Movement patterns and heart rate recordings of South African Rugby Union referees during actual match-play refereeing

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Dissertation submitted in fulfilment of the requirements for the degree Magister Artium at the Potchefstroom Campus of the North-West University

Supervisor: Prof. D.D.J Malan

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FOREWORD

First of all thank you to my heavenly Father who gave me the opportunity to complete this study. Without You I am nothing.

To my wife, Mirinthea, and our baby Wilrique, thank you for your support, love, encouragement and patience throughout the completion of the study.

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Wilbur Kraak

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DECLARATION

The co-authors of the two articles which form part of this dissertation, Prof. Dawie D.J. Malan (supervisor) and Mr Pieter H. van den Berg, hereby give permission for the candidate, Mr Wilbur Kraak, to include the two articles as part of a Master's dissertation. The contribution (advice and support) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as a fulfilment of the requirements for the degree Magister Artium in Sport Science at the Potchefstroom Campus of the North-West University.

Prof. Dawie J. Malan	Mr Pieter H. van den Berg
Supervisor and co-author	Co-author

SUMMARY

Worldwide research regarding the movement patterns, heart rate recordings and work-to-rest ratios of rugby union referees is very limited. It is therefore very important to extend research regarding this topic. The first objective of this dissertation was to determine the frequency, duration and intensity of movement patterns and work-to-rest ratio of different refereeing panels of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007. The second objective was to compare the two halves of the match with regard to the frequency, duration and intensity of the different movement patterns and the work-to-rest ratios of various of SARU referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007.

The South African Rugby Union referees were monitored during match-refereeing by means of video and heart rate recordings for a total of 16 matches within a week tournament. The frequency and duration of the different movement patterns during both halves of the matches were analysed using a Dartfish TeamPro analysis software package. Heart rates were recorded during the matches to determine the movement pattern intensities of the referees for the duration of each match using a Suunto Team pack heart rate monitoring system. The work-to-rest ratios were determined by comparing the time (in seconds) spent working (lateral movements and sprinting) to the time spent resting (standing still, walking and jogging).

The results revealed a moderate practical significant difference (d=0.51) between the mean frequency of jogging movement patterns for the different refereeing panels. A moderate practical significant difference was also found between the mean duration of jogging (d=0.43) and sprinting (d=0.43) movement patterns of different refereeing panels. The mean intensity of the movement patterns by the different refereeing panels showed large practical significant differences between the anaerobic threshold (d=3.68) and sub-threshold (d=1.36) levels and a moderate practical significant difference for the maximal heart rate zones (d=0.43). Both the provincial and contender panel referees had work-to-rest ratios of 1:4 during match-refereeing.

In comparing the two halves of rugby match-refereeing, a large practical significant difference was found between the mean frequency of movement pattern values for standing still (d=2.53), walking (d=2.50), jogging (d=2.42), lateral movements (d=2.86) and sprinting (d=1.31) as well as for mean duration of movement pattern values for standing still (d=2.05), lateral movements (d=0.76) and sprinting (d=0.77). Large practical significant difference were found between the time spent in the maximal threshold (d=2.07), anaerobic threshold (d=0.92) and sub-threshold (d=7.90) heart rate zones measured during the two halves of match-refereeing. Average work-to-rest ratios of 1:3.5 and 1:5 were found for the first and second halves of rugby match-refereeing, respectively.

The information gained regarding the activity profile of SARU referees could be used to determine the influence of rugby refereeing experience on the movement patterns and work-to-rest ratio of rugby referees. It can also provide information for constructing specific training programmes and drills in the development of rugby match-required fitness standards for referees. A key component of a rugby union referee's game is positioning. Being in the right place at the right time is vital. The results of this study suggest that movements associated with positioning – namely standing still, walking and lateral movements are the major components of the game of referees' movement during match-refereeing. However, further research is required on this topic of research.

Key words: Time-motion analysis; heart rate recordings; movement patterns; work-to-rest ratios.

OPSOMMING

Navorsing oor bewegingspatrone, harttempomonitering en werk-tot-rus verhoudings van rugby-unie skeidsregters is wêreldwyd beperk. Dit is derhalwe belangrik om navorsing oor hierdie onderwerp uit te brei. Die eerste doelwit van hierdie studie was daarop gerig om die frekwensie, duur en intensiteit van die onderskeie bewegingspatrone asook die werk-tot-rus verhoudings van Suid-Afrikaanse Rugby-unie skeidsregters tydens wedstryd-hantering te bepaal gedurende die 2007 Nasionale Klubrugby Kampioenskappe in Stellenbosch. Die tweede doelwit was om die twee helftes van die wedstryde ten opsigte van frekwensie, duur en intensiteit van die onderskeie bewegingspatrone en die werk-tot-rus verhoudings van die onderskeie SARU skeidsregters gedurende die 2007 Nasionale Klubrugby Kampioenskappe in Stellenbosch met mekaar te vergelyk.

Die Suid-Afrikaanse Rugby-unie skeidsregters is in 16 wedstryde tydens 'n week lang wedstryd met 'n videokamera en harttemposisteem gemonitor. Die frekwensie en duur van die onderskeie bewegingspatrone wat tydens wedstryd-hantering deur die skeidsregters uitgevoer is, is geanaliseer deur van die Dartfish TeamPro analise sagtewarepakket gebruik te maak. Die harttempos is tydens wedstryde deur middel van 'n Suunto spanpak harttempomonitor gemonitor om sodoende die intensiteite van bewegingspatrone te bepaal. Die werk-tot-rus verhouding is bereken deur die tyd (in sekondes) in werk (laterale bewegings en versnelling) met die tyd in rus (stilstaan, loop en draf) te vergelyk.

Die gemiddelde frekwensie van bewegingspatrone het 'n medium praktiese betekenisvolle verskil vir draf (d=0.51) en vir die duur van draf (d=0.43) en versnelling (d=0.43) bewegingspatrone tussen die onderskeie paneelskeidsregters opgelewer. 'n Groot praktiese betekenisvolle verskil is vir die anaërobiese drempel (d=3.68) en sub-drempel (d=1.36) gevind en 'n medium praktiese betekenisvolle verskil is vir die maksimale (d=0.43) harttemposone tussen die onderskeie paneelskeidsregters gevind. 'n Werk-tot-rus verhouding van 1:4 is vir beide die provinsiale en opkomende paneelskeidsregters gevind.

Groot prakties betekenisvolle verskille is vir die gemiddelde frekwensie van stilstaande (d=2.53), stap (d=2.50), draf (d=2.42), laterale bewegings (d=2.86) en versnelling (1.31) sowel as vir die duur van stilstaande (d=2.05), laterale (d=0.76) en versnelling (d=0.77) *bewegingspatrone tussen die twee helftes gevind. Groot praktiese betekenisvolle verskille is gevind vir die tyd in die maksimale (d=2.07), anaërobiese drempel (d=0.92) en sub-drempel (d=7.90) harttemposones tussen die twee helftes van die wedstryde. Werk-tot-rus verhoudings van 1:3.5 en 1:5 is onderskeidelik vir die eerste en tweede helftes van die wedstryde gevind.*

Die inligting wat oor die bewegingspatrone van SARU skeidsregters bekom is, kan gebruik word om te bepaal of ervaring 'n invloed op bewegingspatrone en werk-tot-rus verhoudings van rugbyskeidsregters het. Dit kan ook inligting verskaf waardeur spesifieke toetsprotokolle en spesifieke kondisioneringsprogramme en oefensisteme vir rugby-unie skeidsregters ontwikkel kan word ten einde aan nasionale fiksheidstandaarde te voldoen. 'n Sleutelkomponent van 'n rugby-unie skeidsregter se wedstrydhantering is posisionering. Dit is noodsaaklik om op die regte plek op die regte tyd te wees. Die bevindings stel voor dat bewegings wat met posisionering geassosieer word, naamlik stilstaan, loop en laterale bewegings die belangrikste komponente van wedstrydskeidregterskap is. Verdere navorsing is egter nodig oor hierdie onderwerp.

Sleutelwoorde: Tyd-beweginganalises; harttempo-opname; bewegingspatrone; werk-tot-rus verhoudings.

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LIST OF ABBREVIATIONS

AFL	Australian Football League
BL	Blood lactate
bpm	Beats per minute
Cm	Centimetres
d-value	Practical significance
ES	Effect size
HR	Heart rate
HRR	Heart rate recordings
Hz	Hertz
J	Jogging movement pattern
Kg	Kilogram
L	Litre
LM	Lateral movements movement pattern
M	Median
MHR	Maximal heat rate
min	Minutes
mm	Millimetre
N	Number of subjects in each group
n	Number of subjects in each subgroup
NCRC	National Club Rugby Championship
NZRU	New Zealand Rugby Union
SARU	South African Rugby Union
SARRA	South African Rugby Referee Association
SD	Standard deviation
s	Seconds
SP	Sprinting movement pattern
SS	Standing still movement pattern
TMA	Time-motion analysis
W	Walking movement pattern

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

The chapter is herewith included according to the guidelines of the North-West University. Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

1.1 PROBLEM STATEMENT

1.2 OBJECTIVES

1.3 HYPOTHESES

1.4 STRUCTURE OF THE DISSERTATION

1.5 REFERENCES

1.1 PROBLEM STATEMENT

Since Rugby Union (hereafter referred to as rugby) turned professional in 1995, there has been an increasing demand on the quality of rugby refereeing, including the physical and psychological attributes needed to perform optimally during the match (Mitchelmore, 2004:3; James *et al*., 2005:63). To perform professionally, referees require a variety of skills as well as physical attributes (Mitchelmore, 2004:3). Furthermore, Seneviratne (2003/04:7) concluded that referees need to be physically fit to keep up with the intensity of play and also to make an accurate interpretation of the laws of the game. According to Mascarenhas *et al*. (2005:254) and Mitchelmore (2004:3), referees need to be in a position on the field that will allow them to make the correct decisions, since inaccurate decision-making by referees especially due to their physical inability to keep up with the physiological demands of their task can change the course of a game and may lead to significant financial implications for the clubs/unions, players and coaches. Referees are also responsible for consistency, control and maintaining flow in matches (South African Rugby Referee Association, 2010:5).

The International Rugby Board (IRB) has put an international fitness test battery in place which all referees have to successfully complete continuously throughout the year so as to prove their fitness for refereeing the game (Honis, 2006:20). The test battery consists of anaerobic (oxygen-independant) and aerobic (oxygen dependant) fitness tests (Watson, 2007). Referees who are not able to successfully complete the test battery are not allowed to referee matches and will thus lose their position on the refereeing panel until they have completed the test battery successfully (Watson, 2007).

To assess the fitness levels of sport participants and in this case referees, Dotter (1998:197) suggested that the duration, frequency and intensity of the activities that referees perform during matches or training need to be considered. Deutsch *et al*. (1998:561) supported this statement by claiming that an accurate time-motion analysis (TMA) needs to be done in conjunction with heart rate recordings (HRR) during the match when the physiological demands of rugby participants are determined. By wearing heart rate monitors, the actual heart rate values attained by referees during a match can, therefore, be used to determine the intensity levels of a match or matches (Parker, 1999:32). The results of the heart rate recording (HRR) can also be used to determine the training zone that referees can apply as a benchmark during their physical training programmes (Parker, 1999:32). Deutch *et al.* (1998:562) concluded that the duration and frequency of events occurring during matches should also be analysed to ascertain the exact fitness requirements for refereeing. In relation to this, the abovementioned authors also proposed that accurate TMA should be performed to get an indication of the referees' work-to-rest ratio on the field (Deutch *et al*., 1998:562). Deutch *et al*. (1998:563) concluded that the combined use of TMA with HRR will give researchers a more comprehensive picture of the physiological demands of rugby during match-play.

The intensities at which movement patterns are performed by Australian Football League (AFL) referees can largely be divided into work and rest categories (Coutts & Reaburn, 2000:133). According to these authors, work during matches refers to lateral movements and sprinting activities, whilst rest refers to activities such as standing still, walking and jogging. Based on this criterion, the work-to-rest ratio can be determined by comparing the time spent working to the time spent resting. The work-to-rest ratio will give an indication of the demands of the game (Catterall *et al*., 1993:193) and the findings can assist sport scientists in developing rugby referee-specific training programmes and training drills and will also indicate the different demands set to different refereeing panels (e.g. novice vs. experienced referee) and between the two halves of match-refereeing.

From an extensive literature review in this regard, only two studies could be found that focused specifically on TMA of rugby referees. Martin *et al*. (2001:1073) found that English Premier Rugby Union referees cover a total distance of 8581 ± 668 meters during a match. On average, they stand still for 37.0 % of the total match-play time, walk for 39.4 %, jog for 12.8 %, run for 9.8 % and sprint for 1.0 % of the time, with no significant difference between the time and distance they covered during the different halves of the game. In the same context, Cochrane *et al*. (2003:69) found that New Zealand Rugby Union (NZRU) referees spend 1.2% of the average game time on maximal sprinting, 6.7% on moderate sprinting, 15.2% on jogging, 20.5% on walking, 4.8% on moving sideways, 3.5% on turning, 32.9% on remaining stationary, 12.6% on moving backwards slowly and 2.6% of the time on moving backwards fast. The authors also found a mean work-to-rest ratio of 1:5. More extensive studies were done on the work-to-rest ratio and movement patterns of referees in other team sport codes. Results of studies that focused on the movement patterns and HRR of rugby league and soccer referees reported the following: Rugby league referees spend 18% of the total game on standing still, 22% on walking, 32% on jogging, 10% on striding, 17% on jogging backwards and sideways, and 1% on sprinting during actual match-refereeing (McLaren & Close, 2000:1529). Kay and Gill (2004:171) found a general work-to-rest ratio of 2:1 for rugby league referees. In a 90 minute game soccer referees spend 31.41% of the time on walking forward, 8.89% on walking backwards, 43.79% on trotting (in other studies referred to as jogging), 4.50% on trotting backwards, 8.89% on running, 1.38% on side movements and 1.13% on sprinting (De Oliveira *et al*., 2007:45). In total, soccer referees spend 21.8% of the time on standing still, 41.4% on walking, 30.2% on low-intensity running and 6.6% on high-intensity running during a game (Krustrup & Bangsbo, 2001:884). Krustrup and Bangsbo (2001:884) reported that soccer referees tend to perform less high intensity activities and were further away from play in the second half of matches, whilst Cochrane *et al*. (2003:69) found that NZRU referees perform more low intensity activities in the second half. Kay and Gill (2004:171) reported that rugby league referees show a decrease in average heart rate of seven beats per minute in the second half. According to Krustrup *et al*. (2002:861) the possibility of fatigue experienced by the referees during the match may also be detected by comparing the heart rate and movement activity data of the referee's movement patterns during the two halves of match-play.

As far as the classification of match intensity (by means of HRR) is concerned, the HRR of referees during matches can be classified into four zones based on research done by Deutsch *et al*. (1998:562). These zones are: 1) maximal threshold (>95% of maximal heart rate (MHR); 2) supra-threshold (85-95% of MHR rate); 3) anaerobic threshold (75–84% of MHR) and 4) sub-threshold (<74% of MHR). These authors found that NZRU referees spend 10% of the total match time at their maximal threshold, 43% at supra-threshold, 36% at anaerobic threshold and 11% at sub-threshold heart rate zones. In this study, the participants' highest heart rate obtained during the aerobic endurance test (bleep test) will be used as the MHR. The highest level and shuttle completed during the bleep test will also be recorded. Narazaki *et al*. (2009:426) made use of an aerobic endurance test (bleep test) to determine the MHR of female basketball players during international and national matches. They found that the average heart rates were 94.6% (international matches) and 90.8% (national matches).

