms Cecilia van der Walt,** hereby confirm that I took care of the editing of the thesis of **Mr Pieter van den Berg** titled ***Global positioning system tracking and kinanthropometrical profiling of Zimbabwean National Rugby Sevens players.***

C. Van der Walt.

MS CECILIA VAN DER WALT

BA (*Cum Laude*)
HOD (*Cum Laude*),
Plus Language editing and translation at Honours level (*Cum Laude*),
Plus Accreditation with SATI for Afrikaans and translation
Registration number with SATI: 1000228

Email address: ceciliavdw@lantic.net

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cumlaude
languagepractitioners

Director: CME Terblanche - BA (Pol Sc), BA Hons (Eng), MA (Eng), TEFL

22 Strydom Street
Baillie Park, 2531

Tel 082 821 3083
cumlaudelanguage@gmail.com

DECLARATION OF LANGUAGE EDITING

I, Christina Maria Etrecia Terblanche, hereby declare that I edited the research study titled:

Global positioning system tracking and kinanthropometrical profiling of Zimbabwean National Sevens Rugby players

for Pieter van den Berg for the purpose of submission as a postgraduate thesis. Changes were suggested and implementation was left to the discretion of the author.

Regards,

CME Terblanche

Cum Laude Language Practitioners (CC)

SATI accr nr: 1001066

PEG registered

APPENDIX B

INFORMED CONSENT FORM AND PARTICIPANT INFORMATION LEAFLET

GENERAL DEMOGRAPHIC AND INFORMATION QUESTIONNAIRE

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

CONFIDENTIAL

Informed consent form

PART 1

1. School/Institute:
School for Biokinetics, Recreation and Sport Science

2. Title of the project/trial:
GLOBAL POSITIONING SYSTEM TRACKING AND KINANTHROPOMETRICAL PROFILING OF ZIMBABWEAN NATIONAL RUGBY SEVENS PLAYERS

3. Full names, surname and qualifications of project leader:
Pieter van den Berg, B.A., B.A. (Hons) and M.A.

4. Rank/position of supervisor:
Lecturer and program leader

5. Full names, surname and qualifications of supervisor of the project:
Andries Zandberg, B.Sc (Hons)

6. Name and address of supervising medical officer (if applicable):
Not applicable

7. Aims of this project
The aims of this project are to determine:

1. the different player positional subgroups of the Zimbabwean National rugby sevens players with regard to kinanthropometric profiles;
2. the time-motion analyses of the Zimbabwean National rugby sevens players with one another during the district, national and international tournaments as well as between the player positional subgroups; and
3. the effect of fatigue on the Zimbabwean National rugby sevens players' movement activities.

8. Explanation of the nature of all procedures, including identification of new procedures:

a) ***Collection procedures and selection of rugby players.***

9. Nineteen elite male, senior rugby sevens players of the Zimbabwean national team will take part in the project. All the players had at least two years' experience of playing rugby sevens. Players will be clustered into three player positional subgroups namely, forward, backline and all-rounder players with

the assumption that each group will be required to perform match-play responsibilities for that relevant subgroup during a match.

a) *Procedures*

i. Anthropometric measurements and components:

Seventeen kinanthropometric measurements will be taken on the players of the Zimbabwean National rugby sevens team by two internationally accredited level II Kinanthropometrists. All measurements (stature, body mass, girths, skinfolds and breadths) will be taken in accordance with the standard procedures as described by the International Standard for the Advancement of Kinanthropometry (ISAK) (Stewart et al., 2011). All kinanthropometric data will be collected in the mornings prior to any physical activity.

ii Time-motion analysis:

Time-motion analysis data will be captured with players wearing a safe, stretchable harness under their playing attire with a small pouch between the shoulder blades in which a minimaxX GPS device (Team Sport v 2.5, Catapult Innovation, Melbourne, Australia) will be fitted. The devices will be activated just before and switched off just after each of the matches to record data at 10 Hz when switched on. Recorded data will be downloaded and analysed using Logan Plus 4.4.0 software developed for this system (Catapult Innovation, Melbourne, Australia). To ensure inter-device validity, each player will be allocated the same GPS device throughout all three tournaments.

