©Journal of Sports Science and Medicine (2008) **7,** 327-334
http://www.jssm.org

Research article

Energy expenditure and intensity of physical activity in soccer referees during match-play

Alberto Inácio da Silva [1] ✉, Luiz Cláudio Fernandes [2] and Ricardo Fernandez [2]
[1] Physical Education Department, State University of Ponta Grossa, UEPG, Paraná, Brasil.
[2] Physiology Department, Biological Science Building, Federal University of Paraná (UFPR), Paraná, Brasil

Abstract
The aim of this study was to determine the caloric expenditure and the intensity of physical activities performed by official soccer referees during a match expressed in Metabolic Equivalent (METs). The physical activity of referees accredited by *CBF* (Brazilian Confederation of Soccer) was video-recorded during twenty-nine official games of Paraná Championship (Brasil), Series A and B of the 2005/2006. Computerized video analysis was used to determine the time spent in 6 locomotor activities (standing still, walking, jogging, backwards running, running and sprint). The frequency and duration of each activity were recorded and these data were utilized to calculate the distance covered by the referee. Energy expenditure values were estimated, utilizing specific equations, from the time players spent in each motor activity. The referees observed in this study had a mean age of 38.9 ± 3.8 years, body mass of 86.1 ± 7.1 kg, stature of 1.80 ± 0.07 m and a body mass index of 26.5±0.6 $kg \cdot m^{-2}$. During match-play, referees covered an average distance of 9155.4±70.3 meters (8411 - 9765), with a mean energy expenditure of 734.7±65 kcal. This energy expenditure was significantly reduced in the second half: 359.9 ± 6.3 vs 374.7 ± 6.6 kcal ($p = 0.006$), and averaged to be moderate energy intensity (5 METs) with predominant utilization of the aerobic energy system. In total, during 67% of match-play the intensity was equal or lower than 3.8 METs and in 33% it was higher than 9.8 METs. The pattern of movement observed in the present study confirms that soccer refereeing may be considered as a highly intermittent exercise mode. The high to low-intensity activity ratio may be defined as 1:7.1. In conclusion, referees officiating in professional soccer matches in Brazil should perform a physical conditioning regime that provides the stamina required at this level and consume appropriate and adequate nutrition to meet the energetic demands for match-play.

Key words: Motion-analysis, referee, football, METs, oxygen consumption.

Introduction

The energy needs for an individual varies according to their age, sex and the physical activities that perform during the day. Healthy male individuals present an average energy demand of $2900 kcal \cdot day^{-1}$ (National Research Council, 1996); however, a professional soccer player's energy demand oscillates from 3500 to 4300 kcal/day (Clark, 1994; Bangsbo et al., 2006; Ebine et al., 2002; Rico-Sanz, 1998a). It should be acknowledged that these values for soccer players vary from week to week, and energy expenditure depends on the frequency and intensity of training sessions, exercises and matches.

In soccer, players and referees require a diet with a high percentage of carbohydrates (Rico-Sanz et al. 1998). In order to elaborate a diet that sufficiently restores the athlete's energy expenditure during training and/or competition, the first step would be to measure energy expenditure during activity. One way is to determine the demand in terms of VO_2 during competition (Rico-Sanz et al. 1998). There have been numerous studies that have investigated the soccer players' maximum oxygen consumption (Bangsbo et al. 1991; Bangsbo and Lindovist, 1992; Ekblom, 1993; Tumilty, 1993). Determination of VO_2 demand during the competition allows the calculation of athlete's energy expenditure with reasonable precision (Coast and Welch, 1985; Daniels, 1985; Daniels and Daniels, 1992). Since, on average, 5 kcal is produced for each liter of consumed oxygen, it is possible to express calorific expenditure during the match in kcal. The intensity of soccer referee's physical activities during official matches has been estimated by the recording of heart rate (Krustrup and Bangsbo, 2001; Weston and Brewer, 2002). The average match heart rate found in these studies attains 85% of referee's maximal heart rate. D`Ottavio and Castagna (2002) directly measured VO_2 responses using a portable light-weight gas analyzer in elite-level soccer referees officiating during a friendly match. They found that over the observed match period (first half) the referees attained 68% of the individual VO_2max, a value lower than that reported in those studies when VO_2 was estimated through heart rate.