The rugby referees in South Africa are ranked on either of the following panels, namely national, provincial, contender, woman, assistant referee and television match official (TMO), depending on their referee performance of the previous year and results of the fitness tests. For the purpose of this study referees on the provincial and contender panels of the South African Rugby Union (SARU) were used to give a better insight into the possible differences in physiological demands as influenced by the experience of the referees indicated by their placement/ranking on the different refereeing panels of SARU. Data on the frequency and duration of movement pattern analyses, intensity of movement patterns and work-to-rest ratios of rugby referees may assist sport scientists and referee coaches to improve referees' fitness levels (Mitchelmore, 2004:3), to develop referee-specific training programmes and training drills and to provide referee coaches with information regarding the demands of different refereeing panels and the different demands between the two halves of match-refereeing in South Africa.

Based on the abovementioned theoretical background, the following research questions have been developed for this study: a) what are the frequency, duration and intensity of movement patterns and work-to-rest ratio of different refereeing panels of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007? b) how do the two halves of the game compare with regards to the frequency, duration and intensity of the different movement patterns and the work-to-rest ratios of various South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007?

1.2 OBJECTIVES

The objectives of this study are to:

1. Determine the frequency, duration and intensity of movement patterns and work-to-rest ratio of different refereeing panels of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007.
2. Compare the two halves of the match with regard to the frequency, duration and intensity of the different movement patterns and the work-to-rest ratios of various South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007.

1.3 HYPOTHESES

The study is based on the following hypotheses:

1. There are practical significant differences between provincial and contender panel referees with regards to the frequency, duration and intensity of movement patterns and work-to-rest ratio of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship.
2. The frequency, duration, intensity and work-to-rest ratios of the different movement patterns of various South African Rugby Union referees, during match-refereeing at the National

Club Rugby Championship, will not differ significantly when the two halves of match-refereeing are compared.

1.2 STRUCTURE OF THE DISSERTATION

The dissertation will be submitted in article format as approved by the Senate of the North-West University and will be structured as follows:

Chapter 1 Research proposal: Introduction and problem statement. The chapter is herewith included according to the guidelines of the North-West University. Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

Chapter 2 Literature overview: Time-motion analysis of team sport participants. The chapter is herewith included according to the guidelines of the North-West University. Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

Chapter 3 Article 1: Analysis of movement patterns and heart rate recordings of South African Rugby Union referees during match-refereeing.

This article was submitted for publication in the International Journal of Performance Analysis in Sport in accordance with the guidelines for authors of this particular Journal (Appendix A). Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

This article was accepted for publication in the International Journal of Performance Analysis in Sport, 11(2), 344-355.

Chapter 4 Article 2: Time-motion analysis and heart rate recordings of South African Rugby Union referees during match-refereeing.

This article was submitted for publication in the African Journal for Physical, Health Education, Recreation and Dance in accordance with the guidelines for authors of this particular Journal (Appendix B). Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

This article has been accepted for publication in the December 2011 issue of the African Journal for Physical, Health Education, Recreation and Dance.

Chapter 5 Summary, discussion, limitations and future research.

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CHAPTER 2

TIME-MOTION ANALYSIS OF TEAM SPORT PARTICIPANTS

The chapter is herewith included according to the guidelines of the North-West University. Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

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2.1 INTRODUCTION

A fundamental requirement for constructing any sport-specific training programme is an understanding of the physiological demands placed upon participants during match-play and training (McLean, 1992:285; Roberts *et al*., 2006:388). Key information on the game demands of team sports not only focuses on movement patterns, but also relates to differences between players in various positions, effects of tactical changes and the effects of rule changes (Wisbey *et al*., 2010:531). This information can be used to enhance the specificity of training to better prepare players for competition (Aughey & Falloon, 2010:348). Various analytical methods have been used to understand the physiological demands of match-play for many team sports, such as time-motion analysis (TMA) (McInnes *et al*., 1995:390; Davidson & Trewartha, 2008:2; Konarski *et al.*, 2006:145), heart rate recording (HRR) (Castagna & D'Ottavio, 2001:420; Barbero-Alvarez & Castagna, 2007:208) and blood lactate (BL) values (Deutsch *et al*., 1998:563; Abdelkrim *et al.*, 2007:70).

Based on these findings, the focus in this chapter will therefore be placed on relevant literature that reviews several aspects of TMA, HRR and BL as applied to different team sports.

TMA involves the quantification of various movement patterns in terms of the speed, duration, and distance travelled during the course of a competitive match (Dogramaci & Watsford, 2006:73; Dobson & Keogh, 2007:48; Petersen *et al*., 2009a:278). Researchers concur that the results of TMA may assist coaches and other sport professionals to increase the specificity of their strength and conditioning programmes, because these results provide insight into the utilisation of the various energy systems and in some cases, specific movement patterns used throughout the match (Martin *et al*., 2001:1073; Kay & Gill, 2003:340; Castagna *et al*., 2004:487). Literature in which TMA was applied to a number of team sports such as rugby union (Martin *et al*., 2001:1073; Cochrane *et al*., 2003:67), rugby league (MacLaren & Close, 2000:1528; Coutts *et al*., 2003:98; Kay & Gill, 2003:340; Kay & Gill, 2004:166), soccer (Catterall *et al*., 1993:193; Krustrup & Bangsbo, 2001:882; Castagna *et al.*, 2004:486), field hockey (MacLeod *et al*., 2007:3), netball (Davidson & Trewartha, 2008:2), Australian football (Appleby & Dawson, 2002:130; Dawson *et al*, 2004:293) and basketball (McInnes *et al.*, 1995:390; Tessitore *et al*., 2006:216; Abdelkrim *et al*., 2007:70) was used for this review.

A number of TMA studies have recorded the heart rate of the participants during competitions and matches (Deutch *et al.*, 1998:563; Cochrane *et al.*, 2003:67; Coutts *et al.*, 2003:98; Konarski *et al.*, 2006:145). The main use of HRR is to determine the exercise intensities of a training session or actual match (Coutts *et al.*, 2003:98; Tessitore *et al*., 2006:215). To determine the physiological demands of rugby union participants, Deutsch *et al.* (1998:561) concluded that one needs to do an accurate TMA (i.e. duration and frequency) in conjunction with HRR (intensity). By wearing heart rate monitors during training or actual match play, the heart rate values can be compared to values recorded during off field training (so-called heart rate zone categories) and thus can be used to determine the intensity levels of a match (Parker, 1999:32). Deutch *et al.* (1998:562) also concluded that the duration and frequency of movement activities during matches also need to be analysed to make an exact prediction of the participants' fitness levels.

A number of studies included measurements of HRR and BL levels of players and referees during actual match-play together with TMA to determine the physiological demands of the games (McLean, 1992:286; Deutch *et al*., 1998:562; Krustrup & Bangsbo, 2001:863; Coutts *et al.*, 2003:99). Recording these physiological variables may give a greater insight into the metabolic demands of the sport than TMA alone. This can assist sport scientists in the construction of appropriate training programmes and testing methods and protocols (McLean, 1992:286; Deutch *et al.*, 1998:562; Krustrup *et al.*, 2002:863; Coutts *et al.*, 2003:99).

The following section of the literature review therefore seeks to address the listed issues so that future researchers can effectively use the available information from TMA studies and heart rate recordings when constructing physical conditioning programmes: 1) detailed description of the different methods of TMA, including video-based, global positioning systems (GPS) and automated tracking systems; 2) validity of TMA, determination of movement patterns and distance; 3) reliability of TMA; 4) limitations; 5) applications of TMA research; 6) background on heart rate recordings; 7) methods to determine MHR, HRR sample intervals, reporting of heart rate data; and 8) the use of TMA in conjunction with HRR and BL values to determine the physiological demands placed on participants.

The next section of this chapter will address the abovementioned issues associated with sport-related TMA.

2.2 TIME-MOTION ANALYSIS TO DETERMINE MOVEMENT PATTERNS OF TEAM SPORT PARTICIPANTS

2.2.1 Methods of time-motion analysis

Three known modes of TMA are used to obtain results for motion analysis in sport, namely video-based, GPS (global positioning system) and automated tracking methods (Edgecomb & Norton, 2006:26).

2.2.1.1 Video-based systems

Video-based systems are currently the most widely used method for time-motion recording and analysis (Spencer *et al*., 2005:384). In this regard, several articles have been published on TMA in which video-based systems were used for research (Cochrane *et al.*, 2003; Castagna *et al.*, 2004; Spencer *et al.*, 2005; Bishop & Wright, 2006). For field sports, one to seven cameras are most common. Most of the cameras are positioned on the halfway line at a height of 5 to 20 meters and 5 to 30 meters from the side line (Deutsch *et al.*, 1998:563, Castagna *et al.*, 2004:487; Da Silva *et al*., 2008:328). When the movements of the participant are being collected by video recording, the common approach is to have one camera that focuses on the participant for the duration of the game. This enables researchers to code each match activity of the participant (Krustrup & Bangsbo, 2001:882; Martin *et al.*, 2001:1071).

A second and less common approach for video-based TMA, involves the use of two cameras (Spencer *et al*., 2005:384). Each camera focuses on one half of the field of play with a small overlap in the field of view between the two cameras. All the movements of the participants can thus be monitored/video-taped during the course of the game and provide the opportunity for all participants to be analysed. The advantage of this approach rather than just following one participant with each camera is that there is less time-consuming taping and analysis required. However, as participants take up less of the field of view, it would be more difficult for the observers to accurately analyse and code the participants' movements (Spencer *et al*., 2005:384).

2.2.1.2 Global Positioning System (GPS)

The use of portable GPS devices has become a popular and convenient method to quantify movement patterns and physiological demands in sport (Wisbey *et al*., 2010:531). A GPS is used for the accurate tracking of a change in position (displacement) by an object (e.g. a player) in real-time by calculating the displacement of the GPS-signal gathered by the receiver which is attached to the player (Edgecomb & Norton, 2006:26). These calculations utilise a Doppler frequency calculation, whereby the phase-shift difference between the satellite and an oscillator-produced signal within the receiver is measured. Because a GPS can assist researchers to collect data during and/or by the end of a game, no time is needed to code different locomotor activities (Carling *et al*., 2005:150), which these authors regard as an advantage over video-based systems. Devices using GPS technology are now available for vehicles, boats, hikers, runners and team athletes (Sykes *et al*., 2009:48). One such commercial product is produced by an Australian company, GPSports Systems (Pty) Ltd. They market two generations of a GPS tracking unit (GPSPI10 and GPS SPI Elite) for use within team sports. Both units are carried by an individual in a padded backpack just below the neck and samples at a rate of 1Hz (position is recorded every second). Published research exists on the use of GPS devices for the measurement of physical activity. However, only a limited number of this research has applied a GPS to team sport TMA. The following examples of research which made use of GPS in different sport code exist: Pino *et al*. (2007:6) measured the distances covered by Spanish second division soccer players using FRWD F 500 GPS devices during a practice match. Weston *et al*. (2007:391) used a GPS to measure the physical performance of English soccer referees and Sykes *et al*. (2009:49) tracked the movement patterns of senior elite rugby players. Barbero-Alvarez *et al*. (2008:6) also used the SPI10 GPS device to determine the activity profile and physiological demands of male futsal players, whilst Petersen *et al.* (2009b:383) used the device to measure the physiological demands of Australian and New Zealand cricket players.

There are a few disadvantages associated with the use of a GPS in TMA. Firstly, one of the requirements for GPS units is to receive multiple satellite signals to calculate positions. This implies that it cannot be used indoors or within developed urban areas where large buildings may interfere with the signals (Dobson & Keogh, 2007:50). Secondly, participants need to wear a small receiver on their upper back supported by shoulder straps (Di Salvo *et al*., 2006:109). This will limit its use in competitive sport. Thirdly, high levels of reliability and high sample rates are required if a GPS is used (Sykes *et al*., 2009:49). Lastly, when official games are played, rules and regulations for certain team sports do not allow participants to wear anything other than the standard apparel approved for the sport (Di Salvo *et al*., 2006:109).

2.2.1.3 Automated tracking methods

Expensive and sophisticated computer tracking equipment has recently been developed that allows the movement patterns to be semi-automatically or automatically quantified (Weston *et al.*, 2007:392). The commercial systems Prozone (Prozone Sports Ltd, Leeds) and Amisco (Amisco.eu, France) are both used extensively in professional sport in Europe. These systems track players by determining the x and y-coordinates of the participants' positions at the start of a discrete activity. The data of the coordinates are obtained with manual input using footage from six to eight fixed-view cameras and a scaled map of the pitch on which the film footage is superimposed. The validity and reliability of these systems have not been reported on although high accuracy has been reported for simulated soccer match activities (Di Salvo *et al.*, 2006:108).

2.2.2 Validity of TMA studies

For the use of TMA, certain requirements need to be met. One such relevant requirement is that TMA must be validated before it can be used for research purposes. It is therefore necessary to address several issues related to the validity of TMA, namely (1) determination of movement patterns, (2) measurement of distance, and (3) determination of work-to-rest ratio.

Validity is an integrated evaluative judgement of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inference and actions based on test scores or other modes of assessment (Messick, 1989:13).

2.2.2.1 Determination of movement patterns

Previous TMA studies have shown that the movement patterns of participants during a game can be divided into discrete categories (Castagna *et al*., 2007:629; De Oliveira *et al*., 2007:43). Although different explanations are given for the different movement patterns, most researchers included three to five generic movements independent of the sport code studied (Krustrup & Bangsbo, 2001:882). These generic movement patterns are standing still, walking, jogging, running and sprinting (Krustrup & Bangsbo, 2001:882; Cochrane *et al.*, 2003:68). According to McInnes *et al*. (1995:392) and O'Donoghue (2002:36), "standing" and "walking" can be combined into one movement. This combination increases the reliability of the analysis because the metabolic cost of these two movement patterns is of the same relative intensity and thus does not affect the physical conditioning of the participants differently. Although different definitions or explanations for these movement patterns are used by various researchers, the grouping of these movements remains the same as illustrated in Table 2.1 (Spencer *et al.*, 2005:384; Davidson & Trewartha, 2008:5; Deutsch *et al*., 2007:463).

Dobson and Keogh (2007:51) and Petersen *et al*. (2009a:278) reported that it is important for researchers who use TMA to have an adequate knowledge of the specific sport if they are to select sport-specific movement patterns. The validity of any TMA study may be compromised if the researcher does not examine the sport-specific movements (Bloomfield *et al*., 2004:27). By using TMA, researchers have also identified a number of sport-specific movements as indicated in Table 2.2. For example, in their TMA of basketball, McInnes *et al.* (1995:392) recorded three levels of shuffling – low, moderate and high. All three levels correspond to the intensity of this movement. Cochrane *et al.* (2003:68) recorded sideways and turning/pivoting movements of rugby union referees. Deutsch *et al*. (2007:463) defined the following movements as sport-specific movements: rucking, mauling, scrummaging, tackling and jumping, sideways and backwards running for soccer (Bloomfield *et al.*, 2004:24), shuffling (low, moderate and high intensity shuffle) in basketball (Tessitore *et al*., 2006:217) and field hockey (Spencer *et al.*, 2005:382) and shuffling movements in netball (Davidson & Trewartha, 2008:5). The abovementioned movements were used because they are examples of sport-specific movements found in the literature.