The following data will be retrieved:•Movement activity data - expressed in percentage of time spent in the activity. Total distance travelled during the match will be calculated with data presented as total distance travelled per minute to account for variations in game time. Work-to-rest ratios will be determined by comparing the time players will spent on low-intensity activities with the time players will spent on high-intensity activities. Low-intensity activities include standing, walking and jogging. The rest of the movement activities will be considered as high-intensity activities. Average speed will be presented as meters per second (m/s) and be determined by dividing total distance travelled with time spent in motion (all movement categories except standing)

10. Description of the benefits which may be expected from this project:

The results could enable coaches, sport scientists, officials, selectors and players to better understand the movement patterns and kinanthropometric profile that exist in Zimbabwean National RS with regard to match play in various tournaments, fatigue management and position-specific training. The knowledge gathered from this study may therefore indirectly lead to position-specific assessment and training programs which ought to enhance the players' overall performance and development (Coughlan *et al*., 2011) and assist coaches with tactical decision making (Wisbey *et al.*, 2010). Understanding the position-specific requirements of RS may also assist in team selection (Quarrie *et al.*, 1996; Du Randt *et al.*, 2006) and provide support for the necessity of subdividing the RS players into three instead of two positional subgroups.

Signature:..... **Date:.....**

Project leader

Contact detail for any questions directed to the Project Leader: pietervandenberg@nwu.ac.za

Tel no: 018 299 1802

PART 2

To the subject signing the consent as part 3 of this document:

You are invited to participate in a research project as described in paragraph 2 of Part 1 of this document. It is important that you read/listen to and understand the following general principles, which apply to all participants in this research project:

1. Participants in this project is voluntary.

2. You will be free to withdraw from the project at any stage without having to explain the reasons for your withdrawal. However, we would like to request that you would rather not withdraw without a thorough consideration of your decision, since it may have an effect on the statistical reliability of the results of this project.

3. We encourage you to ask questions at any stage about the project and procedures to the project leader or the personnel, who will readily give more information. They will discuss all procedures with you.

4. If you are a minor, we need the written approval of your parent or guardian before you may participate.

5. We require that you indemnify the University from any liability due to detrimental effects of treatment by University staff or students or other subjects to yourself or anybody else. We also require indemnity from liability of the University regarding any treatment to yourself or another person due to participation in this project, as explained in Part 1. Lastly it is required to abandon any claim against the University regarding treatment of yourself or another person due to participation in this project as described in Part 1.

PART 3
Consent

Title of the project: Global positioning system tracking and kinanthropometrical profiling of Zimbabwean National Rugby Sevens players

I, the undersigned..... (Full names) read/listened to the information on the project in PART 1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project with the project leader and I declare that I participate in the project as a volunteer. I hereby give my consent to be a subject in this project.

I indemnify the University, also any employee or student of the university, of any liability against myself, which may arise during the course of the project.

I will not submit any claims against the university regarding personal detrimental effects due to the project, due to negligence by the University, its employees or students, or any other subjects.

.....
(Signature of the subject)
Signed at Old Georgian rugby club, Harare, Zimbabwe on 2012/03/

