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Special populations: The referee and assistant referee

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Special populations: The referee and assistant referee

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Abstract

The referee has responsibility for control of players' behaviour during competitive football and implementing the rules of the game. To do this, the referee and the two assistant referees are obliged to keep up with play. Referees cover 10,000 m on average during a game, mean heart rate is about 160 – 165 beats · min^{-1} and oxygen uptake is close to 80% of maximum ($\dot{V}O_{2max}$). Assistant referees cover approximately 7500 m, mean heart rate is about 140 beats · min^{-1} and the corresponding oxygen uptake is 65% $\dot{V}O_{2max}$. Both groups display evidence of fatigue towards the end of the game, a phenomenon that has not been thoroughly examined for nutritional interventions. The estimated energy expenditure of referees during a game exceeds 5600 kJ. Both referees and assistant referees execute unorthodox patterns of movement during match-play that increase energy expenditure over normal locomotion. As high standards of fitness and decision making are expected of professional referees, there are nutritional consequences associated with the training regimes they adopt. The effects of nutritional interventions on cognitive performance during the later stages of a game are in need of further investigation.

Keywords: *Assistant referees, energy expenditure, fatigue, fitness, mental performance*

Introduction

The referee is charged with responsibility for implementing the rules of the game and guaranteeing that players abide by its regulations. These requirements mean that the referee is obliged to keep up with play to be in a good position to notice infringements. In addition to this requirement for mobility about the pitch, the referee must also maintain mental concentration and make split-second decisions about competitive incidents. In many circumstances, he or she has recourse to consult one of the two assistant referees (linesmen).

Most research on nutritional requirements in football has been directed towards the players, with the referee being relatively neglected until recently. The omission reflects the fact that the players form the centre of attention of spectators until refereeing decisions are considered controversial. In a review by Eissmann (1994), it was stated that the physical and psychological demands on referees increased enormously in the 1980s. The claim was based on the health checks and fitness tests imposed by FIFA on referees qualifying for the international list rather than any observations of physiological responses to officiating of match-play. National associations have tended to follow the examples of FIFA and the ruling confederations in implementing these assessments.

Advice on nutritional provision for referees tends to be general rather than specific. The US Soccer Association currently provides guidelines to referees for allowing hydration of players during a game but there is no mention of rules regarding rehydration for referees. Eissmann (1994) recognized that the referee has to "prepare before a game in the same way as a player, i.e. with proper nutrition", but no further direction was given. With the advent of professional referees at the elite level of competition by the turn of the century, a more scientific approach towards the task of officiating is now feasible.

To place the energetic demands of refereeing in a nutritional context, the activities of referees during match-play are reviewed. The physiological demands imposed by these activities are then considered. The training programmes undertaken to meet these demands and the fitness standards set as targets by the ruling bodies are also addressed. These areas are all relevant to any inferences about specific nutritional counselling of referees.

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Activities of referees during match-play

The work rate of referees during matches may be determined by motion analysis using procedures that have been adopted for monitoring players (Bangsbo, 1994; Drust, Reilly, & Rienzi, 1998; Reilly & Thomas, 1976). The overall distance covered yields an indirect indication of the energy expenditure (Reilly & Thomas, 1979) but can be broken down according to exercise intensity. In general, a distinction is made between low-intensity activities such as walking and jogging and high-intensity activity such as striding or cruising (with effort but submaximal) and sprinting. Periods of inactivity when the referee is stationary and bouts of unorthodox movements such as backing or shuffling sideways may also be recorded.