Another means of estimating energy expenditure during physical activity involves the reporting in terms of Metabolic Equivalent (METs). A MET represents the resting VO_2 and is defined as the energy expenditure (VO_2) informed as $ml \cdot kg^{-1} \cdot min^{-1}$ or $L \cdot min^{-1}$ in rest conditions (Ainsworth et al., 1993). Therefore, the energy expenditure of a physical activity can be expressed in multiples of rest VO_2, which simplifies the measuring of energy needs during the exercise. According to Wilmore and Costill (2005), all physical activities can be classified by the intensity according to their needs of oxygen. Therefore, through METs estimations, it is possible to classify the intensity of different physical activities (Ainsworth et al., 1993).

Recent studies have demonstrated that refereeing is an exercise model mainly related to the aerobic pathway (Catterall et al. 1993; Johnston and Mcnaughton, 1994; Da Silva and Rodriguez-Añez 2001; D'Ottavio and Castagna, 2001; Krustrup and Bangsbo, 2001). However, it is also useful to convert this into a calorific expenditure

Received: 07 November 2007 / Accepted: 02 June 2008 / Published (online): 01 September 2008

and the intensity of referee's physical activities performed during a match expressed in METs to assist with conditioning and nutritional programmes. Therefore, the main objective of this study was to evaluate these parameters in professional soccer referees in Brazil in order to provide advice for nutritional strategies and interventions to restore the referee's energy during a match.

Methods

Subjects

The procedures adopted in the present study are in agreement with the 96/1996 resolution from the *Conselho Nacional de Saúde* (National Council of Health), which deals with research procedures in human beings. The project was approved by the Ethic committee of the University Hospital of the Federal University of Paraná (UFPR). All the subjects were volunteers male referees accredited by *CBF* (Brazilian Confederation of Soccer) that were informed verbally and by a written form about the nature and demands of the study, as well as about eventual health risks. They were also informed that they could withdraw from the study at any time. Written consent was obtained from each individual after approval of the experimental protocol by the Ethic Committee, including an authorization to film their activities during the match. The participants were submitted to the official physical tests used by FIFA to evaluate their referees and to a medical evaluation prior to this study. All subjects received approved in both evaluations. These referees officiated in 29 matches of the 2005 and 2006 Paraná Championship of professional Soccer, Series A and B. The State of Paraná (Brazil) Football Federation responsibly by the organization of this championship consent to realize this study, including film referees activity during the matches and made all the other procedures.

Each match was video-recorded using a camera (Sony, model Handycam CCD-TRV 128) attached to a tripod positioned at the side of the pitch, at the halfway line, at a height of about 15 m and at a distance of about 15-20m from the field. The camera filmed the referee close up to evaluate locomotive activities. The following locomotive categories were used: standing (0 $km \cdot h^{-1}$), walking (5.83 $km \cdot h^{-1}$), jogging (8.85 $km \cdot h^{-1}$), running (11.37 $km \cdot h^{-1}$), sprinting (18.28 $km \cdot h^{-1}$), and backwards running (8.85 $km \cdot h^{-1}$). These categories were chosen in accordance with a previous study (Da Silva and Rodrigues-Añez, 1999), whereas the mean speed for each category was determined after studies of the videotapes. The time for the subject to pass knows distances pre-markers in the field was used to calculate the speed for each locomotive activity. The frequency and duration of each activity were digitally recorded by the same experienced observer. These data were utilized to calculate the distance covered by the referee in each activity. The total distance covered during each stage of the match was calculated by adding the distances covered in each motion activity. This time motion analysis methodology utilized in the present study is similar to that employed by other authors (Catterall, 1993; Krustrup, 2001). Reproducibility of the results obtained in the present study was determined in a pilot study. Five matches were analyzed twice by the same observer, separated by at least 3 months. No systematic differences were observed in the test-retest analysis and the intra-individual differences in total distance covered were less than 0.25km. These results of reproducibility and reliability were similar to that obtained by the same observed in a previous study (Da Silva and Rodrigues-Añez, 1999).