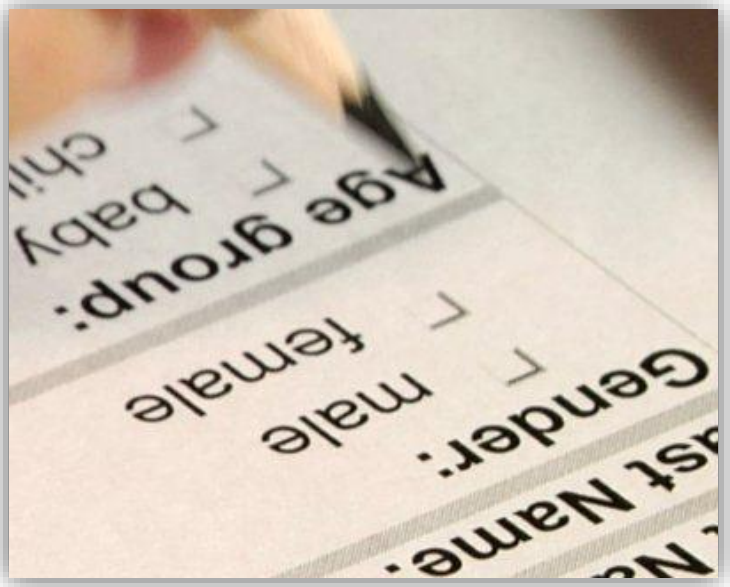
Witnesses

1. .....

2. .....

Signed at Old Georgian rugby club, Harare, Zimbabwe on 2012/03/

APPENDIX C DATA COLLECTION FORMS



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NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

Kinanthropometrical measurements of Zimbabwean national rugby sevens players:

Name and Surname _____ Birth Date _____

High School _____ Province _____

Language _____ Race _____

Position in Sevens 1.Forward, 2. Back,. 3. All-rounder

Station 1			
	Measure 1	**Measure 2**	**Measure 3**
Body length			
Body mass			
Station 2			
Girth measurements	**Measure 1**	**Measure 2**	**Measure 3**
Arm (flexed and tensed)			
Calf			
Forearm			
Mid-thigh			
Station 3			
Breadth measurements	**Measure 1**	**Measure 2**	**Measure 3**
Humerus			
Femur			
Wrist			
Ankle			
Station 4			
Landmarks			
Station 5			
Skinfolds 1	**Measure 1**	**Measure 2**	**Measure 3**
Triceps			
Subscapular			
Supraspinal			
Station 6			
Skinfolds 2	**Measure 1**	**Measure 2**	**Measure 3**
Abdominal			
Front thigh			
Medial calf			
∑ skinfolds		% Muscle mass	
% Skeletal mass		% Fat mass	
X axle		Y axle	

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NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

Time- motion analyses of Zimbabwean national rugby sevens players:

Name and Surname _____ Birth Date _____

Club _____ GPS Unit number _____

Language _____ Race _____

Position in rugby sevens 1.Forward, 2. Back,. 3. All-rounder

Tournament 1

Variables	First half	Second Half	Variables	First half	Second Half
Time played in seconds			Average speed		
Total distance covered in meters			Time standing still		
Time walking			Distance walked		
Time jogging slow			Distance jogged (slow)		
Time jogging fast			Distance jogged (fast)		
Time running			Distance run		
Time sprinting			Distance sprint		

Tournament 2

Variables	First half	Second Half	Variables	First half	Second Half
Time played in seconds			Average speed		
Total distance covered in meters			Time standing still		
Time walking			Distance walked		
Time jogging slow			Distance jogged (slow)		
Time jogging fast			Distance jogged (fast)		
Time running			Distance run		
Time sprinting			Distance sprint		

Tournament 3

Variables	First half	Second Half	Variables	First half	Second Half
Time played in seconds			Average speed		
Total distance covered in meters			Time standing still		
Time walking			Distance walked		
Time jogging slow			Distance jogged (slow)		
Time jogging fast			Distance jogged (fast)		
Time running			Distance run		
Time sprinting			Distance sprint		

APPENDIX D

REBUTTAL LETTER OF EXAMINAR QUESTIONS THAT COULD NOT BE CHANGED

Rebuttal of examiners questions that could not be changed:

Questions:

a) There are no SD reported, so the reader does not know what the data distribution looks like. Please report the SDs. Why report the MSE? What is the importance of this? Please explain this.
b) Movement classifications: Please motivate why these classifications were used. Why not classifications that have been used in previous Sevens studies.