2.2.2.2 Measuring distance

Researchers have indicated that there are some issues related to the measurement of the true distance covered during matches in a video-based analysis (Davidson & Trewartha, 2008:13). One such issue is that participants are often positioned perpendicular to the camera - a problem referred to as a parallax error (Duthie *et al*., 2003a:985). To eliminate this problem and to accurately measure the distance covered by the participants, a unique system was developed by Deutsch *et al*. (1998:563). Before the rugby union game was filmed, specific players were required to have their mean speed determined while sprinting, running, jogging and walking a set distance. The validity of this method was established prior to the analysis by using a 20 minute simulated game, where markings of known distances on the field were compared to the distances on the field using the abovementioned method.

Kay and Gill (2004:167) used another method to determine the distance covered by rugby league referees by plotting the field coordinates (end to end {x}; and side to side {y}) to the nearest metre at the beginning and end of the action. The coordinates were approximated using on-field markings as known points. Following each movement a hypothetical right-angle triangle was constructed, with the line of movement between the starting and ending coordinates being the hypotenuse and x/y movement vectors forming the other two sides. Pythagoras was used to determine the displacement, hence approximate distance covered. Actions which included a sharp directional change were recorded as two separate actions.

2.2.2.3 Work-to-rest ratios

Several studies made use of TMA to determine the work-to-rest ratios of participants during match-play (McLean, 1992:286; Catterall *et al.*, 1993:194; Cochrane *et al.,* 2003:69; Deutsch *et al.*, 2007:465). One way of determining the work-to-rest ratio is by using a computerised system called POWER (Periods Of Work Efforts and Recoveries). The POWER TMA system uses the movement classification scheme as developed by O'Donoghue and Parker (2001:264). The POWER system is a work-to-rest ratio analysis system that specifically focuses on the analysis of work-to-rest ratios with the exclusion of other time-motion data such as the distance covered and the performance of different types of work (such as running and game related activities) and various types of recovery activities such as standing, walking and jogging (O'Donoghue *et al.*, 2005:7). All the activities during a match are classified as either "work" or "rest" activities. For example, Coutts and Reaburn (2000:133) have identified standing still, walking and jogging activities as a form of rest and shuffling movements and sprinting activities as work. Where adjacent rest periods occur (i.e. a period of walking followed by a period of standing still), these periods are grouped together and considered as one rest period. A similar approach is applied if two work periods occur consecutively. Consequently, the total number and the duration of each rest and work period can be calculated.

Because the work-to-rest ratio of match-play is so easily understood and interpreted, several studies have used it as one if not the primary, finding of their studies and as the basis of their recommendations for the physical conditioning of participants (Coutts & Reaburn, 2000:133, Cochrane *et al.,* 2003:69; Deutsch *et al.,* 2007:465).

Table 2.1: Definitions of different movement categories

Motion activities	Definitions as defined by (Davidson & Trewartha, 2008:5)	Definitions as defined by (Deutsch *et al.*, 2007:463)	Definitions as defined by (Spencer *et al.*, 2005:384)
Standing	No locomotor activity.	Standing or lying on the ground without being involved in pushing or any other movement patterns. This can include small movements with no purpose.	Motionless
Walking	Strolling, loco motor activity in either a forwards, backwards or sideways direction.	Walking forwards or backwards slowly with purpose. One foot is in contact with the ground at all times.	Motion, but with both feet in contact with the ground at the same time at some point during the gait cycle.
Jogging	Slow running action where there is no specific goal and no obvious acceleration.	Running forward slowly to change field position, but with no particular haste or arm drive.	Motion with an airborne phase, but with low knee lift.
Striding/cruising or running	A fast running action with distinct elongated strides, effort and purpose.	Running with manifest purpose and effort, accelerating with long strides, yet not at maximum effort (3/4 pace).	Vigorous motion with airborne phase, higher knee lift than jogging (included skirmishing movements of rapid changes of motion, forwards/backwards/laterally).
Sprinting	Running at maximum speed and full effort.	Running with maximal effort. This is discernible from cruising by arm and head movements.	Maximal effort with a greater extension of the lower leg during forward swing and a higher heel-lift relative to striding.

Table 2.2: Sport-specific movement activities of sport participants

Soccer players (Bloomfield *et al.*, 2004:24)	Rugby union refereeing (Cochrane *et al.*, 2003:68)	Rugby union players (Deutsch *et al.*, 2007:463)	Basketball players (McInnes *et al.*, 1995:392; Tessitore *et al.*, 2006:217)	Netball players (Davidson & Trewartha, 2008:5)
Movements: slow down, slide, fall, get-up and impact. *Directions:* forwards, sideways, backwards and diagonal. *Action:* receive, pass, turn, dribble and shoot. *How:* right foot, left foot, header, back-heel, etc. *Touches:* 1-3, 4-6, 7-10, >10. *Turns:* 0-90°, 90-180°, 180-270°, 270-360° and >360°.	*Turning and pivoting:* when a referee alters his direction of movement.	*Utility:* shuffling sideways or backwards to change field position. Usually a defensive or repositioning movement. This does not include walking slowly aimlessly. *Jumping:* jumping in a line-out or to catch a ball in play. *Rucking/mauling:* attached to an active ruck or maul, or the referee calls the end of play, the player is no longer considered to be engaged in rucking/ mauling, and is deemed to be standing still. *Scrummaging*: attached to an active scrum. As above, once the ball exits or the play is no longer active.	*Jumping:* an attempt to leave the floor to make a shot block or intercept. *Shuffle:* low intensity shuffle, moderate intensity shuffle, high intensity shuffle.	*Shuffling:* a sideways movement of the body using a shuffling action of the feet.

2.2.3 Reliability of time-motion analysis (TMA)

The reliability of measurements or assessments made during TMA research is regarded as vital (Lames & McGarry, 2007:62). These researchers stipulate that when the reliability of the testing method is not established, either within the study or in previous literature, the results must be considered with caution. Because of the similarities between some movement patterns during match-play, e.g. jogging and running, it is obvious that in the majority of video-based TMA studies some form of subjective judgement regarding the categorisation of each individual movement is applied (Tenga & Larsen, 2003:91). This places the decision of accurately coding each movement solely on the interpretation of the observers or analysers (Lames & McGarry, 2007:65). It is therefore likely that individuals' interpretation of the defined movement activity may differ slightly, which could affect the reliability of the results.

O'Donoghue (2004:44) used 15-minute segments of 10 matches to analyse the movements of 60 professional soccer players. Movements were classified as high or low intensity movements and the duration of these movements was recorded. Tests of inter-observer reliability and intra-observer reliability were conducted, revealing that there was significant systematic bias between observers for the percentage time spent performing high intensity activities ($p<0.01$) and between the observations of the different halves ($p<0.05$) with higher values being recorded during the first half.

In assessing reliability, Spencer *et al.* (2005:384) analysed the movement patterns of five male hockey players during half of an international match. Test Error Measurement (TEM) values of 5.9-10.2% were reported for the frequency of movements and 5.7-9.8% for the duration of movements.

2.2.4 Limitations of time-motion analysis (TMA)

A potential limitation in TMA studies is that the small sample size of the games and the participants analysed, makes the results and interpretations vulnerable to misinterpretation because of the differences in each individual game (Cochrane *et al.*, 2003:69; Davidson & Trewartha, 2008:13). This may occur because of the different patterns of play followed by different teams, the opposition, the different positions of participants or the experience of participants (Cochrane *et al.*, 2003:69; Davidson & Trewartha, 2008:6; Csataljay *et al.*, 2009:61). In this regard, Csataljay *et al.* (2009:61) are of the opinion that the results of any single TMA study may not accurately represent the sport or the participants because of the fact that the game that was analysed does not represent the sport as a whole. To avoid the potential effect of any such problems with the results, it is thus advisable to increase the sample size of games and participants (Di Salvo, Collins, McNeil & Cardinale, 2006:109). However, due to the time consuming nature of TMA, this is rarely done (Di Salvo *et al*., 2006:109). This issue of sample size lies at the heart of studies looking at the validity of TMA in particular sport codes (James, 2006:71).

Whilst it is likely that there are some differences in movement patterns of individual participants in different games, it is also likely that there are substantial differences in movement patterns of the various participants' positions within a single game. Research (Deutsch *et al.*, 1998:563; Deutsch *et al.*, 2007:462; Davidson & Trewartha, 2008:6) has indicated that participants can be divided into different groups based on the roles that they have to fulfil in their respective positions. For example, significant potential differences have been identified in the duration of movement patterns and time spent in sport specific movements during rugby union match-play (Deutsch *et al.*, 1998:563). Findings of these studies may have significant implications when developing position specific conditioning programmes or training plans for participants.

Another possible problem is the vague definitions of movement patterns. According to James *et al*. (2007:2) this problem can affect the reliability of any movement analyses research. They suggest that operational definitions must be constructed and understood by all analysers or observers. Further issues are the standard of competition under which the data is collected and according to Tenga and Larsen (2003:90) this has a direct effect on the intensity of play by the participants. However, very few TMA studies have actually directly compared the movement patterns of participants to various standards in the same study (Duthie *et al*., 2005:523; Lango-Penas *et al*., 2010:288).

2.2.5 Applications of time motion analysis (TMA)

Information obtained from TMA may prove very useful when developing metabolic and movement pattern-specific conditioning programmes (Martin *et al.*, 2001:1075). Information about movement patterns, HRR and work-to-rest ratios can assist sport scientists when developing strength and conditioning programmes that are sport and position specific (Kay & Gill, 2003:339). However, TMA studies do have a number of potential limitations which are mostly related to the validity and reliability of measurements (James *et al*., 2007:1). To address these limitations, researchers must develop more consistent movement pattern categories and use clearer and more objective definitions for each movement category (James, 2006:72). To lessen the effect of factors previously discussed, it would be useful if researchers could increase their subject size and compare participants of different competitive levels and positional groups (Cochrane *et al.*, 2003:71; Davidson & Trewartha, 2008:13). A possible reason for the lack of this kind of research is the large amount of time that video-based TMA takes. However, technology is continuously improving and GPS based systems and automated tracking systems are more and more used which allow researchers to complete more TMA studies. This would imply that greater subject sizes can be expected in future studies (Di Salvo *et al*., 2006:118). However, currently GPS based TMA appears to have reliability and subject limitations for high speed sports and is still limited to outdoor sports with minimal body contact. Due to the high expense of automated tracking systems, video-based analyses may continue to be used more frequently.

When reading TMA literature, coaches, sport scientists and video analysts should be aware of the abovementioned issues and how these issues may affect the results related to TMA. When using the results of studies to design position or sport specific conditioning programmes, sport scientists should also take into account the different activity related variables like duration, frequency, intensity and work-to-rest ratio (Petersen *et al*., 2009a:278).

As previously mentioned in the above literature on TMA, it is also important to consider the measurement of intensity as determined by HRR. The next section will address the following scientific information related to HRR studies: 1) Background on HHR, 2) Methods on how to determine maximal heart rate, 3) HRR sample intervals, 4) Reporting of HRR data, and 5) Factors that influence HRR.

2.3 HEART RATE RECORDINGS TO DETERMINE INTENSITY OF TEAM SPORT PARTICIPANTS

2.3.1 Background on heart rate recordings

The use of HRR for the monitoring of participants has progressively increased since the early 1980’s when the first wireless HRR devices were developed (Achten & Jeukendrup, 2003:519). Since then the objective measurement of HRR began to replace the subjective measurement of perceived exertion to estimate physiological strain. In this regard Vehkaoja *et al*. (2008) reported that the HRR devices developed by Polar (Polar Electro Oy, Finland)

and Suunto (Amer Sports Corporation, Mäkelänkatu 91, Helsinki, Finland) are regarded as valid devices for measuring physiological strain during movements. These devices have also been featured in training-based research (Deutsch *et al.*, 1998:563; Coutts *et al.*, 2003:98; Weston *et al.*, 2006:258) as a means of providing an accurate, reliable, non-obstructive and socially acceptable method of quantifying training demandsdemandss (Achten & Jeukendrup, 2003:519).

Besides monitoring aerobic training, the application of HHR for team sport athletes is a more recent phenomenon (Cochrane *et al,* 2003:67; Montgomery *et al*., 2009:1489). The proliferation of competition HRR analysis in team sports has been aided by the development of HRR systems such as Team Polar (Polar Electro Oy, Kempele Finland) and Suunto Team Pack (Amer Sports Corporation, Mäkelänkatu 91, Helsinki, Finland). Both these systems do not require participants to wear a watch receiver, but only a chest strap that has an internal memory for the recording of the heart rate during match-play. This allows for the safe recording of the participant's heart rate in body contact situations where the wearing of a watch may be considered inappropriate and/or may be against the rules and regulations of the sport.

2.3.2 Methods to determine maximal heart rate

This section addresses the different methods of determining the MHR of team sport participants. Researchers make use of different methods to determine MHR. Tessitore *et al.* (2006:216) as well as Castagna and D'Ottavio, (2001:421) used the mathematical equation (200 bpm minus age) to determine MHR for male basketball players and soccer referees. Narazaki *et al*. (2009:426) also reported on the MHR of female basketball players during international and national matches. They found that the average heart rates were 94.6% (international matches) and 90.8% (national matches) of the MHR as measured by a progressive shuttle run test. Cochrane *et al*. (2003: 69) used a three kilometre trail run in New Zealand Rugby Union (NZRU) referees and found an average MHR of 189 bpm. Catterall *et al*. (1993:195), Deutsch *et al*. (1998:563) and Abdelkrim *et al*. (2007:70) all used the highest HR value obtained during matches by soccer referees, under 19 rugby players and under 19 basketball players, respectively, as the MHR. Krustrup and Bangsbo (2001:883) and Krustrup *et al*. (2002:869) used a laboratory treadmill test to determine the MHR of soccer and assistant soccer referees. The methods used to determine MHR data of sport participants during match-play and training are still inconsistent.

2.3.3 Heart rate recording sample intervals

The intermittent nature of team sports is reflected in the HRR averages, which confirms that the exercise intensity is constantly changing. Spencer *et al*. (2005:387) reported that international hockey players change intensity every 5.5 seconds. To use HRR as a measure of intensity in the last-mentioned team sport requires a high frequency of sampling to capture these regular changes. De Oliveira *et al.* (2007:43) compared the heart rate traces of soccer match performances using five and 15 second sample intervals and found that all sample intervals provided significantly different representations of the activity and that the five second sample interval was most appropriate for an intermittent sport. The use of five second HRR samples is consistent across literature on soccer research (Catterall *et al*., 1993:194; Castagna & D'Ottavio, 2001:422), rugby union referees (Cochrane *et al.*, 2003:69), hockey players (Konarski *et al*., 2006:146) and basketball players (Abdelkrim *et al*., 2007:70). This sample interval has also been demonstrated to be mathematically adequate for analytical purposes (McCarthy & Ringwood, 2006:1).

2.3.4 Reporting of heart rate recording data

The methods used to report HRR data during team sport competitions are still inconsistent. Many of the early TMA studies simply reported the average heart rate (HR) and most of these studies do not reference the averages to actual or predicted MHR (Castgana & D'Ottavio, 2001:421; Krustrup & Bangsbo, 2001:884). Although average and non-referenced HRR data are regarded as useful, the data usually result in a substantial loss of specific information (Helgerud *et al*., 2001:1926). Clearly, the addition of laboratory or field measures of actual or predicted MHR and the classification of competition HRR data into zones, time periods, and/or playing position makes the analysis more applicable and meaningful (Helgerud *et al.*, 2001:1926).