Observations on referees in the English, Danish, Italian, and Tasmanian leagues indicate that referees cover between 9 and 13 km in a game. The highest individual values recorded were 13.1 km in the Italian League (D'Ottavio & Castagna, 2001) and 11.1 km in the Danish League (Krustrup & Bangsbo, 2001). The Danish referees were found to spend significantly more time standing and less time engaged in high-speed running and sprinting in the second half compared with the first half. Similarly, Catterall, Reilly, Atkinson and Coldwells (1993) reported a significant reduction in the distance covered by English referees during the second half. The Serie A referees studied by Castagna, Abt and D'Ottavio (2004) covered less distance running backwards and sideways in the second half compared with the first half; no differences were observed in the other movement categories. In footballers, a decline in performance in the second half has been linked to a run down of muscle glycogen stores (Saltin, 1973). This cause of fatigue has not been confirmed in referees and it may be linked to the fall in tempo of the game associated with the drop in work rate of the players. Krustrup and Bangsbo (2001) reported that referees were further away from infringements in the second half than in the first, suggesting that the fall in work rate manifests as true fatigue. The referee has to follow movements of the ball rather than those of players and so must be prepared for direct methods of attacking play towards the end of the game. The distance covered at high intensity decreased in the second half compared with the first so that any shift towards a strategy of long passes for distance would increase the load on the referee while sparing the players.

Most of the activity of referees is conducted at a low intensity, comprising walking and jogging (see Figure 1). The time spent inactive by the Danish referees amounted to 21.8% of the total time and constituted on average a 7–8 s period standing still once every 35 s (Krustrup & Bangsbo, 2001). The corresponding figure for Italian referees was 16.9% of the total time played (D'Ottavio & Castagna, 2001). The total number of activities recorded was 1268, representing a change in activity every 4.3 s on average. There were few significant differences in activities between the referees classed as top class and those described as high standard. The data from the studies cited in Table I imply that energy contribution is mainly from aerobic sources but there are episodes of appreciable anaerobic efforts during a match. Altogether, referees sprint for about 10–12% of the total distance (Catterall *et al.*, 1993; Friedman & Klein, 1988). Operating on a time-base and combining high-intensity running and sprinting, Krustrup and Bangsbo (2001) found that on average the referees performed 161 of these runs with a mean duration of 2.3 s during a game.

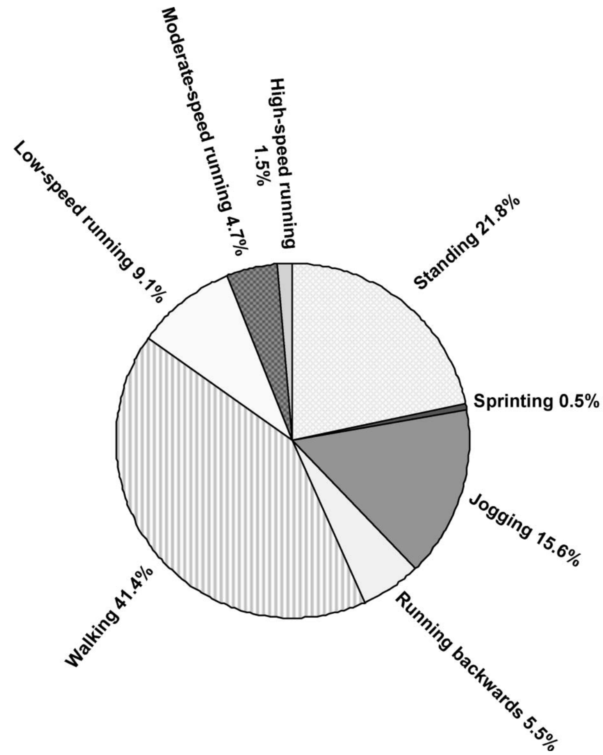

Figure 1. The percent of total time occupied by different categories of activity in top-class Danish referees. The diagram was drawn using the data of Krustrup and Bangsbo (2001).

It would appear that the work rate of referees expressed as total distance covered approximates and overlaps with that of professional players (see Reilly, 1997). A difference is that the referee is not called upon to make angled runs, accelerate and decelerate as abruptly as players or engage with agility and power in game-related actions. All these activities are energetically costly. The Danish referees covered 850 m moving backwards, the distance being greater in the first than in the second half (Krustrup & Bangsbo, 2001). The distance reported for reverse running for English referees was much greater, amounting to an average of 1722 m, while for the Australian referees the value was 1521 m. This unorthodox mode of motion adds to the energy expenditure (Reilly & Bowen, 1984) and is necessitated by moving backwards at free kicks and goal kicks to keep an eye on the ball and anticipate the location of the next possession.