Answers:

a) Report from statistician: The MSE is the estimate of the residual covariance parameter as estimated by the hierarchical linear models (mixed models). This is a measure of the error variance in the model and replaces the use of SD as measure of unexpanded variance in the model.
b) Movement velocities were categorized as suggested by Reid et al. in 2013, which was at the time of data retrieval the most recent published guideline. GPS velocities were set and data were printed out as reports. However, new research projects with the same GPS devices recorded new data over the original Sevens data, making it impossible to change the velocities bands and recalculate the data.

I sincerely hope that the answers on the above questions are explained to the examiners satisfaction.

APPENDIX E INSTRUCTIONS FOR AUTHORS

Contributors are invited to submit their manuscripts in English to the Editor for critical peer review. The *Journal of Science and Medicine in Sport* considers for publication manuscripts in the categories of:
- Original Research
- Review Article

The manuscripts must be in one of the following sub-disciplines relating generally to the broad sports medicine and sports science fields: sports medicine, sports injury (including injury epidemiology and injury prevention), physiotherapy, podiatry, physical activity and health, sports science, biomechanics, exercise physiology, motor control and learning, sport and exercise psychology, sports nutrition, public health (as relevant to sport and exercise), and rehabilitation and injury management. Manuscripts with an interdisciplinary perspective with specific applications to sport and exercise and its interaction with health will also be considered.

Only studies involving **human subjects** will be considered.

Authors must declare that manuscripts submitted to the Journal have not been published elsewhere or are not being considered for publication elsewhere and that the research reported will not be submitted for publication elsewhere until a final decision has been made as to its acceptability by the Journal.

PLEASE NOTE: papers which do not meet the criteria below will be rejected immediately:
- Ensure that English is of good standard
- Ensure Ethics Committee details are as complete as possible
- Ensure all headings and subheadings conform to the Guide for Authors
- References, both in-text and reference list, must be formatted according to the Guide for Authors
- Provide the Figure Legends as part of the text file, at the end of the manuscript
- Include Acknowledgements (this is mandatory)

The review process will consist of reviews by at least two independent reviewers. Contributors must suggest the names and full contact details of 3 possible reviewers. The reviewers must not be from the same institutions as the authors, and one must be from a country different to any of the authors. The Editor may, at his or her discretion, choose no more than one of those suggested. The reviewers will be blinded to the authorship of the manuscript. The Editor will make a final decision about the manuscript, based on consideration of the reviewers' comments.

The journal receives an ever-increasing number of submissions and unfortunately can only publish a small proportion of manuscripts. The journal's Editorial Board does not enter into negotiations once a decision on a manuscript has been made. The Editor's decision is final.

Papers accepted for publication become the copyright of Sports Medicine Australia. Authors will be asked to sign a transfer of copyright form, on receipt of the accepted manuscript by Elsevier. This enables the publisher to administer copyright on behalf of the authors and the society, while allowing the continued use of the material by the author for scholarly communication.

PREPARATION OF MANUSCRIPTS
- Microsoft Word is the preferred software program. Use Arial or Times New Roman font, size eleven (11) point.
- Manuscript is double-spaced throughout (including title page, abstract, text, references, tables, and legends).
- Margins are 1 inch or 2.5 cm all around
- Include **page and line numbers** for the convenience of the peer reviewers.

- Number the pages consecutively, beginning with the title page as page 1 and ending with the Figure legend page.
- All headings (including the Title) should be in sentence-case only, not in capital letters.
- Sub-headings are generally not accepted. Incorporate into the text if required.
- Footnotes are not acceptable.
- Keep the use of tables, figures and graphs to a minimum.
- See notes on Tables, Figures, Formulae and Scientific Terminology at the end.