Several researchers who have investigated basketball, rugby and soccer, have divided the match-related HRR data into time segments to make comparisons between work-to-rest ratios and physiological demands over the course of the match (Krustrup & Bangsbo, 2001:882; Cochrane *et al.*, 2003:69; Abdelkrim *et al.*, 2007:70). Abdelkrim *et al*. (2007:70) reported on the average HRR for each quarter of a basketball match, whilst Krustrup and Bangsbo (2001:882) divided a 90 minute soccer match into 15 minute segments and Cochrane *et al*. (2003:69) compared data of referees during the first and second half of a rugby union match.

It is commonly reported that work-to-rest ratios and HRR decrease in the second half of soccer and rugby matches (Krustrup & Bangsbo, 2001:882; Cochrane *et al.*, 2003:69).

Deutsch *et al*. (1998:563) divided the HRR of under 19 rugby players obtained during matches into four zones. These zones are: 1) maximal (>95% of MHR), 2) supra-threshold (85-95% of MHR), 3) anaerobic threshold (75 – 84% of MHR), and 4) sub-threshold (<74% of MHR). Match HRR was reported as the average percentage of match-time that each player spent in the respective heart rate zones. Cochrane *et al*. (2003:69) used the same heart rate zones to analyse the match HRR of rugby union referees and also reported on the average percentage of match-time spent in each zone. McInnes *et al*. (1995:393) divided match HRR of professional basketball players into six zones: 1) >95% of MHR, 2) 91-95% of MHR, 3) 86-90% of MHR, 4) 81-85% of MHR, 5) 75-80% of MHR, and 6) <75% of MHR. The match HRR was reported as the average percentage of match-time that each player spent in the respective heart rate zones. From the information above, it is clear that authors have divided HRR into several and different zones to capture the intensity of activities. It is therefore important to establish clear heart rate zones for analysing purposes, since it can influence the reliability and validity of the data and the study.

2.3.5 Factors influencing heart rate recordings

Although the measurement of competition HRR proves useful to determine physiological stresses of participants during training and matches, there are certain factors that may influence the accuracy of the data. It is well known that HRR are not only influenced by training intensity and duration, but are also affected by factors such as physiological arousal and anxiety (Tumilty, 1993:82). As far as the emotional influence on HRR is concerned it has been suggested that physiological factors have more influence on HRR at rest or during low intensity work, but at higher intensities the emotional influence on HRR is somewhat neutralised by the higher workload (Saltin & Astrand, 1967:356). Another factor that may influence the HRR is bouts of static work in which participants are maintaining a position against the physical resistance of an opposition player (i.e., scrumming and rucking in rugby union), which also contributes to high HRR responses in certain positions of team sports. Other factors such as temperature, dehydration, hyperthermia and mental stress may also elevate HRR during actual match-play (Achten & Jeukendrup, 2003:517).

The previous two sections covered the use of TMA and HRR to determine exercise intensity and the physiological demands on participants. The next part will look at the use of blood lactate as well as the use of a combination of the methods to determine possible changes during TMA.

2.4 TIME-MOTION ANALYSIS IN CONJUNCTION WITH HEART RATE RECORDINGS AND BLOOD LACTATE TO DETERMINE PHYSIOLOGICAL DEMANDS ON PARTICIPANTS

Deutsch *et al*. (1998:562) stated that the combination of accurate and reliable TMA with HRR and BL data will provide a more comprehensive picture of the physiological demands in Rugby Union match-play. BL concentration measures are frequently used to estimate intensities during team sport competitions and can provide information regarding the aerobic and anaerobic contributions to energy expenditure and can even supplement HRR data (Billat, 1996:158). The high intensity of team sports is verified by the peak BL values above 12 mmol.l^{-1} that was measured during basketball (McInnes *et al.*, 1995:395; Narazaki, *et al.*, 2009:426) and soccer competitions (Krustrup *et al*., 2006:1670). Mean values collected during basketball, field hockey, rugby league, rugby union and soccer competitions are in the range of 4 to 10 mmol.l^{-1} (Deutsch *et al.*, 1998:564; Coutts *et al*., 2003:101; Tessitore *et al*., 2006:217; Abdelkrim *et al*., 2007:70).

Consistent with HRR measures, the mean BL values appear to be lower at the end of the second half when compared to measurements taken after the first half of team sport matches. This is especially apparent in basketball, where BL values have been reported to drop from approximately 7.3 mmol.l^{-1} at half-time to 5.4 mmol.l^{-1} at full-time (Abdelkrim *et al*., 2007:70). The lower BL values reported towards the end of match-play are not surprising, given the declines in game intensity (Abdelkrim *et al*., 2007:70). Equally noticeable is that the BL values of soccer participants have been reported to increase from 4.8 mmol.l^{-1} after the first half to 5.1 mmol.l^{-1} at full-time for elite Danish soccer players (Krustrup & Bangsbo, 2001:886).

As with TMA, certain shortcomings with regard to the use of HR and BL values to determine the demands of team sport participants can also be highlighted. Individual differences in fitness levels and variations in training economy may lead to errors in the estimation of training intensities and energy system contributions when using heart rate guidelines alone (Achten & Jeukendrup, 2003:526). It may not be the most accurate way in predicting the game intensity when the intensity zones for all the participants based on MHR are generalised. The collection of blood samples for BL analyses offers some logistical difficulties during rugby matches because of the fact that blood sampling can only take place when the game is stopped during play (Duthie *et al.*, 2003:986). Thus, if the time span between high intensity bouts for blood sampling is too long, the BL will be metabolised and will not be a true representation of the overall demands of the game (Duthie *et al.,* 2003:986).

2.5 CONCLUSION

The use of technology to analyse players' and referees' performances will no doubt continue to move forward in the way it has done already over the past few years. New and improved computer video systems will be used in the collection, analysis and application of match-play data. Sophisticated, automated tracking systems have already been developed that provide detailed match information without significant manual input. However, these systems remain very expensive and are used predominantly in soccer and rugby in Europe. The literature also indicated that another, less expensive system, namely the GPS receiver, is showing potential from a researcher's point of view. However, video-based TMA (method used in current study) will still be used as it provides researchers a less expensive but effective method to conduct TMA research on sport participants. When doing TMA research, researchers, coaches, sport scientists and video analysts should be aware of certain issues, namely sample size, clear definitions of movement patterns, level of the competition and reliability and how these issues may affect the results related to TMA. When using the results of studies to design position or sport specific conditioning programmes, sport scientists should also take into account the different activity related variables like duration, frequency, intensity and work-to-rest ratio.

With the modern technology and the development and improvement of the portable wireless heart rate monitors by Polar and Suunto, HRR has become the most commonly used method to get an indication of training intensity and intensity on the field during match-refereeing. Key information on the game demands of team sports not only focuses on movement patterns, but also relates to differences between players in various positions/ different levels of refereeing, effects of tactical changes and effects of law changes. This information can be used to enhance the specificity of training to better prepare players/referees for competition.

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CHAPTER 3

ARTICLE 1: ANALYSIS OF MOVEMENT PATTERNS AND WORK-TO-REST RATIOS FOR DIFFERENT PANELS OF SOUTH AFRICAN RUGBY UNION REFEREES DURING MATCH-REFEREEING

The chapter is herewith included according to the guidelines of the International Journal of Performance Analysis in Sport (included as Appendix A). Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation. This article was accepted for publication in the International Journal of Performance Analysis in Sport, 11(2), 344-355.

Analysis of movement patterns and work-to-rest ratios for different panels of South African Rugby Union referees during match-refereeing

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Field of study: Sport Science (Time-motion analysis)

Running head: Time-motion analysis of Rugby Union referees

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Analysis of movement patterns and work-to-rest ratios for different panels of South African Rugby Union referees during match-refereeing

Abstract

The objectives of this study was to determine the frequency, duration and intensity of movement patterns and work-to-rest ratio of different refereeing panels of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007. The referees were monitored during play by means of a video camera in a total of 16 matches within a tournament. The frequency and duration of the different movement patterns were analysed using different functions of the Dartfish 5.5 TeamPro software package. Heart rates (HR) were recorded by a Suunto Team pack HR monitor system to determine the intensities of the movement patterns. The mean frequency of movement activities revealed a moderate practical significant difference between referee panels for jogging (d=0.51) and the mean duration indicated a moderate practical significant difference for jogging (d=0.43) and sprinting (d=0.43). The intensity of movement activities indicated a large practical significant difference for the anaerobic threshold (d=3.68) and sub-threshold (d=1.36) heart rate zones. A work-to-rest ratio of 1:4 was revealed for both referee panels during match-refereeing. The study revealed that contender panel referees completed more jogging activities and spent more time on jogging and sprinting activities than the provincial referees, and regarding intensities the contender panel referees also spent more time in low intensity heart rate zones.

Key words: Movement patterns, time-motion analysis, heart rate recordings, work-to-rest ratio, Rugby Union referees.

3.1 INTRODUCTION

Increased professionalism in rugby has changed the fitness level of players - players have become faster, more powerful and clinical with regard to the interpretation of the laws of the game (Scott *et al*., 2002; Duthie *et al*., 2003). Thus, pressure is also placed on match referees/officials to keep up with the 'pace' of the game and to produce 'flawless' performances during a game. *Beeld* (2010) states that New Zealand Rugby Union (NZRU) coaches are of the opinion that due to changes in the laws of the game, the ball is now longer in play and therefore more emphasis is placed on the fitness of rugby union referees during match-refereeing. Based on this statement, the fitness levels of referees have a big influence on the outcome of the game (*Die Burger*, 2010), yet only two studies could be found that focused specifically on the movement patterns, heart rate recordings and work-to-rest ratios of rugby union (hereafter referred to as rugby) referees during match-refereeing (Martin *et al*., 2001; Cochrane *et al*., 2003). Several other studies were conducted on movement patterns, heart rate recordings and work-to-rest ratios of other sport code referees, such as basketball (Abdelkrim *et al*., 2007), rugby league (Kay & Gill, 2003; Kay & Gill, 2004), soccer (Catterall *et al*., 1993; Castagna *et al*., 2004) and hockey (MacLeod *et al*., 2007).

Seneviratne (2003/04) stated that fitness is a prerequisite for refereeing rugby at any competitive level and all referees need to be fit in order to meet the physiological demands of the game, and also need to apply an accurate interpretation of the laws of the game (Müniroglu, 2007). To assess the fitness levels of participants, Dotter (1998) indicated that the duration, frequency and intensity of activities performed during exercise or competition need to be considered. Deutsch *et al*. (1998) supported this statement by claiming that combining accurate and reliable time-motion analysis (TMA) with heart rate recordings (HRR) and blood lactate data would provide a more comprehensive picture of the demands of rugby match-play.

TMA involves the quantification of various movement patterns related to the speed, duration, and distance travelled during the course of a competitive match (Dobson & Keogh, 2007; Petersen *et al*., 2009). These researchers concluded that the results of a TMA may increase the specificity of strength and conditioning programmes, as these programmes provide insight into the energy system utilisation, and in some cases, specific movement patterns used throughout matches (Martin *et al*., 2001; Kay & Gill, 2003; Castagna *et al*., 2004; Deutsch *et al*., 2007). Although most research related to TMA focuses on the distance covered during the different movement patterns, Mclean (1992) suggested that it is just as effective to analyse the duration of each activity to determine volume. Several researchers (Martin *et al*., 2001; Krustrup *et al*., 2002; Duthie *et al.*, 2003; Price & Halabi, 2005) categorise the different movement patterns as: standing still, walking, jogging, lateral movements, and sprinting activities.

Dotter (1998) indicated that HRR can be used effectively to determine the intensity of activities performed during competition. The results can also be expressed as a percentage of the participant's maximum heart rate (MHR). Catterall *et al*. (1993) stated that HRR are used to determine the cardiovascular strain imposed on referees during actual match-refereeing and training. Heart rate is commonly measured by having the participants wear a chest strap which is fitted with a heart rate monitor/recorder and a wrist watch (Krustrup *et al*., 2002; Müniroglu, 2007). According to Cochrane *et al.* (2003) HRR from matches can be classified into four categories: 1) maximal (>95% of MHR), 2) supra-threshold (85-95% of MHR), 3) anaerobic threshold (75-84% of MHR), and 4) sub-threshold (<74% of MHR). All activities at and above the anaerobic threshold (75-84% MHR) are primarily linked to the anaerobic energy system and the rest of the activities are linked to the aerobic energy system (Cochrane *et al.,* 2003).

Several studies make use of time-motion analyses to determine the work-to-rest ratios of referees (Martin *et al*., 2001; Cochrane *et al*., 2003; Kay & Gill, 2004). This is a subjective procedure whereby a number of movements during refereeing are defined as "rest" periods and others are considered as "work" periods (Coutts & Reaburn, 2000; O'Donoghue, 2002). Studies such as those done by Coutts and Reaburn, (2000) and O'Donoghue, (2002) have identified standing still, walking and jogging as rest periods. Adjacent rest periods (e.g. a period of walking followed by a period of standing still) are grouped together and are considered as one rest period. A similar approach is applied if two work periods occur consecutively. Consequently, the total number and duration of each rest and work period can be calculated. Because the work-to-rest ratios are so easily calculated, understood and interpreted, many studies have used it as one of the, if not the primary, methods in time-motion analysis (Catterall *et al*., 2003; O'Donoghue, 2002; Price & Halabi, 2005). Coutts and Reaburn (2000) stated that these results can thus be used as the basis for the recommendations for the physical conditioning of AFL umpiring.

For the purpose of this study referees on different panels of the South African Rugby Referee Association (SARRA) were used to give a better insight on the possible differences in physiological demands as influenced by the experience of the referees (indicated by their placement/ranking on the different panels of rugby refereeing). The rugby referees in South Africa are ranked on either of the following panels, namely national, provincial, contender, woman, assistant referee and television match official (TMO), depending on their referee performance of the previous year and results of the pre-season fitness tests. However, no studies that have focused on the different levels/panels of referees or officiating in other sport codes could be found.

Based on the abovementioned statements, very few researchers have until now focused on the integrated approach of movement patterns, heart rate recordings and work-to-rest ratios of rugby union referees. Martin *et al*. (2001) found that during an 80 minute rugby match English Premiership Rugby referees stand still for 37.0% of the time, walk for 29.5%, jog for 12.8%, run for 9.9% and sprint for 1.0% of the total match time. On average there were a total of 672 transitions between the various categories of movement during the match. Cochrane *et al*. (2003) found that NZRU referees spent 1.2% of an average game on maximal sprinting, 6.7% on moderate sprinting, 15.2% on jogging, 20.5% on walking, 4.8% on moving sideways, 3.5% on turning, 32.9% on remaining stationary, 12.6% on moving backwards slowly and 2.6% on moving backwards fast. Cochrane *et al*. (2003) also found that these referees spent 10% of a match at their maximum heart rate, 43% at supra-threshold, 36% at anaerobic threshold and 11% at sub-threshold heart rate zones.