Physiological responses to match-play

The monitoring of heart rate has been adopted as a means of indicating the physiological strain during match-play. It has been used also in conjunction with regression equations determining the relationship between heart rate and oxygen uptake ($\dot{V}O_2$) derived from laboratory assessments to estimate energy expenditure. Despite the irregular fluctuations in exercise intensity during match-play, the mean heart rate during a game can provide a reasonable estimate of the energy expended (Bangsbo, 1994; Reilly, 1997).

Catterall *et al.* (1993) reported resting heart rates of 100 beats · min^{-1} in English referees in the dressing room before going on to the pitch. Allowing for emotional tachycardia, the main cause was the light exercise undertaken as a warm-up. A similar value (98 beats · min^{-1}) was reported for the Australian referees studied by Johnston and McNaughton (1994) after a similar light warm-up. Since these studies were published, the warm-up of referees has become more structured but still entails a low outlay of energy and is less intensive than that undertaken by players.

The mean heart rate of referees has shown a remarkable agreement between studies, within a range 162–165 beats · min^{-1} (see Table II). There were no significant differences between halves even when work rates declined towards the end of the game. This consistency in heart rate throughout the game accompanied by a fall in work rate has been attributed to the cardiovascular drift that occurs with prolonged exercise (Catterall *et al.*, 1993). The mean heart rates suggest a similar relative cardiovascular strain on referees as on players, allowing for the greater age of the referees. The relative strain may be decreased at the lower divisions, Weston, Helsen, Bird, Nevill and Castagna (2005) reporting a higher mean heart rate and perception of exertion in the Premier League than in the Football League in England.

The variation in heart rate during competition may prove as insightful as the mean value. The high variability in the referees' responses in the European Nations Championship (Helsen & Bultynck, 2004) in France mid-summer may explain why mean values were lower than those observed in the professional national leagues. In studies of Danish referees, Krustrup and Bangsbo (2001) noted that heart rate was within the range 150–170 beats · min^{-1} for 56% of the time and above 170 beats · min^{-1} for 27% of total time. Heart rate exceeded 90% of maximum for more than 25 min. The highest heart rate observed was 196 beats · min^{-1}, while Catterall *et al.* (1993) reported a peak value of 200 beats · min^{-1} in English referees. Such values reflect the periodic bouts of anaerobic exercise superimposed on the predominantly aerobic activity. For those referees who had been studied twice, intra-individual variation in mean heart rate was 4 beats · min^{-1} (range 2–7 beats · min^{-1}) with a coefficient of variation of 2% (Krustrup & Bangsbo, 2001).

Table I. Distance covered by referees during football matches (mean ± *s*).

Competition	*n*	Age	Distance covered (m)	Reference
Japan Soccer League	10	–	10 168 ± 756	Asami *et al.* (1988)
International matches	7	–	9736 ± 1077	Asami *et al.* (1988)
English Premier League and First Division	14	–	9438 ± 707	Catterall *et al.* (1993)
Tasmanian State League	10	38.1 ± 3.8	9408 ± 838	Johnston and McNaughton (1994)
Italian Serie A	18	37.5 ± 2.1	11 376 ± 1604	D'Ottavio and Castagna (2001)
	13	37.0 ± 3.0	12 956 ± 548	Castagna *et al.* (2004)
Danish Superliga and First Division	27	38.0 (29–47)	10 070 ± 130	Krustrup and Bangsbo (2001)
European Cup matches	13	38.0 ± 3.0	11 218 ± 1056	Castagna *et al.* (2004)

Table II. Heart rate of referees during matches (mean ± *s*).

