Physiological and movement demands of Rugby League referees: Influence on penalty accuracy

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Abstract

Research into the physiological and movement demands of Rugby League (RL) referees is limited, with only one study in the European Super League (SL). To date, no studies have considered decision-making in RL referees. The purpose of this study was to quantify penalty accuracy scores of RL referees and determine the relationship between penalty accuracy and total distance covered (TD), high-intensity running (HIR) and heart rate per 10-min period of match-play. Time motion analysis was undertaken on 8 referees over 148 European SL games during the 2012 season using 10Hz GPS analysis and heart rate monitors. The number and timing of penalties awarded was quantified using Opta Stats. Referees awarded the correct decision on 74 ± 5% of occasions. Lowest accuracy was observed in the last 10-minute period of the game (67 ± 13%), with a moderate drop (ES= 0.86) in accuracy observed between 60-70 minutes and 70-80 minutes. Despite this, there were only small correlations observed between HR_{mean}, total distance, HIR efforts and penalty accuracy. Although a moderate correlation was observed between maximum velocity and accuracy. Despite only small correlations observed, it would be rash to assume that physiological and movement demands of refereeing have no influence on decision-making. More likely, other confounding variables influence referee decision-making accuracy, requiring further investigation. Findings can be used by referees and coaches to inform training protocols, ensuring training is specific to both cognitive and physical match demands.

Key words: Referee, Decision-making, Accuracy, Physical Demands

INTRODUCTION

Rugby league (RL) is a highly demanding contact sport, consisting of bouts of high-intensity efforts interspersed with low-intensity activity played over two 40-minute halves (12). The role of a RL referee is important, as very often a wrong decision may have profound implications on the outcome of the game. European RL referees are required to officiate approximately once per week for 27 rounds of the regular Super League (SL) competition, 5 Challenge Cup games, in addition to a playoff system, Grand Final and on occasions some referees will also act as touch judges or video referees. Despite their key involvement within the game of RL, little is known about their physiological and movement demands in relation to decision-making accuracy during match play. In the context of performance optimisation, knowing variables affecting the interaction between physiological and cognitive processes during match play may provide insight into the true relationship between physiological, movement and decision-making demands of RL referees.

To date, a limited body of research has investigated the physiological and movement demands of RL referees within the Australian National Rugby League (17, 22, 23) and European SL (34). SL referees have been reported to cover 8951 ± 746 m per game, consisting of 395 ± 133 m of high-speed running (5.51-7.00 $m.s^{-1}$) and 120 ± 92m of sprinting (> 7.01 $m.s^{-1}$) distance, eliciting a mean heart rate (HR_{mean}) of 84.2% ± 3.2 % as a percentage of heart rate peak ($HR_{peak)}$ during match play. However, to date no studies have considered decision-making in RL referees, a critical component of refereeing. Research in other sports has attempted to quantify referee decision-making by using retrospective video analysis (15, 26). Utilizing this method, rugby union referees have been reported to be accurate 50% of the time (26), while ice hockey officials have been reported to be accurate

75% of occasions (15). While video-based assessments provide valid examination of decision-making performance, they do not replicate the physical, physiological, and psychological aspects of an actual match environment. Only a limited number of studies have attempted to determine within game decision-making accuracy (8, 9, 24, 27). During match play, soccer referees have been reported to be accurate on 64-86% of occasions per game (24, 27), while Australian football umpires (8) have been reported to be accurate 84% of the time when awarding free kicks during match play. Furthermore, Elsworthy et al., (8) reported that Australian football umpires accuracy was consistent across all four quarters when awarding free kicks. Both Mascarenhas et al., (27) and Mallo et al., (24) analysed decision-making accuracy of soccer referees per 15-minute period, however the authors reported conflicting findings. Mallo et al, (24) reported that lowest accuracy was observed in the last 15-minute period of the game, suggesting that physical and mental fatigue occurs in the final stages of a match. Conversely, Macarenhas et al., (27) reported that lowest accuracy of New Zealand soccer referees occurred in the opening 15-minutes of each half, attributing poorer decision-making to some form of warm up decrement. While only a limited number of studies have been carried out during match play, the influence of physical fatigue on cognitive function has been extensively investigated in a laboratory setting (21, 30, 31, 32, 40) and during sport specific simulation protocols (37). Findings have been equivocal, with more recent studies suggesting that the effects of exercise-induced fatigue may be task specific, with greater effects on perceptual tasks, which involve relatively automatic processing, compared to effortful memory-based task (32). Research suggests that if sufficient cognitive effort is applied, the subsequent allocation of resources to task-relevant information can maintain decision-making performance even during maximal intensity exercise, although response time is increased (30, 37). Therefore, given conflicting findings within the literature and the limited research undertaken during actual match play, it is important to not only determine the decision-making accuracy of RL referees but to investigate the association between physical demands and accuracy across periods of the game during actual match play. Accordingly, the purpose of this study was to quantify penalty accuracy (decision-making accuracy) scores of RL referees and determine the association between total distance covered (TD), high intensity running (HIR) efforts and heart rate (HR_{mean}). Furthermore, this study analysed match demands per 10-minute period, which is a more sensitive analysis of match demands compared to previous literature, which has determined physiological and movement demands per half (17, 34). This may pervade novel training methods and match day strategies that can be utilised by strength and conditioning coaches working with RL referees to facilitate the acquisition of the skills underlying superior performance.