Based on the abovementioned background, the following research question are posed: what are the frequency, duration and intensity of movement patterns and work-to-rest ratio of different refereeing panels of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007? Research on the movement pattern analyses, heart rate recordings and work-to-rest ratios of rugby union referees may assist sport scientists and rugby referee coaches to improve their fitness levels (Mitchelmore, 2004), develop match-specific training programmes, and lastly to provide information regarding the physiological demands of different panels of refereeing in South Africa.

3.2 METHODS

3.2.1 Participants

All the referees (N=8) who participated in the 2007 National Club Rugby Championship (NCRC) held in Stellenbosch were used as test subjects in this study. The referees had to be injury-free as well as complete a demographic questionnaire consisting of: geographic information, training habits, medical information and referee data to participate in this study. Written and verbal permission was obtained from the South African Rugby Referee Association (SARRA) as well as from each rugby referee to voluntarily partake in the research. Based on the level of experience, four referees (mean age 31.25 ± 6.5 years) affiliated to the SARRA were ranked on the provincial panel (average 6.75 ± 0.95 years experience) and four referees (mean age 28.25 ± 6.75 years) were ranked on the contenders panel (average 5.75 ± 2.2 years experience). Ethical approval (included as Appendix E) was obtained from the North-West University (NWU-00019-11-S2).

3.2.2 Test protocol

3.2.2.1 Video analysis

Video recordings: The referees were monitored during match-refereeing in a total of 16 matches (each referee was monitored twice during two different matches). Video recordings were collected by using one video camera (Panasonic NV-GS400) during each match.

Motion analysis: The video data of the various games were downloaded onto a computer by means of Dartfish 5.5 TeamPro (5.0.20909.0) software package. Subsequently the data were analysed by an accredited performance analyst (International Society of Performance Analysis of Sport). The time each referee spent during the game on the different movement patterns (standing still, walking, jogging, lateral movements and sprinting) was analysed by the tagging and analyser functions of the Dartfish 5.5 TeamPro (5.0.20909.0) software package.

Reliability: According to Hopkins (2000), reliability refers to the reproducibility of values of a test, in repeated trials on the same individuals. The reliability of the movement patterns was tested by using the intra-reliability method. The method entails that the same analyser does a reanalysis of the video material one month after the original analysis. For the purpose of this study, 25% of the frequencies and duration of standing still, walking, jogging lateral movements and sprinting categories of one half was analysed twice. The Pearson product moment correlation was calculated to assess the reliability of the analysis.

3.2.2.2 Heart rate recordings

Maximal heart rate: To determine the individual maximal heart rates, the referees were fitted with a heart rate monitor, chest strap and wrist watch (Suunto t4 Team Pack and Smartbelt) prior to the start of the aerobic endurance test (multi-stage bleep test). The multi-stage bleep test in this study was identical to the one described in Ramsbottom *et al.* (1998). The highest heart rate value obtained during the aerobic endurance test was used as the MHR. The highest level completed during the multi-stage bleep test was also recorded.

Heart rate recordings during matches: Ten minutes prior to the kick-off of every match, each referee was fitted with a heart rate monitor, chest strap and wrist watch (Suunto t4 Team Pack and Smartbelt). Ten minutes after the completion of the match the heart rate monitor was removed and the heart rate data were downloaded onto a laptop by means of the Suunto Team Manager Software. This enabled the researchers to determine the intensity of the referees' movement patterns during the matches and to correlate this recording with their predetermined MHR.

Classification of heart rate recordings: The recorded heart rate readings of each referee were used to classify the movement patterns of the referees during the matches in accordance with the four heart rate zones (Deutch *et al.*, 1998). These zones are 1) maximal (>95% of MHR), 2) supra-threshold (85-95% of MHR), 3) anaerobic threshold (75-84% of MHR), and 4) sub-threshold (<74% of MHR).

3.2.2.3 Work-to-rest ratios

The type and duration of the different movement activities were used to calculate the work-to-rest ratios of the rugby union referees during match-play (Coutts & Reaburn, 2000; O'Donoghue *et al*., 2005). The work-to-rest ratios were determined by comparing the time (measured in seconds) spent working (lateral movements and sprinting) to the time (measured in seconds) spent during static or active rest (standing still, walking and jogging) (Coutts & Reaburn, 2000; O'Donoghue *et al*., 2005).

3.3 STATISTICAL PROCEDURES

The Statistical Consultation Services of The North-West University were used to assist with the statistical methods and analysis of the research data. The Statsoft Data Processing package (Statsoft

Inc., 2009) was used to process the data. For the purpose of this study the researchers made use of mixed-method methodology. Mixed method research is when a researcher or a team of researchers combine elements of qualitative and quantitative research approaches (e.g. the use of qualitative and quantitative viewpoints, data collections, analysis and inference techniques) to gain in-depth understanding and corroboration (De Vos *et al*., 2005).

The descriptive statistics for each of the different variables for both referee groups (provincial and contender panel) were calculated. In addition, because the subjects were not randomly selected, but all participants were tested effect sizes (ES) will be used to indicate practical significant differences between the various parameters, in which $ES = (M_1 - M_2)/S_{(max)}$. Here, M_1 is the mean value for the provincial panel referees, M_2 the mean value for the contender panel referees and $S_{(max)}$ the largest standard deviation of the two test points in the comparison. Effect size is expressed as Cohen's d-value and can be interpreted as follows: $d \approx 0.20$, 0.50 and 0.80 indicate small, moderate and large practical significant differences, respectively (Steyn, 2009). The work-to-rest ratios were determined by comparing the time (duration of movement patterns) spent in the working zone to the time spent resting during the various matches (Coutts & Reaburn, 2000).

3.4 RESULTS

The results will be discussed under the following headings: movement patterns, heart rate recordings and work-to-rest ratios.

3.4.1 Movement patterns

The results for mean frequency and duration of movement patterns by referees for the different panels during the 2007 NCRC are displayed in Table 3.1. A moderate practical significant difference was found between the mean frequency of jogging (d=0.51) between the contender and provincial referees during match-refereeing. A moderate practical significant difference was also found between the mean duration of jogging (d=0.43) and sprinting (d=0.43) in the different referee panels. The provincial referees spent less time on jogging match activities compared to the provincial referees who spent more time on lateral match activities.

The results of the reliability correlation coefficient test revealed an excellent reliability for the frequency of walking (provincial $r = 0.98$ and contender $r = 0.96$) and sprinting activities (provincial $r = 0.97$ and contender $r = 0.96$) for the different referee panels. The standing still (provincial *r* = 0.94 and contender *r* = 0.94), jogging (provincial *r* = 0.91 and contender *r* = 0.93) and lateral movement activities (provincial *r* = 0.93 and contender *r* = 0.94) revealed a very good reliability for the different referee panels. The reliability correlation coefficient test revealed an excellent reliability for the duration of walking (provincial r = 0.98 and contender r = 0.96) and sprinting activities (provincial r = 0.97 and contender r = 0.96) for the different referee panels. The standing still (provincial r = 0.94 and contender r = 0.94), jogging (provincial r = 0.91 and contender r = 0.93) and lateral movement activities (provincial r = 0.93 and contender r = 0.94) revealed a very good reliability for the different referee panels.

Table 3.1: Mean frequency and duration of movement patterns completed by the different panels of rugby union referees during the 2007 National Club Rugby Championship.

Frequency (n)	**M_1**	**M_2**	**SD_1**	**SD_2**	**d-value**
Standing still	125.37	119.50	17.95	19.38	0.32
Walking	109.68	107.81	24.34	15.51	0.1
Jogging	**51.75**	**57.37**	**8.70**	**12.95**	**0.51°°**
Lateral movements	46.44	45.37	10.43	10.97	0.1
Sprinting	3.25	3	1.84	2.03	0.13
Duration (s)	**M_1**	**M_2**	**SD_1**	**SD_2**	**d-value**
Standing still	881.16	891.68	58.14	53.11	0.19
Walking	748.89	752.37	43.06	26.75	0.1
Jogging	**318.29**	**342.62**	**54.72**	**57.79**	**0.43°°**
Lateral movements	349.06	333	54.43	71.59	0.25
Sprinting	**141.60**	**122.62**	**60.53**	**21.20**	**0.42°°**

Note: M_1 – Mean for provincial panel referees; M_2 – mean for contender panel referees, SD_1 - standard deviation: provincial panel referees; SD_2 - standard deviation: contender panel referees and practical significance = °°°d ≈ 0.8 (large); °°d ≈ 0.5 (moderate) and °d ≈ 0.2 (small).

3.4.2 Heart rate recordings

Maximal heart rate: The mean MHR for provincial and contender panel referees obtained during the bleep test was 186 beats/min and 179.5 beats/min, respectively, and are displayed in Table 3.2. The statistical analysis of the data revealed a moderate practical significant difference (d=0.71) between the MHR of the referees on the different panels.

Classification of heart rate recordings: The mean time spent by the provincial (M_1) and contender (M_2) panel referees in each heart rate zone during refereeing of the 2007 NCRC matches are also displayed in Table 3.2. Large practical significant differences were found between the anaerobic threshold (d=3.68) and sub-threshold (d=1.36) heart rate zones of the referees on the two referee panels, whilst the maximal heart rate zone showed a moderate practical significant difference (d=0.43) between the referees on the different panels.

Table 3.2: Maximal heart rate (bleep test) and time spent in each heart rate zone by the different panels of rugby union referees during the 2007 National Club Rugby Championship.

Heart rate recordings (beats.min^{-1})	M_1	M_2	SD_1	SD_2	d-value
Bleep test	**186**	**179.5**	**9.13**	**11.79**	**0.71°°**
Heart rate recordings (s)	**M_1**	**M_2**	**SD_1**	**SD_2**	**d-value**
Maximal	**141.56**	**122.63**	**60.54**	**21.20**	**0.43°°**
Supra-threshold	349.06	333	54.44	71.59	0.26
Anaerobic threshold	**541.66**	**794.05**	**93.03**	**37.45**	**3.68°°°**
Sub-threshold	**976.66**	**1053.32**	**56.27**	**59.80**	**1.36°°°**

Note: M_1 – Mean for provincial panel referees; M_2 – mean for contender panel referees, SD_1 - standard deviation: provincial panel referees; SD_2 - standard deviation: contender panel referees and practical significance = °°°d ≈ 0.8 (large); °°d ≈ 0.5 (moderate) and °d ≈ 0.2 (small).

3.4.3 Work-to-rest ratios

A small practical significant difference was revealed when comparing the time spent at rest (d=0.17) and time spent at work (d=0.29) between the different referee panels. The study revealed a work-to-rest ratio of 1:4 for both provincial and contender panel referees.

3.5 DISCUSSION

To the knowledge of the research team, this is the first study where different panels of rugby refereeing are being compared. However, the results of this study should not be generalised as the study population is not a randomised sample of referees from the SARRA panels. The difference in the mean frequency and duration during match-refereeing for the different panels as displayed in Table 3.1 may be attributed to the following reasons: a) referee experience - the study revealed that that the contender panel referees completed more jogging activities during match-refereeing. Jogging would mostly be used by referees to "*run through the tackle*", a term used by referee coaches to improve anticipation during match-refereeing. Martin *et al*., 2001 stated that experienced referees tend to move less because they anticipate play better; b) the aerobic fitness levels of the contender panel referees - they completed more jogging activities and also spent more time on this type of activity during match-refereeing when compared to provincial referees. The study also revealed that the contender referees spent less time on sprinting activities. The contender panel referees also performed weaker in bleep tests and this can indicate that fitness could be the reason for the findings and this could be an indication of lower fitness levels in this group of referees; c) the intensity and different activities (types of play) completed by the teams may have contributed to a difference in results between the two referee panels, as the teams played different teams on different game days – more rucks may have occurred in the latter part of the match thus forcing referees to make more use of low intensity activities. In this regard, Docherty *et al*., 1998 found that the intensity of different activities decreased as matches neared full-time; and d) fatigue - the tournament took place over seven days with a rest day in between game days. Thus, fatigue could have influenced the referees' performance on match days.

The results of the MHR as displayed in Table 3.2 show that the provincial panel referees obtained a higher MHR and performed better during the bleep test. The difference can perhaps be attributed to the better aerobic fitness levels of the provincial referees, as the contender panel referees performed worse on the bleep test (11.5) compared to the provincial panel referees (12.7). The results also indicate that the contender panel referees spent more time in the low intensity heart rate zone (anaerobic threshold and sub-threshold) than in the high intensity zones (supra-threshold and maximal). The study found large practical significant differences between the anaerobic threshold and sub-threshold heart rate zones and a moderate significant difference between the maximal heart rate zone of the referees on the different panels. This can probably be attributed to the following reasons: a) a lower fitness level of the contender panels, as the same tendency was revealed for the frequency and duration of completed match activities during match-refereeing. They also performed worse in the bleep test and MHR; b) the positioning of referees during match-refereeing as more experienced referees tend to move less and anticipate play better; c) the impact of fatigue as the four games were refereed during seven days with a rest day in between; and d) the time at which the game took place so the temperature might have influenced the completion of movement patterns by the referees and players. Achten and Jeukendrup (2003) states that any activity that takes place in heat will lead to HR increase of the participant.

No significant difference was revealed when comparing the work-to-rest ratios of the different referee panels. The provincial and contender panel referees had a work-to-rest of 1:4 during match-refereeing, thus indicating that TMA and HRR are better methods to determine the physiological demands placed on referees during match-refereeing, as the two mentioned methods revealed differences between the two panels and gave a more comprehensive picture of the demands placed on the referees.

3.6 CONCLUSION

In conclusion the study firstly revealed that match-refereeing is a multi-movement type of activity and all these components should be included in testing and conditioning protocols. Secondly, that there is a difference between the physiological demands (frequency, duration and intensity of movement patterns) placed on different referee panels during match-refereeing, which therefore indicates that testing protocols and conditioning programmes should be constructed in line with the level of competition. Since the game turned professional, any information on how to improve match-specific programmes and training drills for rugby union referees can be useful, as this will prepare them to comply better with the physiological demands posed on them during match-refereeing.

The researchers identified certain limitations regarding this study. Firstly, the sample size was quite small and the findings are not representative of the physiological load placed on referees in South Africa as a whole, but only of those who participated in the study. Secondly, the research took place during one week. The ideal would be to assess referees over a course of a season on their selected competition level as well as to determine the effect fatigue levels that may develop and have a possible influenced on the data and study findings. Lastly, the level of competition should also be considered. There was quite a big gap between the qualities of the teams who participated in the study.

The results of this study emphasise the importance of further research regarding the physiological load imposed on rugby union referees during match-refereeing. Future studies should not only be limited to the physiological demands (using GPS systems) imposed on referees during match-refereeing, but should also give attention decision-making and accuracy skills of rugby referees.

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CHAPTER 4

ARTICLE 2: TIME-MOTION ANALYSIS AND HEART RATE RECORDINGS OF SOUTH AFRICAN RUGBY UNION REFEREES

The chapter is herewith included according to the guidelines of the African Journal for Physical, Health Education, Recreation and Dance (included as Appendix B). Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation. Note, that the tables will be included in the article for the purpose of the dissertation. This article has been accepted for publication in the December 2011 issue of the African Journal for Physical, Health Education, Recreation and Dance.