Energy expenditure values were estimated from the time they spent in each motor activity. To calculate the oxygen uptake during running and sprinting we utilized the equation: $VO_2 = 3.5 + (0.2 \times m \cdot min^{-1})$, and for walking the equation: $VO_2 = 3.5 + (0.1 \times m \cdot min^{-1})$, both suggested by the American College of Sport Medicine (1988). Oxygen uptake during jogging and backwards running was calculated by the equation suggested by Bubb et al. (1985), $VO_2 = 3.5 + (km \cdot h^{-2} \times 0.394)$. Energy expenditure during the time subjects remained still was calculated multiplying the basal metabolism constant 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ by the mean body weight. The value of consumption of O_2 was then transformed in kcal, multiplying it by 5 (Wilmore and Costill, 2005).

The determination of referee's energy expenditure during the match in METs was possible by measuring the VO_2 spent for the execution of each locomotor activity. For an adult, 1 MET is approximately 3.5 ml of consumed O_2, for kilogram of body mass per minute (1 MET = 3.5 $ml.kg^{-1}.min^{-1}$). Therefore, the energy expenditure was estimated by dividing the VO_2 of each motion action by the constant 3.5.

Statistical analysis

The results are reported as mean and the respective standard error. Differences between the first and second halves of the match were determined using two-tailed Student's paired *t*-test, utilizing the statistical software Instat 3.0 (Graphpad Inc, San Diego, CA, USA). Values for $p < 0.05$ were considered statistically significant.

Results

The referees observed in this study had a mean age of 38.9±3.8years, body mass of 86.1 ± 7.1kg, a stature of 1.80 ± 7 m and a body mass index of 26.5 ± 0.6 $kg \cdot m^{-2}$. These characteristics were similar to other groups of official soccer referees observed in previous studies (Castagna et al., 2004; Krustrup and Bangsbo, 2001; Rebelo et al., 2002). The environmental conditions during the matches were considered to be warm with an average temperature of 23.1 ± 0.54 °C and humidity of 67.3 ± 3.5%.

Table 1. Time in minutes spent in each motion activity.

Sprinting	Running	Jogging	Backward running	Walking	Standing	Total
.24 (.03)	5.20 (.38)	17.26 (.78)	5.46 (.27)	47.06 (.74)	13.59 (.44)	90.00

The values represent the mean (± standard error) of the duration of each motion action expressed in minutes and seconds.

Table 2. Breakdown of the movements of the referees during the match.

Walking	Jogging	Running	Sprinting	Backward running	Total
4591.9 (73.4)	2577.2 (127.2)	1010.9 (74.6)	122.7 (19.3)	852.6 (48.7)	9155.5 (70.3)

The distances are described in meters. The values represent the mean (± standard error).

Table 1 shows the total mean time expended in each physical activity during the match. We observed that referees spent more of the time walking, and high intensity activities (running and sprint) accounted for less than 6 minutes. After the determination of the time that referees spent in each motion action, it was possible to determine the distances covered during the match. The mean total distance covered over the period of a whole match was 9155.5 ± 70.3m (8411.1m – 9765.4m). Table 2 shows the mean total distances covered in each motion action during match-play. In all matches, the total distance covered during the two halves was not significantly different with 4625.2 ± 43.1m covered in the first half and 4530.2 ± 43.0m in the second half, respectively (see Figure 1). The distance covered by walking increased significantly in the second half, to 2365.0±45.86m from a first half total of 2226.8 ± 41.3m, ($p < 0.01$). In contrast, the distance covered by jogging significantly reduced in the second half from 1353.6 0 ± 355.3m to 1224.0 ± 347.0m ($p < 0.05$). The total distance covered by backwards running was 852.6 ± 262.6m, with significant differences observed from: 467.3 ± 33.1m in the first half to a much reduced 385.3 ± 27.5 meters in the second half ($p < 0.05$). The total distance covered in high-intensity activities (running and sprint) were: 1010.9 ± 74.5 and 122.7 ± 19.3m respectively. There were no significant differences for these activities between the two halves.

