African Journal for Physical, Health Education, Recreation and Dance (AJPHERD)
Vol. 17, No. 4 (December: 2) 2011, pp. 842-852.

Time-motion analysis and heart rate recordings of South African rugby union referees

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(Received 21 January 2011; Revision Accepted 20 April 2011)

Abstract

The objective of this study was to determine the movement patterns, heart rates and work-to-rest ratios of South African Rugby Union referees during the two halves of match-refereeing. 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.

Keywords: Time-motion analysis; heart rate recordings; Rugby Union.

How to cite this article:
Kraak, W.J., Malan, D.J.M & Van Den Berg, P.H. (2011). Time-motion analysis and heart rate recordings of South African rugby union referees. *African Journal for Physical, Health Education, Recreation and Dance,* 17(4: 2), 842-852.

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*et al*., 2004). According to Kuklinski (2007) 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*., 2004; *Beeld*, 2010). Cochran, Keller 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 (Watson2010). 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 *et al*. (1998) supported this statement by claiming that an accurate time-motion analysis (TMA) (duration and frequency) in conjunction with heart rate recordings (HRR) (intensity) would provide a more comprehensive picture of the physiological demands of rugby union match-refereeing. By wearing heart rate monitors during match-play, the actual heart rate values attained by referees can therefore be compared to prescribed values to determine the referees heart rate values (Parker, 1998). 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 union referees. Martin *et al*. (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 dearth of research done on rugby union referees worldwide, the researchers found it necessary to determine the physiological load 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 *et al*., 2007), b) the level of aerobic performance ability positively influenced the quality of the performances on the field 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 union 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 determine the frequency, intensity and duration of the different movement patterns and work-to-rest ratios of preselected (by the South African Rugby Referee Association) South African Rugby Union referees during the two halves of match-refereeing.

Methods

Research design

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

Participants

All the referees (n=8) who participated in the 2007 National Club Rugby Championship (NCRC) tournament held in Stellenbosch served as subjects 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 was obtained from the North-West University (NWU-00019-11-S2).

Data collection procedures

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.

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 by 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).

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).

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 = $(M_1 - M_2)/S_{(max)}$, where, M_1 is the mean valuefor 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).

Results and Discussion

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

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 1.

Table 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°°°**

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)

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.

The results in Table 1 also indicate that the rugby union 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) fitness levels of the referees (Kay & Gill 2004) , b) decrease of players' fitness levels in the second half of match-play (Docherty *et al*., 1988; Deutch, Kearney & Rehrer, 2007), and c) the increase of rucking and mauling activities performed by the players during the second half of rugby matches.

A typical approach to a tackle would see referees jog within five meters of a tackle, ruck or maul and 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 (Boksmart, 2009). Due to the lack of research on this topic it is difficult with compare the results to other studies, however, the same trends were observed between the two halves of match-refereeing in the analysis of soccer referees (Castagna *et al*., 2007).

Heart rate recordings

Table 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°°°**

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)

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 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. This can probably be attributed to a) the difference in the structure and level of play or competition, since the NCRC was played within a week tournament and a knock-out basis, thus placing higher match-play demands on the players and referees (Watson, 2010), and b) the experience and fitness levels of the referees (Martin *et al.*, 2001; Kay & Gill, 2004). In comparing the results of match refereeing intensities with that found by Cochrane *et al*. (2003) with NZRU referees, it appears that the time spent in the maximal and sub-threshold heart rate zones for SARRA referees increased from the first to the second half of the match, while in the case of the NZRU referees, these values decreased for the same respective halves of the rugby matches.

In the case of the SARRA referees, the group also consisted of contender-level referees. The same trends 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.

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. 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 experienced by the referees during the second half of match-refereeing.

Conclusions

This is probably 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 rugby-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.

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 to the demands placed on the referees in the two halves of match-refereeing.

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