

Physiological Aspects of Refereeing Performance and Training

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Abstract

The football referee is charged with the responsibility for implementing the laws of the game. To undertake this role effectively the referee and the two assistant referees must strive to keep up with play. Referees routinely cover 11 km during a game with match activities placing high demands upon both aerobic and anaerobic energy systems. Assistant referees cover approximately 7 km, with moderate and high requirements for aerobic and anaerobic energy production respectively. Both groups display evidence of fatigue towards the end of a game that can be partially offset by high-intensity training regimes. Along with the physical demands, referees must also make two to three observable decisions per minute throughout the course of a game with the frequency of critical decisions often increasing during the latter stages of the game. High standards of both physical fitness and perceptual-cognitive functioning are therefore expected of elite referees. This necessitates the implementation of well structured training programmes that address the multi-dimensional requirements of elite refereeing.

Keywords: Assistant Referees, decision making, fatigue, heart rate, UEFA

Introduction

The football referee is charged with the responsibility for implementing the laws of the game. To perform this role effectively the referee and the two assistant referees must strive to keep up with play in order to attain the best possible position for observing infringements. Added to these physical demands, the referees must also maintain mental concentration and the ability to make split second decisions about competitive incidents. High standards of both physical fitness and perceptual-cognitive functioning are therefore expected of elite referees (Reilly and Gregson, 2006). The current article attempts to provide a brief overview of the physiological and cognitive demands of soccer refereeing performance and training.

Activities of Referees During Match-Play

Referees routinely cover a distance of approximately 11 km during match-play (D'Ottavio and Castagna, 2001). This distance approximates and overlaps with that of professional players and highlights to some extent the significant physical demands placed upon referees during match-play. The total distance covered during a game provides only a crude estimate of work rate due to the frequent change in exercise intensity and category of activity throughout the course of a match. The latter have been shown to exceed 1200 discrete events, representing a break or change in activity every 4.3 s on average (Krustup and Bangsbo, 2001). The physical demands of refereeing can therefore be more closely examined by breaking down the required activities according to exercise intensity.

A large proportion of the time during match-play is occupied by periods of inactivity when the referee is stationary (21.8 %) or engaged in low-intensity activities such as walking (41.4 %) and jogging (15.6 %) (Krustup and Bangsbo, 2001). However, referees are also required to perform high intensity activities including moderate (4.7 %) and high speed running (1.5 %) and sprinting (0.5%) and unorthodox energy demanding movements such as backward running (5.5 %) (Krustup and Bangsbo, 2001). Operating on a time basis, elite Danish referees have been shown to perform 161 (range 89-272) high-intensity efforts with each bout

lasting approximately 2 seconds and accounting for 16 % of the total distance completed during match-play (Krustup and Bangsbo, 2001). Despite the smaller contribution to total work rate, the ability to perform short repeated bouts of high intensity exercise is essential for the referee to keep up with high-intensity periods of play and attain optimal viewing positions. Indeed the capacity to perform high-intensity exercise provides the best indication of the referees physical performance during match-play (Krustup and Bangsbo, 2001). This suggestion stems from research that has reported a reduction in high-intensity running and an increase in distance away from infringements during the second half of match-play (Krustup and Bangsbo, 2001).

Physiological Responses to Match-Play

The monitoring of heart rate has been adopted as the predominant means through which to assess the referee's exercise intensity during match-play. Due to the relationship between heart and oxygen uptake, heart rate can be used to estimate match oxygen uptake and therefore the aerobic contribution to the referees match activity. Mean heart rate across the whole match has frequently been reported in the range of 162-165 beats \times min⁻¹ (Reilly and Gregson, 2006). This equates to 85-95 % of the age predicted maximum. Krustup and Bangsbo (2001) used the relationship between heart rate and oxygen uptake to estimate the oxygen consumption during match-play. Oxygen uptake was calculated to be 3.03 litres \times min⁻¹ which corresponded to 81 % (73-88 %) of maximum oxygen uptake. The mean relative heart rates and estimated rates of oxygen uptake reported for referees are in agreement with values reported for players and suggest that elite referees have appreciable aerobic energy expenditure during match-play.