Energy expenditure values of each motion action were estimated from the time they spent in each motor activity during the match applying the equations provided by American College of Sport Medicine (1988). The total energy expenditure during the match was 734.7±11.9kcal with significant differences observed between 374.7 ± 6.6kcal in the first half and 359.9 ± 6.3kcal in the second half ($p < 0.01$) (see Figure 2). Table 3 provides the results for the calorific expenditure for each motion type. Walking and jogging represented 71% of the total energy expenditure during the match (522.3kcal); on the other hand, the calorific expenditure in high-intensity activities (running and sprint) corresponded to only 14% (105.8kcal).

Discussion

In the present study, it was observed that during officials matches soccer referees perform physical aerobic activities of low and moderate intensity, and present a significant decline in energy expenditure between the first and second half. Other studies involving soccer referees have also confirmed that the physical activity of referees during match-play predominantly involves the utilization of energy originating from aerobic metabolism (Asami et al., 1988; Castagna et al., 2004; Catterall et al., 1993; Da Silva and Rodriguez-Añez, 1999; Johnston and McNaughton, 1994; Krustrup and Bangsbo, 2001).

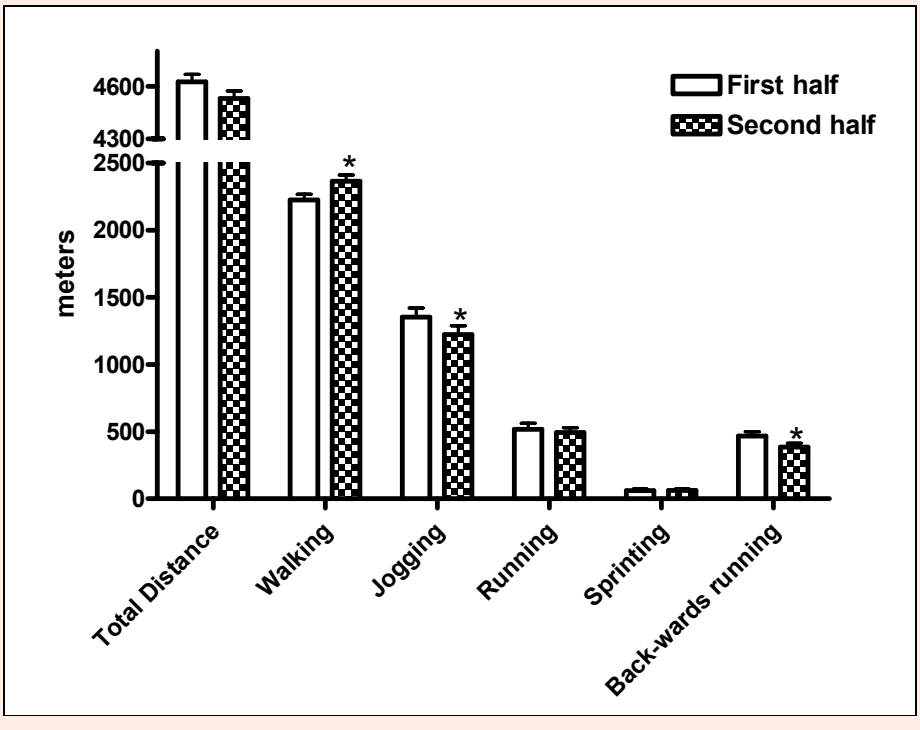

Figure 1. Summary of distances covered (meters) in each activity category during the first and second half of official matches by Brazilian referees.

* Significant difference ($p < 0.05$) between first and second halves.

Table 3. Calorific expenditure per motion action during the match.

	speed ($m \cdot s^{-1}$)	speed ($m \cdot min^{-1}$)	VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	VO_2 ($L \cdot min^{-1}$)	Time (mm:ss)	Kcal
Sprinting	5.08	304.8	64.46	5.55	0.24	11.07
Running	3.16	189.8	41.46	3.56	5.20	94.68
Jogging	2.46	147.9	34.52	2.97	17.26	256.25
Back running	2.46	147.9	34.52	2.97	5.46	85.57
Walking	1.62	97.5	13.25	1.14	47.06	266.05
Standing			3.5	0.30	13.59	21.08
Total						**734.71**