Competition	*n*	Heart rate (beats · min^{-1})	Reference
EnglishPremier League and First Division	14	165 ± 8	Catterall *et al.* (1993)
Tasmanian State League	10	163	Johnston and McNaughton (1994)
Italian Serie A	18	163 ± 5	D'Ottavio and Castagna (2001)
Danish Superliga and First Division	27	162 (137–179)	Krustrup and Bangsbo (2001)
UEFA 2000 Finals	17	155 ± 16	Helsen and Bultynck (2004)

The cardiovascular strain does not seem to be accentuated at international championship finals. Helsen and Bultynck (2004) monitored 17 top-class referees at the 2000 UEFA Championship, recording heart rates throughout matches (see Figure 2). The mean value was 155 ($s = 16$) beats · min^{-1} and was higher at the beginning of the first half than after the resumption following the half-time interval. It is in the first 15 min that tackles with a high risk of injury are most frequently executed (Rahnama, Reilly, & Lees, 2002), which may have an impact on the referee's behaviour. The risk rises again in the last 15 min, the period in which both players and referee are most likely to experience fatigue. The authors, Helsen and Bultynck (2004), concluded that their results supported the adoption of specialized intensive and intermittent training sessions by referees.

Krustrup and Bangsbo (2001) used the relationship between heart rate and oxygen uptake to estimate the oxygen consumption during a game. Oxygen uptake was calculated to be 3.03 litres · min^{-1}, which corresponded to 81% (73–88%) of maximum ($\dot{V}O_{2max}$). This value is in agreement with estimates of relative metabolic loading on players (Bangsbo, 1994). Assuming the transformations employed by Reilly and Thomas (1979), this value would amount to 5616 kJ over 90 min.

Mean blood lactate concentration has been recorded as 4.8 and 5.1 mmol · l^{-1} at the end of the first and second halves (Krustrup & Bangsbo, 2001). Values tend to reflect the activities before sampling, a significant correlation being observed between blood lactate concentration and mean heart rate in the 5 min before sampling the blood. The intra-individual variability was high with a coefficient of variation of 31%. These data are broadly in line with observations on players (Bangsbo, 1994).

Exercise at an intensity of 75–85% $\dot{V}O_{2max}$ over 90 min has consequences for thermoregulation, especially when matches are played in hot conditions. Da Silva and Fernandez (2003) focused on changes in hydration status of referees in Brazil during the autumn months. Mean temperature over six games was 20.3°C and relative humidity averaged 76.8%. Nude body mass was determined before and after matches and values were used together with water intake at half-time and urinary volume to estimate total body water loss. The referees lost 1.22 ($s = 0.10$) kg during the match, amounting to 1.55% of their pre-match body weight. Total water lost averaged 1.6 ($s = 0.13$) litres, corresponding to a sweat rate exceeding 1 litre · h^{-1} and representing 2.05% ($s = 0.18\%$) of body weight determined before the start of the game. These changes are close to the dehydration of 2% body weight thought to induce negative changes in exercise performance (Barr, 1999). The significant reduction in plasma volume of 5% was linearly related to total body water loss. The volitional intake of water during the half-time interval represented only 24% of the total water lost during the game. The question remains as to whether a more aggressive approach towards rehydration and attention to the content of fluid provided for referees would enhance their performance, particularly during the later stages of the game and when environmental temperatures are likely to induce heat stress.

Fitness and health-related assessments

The fitness targets for referees have been based on performance criteria rather than physiological