TIME-MOTION ANALYSIS AND HEART RATE RECORDINGS OF SOUTH AFRICAN RUGBY UNION REFEREES

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TIME-MOTION ANALYSIS AND HEART RATE RECORDINGS OF SOUTH AFRICAN RUGBY UNION REFEREES

Abstract

The objective of this study was to compare the two halves of the match with regard to the frequency, duration and intensity of the different movement patterns and the work-to-rest ratios of various South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007. The referees were monitored by means of a video camera in 16 matches during a tournament. The frequency and duration of the different movement patterns (standing still, walking, jogging, lateral movements and sprinting) during each half of the matches were analysed using the Dartfish TeamPro software package. Heart rate (HR) was recorded to determine the intensity of the movement patterns by a Suunto Team pack monitor system. A large practical significance difference was found between the mean frequency for standing still (d=2.53), walking (d=2.50), jogging (d=2.42), lateral movements (d=2.86) and sprinting (d=1.31), as well as for the mean duration for standing still (d=2.05), lateral movements (d=0.76) and sprinting (d=0.77) between the two halves of match refereeing. The intensity displayed a large practical significant difference between the time spent in the maximal (d=2.07), anaerobic threshold (d=0.92) and sub-threshold (d=7.90) heart rate zones between the two halves. The first and second halves had a work-to-rest ratio of 1:3.5 and 1:5 respectively. The study revealed that several of the measures for movement patterns increased significantly during the second half.

KEY WORDS: Time-motion analysis; Heart rate recordings; Rugby Union

4.1 INTRODUCTION

Rugby union (hereafter referred to as rugby) referees are responsible for consistency, control and maintaining the flow in matches (International Rugby Board, 2009). Since Rugby Union turned professional in 1995, there has been an increased demand on the standard of refereeing (Mascarenhas, Collins & Mortimer, 2005). According to Seneviratne (2003/04) referees need to be physically fit to keep up with the intensity of play and also be able to apply the laws of the game accurately (Mitchelmore, 2004). Inaccurate decision-making by rugby union referees can change the course of a game, and may even lead to significant financial implications for the clubs, players and coaches (Mascarenhas, *et al*., 2005; *Beeld*, 2010). Cochrane, Kelly and Legg (2003) stated that during a match, referees need to be in a position on the field which allows them to make the correct interpretation/decision – thus placing demands on their fitness. The International Rugby Board (IRB) has put an international test battery in place and it is required that all referees need to successfully complete this test battery throughout the year to show the necessary fitness levels to referee the games (Honis, 2006). The test battery consists of anaerobic (in the absence of oxygen) and aerobic (in the presence of oxygen) fitness tests (Watson, 2007). If referees do not perform well during matches, their poor performance (assessed by an appointed performance reviewer) has significant implications for them (e.g. lose position on panels or can be withdrawn from future games (*Die Burger*, 2010)

Dotter (1998) suggested that the duration, frequency and intensity of the movement patterns completed during a game need to be considered before the fitness levels of participants are assessed. Deutsch, Maw, Jenkins and Reaburn (1998) supported this statement by claiming that an accurate time-motion analysis (TMA) in conjunction with heart rate recordings (HRR) would provide a more comprehensive picture of the physiological demands on rugby participants. By wearing heart rate monitors during exercise or competition, the actual heart rate values attained by participants can therefore be compared to prescribed values to determine the participants heart rate values (Parker, 1999). These results can be used to determine a training heart rate which the referees can use as a benchmark during their training (Cochrane *et al*., 2003). Deutch *et al.* (1998) concluded that the duration and frequency of events during match-play also need to be analysed to make a more exact prediction of participants' fitness levels. They proposed that an accurate TMA should be performed to get an indication of the participant's movement patterns and work-to-rest ratios on the field during match-play. Krustrup, Mohr and Bangsbo (2002) stated that the possibility of fatigue during the match can also be detected by comparing data of heart rate recordings and movement patterns during the two different halves of the match. Due to the lack of research comparing the physiological demands placed on rugby union referees between the two halves, the authors found the suggestion of Krustrup *et al.* (2002) useful as this will provide a comprehensive picture of the demands placed on rugby union referees during match-refereeing.

To the researcher's knowledge, there are only two previous studies that focused specifically on TMA analyses of rugby referees. Martin, Smith, Tolfrey and Jones (2001) found that English Premiership Rugby Union referees cover a total distance of 668 meters during a match. In analysing their movement patterns during match-refereeing, they found that on average during an 80-minute rugby match, they stand still for 37 % of the time, walk for 39.4 %, jog for 12.8 %, run for 9.8 % and sprint for 1.0 % of the time. They also found no significant difference between the duration of match activities and the distance covered during the two halves of the matches. Similarly, Cochrane *et al*. (2003) found that New Zealand Rugby Union (NZRU) referees spent on average 1.2% of the game at maximal sprinting, 6.7% at moderate sprinting, 15.2% on jogging, 20.5% on walking, 4.8% on moving sideways, 3.5% on turning, 32.9% on remaining stationary, 12.6% on moving backwards slowly and 2.6% on moving backwards fast. As far as intensity of the movement patterns is concerned, Cochrane *et al*. (2003) also found that on average the rugby union referees spent 10% of a match at their maximum, 43% at supra-threshold, 36% at anaerobic threshold and 11% at sub-threshold heart rate zones. They also reported that the mean work-to-rest ratio was 1:5. There was however no indication whether the movement patterns or the work-to-rest ratio differed between the two halves of match-refereeing.

Due to the limited amount of research done on rugby union referees worldwide, the researchers found it necessary to determine the physiological demands placed on referees during match-refereeing as this will assist rugby union referees, coaches and sport scientists in constructing referee-specific training programmes and protocols so that referees can comply with the physiological demands of the game. However, the results of studies on soccer and rugby league in this regard might be applicable to rugby union (Gabbett, 2007). Studies that focused on the physiological demands of soccer referees, found that a) on average the soccer referees cover between 9 and 13 kilometres per match (Castagna, Abt & D'ottavio, 2007), b) the level of aerobic performance ability positively influenced the quality of the performances on the field (Bellafiore *et al*., 2005) and c) soccer referees mostly relied on the aerobic energy system (Castagna & D'Ottavio, 2001). Results of studies that focused on the physiological demands of rugby league referees, found that the referees covered 6.7 kilometres per match (Kay & Gill, 2003; Kay & Gill, 2004). These authors also found a work-to-rest ratio of 2:1 across the matches and that match-refereeing may be significantly anaerobic in nature. The named studies did, however, not look at the development of fatigue during the progression of the match during the two halves, which may provide researchers with a better understanding of the fitness requirements of match-refereeing.

Therefore the physiological demands placed upon rugby referees between the two halves of match-refereeing, as indicated by the frequency, duration and intensity of movement patterns are not well known. Consequently, the objective of this study was to compare the two halves of the match with regard to the frequency, duration and intensity of the different movement patterns and the work-to-rest ratios of various South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007.

4.2 METHODS

4.2.1 Research design

The design of this study was an observational, descriptive and ex post facto design.

4.2.2 Participants

All the (N=8) referees who participated in the 2007 National Club Rugby Championship (NCRC) tournament held in Stellenbosch served as test subjects in this study. The referees had to be injury-free as well as complete a demographic questionnaire consisting of: geographic information, training habits, medical information and referee data to participate in this study. Written and verbal permission were obtained from the South African Rugby Referee Association (SARRA) as well as from each rugby union referee who voluntarily agreed to participate in the research. Based on the level of experience, these eight participating referees (mean age 29.75 ± 6.3 years and an average of 5.75 ± 2.2 years experience) were all affiliated to the SARRA. Ethical approval (included as Appendix E) was obtained from the North-West University (NWU-00019-11-S2).

4.2.3 Data collection procedures

4.2.3.1 Video analysis

Video recordings: The referees were monitored during a total of 16 matches (each half was recorded separately). Video recordings were made by using one video camera for each match.

Motion analysis: The video data of the various games were downloaded onto a computer by means of the Dartfish 5.5 TeamPro (5.0.20909.0) software package. Subsequently, the data were analysed by an experienced motion analyser. The time each referee spent on the different movement patterns (standing still, walking, jogging, lateral movements and sprinting) during each half of the game, was analysed by the tagging and analyser functions of the Dartfish 5.5 TeamPro (5.0.20909.0) software package.

Reliability: According to Hopkins (2000), reliability refers to the reproducibility of values of a test, in repeated trials on the same individuals. The reliability of the movement patterns was tested by using an intra-reliability method. The method entails that the analyser does a reanalysis of the video material one month after the original analysis. For the purpose of this study, 25% of the standing still, walking, jogging, lateral movements and sprinting activities of the two halves was analysed twice. The Pearson product moment correlation was calculated to assess the reliability of the analysis.

4.2.3.2 Heart rate recordings

Maximal heart rate (MHR): To determine the individual maximal heart rate, the referees were fitted with a heart rate monitor, chest strap and wrist watch (Suunto t4 Team Pack and Smartbelt) prior to the start of the aerobic endurance test (multi-stage bleep test). The multi-stage bleep test in this study was identical to the one described in Ramsbottom, Brewer and Williams (1998). The highest heart rate value of the test was used as the MHR. The highest level of the test at which the MHR was attained was also recorded.

Match heart rate recordings: Ten minutes prior to the kick-off of every match, each referee was fitted with a heart rate monitor, chest strap and wrist watch (Suunto t4 Team Pack and Smartbelt). Ten minutes after the completion of the match the heart rate monitors were removed and the recorded heart rate data for each half were downloaded separately to a laptop by means of the Suunto Team Manager Software. This enabled the researchers to determine the intensity of the referees' movement patterns during the matches and to correlate this recording with their predetermined maximum heart rate (MHR).

Classification of heart rate recordings: The recorded heart rate readings of each rugby referee were used to classify the movement patterns during the matches in accordance with the four heart rate zones as stipulated by Deutch *et al*. (1998). These zones are: 1) maximal (>95% of MHR), 2) supra-threshold (85-95% of MHR), 3) anaerobic threshold (75 – 84% of MHR) and 4) sub-threshold (<74% of MHR).

4.2.3.3 Work-to-rest ratios

The type and duration of the different movement patterns were used to calculate the work-to-rest ratios of the rugby union referees during match play in accordance with the classification by Coutts and Reaburn, (2000) and O'Donoghue *et al*. (2005). The work-to-rest ratio for each half was determined by comparing the time spent working to the time spent resting (Coutts & Reaburn, 2000; O'Donoghue *et al.,* 2005).

4.2.4 Data analysis

The Statistical Consultation Services of The North-West University, Potchefstroom Campus, South Africa assisted with the data analysis by using the Statistical Data Processing package (Statsoft Inc., 2009). For the purpose of this study the researchers used mixed-method methodology which combined qualitative and quantitative research approaches (De Vos et al., 2005).

The descriptive statistics were calculated for each of the different variables for both halves of the matches. In addition, because the subjects were not randomly selected, effect sizes (ES) were used to indicate practical significant differences between the various parameters measured during each half, in which ES = $(M_1 - M_2)/S_{(max)}$. Here, M_1 is the mean value for the first half, M_2 the mean value for the second half and $S_{(max)}$ the largest standard deviation of the two test points in the comparison. Effect size is expressed as Cohen's d-value and can be interpreted as follows: $d \approx$ 0.20, 0.50 and 0.80 indicate small, moderate and large practical significant differences, respectively (Steyn, 2009). The work-to-rest ratios were determined by comparing the time (duration of movement patterns) spent in the working zone to the time spent resting during the various matches (Coutts & Reaburn, 2000).

4.3 RESULTS

The results of the reliability correlation coefficient test revealed an excellent reliability for standing still (1^{st} $r = 0.96$ & 2^{nd} $r = 0.97$) and sprinting activities (1^{st} $r = 0.95$ & 2^{nd} $r = 0.98$) for the first and second half respectively. The walking (1^{st} $r = 0.94$ & 2^{nd} $r = 0.92$), jogging (1^{st} $r = 0.93$ & 2^{nd} $r = 0.90$) and lateral movement activities (1^{st} $r = 0.91$ & 2^{nd} $r = 0.94$) revealed a very good reliability between the first and second half of match-refereeing.

4.3.1 Movement patterns

The results for the mean frequency and duration of the various movement patterns performed by the rugby referees during the two halves of the matches are displayed in Table 4.1. Large practical significant differences between the values of the two halves were found for the mean frequency in standing still (d=2.53), walking (d=2.50), jogging (d=2.42), lateral movements (d=2.86) and sprinting (d=1.31). The mean duration of the various movement patterns also revealed large practical significant differences for standing still (d=2.05), sprinting (d=0.77) and lateral movements (d=0.76) performed in the two halves, whilst walking and jogging movements did not differ significantly between the two halves of the matches.

TABLE 4.1: **MEAN FREQUENCY AND DURATION OF MOVEMENT PATTERNS COMPLETED BETWEEN THE TWO HALVES OF RUGBY UNION REFEREEING DURING THE 2007 NATIONAL RUGBY CHAMPIONSHIP**

Frequency (n)	**M_1**	**M_2**	**SD_1**	**SD_2**	**d-value**
Standing still	**108**	**137**	**7.46**	**14.99**	**2.53°°°**
Walking	**91**	**124**	**7.10**	**17.91**	**2.50°°°**
Jogging	**46**	**64**	**6.41**	**8.75**	**2.42°°°**
Lateral movements	**37**	**53**	**5.48**	**6.07**	**2.86°°°**
Sprinting	**4**	**2**	**1.96**	**1.07**	**1.31°°°**
Duration (s)	**M_1**	**M_2**	**SD_1**	**SD_2**	**d-value**
Standing still	**859**	**930**	**45.80**	**21.23**	**2.05°°°**
Walking	736.5	748	32.75	38.92	0.33
Jogging	346	337	41.80	69.42	0.16
Lateral movements	**372**	**331**	**23.98**	**74.58**	**0.76°°°**
Sprinting	**138.5**	**103**	**66.06**	**12.97**	**0.77°°°**

Note: M_1 – Mean for the first half; M_2 – mean for the second half, SD_1 - standard deviation: provincial panel referees; SD_2 - standard deviation: contender panel referees and practical significance = °°°d ≈ 0.8 (large); °°d ≈ 0.5 (moderate) and °d ≈ 0.2 (small)

4.3.2 Heart rate recordings

Maximal heart rate: The mean MHR for SARU referees obtained during the multi stage bleep test was 182.75 ± 10.36 beats/min.

Classification of heart rate recordings: The mean time the referees spent in each heart rate zone during the first half (M_1) and the second half (M_2) is displayed in Table 4.2. A large practical significant difference was found between the time spent in the maximal (d=2.07), anaerobic threshold (d=0.92) and sub-threshold (d=7.90) heart rate zones during the two halves of match-refereeing. No significant difference was, however, found for the time spent by the referees in the supra-threshold heart rate zone during the two halves of the rugby matches.

TABLE 4.2: **MEAN TIME SPENT IN EACH HEART RATE ZONE BETWEEN THE TWO HALVES OF RUGBY UNION REFEREEING DURING THE 2007 NATIONAL CLUB RUGBY CHAMPIONSHIP**

Time spent in different HR zones (s)	M_1	M_2	SD_1	SD_2	d-value
Maximal	**1153**	**1232**	**45.89**	**28.91**	**2.07°°°**
Supra-threshold	1178	1197	52.40	60.27	0.34
Anaerobic threshold	**372**	**324**	**23.98**	**73.56**	**0.92°°°**
Sub-threshold	**179**	**105**	**5.77**	**12.53**	**7.90°°°**

Note: M_1 – Mean for the first half; M_2 – mean for the second half, SD_1 - standard deviation: provincial panel referees; SD_2 - standard deviation: contender panel referees and practical significance = °°°d ≈ 0.8 (large); °°d ≈ 0.5 (moderate) and °d ≈ 0.2 (small)

4.3.3 Work-to-rest ratios

In analysing the work-to-rest ratios between the two halves of match-refereeing it was found that the ratio was 1:3.5 for the first half and 1:5 for the second half, respectively. In comparing the ratios between the two halves, a moderate practical significance was found between the time spent at rest (d=0.62) and the time spent at work (d=0.62) of match-refereeing.