METHODS

Experimental Approach to the Problem

The physiological and movement demands of SL referees were analysed over a full season for the full population of professional SL referees. Penalty accuracy of the referees per 10-minute period of a game was also quantified. This approach allowed analysis of the association between penalty accuracy and physiological and movement demands of elite RL referees.

Participants

All eight full-time professional SL referees (age 35.3 ± 7.1 yrs; stature 175.8 ± 4.7 cm, body mass 77.3 ± 6.0 kg) participated in the study. All referees had a minimum of two years' experience of refereeing SL matches (7.3 ± 4.3 years). Institutional ethical approval was granted and permission to undertake the research was granted by the Rugby Football League (RFL) Match Officials Director. Each referee received a detailed explanation of the purpose of the research and gave written informed consent.

Procedures

Time motion analysis was undertaken on 148 European SL games during the 2012 season using portable 10Hz global positioning system (GPS) units (MinimaxV4; Catapult Sports, Australia) and 1-Hz heart rate monitors (Polar Electro, Kempele, Finland). This resulted in 18 ± 4 matches per referee, ranging from 12 – 22 matches. 10Hz GPS devices have been reported to be two to three times more accurate than 5Hz devices (CV = 3.1–11.3%) when compared with a criterion value for instantaneous velocity during tasks completed at a range of velocities (4). These devices have also been reported to being more reliable, yielding a CV = 1.3% and CV = 0.7% for sprints over 15 m and 30 m, respectively (4). However, a limitation still of the 10Hz units is the decrease in reliability when assessing high speed running and change of direction (typical error: 2.6m, CV: 7.9-9.2%) (19). Thus it is acknowledged that caution must be taken when analyzing these results. The number of satellites ranged from 9 to 12 (7.2 ± 0.7) with a horizontal dilution of precision of 2.1 ± 0.5. The lower the horizontal dilution of precision (within range of 0 to 50) the better as this indicates an optimal geometrical positioning of orbiting satellites for accurate monitoring of position (19). All data was downloaded to a PC and analysed using Logan Plus 4.0 (Catapult Innovations, Australia) software. Once appropriately formatted, data were exported to Microsoft Excel (Microsoft Corporation, USA) for the purpose of data management.

Physiological and movement demands

Prior to warming up on match day, the GPS device (88 x 50 x 19mm in size, 67g in weight) was activated by the referee to ensure an appropriate signal had been obtained. The referees were fitted with an appropriately sized vest which allowed the portable GPS unit to be positioned between the scapulae at the base of the cervical spine. Each referee was allocated a specific GPS unit for the entire duration of the study. The referees had been wearing the units during match play for several seasons so were familiar with the process. The Polar HR monitor was positioned around the chest with a referee shirt worn over the top of the vest. Heart rate (beat.min^{-1}) was recorded during match play and later calculated as a percentage of peak heart rate achieved during match play, which is in line with similar methods adopted for RL players (41).

Total and relative (m.min^{-1}) distance covered was examined per half and per 10-minute period of match play. The mean frequency of movement ‘efforts’ (a discrete movement spurt lasting 0.2 s before a change in velocity or direction) above 5.51 m.s^{-1} were classified as HIR efforts. This is similar to the velocity boundary used previously for HIR efforts for rugby referees (34) and used in the literature to define high speed running (41) and very high intensity running for players (39).