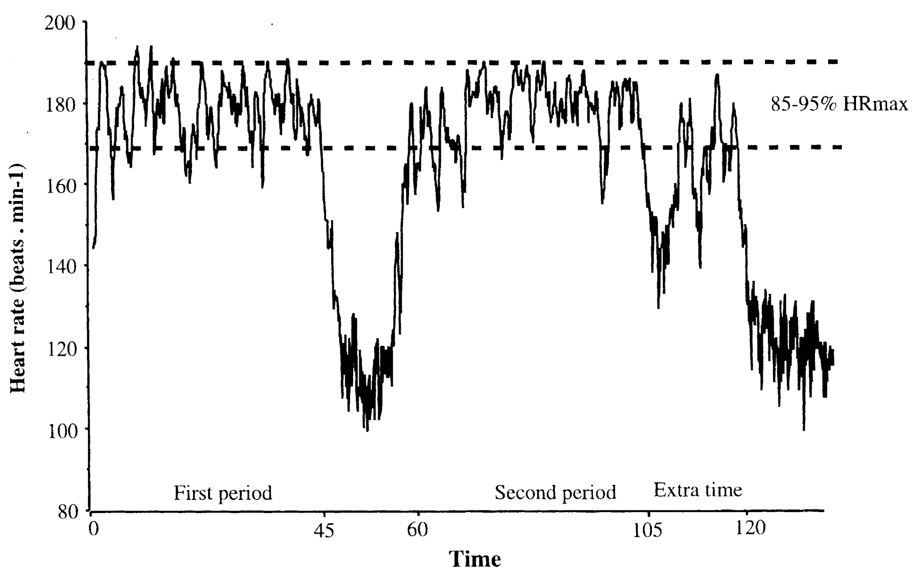

Figure 2. Graphical output of heart rate recordings, showing heart rate versus time for the referee during the final of the 2000 European Championship between France and Italy (from Helsen & Bultynck, 2004 Physical and perceptual-cognitive demands of top-class refereeing in association football, *Journal of Sports Sciences*, *22*, 179–189).

measures. Standards to achieve accreditation at national and international level have been raised successively to improve fitness. Unless referees maintain their level of performance in these tests, their accreditation is withdrawn.

At the time of Eissmann's (1994) review, Cooper's 12 min run test was used for endurance. The minimum distance allowed was 2700 m for males and 2000 m for females. The test was performed 15 min after completing a series of four sprints alternating between 50 m and 200 m with 15 min allowed between sprints. The maximum time permitted for 50 m was 7.5 and 9.0 s, and for the 200 m 32 and 42 s, for males and females respectively. A 4 × 10 m shuttle run was added in 1994 with an upper limit of 11.5 s.

The mean distance covered in the 12 min run by 10 top-class Danish referees was 2905 m (range 2720 – 3200 m) (Krustrup & Bangsbo, 2001). Their mean $\dot{V}O_{2max}$ was 46.3 ml · kg^{-1} · min^{-1}, while mean performance in the Yo-Yo recovery test of Bangsbo (1995) was 1308 m (range 1040 – 1960 m). The distance covered when performing high-intensity running was more highly correlated with performance in this Yo-Yo test ($r = 0.75$, $n = 18$) than was $\dot{V}O_{2max}$ ($r = 0.54$) or performance in the 12 min run test ($r = 0.46$).

Rontoyannis, Stalikas, Sarros and Vlastaris (1998) reported data from medical and functional assessments of 188 referees in Greece aged 36.3 ($s = 4.5$) years. Performances in all the FIFA running tests were satisfactory, being 7.45 ($s = 0.3$) and 7.5 ($s = 0.3$) s for 50 m, 31.2 ($s = 1.7$) and 31.9 ($s = 1.6$) s for 200 m, and 10.25 ($s = 0.3$) s for 4 × 10 m shuttle run. Performance in the 12 min run test was 2719 ($s = 172$) m, but there was a systematic decline from Divisions A to D of the league. Despite the broadly satisfactory performances, a majority of referees displayed a predisposition to coronary heart disease based on one to four risk factors. The mean body mass index was 25.9 ($s = 2.1$) and percent body fat was estimated to be 16.7 ($s = 2.5$) %. These values are higher than those found in professional players. Over 40% of the referees smoked more than 20 cigarettes a day, and 27% had resting blood pressures above upper normal limits. For these referees, a restriction of safe cigarette consumption to five-a-day was recommended and a decrease in energy intake was advised for the referees deemed to be overweight.

Assessment of body composition of referees provides insight into health-related status and indirectly yields information of nutritional relevance. The percent body fat values (mean 18.9%) of the sample of Premier League referees represent normal figures for their respective age but are much higher than values for players (see Table III). The body

Table III. Body composition data for Premier League referees and for Premier League players measured November 2004 (mean ± *s*).