4.4 DISCUSSIONS

The results in Table 4.1 also indicate that the rugby referees performed less sprinting activities and more standing still, walking, jogging and lateral movement activities in the second half of match-refereeing. The difference observed in the second half may be attributed to a) aerobic and anaerobic fitness levels of the referees as they didn't comply to the physiological demands placed on them over a 80-minute of match-refereeing; b) fatigue and insufficient recovery of players' in the second half of match-play and possibly the fatigue during the week tournament, thus impacted the game by creating more breakdowns (tackle, rucks and mauls). This forced the referees to make use of more standing still, walking, jogging and lateral movement activities, as a referees approach to a tackle would see referee jog within five meters of a tackle, ruck or maul and they would then position themselves by using lateral movements in order to locate the ball. Once that was completed, they would walk towards the defending team, check offside lines and move as the ball is cleared from the tackle, ruck or maul; and c) insufficient recovery and fatigue of referees during the second half of match-play, it can be that they didn't recover fully during the break between the two halves of match-refereeing as well as the fatigue factor during the week tournament. Due to the lack of research on this topic it is difficult to compare the results to other studies, however, the same trends regarding frequency and duration of movement patterns were observed between the two halves of match-refereeing in the analysis of soccer referees (Castagna *et al*., 2007).

The mean time the referees spent in each heart rate zone during the first half (M_1) and the second half (M_2) is displayed in Table 4.2. The findings in Table 4.2 can probably be attributed to a) insufficient heart rate recovery after completion of a high intensity movement pattern, as they spent more time in the maximal intensity heart rate zone in the second half of match-refereeing; b) the effect of fatigue since the NCRC was played within a week tournament and a knock-out basis, thus placing higher match-refereeing demands on the referees; c) the experience of the referees as more experienced referees tend to move less and anticipate play better, thus spending more time in the low intensity heart rate zones. The same trends (time spent in different heart rate zones) of change between the anaerobic threshold and aerobic threshold heart rate zones during the two halves found in this study were also reported by Cochrane *et al*. (2003) regarding rugby referees, Krustrup and Bangsbo (2001) on soccer referees and Kay and Gill (2004) on rugby league referees. These results cannot, however, be used to indicate an increase in fatigue experienced by the referees during the second half of match-refereeing, since it was indicated that they were able to work at higher intensity levels for a longer period of time during the second half.

No research could be found where the work-to-rest ratios of the two halves in rugby match-refereeing or for other sport code officials were compared. The results cannot, however, be used to indicate an increase in fatigue of the referees during the second half of match-refereeing.

4.5 CONCLUSIONS

Based on an extensive literature review, this is the first study that compared the physiological demands of rugby refereeing during two halves of a match. The study revealed that several of the measures of movement patterns increased significantly during the second half of match refereeing. It can however not be concluded that fatigue set in during the second half of match-refereeing, since not all of the parameters measuring movement patterns showed the same change (increase or decrease) from the first to the second half of the matches. However, the results of this study revealed that the aerobic fitness components of the referees need to improve for them to comply with the physiological demands placed on them during the match. The modern game is faster, more technical and the ball is now longer in play. Consequently, the game demands better and fitter referees than ever before.

The research identified the following limitations: firstly the small sample as it only represented the referees who participated in this study; and secondly, the referees were monitored during a weekly tournament and the effect of fatigue and insufficient recovery could have influenced the findings of the study .

Future studies should be conducted in this field by a) involving a bigger sample (all the national, provincial and contender panel referees); b) using a GPS unit to determine the movement patterns and heart rate recordings (duration, distance and intensity); and c) incorporating the results of the referees' pre-season fitness testing to determine if the testing protocol complies with the demands placed on the referees in the two halves of match-refereeing.

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CHAPTER 5

SUMMARY, CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

The chapter is herewith included according to the guidelines of the North-West University. Subsequently, the referencing style used in this chapter may differ from that used in the rest of this dissertation.

5.1 SUMMARY

5.2 CONCLUSIONS

5.3 LIMITATIONS

5.4 FUTURE RESEARCH

5.1 SUMMARY

A relatively small amount of published literature exists on rugby union referees during match-refereeing. This dissertation sought to provide a detailed analysis of physiological demands of selected rugby referees in South Africa and also to determine if any differences exist across the different panels and halves of match-refereeing. The first objective of this dissertation was to determine the frequency, duration and intensity of movement patterns and work-to-rest ratio of different refereeing panels of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007. The second objective was to compare the two halves of the match with regard to the frequency, duration and intensity of the different movement patterns and the work-to-rest ratios of various South African Rugby Union referees during match-refereeing at the National Club Rugby Championship in Stellenbosch during 2007.

This dissertation was presented in four main parts, namely an introduction and problem statement (Chapter 1), a literature review (Chapter 2) and two research articles (Chapters 3 and 4). The article format of the dissertation has been approved by the Senate of the North-West University and the two research articles were presented in accordance with the guidelines of the specific journals. Chapter 1 introduced the problem and stated the objectives and hypotheses of this study.

The literature review (Chapter 2) focused on performance analysis of team sports' participants. The chapter highlighted that the use of technology to analyse participants' performances will no doubt continue to move forward in the way it has done already over the past few years, and that video-based TMA provides researchers a less expensive but effective method to conduct TMA research on rugby participants during match-refereeing. GPS is another less expensive method that can be used to conduct TMA research on participants during training and competition. This method allows researchers to use a bigger sample group and will provide a comprehensive picture of the physiological demands placed on participants during training and competitions. The chapter also highlighted certain limitations of TMA research.

Chapter 3 is in a research article format entitled: *Analysis of movement patterns and heart rate recordings of South African Rugby Union referees during match-refereeing***.** This article was published in the International Journal of Performance Analysis in Sport, 11(2), 344-355.

The results revealed a moderate practical significant difference (d=0.51) between the frequency of jogging movement patterns for the two referee panels.

A moderate practical significant difference was also found between the duration of jogging (d=0.43) and sprinting (d=0.43) movement patterns of the two referee panels. The intensity of the movement patterns by the two levels of rugby referees showed large practical significant differences between the anaerobic threshold (d=3.68) and sub-threshold (d=1.36) levels and a moderate practical significant difference for the maximal (d=0.43) heart rate zones. Both the provincial and contender panel referees had work-to-rest ratios of 1:4 during match-refereeing. The study revealed that there is clear difference in the demands placed on the different panels of refereeing during match-refereeing. It also concluded that match-refereeing is a multi-movement activity and all the components should be considered by sport scientists and rugby referee coaches when trying to improve referee fitness levels, developing match-specific training programmes and testing protocols.

Chapter 4 is a second research article entitled: *Time-motion analysis and heart rate recordings of South African Rugby Union referees*. This article has been accepted for publication in the December 2011 issue of the African Journal for Physical, Health Education, Recreation and Dance.

In comparing the two halves of rugby match-refereeing, a large practical significant difference was found between the mean frequency of movement pattern values for standing still (d=2.53), walking (d=2.50), jogging (d=2.42), lateral movements (d=2.86) and sprinting (d=1.31), and a large practical significant difference for the mean duration of movement pattern values for standing still (d=2.05), lateral movements (d=0.76) and sprinting (d=0.77)**.** A large practical significant difference was found between the time spent in the maximal (d=2.07), anaerobic threshold (d=0.92) and sub-threshold (d=7.90) heart rate zones measured during the two halves of match-refereeing. A work-to-rest ratio of 1:3.5 and 1:5 was found for the first and second half of rugby match-refereeing respectively. The study revealed that several of the measures of movement patterns increased significantly during the second half of match refereeing. It can however not be concluded that fatigue set in during the second half of match-refereeing, since not all of the parameters measuring movement patterns showed the same changes (increase or decrease) from the first to the second half of the matches.

In summary, the game of Rugby Union has transformed into a very fast and running game that requires and deserves referees that can keep up with the game. By carrying out fitness tests we can accurately benchmark and rank referees on their fitness and use it as a selection tool. It will also ensure that referees work hard at building their fitness through a structured training programme. If a referee is not in the right position it becomes very difficult to be sure you make the right decision.

5.2 CONCLUSIONS

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

Hypothesis 1: There are practical significant differences between provincial and contender panel referees with regards to the frequency, duration and intensity of movement patterns and work-to-rest ratio of South African Rugby Union referees during match-refereeing at the National Club Rugby Championship.

Hypothesis 1 was partially accepted with regards to the *mean frequency* of jogging movement patterns (0.51 – moderate practical significance), *mean duration* of jogging (0.43 – moderate practical significance) and sprinting (0.42 – moderate practical significance) movement patterns and *mean intensity* of the maximal heart rate during the bleep test (0.71 – moderate practical significance) and for time spent in maximal (0.43 – moderate practical significance), anaerobic threshold (3.68 – large practical significance) and sub-threshold (1.36 – large practical significance) heart rate zones.

Hypothesis 2: The frequency, duration, intensity and work-to-rest ratios of the different movement patterns of various South African Rugby Union referees during match-refereeing at the National Club Rugby Championship will not differ significantly when the two halves of match-refereeing are compared.

Hypothesis 2 was partially accepted with regards to *mean duration* of walking and jogging movement patterns and *mean intensity* of time spent in the supra-threshold zone. The study revealed no clear practical significance for these movement activities.

5.3 LIMITATIONS

Certain limitations regarding this study can be indicated:

- Firstly, the sample size was quite small. The findings can therefore not be representative of the physical demands placed on referees in South Africa as a whole but only of those who participated in the study. It would therefore be ideal to investigate all the panels of refereeing in South Africa on different competition levels (national, provincial, contender, women's and assistant referees) as it will provide a broader picture of the physical demands on the different refereeing panels in South Africa.
- Secondly, the research took place during one week. The ideal would be to assess referees over a course of a season on their selected competition level as well as to determine the fatigue levels that may develop and have a possible influence on the data and study findings.
- Lastly, the level of competition should also be considered. There was quite a big gap between the quality of rugby when the open clubs competed against the university teams, which could have an effect on the study results. The ideal would be to assess the referees on the level which he/she referees, for example the provincial referees on the Varsity Cup and the contenders on the Varsity Shield.

5.4 FUTURE RESEARCH

The results of this study emphasise the importance of further research regarding the physiological demands imposed on rugby union referees during match-refereeing, as there is clearly a shortage of literature that focuses on this research topic. Future studies should not only be limited to the physiological demands (using GPS systems) imposed on referees during match-refereeing, but should also give attention to the impact on the referees' decision-making abilities. The results of the pre-season testing should be incorporated to determine if the test protocol complies with the physiological demands of the game.

The debate on whether physical fitness does indeed have an effect on the referees' ability to make correct decisions should also be researched.

APPENDIX A

Instructions for Authors: International Journal of Performance Analysis in Sport

1. Scope

The International Journal of Performance Analysis in Sport is published on behalf of the Centre for Performance Analysis, School of Sport, PE and Recreation, UWIC, and in association with the International Society of Performance Analysis. The emphasis is on the analysis of performance in sport and exercise. Topics covered also include technologies such as design of analysis systems, sports equipment, research into training, and modelling and predicting performance; papers evaluating (rather than simply presenting) new methods or procedures will also be considered.

2. Submission

Authors must submit an original article in electronic form, (preferably by e-mail) in Microsoft Word 97, 98 or 2000, to the General Editor (see the editorial board list). Papers submitted to The Journal will be refereed blind by acknowledged experts in the subject; at least two such referees will be involved in this process. In the event of conflicting reviews, the Editor will normally seek a further independent review. The General Editor has the final decision on publication. No word limits are specified for papers, but discursive treatments of the subject matter are discouraged. Submissions in two or more parts will not be accepted unless the General Editor has agreed this in advance. As well as normal length communications of original research, shorter communications are also considered subject to the same refereeing process. Review papers will normally be by invitation of the General Editor; authors wishing to submit a review paper are advised to consult the General Editor before doing so. Book reviews are by invitation only. The Journal does not normally publish letters to the editor.

3. Originality

All material submitted for publication in the Journal must be accompanied by a statement by the lead author, with the authority of all of the authors, making it clear that: the material submitted is original and unpublished, and is not under consideration for publication elsewhere; the material will not be submitted for publication elsewhere while it is under consideration for publication in the International Journal of Performance Analysis in Sport; if accepted for publication in the eIJPAS, the material will not be submitted elsewhere for publication, either in part or in whole, without the written consent of the General Editor. Material submitted will not enter the refereeing process until such an undertaking has been received.

4. Effective Communication

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. The writing should conform to the recommendations of any of the excellent texts on good style in scientific writing (e. g. M. O'Connor, 1991, Writing Successfully in Science. London: Chapman & Hall). 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. 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.