Decision-making analysis

All matches were video recorded and analysed using a video-computerised, semi-automatic, match analysis image recognition system (Opta Stats). The number and timing of each penalty was then coded retrospectively using Opta Stats coding methods by a trained Opta Stats technician. Two additional camera angles were used (pitch side camera was used to provide a close up view of the action while the grandstand camera recorded a wide angle view), providing both a view of the active play and view of the referee. Penalty accuracy of the referees was identified *post-hoc* by two experienced RFL referee coaches. Each coach had previously refereed a minimum of 275 games at the elite level and had been employed as an elite referee coach for a minimum of 7 years. Within two days following each game, the coaches viewed each game in its entirety using the Opta stats match analysis system and the two additional camera angle views. There was no significant difference in inter-observer reliability between the RFL Match Director and the Opta technician, Kappa = 0.74, ($p < 0.05$), 95% CI (0.71-0.77). With the use of a video analysis system the coaches were allowed to play and replay all the situations to decide whether the decision taken by the referee was correct or incorrect and also identified any 'missed' penalties by the referee. It is acknowledged that previous research has suggested only modest agreement rates **(**circa 60-85%) between panels of 'experts' and the decisions made by actual referees in situ (1, 11, 14), however this allows determination of accuracy in comparison to the laws of the game and is in-line with similar methods adopted in other sports to analyse referee decision-making (8, 24). While it is acknowledged that RL referees are continuously making decisions throughout a game and penalties only represent a small portion of the overall decision-making demands, it can be difficult to identify and measure all decisions the referee makes. Thus, quantifying penalty accuracy provides a method of analysis that is easy to measure yet still requires complex decision-making and rule interpretation. This level of decision-making analysis is similar that employed in other sports where the difficulty in quantifying all decision-making scenarios is acknowledged (8, 9, 24).

Penalties were assessed as correct, unwarranted or missed. Unwarranted and missed penalties were then grouped together and collectively accounted for incorrect decisions. In line with methods adopted by Mallo et al., (24), the RFL referee coaches retrospectively analysed video footage of 30 penalty scenarios to examine inter-observer reliability with no significant differences observed, Kappa = 0.81 ($P < 0.05$), 95% CI (0.78-0.84). Penalty accuracy data was analysed in conjunction with GPS and heart rate data for total match play and separately per 10-minute period of the match to ascertain if there were any relationship between physiological and movement demands and referee penalty accuracy scores. Each 10-minute segment was coded into periods for analysis (i.e. Period 1: 0-10 minutes, Period 2: 10-20 minutes) which will be referred to in the discussion.

Statistical Analysis

All data are presented as the mean (± standard deviation). Preliminary analysis was conducted to establish that the assumption of homogeneity of variance was confirmed prior to any further statistical analysis being conducted. To assess the difference in physiological demands per 10-minute period of the game, a repeated measures analysis of variance (ANOVA) was conducted and partial eta squared effect sizes reported (n^2). Bonferroni post-hoc procedure was used to further evaluate any significant effect suggested by the analyses of variance. As penalty accuracy data was non-parametric, a Friedman's analysis of variance was used to compare differences in accuracy in each period of the game. Statistical significance was set at $P<0.05$ (10). Hopkins effect sizes (ES) were calculated between 10-minute periods for all variables. Using a Hopkins ES, 0 – 0.2 was considered to be a trivial effect, 0.2 – 0.6 a small effect, 0.6 – 1.2 a moderate effect, 1.2 – 2.0 a large effect, and >2.0 a very large effect (18). Thresholds for correlations were interpreted as < 0.1, trivial; 0.10-0.29, small; 0.3-0.49, moderate, 0.50-0.69, large; 0.70-0.90, very large; > 0.9, nearly perfect (18). Cohen's Kappa method was used to calculate the inter- rater reliability. Inter-rater agreement is poor for a Kappa <0.21, moderate 0.21-0.40, substantial 0.61-0.80 and excellent for >0.81 (6). A 95% level of confidence used to define statistical difference (P<0.05).

RESULTS

The mean physical demands and penalty accuracy of SL referees are presented in Table one. The mean number of penalties awarded per match was 15 ± 2, with referees having an overall accuracy of 74 ± 5 % (Table 1). A moderate increase (ES = 0.70) in accuracy was observed from 40-50 minutes (Period 5) to 50-60 minutes (Period 6) and a moderate drop (ES = 0.86) in accuracy was observed in the last 10-minute period of the game (Period 8), despite no significant difference (P = 0.557) in penalty accuracy scores per 10-minute period observed. Large between-match variability (CV: 21%) was observed for referee penalty accuracy.