WORD COUNT LIMITS

Original Research papers

- 3000 word count limit (excluding title, abstract, tables/figures, figure legends, Acknowledgements, and References)
- Maximum number (combined) of tables and figures is 3
- Long tables should only be included as supplementary material and will be made available on-line only
- Maximum number of references is 30
- A **structured abstract** of less than 250 words (not included in 3000 word count) should be included with the following headings: Objectives, Design, Method, Results, and Conclusions

Review articles

- 4000 word count limit (excluding title, abstract, tables/figures, figure legends, Acknowledgements, and References)
- Maximum number (combined) of tables and figures is 3
- Long tables should only be included as supplemental files and will be available online only
- Maximum number of references is 60
- A **structured abstract** of less than 250 words (not included in 4000 word count) should be included sticking as closely as possible to the following headings: Objectives, Design, Method, Results, and Conclusions

SUBMISSION OF MANUSCRIPTS

All manuscripts, correspondence and editorial material for publication should be submitted online via the Elsevier Editorial System at http://www.ees.elsevier.com/jsams.

Authors simply need to "create a new account" (i.e., register) by following the instructions at the website, and using their own e-mail address and selected password. Authors can then submit manuscripts containing text, tables, and images (figures) online. The entire peer-review process will be managed electronically to ensure timely review and publication. Authors can expect an initial decision on their submission within 8 weeks.

Following registration, enter the "Author area" and follow the instructions for submitting a manuscript, including the structured Abstract, suggested reviewers, Cover letter, Tables, Figures, and any supplementary material.

If you wish to publish colour figures and agree to pay the "colour charge", tick the appropriate box. Colour illustrations incur a colour charge of 312 US dollars for the first page and 208 US dollars for every additional page containing colour. Figures can be published in colour at no extra charge for the online version. If you wish to have figures in colour online and black and white figures printed, please submit both versions.

The entire peer-review process will be managed electronically to ensure timely review and publication. Authors can expect an initial decision on their submission within 6 weeks.

Note: the online manuscript submission program requires separate entries of some information that also appears in the manuscript. These separate entries are needed to manage processing and review of your manuscript and correspondence.

Regulatory requirements

- *Research protocol*: Authors must state that the protocol has been approved by the appropriate ethics committee. Name the committee.
- *Human investigation*: The Ethical Guidelines followed by the investigators must be included in the Methods

section of the manuscript.

STRUCTURE OF THE MANUSCRIPT (in order):

1. Cover Letter - Every submission, regardless of category must include a letter stating:
- the category of article: Original Research or Review article
- the *sub-discipline*: sports medicine, sports injury (including injury epidemiology and injury prevention), physiotherapy, podiatry, physical activity and health, sports science, biomechanics, exercise physiology, motor control and learning, sport and exercise psychology, sports nutrition, public health (as relevant to sport and exercise), rehabilitation and injury management, and others having an interdisciplinary perspective with specific applications to sport and exercise and its interaction with health.
- Sources of outside support for research (including funding, equipment and drugs) must be named.
- Financial support for the project must be acknowledged, or "no external financial support" declared.
- The role of the funding organisation, if any, in the collection of data, their analysis and interpretation, and in the right to approve or disapprove publication of the finished manuscript must be described in the Methods section of the text.
- When the proposed publication concerns any commercial product, either directly or indirectly, the author must include a statement (1) indicating that he or she has no financial or other interest in the product or distributor of the product or (2) explaining the nature of any relation between himself or herself and the manufacturer or distributor of the product.
- Other kinds of associations, such as consultancies, stock ownership, or other equity interests or patent-licensing arrangements, also must be disclosed. Note: If, in the Editor's judgment, the information disclosed represents a potential conflict of interest, it may be made available to reviewers and may be published at the Editor's discretion; authors will be informed of the decision before publication.
- The *Ethical Guidelines* that have been followed must be stated clearly. Provide the Ethics Committee name and approval number obtained for Human investigation.
- *Authors must declare* that manuscripts submitted to the Journal have not been published elsewhere or are not being considered for publication elsewhere and that the research reported will not be submitted for publication elsewhere until a final decision has been made as to its acceptability by the Journal.