During the match, referees covered an average distance of 9155.4 ± 70.3 meters (8411 - 9765), a value similar to that observed in other studies (Catterall et al., 1993; Johnston and McNaughton, 1994; Krustrup and Bangsbo, 2001), but lower than that observed by Castagna et al. (2004), in Italian referees. The differences observed in match coverage between these studies could be partially related to different competitive level of the official matches analyzed. The referee's total distance covered during the match is similar to that described for soccer player, in particular to midfield players (Bangsbo et al., 1991; Mohr et al., 2003; Rienzi et al., 2000; Tumilty, 1993). The total distance covered provides an overall index of work rate, based on the assumption that the energy expenditure during the match is directly related to total work output (Drust et al., 1998). Also, the distance covered at high intensity activities (running and sprinting) is correlated with referee's aerobic fitness (Castagna, 2002; Krustrup, 2001).

During a soccer match the referee must observe the actions of players in an area that measures 8.250 m^2 on average (Castagna et al., 2007). Approximately every 4-6 seconds, the referee changes motion activity (D'Ottavio and Castagna, 2001; Krustrup and Bangsbo, 2001), equating to 1268 different activities during 90 minutes of an official match. Of these, 588 are consequence of low-intensity activities (standing, walking, jogging) and 161 of high intensity (running and sprint) (Krustrup and Bangsbo, 2001). These indicate that soccer referring is a highly intermittent exercise mode. In other words, soccer referees have significant aerobic energy expenditure throughout a match and episodes of considerable anaerobic energy turnover. The aerobic energy production accounted for approximately 90% of total energy consumption (Bangsbo, 1994). This percentage present a large inter-individual differences due to the variety of factors which influence exercise intensity. All the evidence presented above support the necessity of improving aerobic metabolism in soccer referees, but without forgets anaerobic fitness (Castagna et al., 2007).

In the present study, a similar pattern was observed with referees spending 52% of the total match time walking, 19% jogging and 15% standing. These prevalence of a pattern of movements at low speed (walking and jogging) have been observed in others studies (Asami et al., 1988; Catterall et al., 1993; Da Silva and Rodriguez-Añez, 1999; D'Ottavio and Castagna, 2001; Johnston and Mcnaughton, 1994; Krustrup and Bangsbo, 2001), which a range between 41.8% and 73.8% of match coverage (Castagna et al., 2007). The results of this study were found to be in the upper limit of this range (71%). It has previously been described that low-intensity activities are negatively correlated with aerobic fitness (Castagna and D`Ottavio, 2001). Differences in game style and match intensity among countries are other factors that should also be taken into account when results are compared (Rebelo et al., 2002; Helsen and Bultynck, 2004). For example, it has been reported that South American international soccer players cover significantly less total distance during a match (8638meters) than English premier league players (10104meters) or elite Danish players (10800meters) (Rienzi et al., 2000; Bangsbo et al., 1991). Recently, it has been reported that work-rates of referees during match-play were partly related to the physical activities of the players (Weston et al., 2007). The high percentage (71%) of movements at low speed (walking and jogging) found in the present study could be the result of a lower match intensity of the regional championship where referees officiated, and/or differences in game style between south American and Europeans players. A recent work with English referees found that match intensity (evaluated by ratings of perceived exertion – RPE)

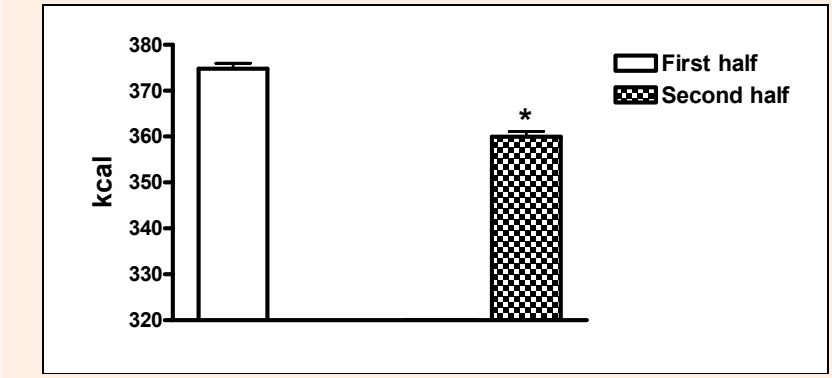

Figure 2. Summary of energy expenditure of soccer referees during official matches.

was correlated to competition standard (Weston et al., 2006). Other studies observing match intensities, player's physical activities and referee work-rates in the same match of official Brazilian soccer championship are necessary to explain this point.