*****Table 1 about here*****

Movement Demands

The mean distance covered by a SL referee per match was 7114 ± 748 m, with trivial to moderate differences in total distance observed between 10-minute periods (Table 2). Significant differences (n^2 = 0.64, P = 0.002,) in total distance covered between 10-minute periods was observed. Greatest distance was covered in the first 10-minute period of the game (Period 1: 1052 ± 596 m), with a moderate drop observed from Period 1 to Period 2. Conversely, a moderate increase in distance covered was observed from the first 10-minute period of the second half (Period 5) to Period 6. SL referees completed 12 ± 7 HIR efforts per match, with HIR distance accounting for 2.8 % of total distance covered. There was only small to trivial differences observed between 10-minute periods for HIR running (Table 2), with no significant differences (P = 0.317) observed in the number of HIR efforts or HIR distance per 10-minute period (P = 0.813).

Physiological Demands

Overall, HR_{mean} for SL referees was 151 ± 9 beats.min^{-1}, equating to a mean match intensity of 79 ± 2 percent of heart rate peak (%HR_{peak}). HR_{mean} between 10-20 minutes and 20-30 minutes, was higher (ES = 0.36-0.81, P = 0.01) than all other periods, however differences between 10-minute periods was only trivial to small except for the first 10-minute period of the second half (Table 2).

Insert Table 2 about here

The correlations between penalty accuracy and match demands

Correlations between HR_{mean}, total distance and HIR efforts and penalty accuracy per 10-minute period were all trivial to small (Table 3). Contrary, a large correlation was observed between HR_{mean} and distance covered.

When physical performance in a 10-minute period was correlated to accuracy in the subsequent 10-minute period, only small correlations were observed between accuracy and total distance (r = -0.236) and trivial correlations were observed between HIR distance (r = -0.101) and HR_{mean} (r = -0.129) and accuracy.

Insert Table 3 about here

DISCUSSION

This is the first study to attempt to quantify RL referee's decision-making accuracy during match play and investigate the relationship between physical demands and decision-making accuracy. Furthermore, this is the most sensitive analysis of RL referee physical demands during match play to date. Findings provide novel data that determines the physical demands and penalty accuracy of an entire population of elite SL referees. This information has important implications for the development of specific training methods and match day strategies for RL referees.

The penalty accuracy of SL referees is similar to that reported for ice hockey referees (15) and is higher than reported rugby union referees (26) and some soccer referees (16, 27) but lower than that reported for Australian football umpires (8). Differences in accuracy scores between RL and other sports may reflect differences in the nature of the sports (i.e. the additional need to control the 10 m defensive line in RL) and methods of quantifying accuracy (i.e. quantification during match play versus accuracy on a video based test). Further, this is only the fourth study to analyse decision-making accuracy of referees in any sport in a naturalistic environment (8, 24, 27) and the first in RL. However, analysis in this study was more comprehensive than that in previous studies, as data was collected for a full season, with referees observed over 12 – 22 matches each. Contrary, Mascarenhas and colleagues (27) only observed New Zealand soccer referees over 7 games and Elsworthy et al., (8) observed each Australian football umpire over 1-4 matches. Other studies have determined decision- making accuracy of referees using video recordings of match play in training interventions (5, 26, 38). Analysing decision-making accuracy during live match play, as in this study, provides a more accurate evaluation of the decision-making performance of referees versus video recordings, which lack ecological validity and fails to replicate the naturalistic environment of decision-making during match play.

An interesting finding of this study was that a moderate drop in accuracy was observed in the last 10-minute period of the game. Penalty accuracy was >70%, except for the last 10-minute period of the match. This is contrary to the findings of Elsworthy et al., (8) who reported that Australian Football Umpires free kick accuracy was consistent across all quarters despite a reduction in movement demands. The reduction in accuracy scores during the last 10-minutes of the game compared to the average accuracy score reported is a key finding considering the implications of incorrect decisions on the outcome of the game. This may have implications for the design of training drills by strength and conditioning coaches working with referees to ensure that referees can maintain performance into the final periods of the game. A moderate increase in accuracy scores was observed from the first 10-minute period of the second half (40-50 minutes) to the subsequent period (50-60 minutes). This is consistent with the findings of Mascarenhas et al., (27) who reported that soccer referees accuracy was lowest in the opening period of the half which the authors attributed to a warm up decrement. Anecdotally, SL referees perform no form of cognitive warm up before a game or re-warm at half time. Therefore, it may be recommended that coaches working with referees look to integrate some form of mental preparation as part of warm up before the game and their half time re-warm up routine.