5. Article

a. General

The article must be in English; UK English spellings and words should be used in preference to other versions of English. It must be in Times New Roman size 12 font throughout, fully justified, with a 3 cm margin on both sides, with pages numbered consecutively, with no line numbering and no 'headers and footers' (other than page numbers), and without footnotes unless these are absolutely necessary. Arrange the article under headings (such as Introduction, Methods, Results, Discussion, Conclusions) and subheadings. Generally the Journal style and format conform to the CBE Manual for Authors, Editors and Publishers (Council of Biology Editors, 1994, Scientific Style and Format. Cambridge: Cambridge University Press); authors are advised to consult that publication in case of difficulty. The Editors cannot consider for publication papers that are seriously deficient in presentation or that depart substantially from these 'Notes and Guidelines'. (See previous issues of eIJPAS).

b. Blind refereeing

Papers will be reviewed by a process of blind refereeing.

c. Title page

Include the following information on the first page of the article: the full title; a running title of no more than 75 characters and spaces; and up to six keywords for indexing purposes.

d. The abstract

The abstract must not exceed 200 words and it must summarize the paper, giving a clear indication of the conclusions it contains. It should be inserted in the article after the Authors' addresses, indented by 1 cm. from both sides of the normal text (i.e. 4 cm. margin in total), in bold and in italics. The abstract must not contain figures or tables.

e. Tables and illustrations

Illustrations, plates, tables and any other artwork should be included in the electronic submission if possible. If this is not possible then they must accompany the article in electronic form either as email attachments or on disk. In this case, authors may wish to express a preference for the location of tables and figures by including comments such as ****Table 1 near here**** or ****Figure 2 near here**** separated by at least one line space from the main text. Tables, referred to as 'Table 1', 'Table 2', and so on, must be numbered in the order in which they occur in the text. Tables must be clearly and simply laid out with clear row and column legends, units where appropriate, no vertical lines and horizontal lines only between the table title and column headings, between the column headings and the main body of the table, and after the main body of the table. Photographs and line drawings, referred to as 'Figure 1', 'Figure 2', and so on, must be numbered in the order in which they occur in the text.

f. Symbols, units and abbreviations

Symbols, units and abbreviations in papers must conform to the Système International d'Unités (SI Units). Authors are advised to consult the National Physical Laboratory publication (R.J. Bell (ed.), 1993, SI: The International System of Units. London: HMSO). For all abbreviations other than units, write the word or words to be abbreviated in full on the first mention followed by the abbreviation in parentheses. If at all possible, group these definitions together near the beginning of the article. As indicated earlier, avoid use of nonstandard abbreviations, especially fabricated ones, within the text; words are much easier to read and follow than abbreviations. When numeric values are given, a space must appear between the number and unit, as in 95.6 W and 25.0 N (exceptions are angles in degrees, e.g. 23.5o, and percentages, e.g. 15%). Separate compound units by a dot (N.m) and not by a space (N m); a compound unit formed from others by division should be indicated, for example, as ml. min-1 not as ml/min. Angular velocities should be expressed in rad.s-1. Some exceptions to the use of the SI are allowed, for example for heart rate (beats. min-1) and blood or gas pressure (mmHg). Other units and abbreviations should conform to Bell (1993) or Council of Biology Editors (1994). Scalar variables or constants that are represented by a single letter should appear in italics (e. g. v, k, x). Where the abbreviation is of more than one letter (excluding suffices orsuperficies), it should be set in Roman typeface, as should abbreviations of mathematical functions (thus a = dv / dt).. Vectors should be indicated in bold and italics (e. g. F, v). For further and more detailed examples, authors should consult

Council of Biology Editors(1994).Equations and formulae should, wherever possible, be presented on one line: for example: use v = (dP/dt)/a rather than v = dP dt a

Statistical definitions and symbols should conform to ISO3534(1977) summarized briefly inCouncil of Biology Editors (1994).

g. References

The Journal uses one of several variations of the Harvard system. The following examples should make clear the most important points. References in the text are cited as follows: Smith (1985) ... or (Brown and Green, 1996) ... or, if there are more than two authors, as Jones et al. (1993) ... or (Jones et al. , 1993). Citations of different publications by the same author(s) are differentiated as Green (1993a) ... (Brown et al. , 1995b); the a, b, c, etc. , are normally in order of citation in the text. Multiple citations are listed in ascending chronological order. Within a year, they are organized in alphabetical sequence of the first author. Examples: Smith (1995), Brown and Green (1996), Jones et al. (1996); or (Smith, 1995; Brown and Green, 1996; Jones et al., 1996). The following should make clear how multiple publications by the same authors are treated in such lists: Smith (1991, 1995),

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

Books

Zatsiorsky, V.M. (1995). Science and Practice of Strength Training. Champaign, IL: Human Kinetics.

Journals (Papers or Abstracts)

Elliott, B., Marshall, R. and Noffal, G. (1996). The role of upper limb segment rotations in the

development of racket head speed in the squash forehand. Journal of Sports Sciences, 14,159:165.

Chapters in Books

Stephenson, D.G., Lamb, G.D., Stephenson, G.M.M. and Fryer, M.W. (1996). Mechanisms of excitation/contraction coupling relevant to skeletal muscle fatigue. In Fatigue: Neural and Muscular Mechanisms (edited by S.C. Gandavia, R.M. Enoka, A.J. McManus, D.G. Stuart and C.K. Thomas), pp. 45-56. New York: Plenum Press.

Chapters in Published Books of Conference Proceedings or Abstracts

Howe, B.L. and Bell, G.J. (1986). Mood states and motivation of triathletes. In Sports Science: Proceedings of the VII Commonwealth and International Conference on Sport, Physical Education, Dance, Recreation and Health (edited by J. Watkins, T. Reilly and L. Burwitz), pp. 273-278. London: E & FN Spon.

The issue number of a journal should be included only to avoid confusion, as when for example the pagination starts from 1 in each issue rather than being continuous across a volume; in such cases use 16(4), etc. Authors should seek to minimize references to unpublished material, including collections of conference abstracts that are not generally available through libraries or electronic databases. When it is absolutely necessary to reference unpublished material, this must be done within the citation in the body of the paper, for example (Bartlett and Bremble, unpublished data); the material must not be included in the list of references. Secondary references should be avoided if at all possible; if not, the reference should be listed as, for example: Full reference (cited in Zatsiorsky, V. M. , 1995, Science and Practice of Strength Training. Champaign, IL: Human Kinetics).

6. Proofs

Proofs will, if necessary, be sent (electronically) to the corresponding author for correction.

The difficulty and expense involved in making amendments at proof stage make it essential for authors to prepare their article carefully; any alterations to the original text are strongly discouraged. Our aim is rapid publication; this will be helped if authors provide good copy, follow the above instructions, and return their proofs as quickly as possible.

7. Copyright

Submission of a paper to the International Journal of Performance Analysis in Sport is taken to imply that it represents original, unpublished work, not under consideration for publication elsewhere. Authors will be asked to transfer the copyright for their paper to the Publisher, using the form provided, if and when the paper is accepted for publication. The copyright covers the exclusive rights to reproduce and distribute the paper, including reprints, photographic reproduction, microfilm or any reproduction of a similar nature, and translations. Authors must obtain permission to publish copyrighted illustrations before submission; any acknowledgements should be included in the figure captions.

APPENDIX B

The African Journal for Physical, Health Education, Recreation and Dance (AJPHERD)

Guidelines for authors

The African Journal for Physical, Health Education, Recreation and Dance (AJPHERD) is a peer-reviewed journal established to:

i) Provide a forum for physical educators, health educators, specialists in human movement studies and dance, as well as other sport-related professionals in Africa, the opportunity to report their research findings based on African settings and experiences, and also to exchange ideas among themselves.

ii) Afford the professionals and other interested individuals in these disciplines the opportunity to learn more about the practice of the disciplines in different parts of the continent.

iii) Create awareness in the rest of the world about the professional practice in the disciplines in Africa.

GENERAL POLICY

AJPHERD publishes research papers that contribute to knowledge and practice, and also develops theory either as new information, reviews, confirmation of previous findings, application of new teaching/coaching techniques and research notes. Letters to the editor relating to the materials previously published in AJPHERD could be submitted within three months after publication of the article in question. Such letter will be referred to the corresponding author and both the letter and response will be published concurrently in a subsequent issue of the journal.

Manuscripts are considered for publication in AJPHERD based on the understanding that they have not been published or submitted for publication in any other journal. In submitting papers for publication, corresponding authors should make such declarations. Where part of a paper has been published or presented at congresses, seminars or symposia, reference to that publication should be made in the acknowledgement section of the manuscript. AJPHERD is published quarterly, i.e. in March, June, September and December. Supplements/Special editions are also published periodically.

SUBMISSION OF MANUSCRIPT

Three copies of original manuscript and all correspondence should be addressed to the Editor-In-Chief:

Professor L. O. Amusa

Centre for Biokinetics, Recreation and Sport Science,

Tel: +27 15 9628076

University of Venda for Science and Technology

Fax: +27 15 9628647/9628035

P. Bag X5050, Thohoyandou 0950

E-mail: amusalbw@yahoo.com

Republic of South Africa

Articles can also be submitted electronically, i.e. via email attachment. However, the corresponding author should ensure that such articles are virus free. AJPHERD reviewing process normally takes 4-6 weeks and authors will be advised about the decision on submitted manuscripts within 60 days. In order to ensure anonymity during the reviewing process authors are requested to avoid self referencing or keep it to the barest minimum.

PREPARATION OF MANUSCRIPT

Manuscripts should be type written in fluent English (using 12-point Times New Roman font and 1½ line spacing) on one side of white A4-sized paper justified fully with 3 cm margin on all sides. In preparing manuscripts, MS-Word, Office 98 or Office 2000 for Windows should be used. Length of manuscripts should not normally exceed 12 printed pages (including tables, figures, references, etc.). For articles exceeding 10 typed pages US$ 10.0 is charged per every extra page. Longer manuscripts may be accepted for publication as supplements or special research reviews. Authors will be requested to pay a publication charge of US$ 350.0 to defray the very high cost of publication.

The pages of manuscripts must be numbered sequentially beginning with the title page. The presentation format should be consistent with the guidelines in the publication format of the American Psychological Association (APA) (4th edition).

Title page:

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

Concise and informative title.

Author(s') name(s) with first and middle initials.

Authors' highest qualifications and main area of research specialisation should be provided.

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

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

A short running title of not more than six words.

Abstract

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

Text

Text should carry the following designated headings: Introduction, Materials and Methods, Results, Discussion, Acknowledgement, References and Appendices (if appropriate).

Introduction

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

Materials and Methods

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

Results

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

Discussion

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

References

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

Authors are advised to consider the following examples in referencing:

Examples of citations in body of the text:-

For one or two authors; Kruger (2003) and Travill and Lloyd (1998). These references should be cited as follows when indicated at the end of a statement: (Kruger, 2003); (Travill & Lloyd, 1998).

<u>For three or more authors</u> cited for the first time in the text; Monyeki, Brits, Mantsena and Toriola (2002) or when cited at the end of a statement as in the preceding example; (Monyeki, Brits, Mantsena & Toriola, 2002).

For subsequent citations of the same reference it suffices to cite this particular reference as: Monyeki et al. (2002).

Multiple references when cited in the body of the text should be listed chronologically in ascending order, i.e. starting with the oldest reference. These should be separated with semi colons. For example, (Tom, 1982; McDaniels & Jooste, 1990; van Heerden, 2001; de Ridder at al., 2003).

Reference List

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

Examples of journal references:

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

<u>For one author</u>: McDonald, A.K. (1999). Youth sports in Africa: A review of programmes in selected countries. *International Journal of Youth Sports*, 1(4), 102-117.

<u>For two authors</u>: Johnson, A.G. & O'Kefee, L.M. (2003). Analysis of performance factors in provincial table tennis players. *Journal of Sport Performance*, 2(3), 12-31.

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

Examples of book references:

Book references should specify the surname and initials of the author(s), year of publication of the book, title, edition, page numbers written in brackets, city where book was published and name of publishers. Chapter references should include the name(s) of the editor(s) and other specific information provided in the third example below:

<u>For authored references</u>: Amusa, L.O. & Toriola, A.L. (2003). *Foundations of Sport Science* (1st ed.) (pp. 39-45). Mokopane, South Africa: Dynasty Printers.

For edited references: Amusa, L.O. and Toriola, A.L. (Eds.) (2003). *Contemporary Issues in Physical Education and Sports* (2nd ed.) (pp. 20-24). Mokopane, South Africa: Dynasty Printers.

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

Example of electronic references:

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

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

PROOFREADING

Manuscript accepted for publication may be returned to the author(s) for final correction and proofreading. Corrected proofs should be returned to the Editor-In-Chief within one week of receipt. Minor editorial corrections are handled by AJPHERD.

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COMPLIMENTARY COPY OF AJPHERD AND REPRINTS

Principal authors will receive ten (10) complimentary copies of the relevant pages in which their article has been published. In case of two or more joint authors the principal author distributes the copies to the co-authors. Reprints of published papers can be ordered using a reprint order form that will be sent to the corresponding author before publication. Bound copies of the journal may be ordered from: Leach Printers & Signs, 16 Rissik Street, P. O. Box 143, Makhado 0920, South Africa. Tel: +27 15 516 5221; Fax: +27 15 516 1210. Email: info@leachprinters.co.za; website: www.leachprinters.co.za.

APPENDIX C

DEMOGRAPHIC INFORMATION AND INFORMED CONSENT

DEMOGRAPHIC INFORMATION

Please write clearly!

1. <u>Geographic information</u>

1.1 Surname: **Initials** **First Name**

1.2 Age:

Years:

1.3 Date of birth:

Year:	Month:	Day:

1.4 Job description (cross out the one that is applicable):

Student	*Part-time employment	*Full-time employment

** Please specify if you marked any one of these two options:*

1.5 Permanent residential address in South Africa:

____

____

____

____

____

1.6 Permanent postal address in South Africa:

____

____

____

____

____

1.7 Phone numbers:

Home:	Work:

Fax:	Cell:
Email:	

1.8 Ethnic group

White	Coloured	Black	Indian

For the next few questions cross out the answers that are applicable to you.

2. INFORMATION REGARDING TRAINING HABITS

2.1 Years you've been refereeing:

1-2 years	3-4 years	5-6 years	7-8 years	8-9 years	10-11 years	12 or more

2.2 Frequency of training - how many days per week do you normally train?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.3 Frequency of training - how many days per week do you normally do weight training?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.4 Frequency of training - how many days per week do you normally have field sessions?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.5 How many hours per day do you normally train?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.6 How many hours per day do you normally spend on weight training?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.7 How many hours per day do you normally spend on training on the field?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

3. MEDICAL INFORMATION

3.1 Please describe any past or current musculoskeletal conditions you have suffered from (i.e., muscle pulls, sprains, fractures, surgery, back pain, or any general discomfort):

Head/Neck:

____

____

Shoulder/Clavicle:

Arm/Elbow/Wrist/Hand:

Back:

Hip/Pelvis:

Thigh/Knee:

Lower leg/Ankle/Foot:

3.2 Please list any medication being taken currently and/or taken during the last year:

3.3 List any other illness or disorder that a physician has treated:

4. REFEREE DATA

4.1 At what panel are you refereeing this year?

4.2 What is the highest panel that you completed at the end of last year?

School	Club	Contender	Provincial

4.3 How many matches, approximately, have you refereed?

Club =	Provincial/National =

4.4 What are the highest achievements you achieved the past two years?

Achievement:	**Competition:**	**Date:**

4.5 What are your most important competitions this year and when will these take place?

No. of importance:	Competition:	Date:
1.		
2.		
3.		
4.		

Consent form

Title of the project: Physical demands of South African Rugby Union referees during match-play.

I, the undersigned ……………………………………………………………… (full names) had the opportunity to discuss aspects of the project with the project leader and I declare that I participated in the project as a volunteer. I hereby give my consent to be a subject in this project.

I indemnify the University, also any other 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: on: ………………………………………..

Witnesses:

1.

2.

Signed at: on: ……………………………………

APPENDIX D

TEST PROTOCOL

NAME AND SURNAME		M	F
AGE			
DATE OF BIRTH			

BODY COMPOSITIONING	**READING 1**	**READING 2**	**AVERAGE**
STATURE (cm)			
BODY MASS (kg)			
TRICEPS SKINFOLD (mm)			
SUBSCAPULAR (mm)			
SUPRASPINAL (mm)			
ADOMINAL(mm)			
THIGH(mm)			
CALF(mm)			
PERCENTAGE BODY FAT	%		
FAT PERCENATGE			
BLEEP TEST	**LEVEL**	**SHUTTLE**	**MAX HEART RATE**
READING			

<u>Additional information</u>

APPARATUS	**GAME 1**	**GAME 2**
SUUNTO WATCH NUMBER		
VIDEO TAPE NUMBER		

APPENDIX E

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

Private Bag X6001, Potchefstroom
South-Africa, 2520

Tel: (018) 299-1111/2222
Web: http://www.nwu.ac.za

Faculty of Health Sciences
Tel: (018) 299 4237
Fax: (018) 299 2464
E-mail: Este.Vorster@nwu.ac.za

To whom it may concern

15 November 2011

Dear Sir/Madam

ETHICS APPLICATION: NWU-00019-11-S2 (P.H. VAN DEN BERG)

"Analysis of Movement Patterns, Heart Rates and work: rest ratios of SA Rugby Union Referees"

The applicants responded in a satisfactorily way to the comments made by the panel members.

Ethical approval is recommended.

Yours sincerely

Esté (H.H.) Vorster

Prof. H.H. Vorster