	Referees ($n = 6$)	Players ($n = 13$)
Age (years)	37.5 ± 4.7	26.3 ± 5.0
Height (m)	1.82 ± 0.03	1.84 ± 0.05
Body mass (kg)	89.8 ± 4.8	84.7 ± 6.9
Body mass index	27.1 ± 5.3	25.0 ± 2.4
Body fat (%)	18.9 ± 3.7	13.0 ± 2.0
Bone mineral density (g · cm^{-2})	1.37 ± 0.34	1.46 ± 0.1

Note: Body composition was assessed using dual-energy X-ray absorptiometry.

mass index would place the referees within the overweight category but is likely explained by the higher than normal values for bone mineral density. While weight control may be a concern for some referees (the range for percent body fat was 14.0 – 22.7), the data demonstrate the limitations of the body mass index for both referees and footballers. The high bone mineral density for both groups suggests that the exercise stimulus for bone health and the dietary mineral content were adequate for both samples.

Training

A common feature in feedback to referees after fitness assessments is advice on training requirements. Generally, improvement of aerobic power is advocated and intermittent running is recommended to provide specificity for match activities. In an era of full-time professional referees, an optimization of training regimens would be expected. Compliance with guidelines for players on sports nutrition should be of benefit in the conduct of training as well as in matches, the referees being deemed athletes in their own right.

Castagna *et al.* (2004) attributed the difference of 1738 m between Serie A referees and international-match referees to the high-volume training conducted by the Italian officials. Krustrup and Bangsbo (2001) demonstrated how a systematic regimen of training can improve performance of match activities. The programme entailed three to four sessions per week of intermittent exercise over 12 weeks during a break in the competitive season. The first 4 weeks consisted of three long-duration interval sessions (4 × 4 min or 8 × 2 min), the second 4 weeks compromised three long-duration interval sessions and one short-duration session (16 × 1 min or 24 × 30 s), while the final weeks involved two short-duration and two long-duration interval sessions. There was a 2:1 ratio for exercise and rest. The programme improved performance in the Yo-Yo recovery test by 31 ($s = 7$) % and increased the amount of high-intensity running in a match by 23 ($s = 8$) %. This effect was evident in the number rather than in the distance of high-intensity runs, which remained at an average of 17 m.

Weston, Helsen, MacMahon and Kirkendall (2004) adopted a programme of high-intensity running in training sessions on both playing pitch and running track. Mean heart rate and intensity during these sessions were 86 ($s = 3$) % and 88.2 ($s = 2.4$) % maximal heart rate respectively. Over a period of 16 months, the performance of the referees on the Yo-Yo intermittent recovery test improved by 46.5% to a level deemed comparable with that of professional players.

It is clear that a regimen of physical training is required to enable professional referees to keep up with play at an elite level in contemporary football. The main emphasis may rightly be on aerobic training, but anaerobic elements, agility, and unorthodox movements should also be included. To cope with the repeated cycles of training and matches, referees must adopt nutritional strategies that resemble those used by players.

Assistant referees

Assistant referees would appear to have a physically less demanding task 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. Assistant referees tend to be drawn from accredited referees and so might be expected to have similar fitness levels even if activity is not as strenuous as that of the referee. Indeed, assistant referees in the top Danish league had mean $\dot{V}O_{2max}$ values of 45.9 (40.9 – 53.6) $ml \cdot kg^{-1} \cdot min^{-1}$, covered 2889 (2760 – 3175) m in the 12 min run, and were aged 40 (32 – 47) years (Krustrup, Mohr, & Bangsbo, 2002).