Permission from the publisher (copyright holder) must be submitted to the Editorial Office for the reproduction of any previously published table(s), illustration(s) or photograph(s) in both print and electronic media or from any unmasked participants appearing in photographs.

2. Title Page (first page) should contain:
a. *Title*. Short and informative
b. *Authors*. List all authors by first name, all initials and family name
c. *Institution and affiliations*. List the name and full address of all institutions where the study described was carried out. List departmental affiliations of each author affiliated with that institution after each institutional address. Connect authors to departments using alphabetical superscripts.
d. *Corresponding author*. Provide the name and e-mail address of the author to whom communications, proofs and requests for reprints should be sent.
e. *Word count* (excluding abstract and references), the Abstract word count, the number of Tables, the number of Figures.

3. Manuscript (excluding all author details) should contain: (in order)

a. *Abstract* - must be structured using the following sub-headings: Objectives, Design, Methods, Results, and Conclusions. Avoid abbreviations and acronyms.

b. *Keywords* - provide up to 6 keywords, with at least 4 selected via the Index Medicus Medical Subject Headings (MeSH) browser list: http://www.nlm.nih.gov/mesh/authors.html. These keywords should not reproduce words used in the paper title.

c. Main body of the text.

For Original Research papers, text should be organised as follows:

i. *Introduction* - describing the (purpose of the study with a brief review of background

ii. *Methods* - described in detail. Include details of the Ethics Committee approval obtained for Human investigation, and the ethical guidelines followed by the investigators. This section is not called Materials and Methods, and should not include subheadings. Do not use the term "subjects" - use terms such as "participants", "patients" or "athletes", etc.

iii. *Results* - concisely reported in tables and figures, with brief text descriptions. Do not include subheadings. Use small, non-italicized letter p for p-values with a leading zero, e.g. 0.05; Measurements and weights should be given in standard metric units. Do not replicate material that is in the tables or figures in the text.

iv. *Discussion* - concise interpretation of results. Cite references, illustrations and tables in numeric order by order of mention in the text. Do not include subheadings.

v. *Conclusion*

vi. *Practical Implications* - 3 to 5 dot (bulleted) points summarising the practical findings derived from the study to the real-world setting of sport and exercise - that can be understood by a lay audience. Avoid overly scientific terms and abbreviations. Dot points should not include recommendations for further research.

vii. *Acknowledgments* - this section is compulsory. Grants, financial support and technical or other assistance are acknowledged at the end of the text before the references. All financial support for the project must be acknowledged. If there has been no financial assistance with the project, this must be clearly stated.

viii. *References* - authors are responsible for the accuracy of references.

ix. *Tables* - may be submitted at the end of the text file, on separate pages, one to each page.

x. *Figure Legends* - must be submitted as part of the text file and not as illustrations.

4. Figures - must be submitted as one or more separate files that may contain one or more images.

5. Supplementary material (if any) - tables or figures to be viewed online only

REFERENCES

- References should be **numbered consecutively** in un-bracketed superscripts where they occur in the text, tables, etc, and listed numerically (e.g. "1", "2") at the end of the paper under the heading "References".

- For Original Research papers, **no more than three references** should be used to support a specific point in the text.

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The editorial mission of the JSCR, formerly the Journal of Applied Sport Science Research (JASSR), is to advance the knowledge about strength and conditioning through research. Since 1978 the NSCA has attempted to ''bridge the gap'' from the scientific laboratory to the field practitioner. A unique aspect of this journal is the inclusion of recommendations for the practical use of research findings. While the journal name identifies strength and conditioning as separate entities, strength is considered a part of conditioning. This journal wishes to promote the publication of peer-reviewed manuscripts that add to our understanding of conditioning and sport through applied exercise and sport science. The conditioning process and proper exercise prescription impact a wide range of populations from children to older adults, from youth sport to professional athletes. Understanding the conditioning process and how other practices such as such as nutrition, technology, exercise techniques, and biomechanics support it is important for the practitioner to know.