Like exercise intensity, evaluation of the variation in heart rate during competition provides useful information when attempting to determine the referee's physiological responses to match-play. Studies in Danish referees have reported heart rates within the range of 150 -170 beats \times min⁻¹ for 56 % of the time and above 170 beats \times min⁻¹ for 27 % of total time (Krustup and Bangsbo, 2001). Heart rate exceeded 90 % of maximum for more than 25 min and peak heart rate during the game was 184 beats \times min⁻¹ (175-196 beats \times min⁻¹), corresponding to 97 % (92-100 %) of the individual maximum heart rate. These periods of elevated heart rate reflect the periodic bouts of anaerobic exercise superimposed on the predominately aerobic activity. Blood lactate concentrations measured during match-play provide a more in-depth insight of the involvement of anaerobic energy provision. Mean blood lactate concentration has been recorded as 4.8 (2.0 – 9.8) and 5.1(2.3 – 14.0) mmol \times l⁻¹ at the end of the first and second half (Krustup and Bangsbo, 2001). Like heart rate, these values relate closely to those observed in players and highlight the considerable anaerobic energy turnover during match-play.

Physiological and Training Profile of the Soccer Referee

The physical demands of refereeing are very similar to the demands placed upon professional players, despite the referees occupying a significantly older age range (35-45 years of age). Therefore, to ensure that referees can meet the physical demands of their games through keeping up with play at all times and ensuring optimal viewing positions, it is important that their physical training has the correct structure of training volume, intensity, specificity and recovery. This in itself is a challenge. However, when combined with the fact that ageing has a negative effect upon fitness levels, referees have to work extremely hard in training to

ensure that they attain, and maintain, an appropriate level of match fitness. Also, in most countries referees still work full-time and their physical training sessions often have to be arranged around work and family commitments. Therefore, in order to ensure soccer referees can attain an optimal level of match fitness, emphasis within their fitness preparation programmes has to be firmly placed upon quality structured training sessions that provide an appropriate training stimulus to enable the attainment of such fitness whilst also addressing a multi-dimensional approach to fitness training.

The ability to perform high-intensity exercise along with good “repeated sprint ability” is a vital physiological attribute for the soccer referee. Consequently, the training programmes which referees follow on a weekly basis should have a structured blend of high-intensity aerobic sessions, complemented with training sessions dedicated towards the improvement of speed (5 – 50-m sprints with a work:rest ratio of 1:10) and speed endurance (30 – 100-m sprints with a work:ratio ratio of 1:3). Also, as research has demonstrated referees change activity on average every 5 seconds during matches good levels of agility are required to ensure comfortable and efficient changes of activity and direction. Therefore, a certain amount of training time should be dedicated to agility training and this can be performed through exercises such as “fast feet drills” and reaction sprints, where a referee changes direction upon an audio or visual command by the fitness coach.

Specific high-intensity aerobic training performed two to three times per week can significantly improve fitness levels in soccer referees. Krstrup and Bangsbo (2001) reported that following a 12-week period of intense, intermittent training performed three times per week, the distance covered by referees on the Yo-Yo test, which has been highly correlated with a referees’ physical match performance, improved by 31%. The characteristics of the training sessions were based around high-intensity running at 90% HRmax with a work rest ratio of 2:1. The sessions were intermittent with either long intervals (4 or 8-min) or short intervals (30 s or 1 min). Weston et al. (2004) reported that following 16-months of intermittent high-intensity training performed twice weekly, referees improved their performance on the Yo-Yo intermittent recovery test by 46.5%. However, it is recommended that the referees do not perform more than two to three high intensity training sessions within one week.

When training referees it is important not to lose sight of the main goal, i.e. improving performance in the match, as it is no good improving fitness levels if it does not improve match performance. Therefore, it is important that improvements in the referees’ fitness levels translate to improvements in the referees’ on-field technical performances. As the Yo-Yo intermittent recovery test is highly correlated with a referees’ match performance, we can be confident that improvements in referees’ fitness levels will have a positive impact upon the referees on-field technical performance. This improvement in technical performance will be achieved through a marked increase in the referees’ ability to perform repeated intense work. This means the referee becomes able to keep up with play more efficiently and obtain optimal viewing positions, especially during the second half of matches where a decrease in work-rate owing to fatigue may be often observed.