Running at high (sprint) and moderate intensity speeds (running) are rarely performed by soccer referees. In the present study this did not occur for more than 6% of total time (Table 1). They covered a mean distance of 1010.9 ± 74.5 meters running and 122.7 ± 19.3 meters sprinting, without a significant difference in performance between the two halves (Table 2 and Figure 1). In other studies, it has been reported that the percentage of match time spent performing high intensity activities varies from 4 to 18% (Asami et al., 1988; Catterall et al., 1993; Da Silva and Rodriguez-Añez, 1999; Johnston and Mcnaughton, 1994; Krustrup and Bangsbo, 2001; Rebelo et al., 2002), with a significant reduction during the second half (Krustrup and Bangsbo, 2001) a result suggesting that referees experience fatigue towards the end of the match. In the present study, a significant reduction was not observed for these activities during the second half, however, a significant reduction in backwards running was observed (see Figure 1). This type of motor activity represented 6% of total match time. We know from several studies that backwards running is more demanding in terms of energy expenditure than forward running (Flynn et al., 1994; Reilly and Bowen, 1984; Williford et al., 1998). The results of this study could therefore suggest that referees experience fatigue towards the end of the match. However, the absence of a significant difference in high intensity activities between halves does not allow us to confirm this point. Factors such as depletion of glycogen stores, dehydration and hyperthermia may contribute to the development of fatigue in the later stages of a soccer game. These factors were better studies in soccer players than in referees (Bangsbo et al., 2006; Castagna et al., 2007; Da Silva and Fernandez, 2003; Reilly, 1997). The most important aspect of refereeing is the decision-making process, but the effect of physical performance on this aspect has received little attention. Helsen and Bultynck (2004) quantified the perceptual cognitive workload of elite soccer referees and observed that they undertakes about 137 observable decisions during a match, uniformly distributed throughout the six 15min intervals. On the other hand, mean distance from infringements increased in the second period of the match only in the left attacking zone, a zone where the ability of assistant referees to help was limited (Mallo et al., 2007). This observation reinforces the idea of fatigue at the end of the match, and its possible negative effect on the decision-making process. At the present time is not clear if improving exercise capacity may decrease the probability of incurring judgments errors during the match.

Energy expenditure during a physical activity can be measured directly in laboratory or estimated indirectly from oxygen uptake or from core temperature. Several reports have shown that it is possible to estimate the energy expenditure of a physical activity with reasonable precision using the consumption of oxygen (Hopkins and Powers, 1982; Coast and Welch, 1985; Daniels, 1985; Daniels and Daniels, 1992). Indirect measurements are generally used to estimate energy expenditure during soccer matches (Bangsbo et al., 2006). As described above, measures of heart-rate were utilized in several studies to estimate exercise intensity and aerobic involvements of soccer players and referees (Bangsbo et al., 2006; Castagna, 2007). Factors like dehydration, hyperthermia, and mental stress elevate the heart rate without affecting oxygen uptake, leading to an overestimation of this variable. In the present study the VO_2 was estimated for each motion action. A principal limitation of the present time-motion technique may be the reliability of the match observer. No systematic differences were observed in the test-retest analysis and the intra-individual differences in total distance covered were less than 0.25km. Further studies are necessary to measure directly VO_2 uptake during the match, through online measurements, and compare it against the VO_2 values estimated from time-motion analysis or recording of heart rate.