The findings of this study suggest that the physiological and movement demands of refereeing have no significant effect on penalty accuracy of RL referees. This is consistent with the findings for soccer referees (24, 27) and Australian Football Umpires (8). Consistent with findings of Mascarenhas et al., (27), referee penalty accuracy was not significantly affected by mean heart rate, distance covered or high speed distance. Mallo et al., (24) suggested that a drop in accuracy in the last 15-minute of a game for soccer referees may be attributed to both physical and mental fatigue. However, findings of this study contradict this theory and previous RL research, which has suggested referees demonstrate a significant reduction in high speed running distance in the second half of games (34). Only a trivial to small difference in high speed distance was observed between 10-minute periods, which would suggest referees are capable of maintaining high speed distance throughout a game and is consistent with findings reported for soccer referees (42). Noteworthy, a moderate correlation between maximum velocity and accuracy was observed. Speculatively, this may suggest that when referees achieved higher velocities, they were able to get into a better position to view the decision. However, conflicting findings have been reported in the literature for both soccer (24) and Australian football umpires (9), therefore this requires further research to be substantiated.

Given that large differences in distance covered (RL = 7114 ± 748 m versus. Soccer = 11622 ± 739 m (43), HIR efforts [RL from 2.6-5.5% versus soccer = 7-17% (44)] and mean accuracy scores (74 % versus 64-86 % (24, 27) of RL and soccer referees have been observed, with no significant relationship between physiological and movement demands and decision-making accuracy in either sports, this would suggest that other factors may influence physiological responses and decision-making accuracy of referees (25). This is supported by the large between-match variability observed (CV: 21%) for penalty accuracy. As observed for referees in other sports, it is possible external factors such as crowd size (7), crowd noise (33), prior decisions in the game (35, 36) as well as referee positioning (24) may influence referees decision-making and require further investigation in RL referees. Furthermore, while a 10-minute analysis of movement demands included in this study is the most detailed analysis to date, findings suggest that this still may be not be sensitive enough to highlight periods of transient fatigue, which may only last seconds but temporarily impairs referee decision-making. Elsworthy et al., (9) reported that higher relative running speeds five seconds prior to a decision increased the likelihood of a decisional error for Australian

Football Umpires. Thus future research should aim to analyse referee demands over a much more sensitive time period to determine the influence of transient fatigue on penalty accuracy. However, despite this, these findings should not be construed as implying that the physiological and movement demands of refereeing have no influence on decision-making accuracy. The lack of any simple relationships observed between penalty accuracy scores with TD, HIR or heart rate found in the present study simply indicates that none of these variables can be used in isolation to predict the likelihood of a correct or incorrect decision. Therefore it is likely that a more complex multivariate relationship between referee accuracy scores and physical performance exists that must additionally be considered in relation to the work rate of players, which were not simultaneously measured during this study and additional external factors.

CONCLUSION

This is the first study to address empirically the physical and decision-making demands of an entire population of RL referees over an entire season. This provides novel data on RL referee decision-making and physical performance during match play, which can be used to inform training prescription for referees. While it has been observed that there was no significant relationship between distance covered, HIR efforts, mean heart rate and penalty accuracy, it would be rash to assume that this has no influence. More likely, there are several other confounding variables that further influence referee decision-making accuracy. Future research should aim to determine the influence of referee movement demands on decision making accuracy using more sensitive time periods (5-second, 10-second analysis) and investigate the influence of external factors such as crowd noise on performance.

PRACTICAL APPLICATIONS

This study provides RL referees with an understanding of their decision-making accuracy and comparative data to enhance penalty accuracy. Referees need to be aware that accuracy is decreased in the final 10-minutes to enhance maximum concentration during this period. The analysis of physiological and movement demands of RL referees in this study is the most detailed analysis to date and can be used by strength and conditioning coaches working with RL referees to inform training practices and conditioning drills, that allow overload and mimic the demands of the game. As referees are subjected to a high physical load during matches, they should follow structured weekly training plans that have an emphasis on intensive, intermittent training sessions. Referees should perform training drills that replicate not only the movement demands of the game but also elicit appropriate average and peak heart rates (i.e., average HR of at least ~79% HR_{max}) to replicate the physiological demands of refereeing. Furthermore, coaches working with referees should be aware that multiple variables may confound decision-making accuracy and consider incorporating decision-making tasks into running based training interventions. Future research should look to investigate other factors that may influence the drop in accuracy observed during the final period of the game and methods of training decision-making in RL referees.

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