Whilst it is the aerobic and anaerobic energy systems that are predominantly taxed during match play, referees need also to train other aspects of fitness that will help develop their all-round fitness levels and ultimately physical performances in matches. For example, strength training should ideally be performed one to two times week and the training should be focused upon whole-body exercises and developing an appropriate level of strength to enhance physical performance and help to prevent against injury.

Flexibility is another fitness variable required by the soccer referee. Good levels of flexibility will help to promote more efficient movements during training and matches, whilst also helping to prevent against injury. Flexibility can easily be trained for during structured and controlled stretching sessions at the end of regular training sessions. Due to factors associated with the ageing process both the strength and flexibility of muscles and tendons decrease significantly with advancing years and therefore time should be set aside in the referees weekly training plan for the training of these particular components of match fitness. Referees, like all athletes, require optimal levels of body composition. Excessive levels of body fat will only serve to hinder a referee's match performance through increasing the amount of weight that needs to be carried without adding to the body's ability to generate force and overcome this weight. Excessive bodyfat levels also increase the risk of dehydration during matches. Therefore, it is important that referees follow correct sports nutrition plans to support their fitness training regime.

Table 1 below provides an ideal breakdown for a referee's weekly fitness regime. This programme ensures that all the physiological attributes that constitute a referee's physical performance in a match are targeted.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Training Session	Strength Training	Agility & Speed	Rest Day	High Intensity Aerobic Training	Speed Training	Match Day	Recovery Training

Assistant Referees

The role of the assistant referee would appear to be less physically demanding than that of the main match official. Their path is approximately 50 m along the verge of the sideline, from end-line to half-way line. Despite the reduced physical demands placed upon assistant referees, they are frequently recruited from accredited referees and often possess similar levels of fitness (Krustrup et al., 2002).

Elite assistant referees have been shown to cover a mean total distance of approximately 7 km during match-play (Krustrup et al., 2002). Like the main official, the majority of the assistants time is associated with periods of inactivity (44 %) and low-intensity activities such as walking (33 %) and to a lesser extent high intensity running (4 %) and unorthodox energy demanding movements (e.g. sideways running) (Krustrup et al., 2002). However, both high-intensity exercise (16 %) and sideways running (16 %) account for a significant proportion of the total distance covered by assistant referees during match-play (Krustrup et al., 2002). This indicates that the physical demands of assistant refereeing are high at specific points in the game. Decrements in high-intensity and sideways running and impairment of sprint performance during the later stages of match-play have been shown to be closely associated with the assistant referee's inability to keep up with play (Krustrup et al., 2002). Both high-intensity and sprint-related training should therefore form an important component of the physical preparation programme for assistance referees.

Mean heart rates of 137 beats×min⁻¹ corresponding to 73 % of individual maximal heart rate and 65 % of maximal aerobic capacity have been observed during match-play for elite Danish assistant referees (Krustrup et al., 2002). Heart rate is also maintained above 80 % of age predicted maximum for 31 % of match-play. These values are lower than equivalent values

for the main officials and players, and suggest that the demand for aerobic energy production is therefore moderate with episodes of high aerobic turnover during certain parts of the game. Mean blood lactate concentrations of 4.7 (1.6 – 11.0) and 4.8 (1.1 – 13.7) mmol×l⁻¹ have been observed at the end of the first and second half (Krustup and Bangsbo, 2001). These values are similar to those recorded for main officials and players and confirm findings from the work rate data which suggest that the anaerobic energy systems are highly stimulated during specific parts of the game.

Perceptual-Cognitive Demands of Elite Refereeing

Football refereeing represents a highly demanding information processing task. Referees must possess both declarative and procedural knowledge of the Laws of the Game and the subsequent skills to implement them in a correct and consistent way. Despite significant attention in the literature that has focused upon the physical demands and skills requirements of refereeing performance, few attempts have been made to evaluate the perceptual-cognitive demands of top-class refereeing (Helsen and Bultynck, 2004).

Helsen and Bultynck (2004) analysed the video-recordings of all 31 games from the UEFA 2000 Championships in order to obtain the average number of ‘observable’ decisions taken by a referee. On average, 137 observable decisions per match (range 104-162) were noted, 64.2% of which were based on communication with the assistant referees and/or the fourth official. With an effective match playing time of approximately 50 minutes, this figure indicated that that top-class referee made two to three observable decisions per minute throughout the course of a match. The number of observed decisions was also uniformly distributed throughout the six 15-min intervals.