The movement patterns of 15 Danish Superliga assistant referees were monitored over 22 matches. The mean total distance covered was 7.28 ($s = 0.17$) km. This figure included 0.31 ($s = 0.04$) km of sprinting, 0.34 ($s = 0.03$) km of high-speed running, and 0.50 ($s = 0.03$) km of moderate-speed running. When these three categories were combined as high-intensity running, the total was significantly correlated with performance of repeated sprints. Sideways and backwards running accounted for 1.22 ($s = 0.15$) km or 16.8% of the total distance covered, while on 240 occasions the officials were standing for a mean duration of 10.9 s. Mean heart rate was 137 ($s = 3$) $beats \cdot min^{-1}$, corresponding to 73% of individual maximal heart rate and 65% $\dot{V}O_{2max}$. Blood lactate concentration was 4.7 (1.6 – 11.0) $mmol \cdot l^{-1}$ at half-time and 4.8 (1.1 – 13.7) $mmol \cdot l^{-1}$ at the end of the game; blood glucose concentrations at these times were 5.1 ($s = 0.1$) and 4.4 ($s = 0.2$) $mmol \cdot l^{-1}$. The officials spent more time standing, less time walking, and less time moving backwards and sideways in the second half than in the first. Sprinting performance in three 30 m runs was poorer after the game than it was pre-match, suggesting a fatigue effect. The peak distance to the offside line was greater in the second half than it was in the first half, reflecting the decreased ability of the officials to keep up with play. These observations indicate frequent short periods of inactivity during the game, a moderate aerobic energy production with episodes of high aerobic and anaerobic energy turnover.

Assistant referees ($n = 17$) at the 2000 European Championship finals were monitored by Helsen and Bultynck (2004). Mean heart rate was 144 ($s = 14$) $beats \cdot min^{-1}$ for the game as a whole and was higher at the beginning of the first half (0 – 15 min) than at the beginning of the second half (45 – 60 min). The mean value was 77 ($s = 7$) % of individual maximal heart rate and was lower than that for referees (85 $\pm$ 5%) at the same tournament.

In the Danish study (Krustrup *et al.*, 2002), the weight loss of the assistant referees during a game was 0.81 (0.49 – 1.56) kg or 1.0 (0.6 – 2.0) % of body mass. Mean fluid intake was 360 (200 – 500) ml and sweat loss was estimated to be 1.17 (0.83 – 1.81) litres, corresponding to 1.5 (1.0 – 2.3) % of body mass. These values are higher than observed for assistant referees in Brazil who consumed 250 ($s = 9$) ml of fluid, lost 0.63% of body mass and 1.05% of total body water (Da Silva & Fernandez, 2003). These figures amounted to less than half of the dehydration levels of the main official in Brazilian matches and may reflect the more conservative pace of the game in South America (Rienzi, Drust, Reilly, Carter, & Martin, 2000).

Cognitive function

Referees and assistant referees as well as players must make frequent game-related decisions during match-play. The intensity of exercise undertaken by the match officials during matches is frequently in the zone where cognitive function can be affected (Reilly & Smith, 1986). Although referees may experience increased difficulty in keeping up with play in the later stages of a game when carbohydrate reserves in active muscles are reduced, whether there is a concomitant change in the quality of decision making is unknown.

Helsen and Bultynck (2004) calculated that a top referee makes 137 observable decisions on average in a match, manifested as an intervention in play. They estimated also the frequency of invisible decisions and made allowance for the effective playing time to conclude that referees take three to four decisions each minute. The number of observed decisions is uniform throughout a match and in roughly two-thirds of cases is based on communication with the assistant referee. Choices are made against a background where noise from an excitable crowd and a home advantage can have an influence on the result.

There are numerous questions with respect to the influence of ergogenic aids and nutritional preparation on cognitive function. First, it is uncertain whether physiological fatigue necessitates a decline in mental performance related to the game. Nor is it known whether the executive function of the brain is aloof from the physiological strain and the performance deteriorations experienced by referees and assistant referees. It may be that deterioration in decision making occurs when cerebral metabolism is affected but existing laboratory-based assessments of cognitive function are not sensitive enough to detect the decline. While rehydration and energy provision can help to delay and offset muscular fatigue, their effects on "central factors" in match officials are not established.

Recommendations

Based on research already conducted, the following recommendations can be made:

1. Access to fluids should be equally available to match officials as to players during natural breaks in match-play.
2. Referees at the top level can adopt the nutritional guidelines used by players in preparing for and recovering from training and matches.
3. At lower standards of play, attention may need to be directed towards harmonizing nutritional and fitness measures in any instance of health-related concern.
4. At the international standard of refereeing, further research is needed to examine the variations in the physiological responses to match-play.

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