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Howard, A. Moments ½software_. University of Queensland, 1992.

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Contents List

Manuscript preparation

1. General guidelines

- Manuscripts are accepted in English. British English spelling and punctuation are preferred. Please use double quotation marks, except where "a quotation is 'within' a quotation". Long quotations should be indented without quotation marks.
- Manuscripts should be compiled in the following order: title page (including Acknowledgements as well as Funding and grant-awarding bodies); abstract; keywords; main text; acknowledgements; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figure caption(s) (as a list).
- A typical article will not exceed 4,000 words not including references, tables, figures and captions. Footnotes should not be used unless they are absolutely necessary. Papers that greatly exceed this will be critically reviewed with respect to length. Authors should include a word count with their manuscript.
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- Authors must adhere to SI units. Units are not italicised.
- When using a word which is or is asserted to be a proprietary term or trade mark, authors must use the symbol ® or TM.
- Authors must not embed equations or image files within their manuscript

2. Style guidelines

- Description of the Journal's article style.
- Description of the Journal's reference style.
- Guide to using mathematical scripts and equations.

Papers should be written and arranged in a style that is succinct and easy to follow. An informative title, a concise abstract and a well written introduction will help to achieve this. Authors should avoid some of the more common pitfalls, such as excessive use of the passive voice and past tense and unnecessary use of fabricated abbreviations within the text. The Journal would prefer authors to describe human volunteers as participants rather than subjects in the methods section. Figures and tables should be used to add to the clarity of the paper, not to pad it out. At all times, please try to think about your readers, who will not all be specialists in your discipline.

(a) *General*
The manuscript must be in English; British English spellings and words should be used in preference to other versions of English. It must be word-processed, double-spaced throughout, with a 4 cm margin on the left side, with no 'headers and footers' (other than page numbers), and without footnotes unless these are absolutely necessary. Arrange the manuscript under headings (such as Introduction, Methods, Results, Discussion, Conclusions) and subheadings. Ideally, the main body of the text should not exceed 4,000 words, excluding references. Longer manuscripts may be accepted at the discretion of the respective Section Editor. Authors must make every effort to ensure that manuscripts are presented as concisely as possible. The Editors cannot consider for publication papers that are seriously deficient in presentation or that depart substantially from these 'Notes and Guidelines'.

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The Symbols Committee of the Royal Society (1975, addenda 1981). *Quantities, Units and Symbols*. London: The Royal Society.

For a comprehensive review of applications to sport and physical activity, please consult the following publication:

Winter, E.M. and Fowler, N. (2009). Exercise defined and quantified according to the Système International d'Unités. *Journal of Sports Sciences*, 27, 447-460

(h) *Statistical analyses*

Authors must at least accompany conventional *P* values with metrics such as effect sizes, confidence intervals of difference/change and minimum clinically or practically important difference.

An effect size expresses a difference between groups or change within groups as a fraction of the variability between participants. Usually, this denominator is the standard deviation.

Effect sizes can be evaluated as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and greater) (Cohen, J. [1992]. *Psychological Bulletin*, 112, 155–159). Similarly, confidence intervals of difference/change (Cumming, G. & Finch, S., [2001]. *Educational and Psychological Measurement*, 61, 532–574) can evaluate outcomes on the basis of their inclusion of zero, i.e. no effect.

The confidence interval represents a plausible range of values within which the true (but unknown) population value lies (Cumming, G. [2012]. *Understanding the new statistics*. New York: Routledge). The greatest likelihood will arise from effects with narrow confidence intervals and therefore high precision.

Another way to evaluate the effectiveness of an intervention is by way of the minimum clinically (or practically) important difference. This difference should be stated before a study commences and expresses the smallest change in the principal outcome measure that must occur if the intervention is to be considered effective. It is usually taken to be equivalent to an effect size of 0.20.

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