A further analysis of the frequency and distribution of referees’ decisions during the FIFA 2002 World Cup was recently undertaken by Helsen et al. (in press). In addition, particular emphasis was placed upon ‘critical incident’ decisions made by the referees. A critical incident was defined as either a red card or a penalty, as Nevill et al., (1986) claimed that these incidents are likely to affect the match outcome and are easily quantifiable. In terms of perceptual-cognitive demands, the data obtained are in line with the results reported during the UEFA 2000 European Championship (Helsen and Bultynck 2004). Referees made approximately 135 observable decisions per match, most of these (64.3%) based on communication with the other match officials. Given an effective playing time of 56.3% or 51 minutes during the World Cup, this equated to two to three observable decisions per minute. When grouped together per 15-min period, the referees’ decisions were uniformly distributed throughout matches as previously observed (Helsen and Bultynck 2004). With respect to the ‘critical incident’ group, it was observed that there was a significant difference between the expected and observed number of observations. Figure 1 clearly shows that the number of ‘critical incidents’ is consistent between match periods 1 to 5, but increases significantly

during the final match period.

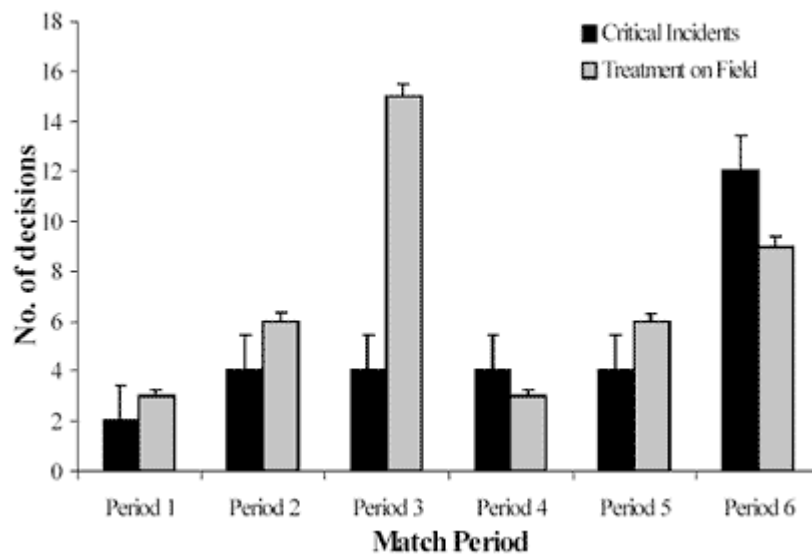


Figure 1 Distribution of critical incidents and on-field treatments during the FIFA 2002 World Championships.

The final minutes of a match have been reported to be the most urgent as players attempt to impact upon the final result. Whilst the physical demands associated with the final phase of play do not increase, Figure 1 clearly demonstrates that the perceptual-cognitive demands on the referees were greatest during this phase of the match in terms of the amount of 'critical incident' decisions awarded by the referee. These particular incidents were red cards and penalty kicks, which were highlighted by Nevill et al. (1996) as being decisions which were likely to affect the outcome of the match. From the perspective of the referee, this category of decision more accurately reflects the perceptual-cognitive demands of refereeing, with the accuracy of the decision being dependent upon the referee's ability to perceive and interpret the situation correctly. McMorris et al. (1999) reported that accuracy of decision making is dependent on an individual's ability to perceive what is presented, to hold that information in the short-term memory, to compare this information with similar past experiences held in long-term memory and, on the basis of this comparison, to decide what is the optimal action. Therefore, this complex series of events is far more demanding than the awarding of a goal kick, throw-in etc., which is performed in communication with the assistant referee.

The current finding reinforce the need for referees to develop appropriate levels of fitness in order to keep up with play at all times and obtain optimal viewing positions. Reducing fatigue by improving fitness levels in football referees may also delay the onset of mental fatigue, thus reducing the possibility of error in the decision making process. This remains an area that warrants further research.

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