In the present study, a soccer referee's estimated energy expenditure during the match was 734.7 ± 11.9 kcal (903.2 - 641.3). This energy expenditure was significantly reduced in the second half (see Figure 2), a fact that could be explained by the reduction in jogging and back-wards activities observed in this period. Direct measurements of oxygen consumption in soccer players during a match reported a value of energy expenditure of 1195kcal, and the value estimated by the recording of heart rate was 1565kcal, in mean (Shephard, 1992). These values of energy expenditure are significantly lower than the value of 1702 kcal reported in English referees by Weston and Brewer (2002), who determined in laboratory conditions, a HR-VO_2 relationship to estimate this parameter. The differences observed between field and laboratory assessment of energy expenditure in referees is not completely clear, but it is known that the treadmill protocol of determining HR-VO_2 could overestimate the match VO_2. As described above backward movement elicits a greater metabolic demand and cardiopulmonary response than forward locomotion (Flynn et al., 1994; Reilly and Bowen, 1984; Williford et al., 1998). Williford et al. (1998), working with collegiate tennis players, found that at running speed (8 $km \cdot h^{-1}$) the VO_2 and heart rate were both 15% greater for backwards running compared with forward running. Furthermore, the energy expended per minute by soccer players at 9 $km \cdot h^{-1}$ at backwards movements increased 4.93kcal over forward running, an increase of approximately 40% (Reilly and Bowen, 1984). The equations utilized in the present study to calculate the oxygen uptake during motor activities use the mean speed for each category. Backwards displacements happen at the same mean speed that jogging (8.85 $km \cdot h^{-1}$), so the calculated value for oxygen uptake is the same. This is a limitation to our study, because the expected greater metabolic demand with backward movements is probably underestimated by the equation. If we utilized the data of Williford work to correct the VO_2 in 15%, the estimated total energy expenditure during the match will be 768,1kcal, a value still lower than that reported by Weston and Brewer (2002).

If we take into consideration the fact that a male person consumes, on average, 2.900 kcal·day^{-1} (National Research Council, 1996), then the referee's energy demand during a match would be from 3.500 to 4.000 kcal/day. A professional soccer player, in order to cope with the daily physical activity and the physical effort due to a soccer training and competition, should consume 3500 to 4.500 kcal·day^{-1} (Clark, 1994; Bangsbo et al., 2006; Ebine et al., 2002; Rico-Sanz, 1998; Shephard, 1992). A soccer player's training is generally more frequent and longer in duration than a referee, with a higher energy cost (Bangsbo et al., 2006). Considering that the energy expenditure of referees is lower to that for a player during a match, their energy needs to support daily physical activities (training and refereeing) will generally be lower.

Based on the total or partial caloric expenditure of each action expressed in kcal, we could not determine the intensity of the physical activity. However, with the estimated VO_2 of each motion action it is possible establish another way to enunciate the energy expenditure and also of classifying the physical activity according to its intensity, using MET (Metabolic Equivalent). As discussed above referees spent 52% of the match walking, an activity with an estimated consumption of oxygen of 13.25 ml·kg^{-1}·min^{-1}, which corresponds to an energy expenditure of 3.8 METs. Another action of low consumption of oxygen during the match is the time spent standing, with an estimated consumption of oxygen of 3.5 ml·kg^{-1}·min^{-1}, and an energy expenditure of 1 MET. Therefore, during 67% of the match, they perform physical activities that could be classified as low intensity, aerobics (Ainsworth et al., 1993; Durnin and Passmore, 1967). The remaining 32% of match time is spent performing physical activities using energy originating from the aerobic and anaerobic system (backwards running, jogging, running and sprint). In backwards running and jogging, the estimated consumption of O_2 was 34.52 ml·kg^{-1}·min^{-1}, which corresponds to 9.8 METs, an activity considered as intense (Durnin and Passmore, 1967). During only 7% of match time referees performed running or sprinting movements, with an energy consumption of 41.46 VO_2 ml·kg^{-1}·min^{-1} (11.8 METs) and 64.46 VO_2 ml·kg^{-1}·min^{-1} (18.4 METs). Activities with energy consumption above 10 METs are classified as extremely intense (Durnin and Passmore, 1967).

To obtain an unbiased measure of the mean intensity of referee's physical activity during the match, the mediated average instead of the simple arithmetic average was used. The amount of METs expenditure depends on the speed, divided in 6 categories in this study. For example, the amount of METs spent in the condition "standing still" is relatively lower than during sprint. Besides, there is a great difference in the total time of permanence in activities of high and low speed. Therefore, measurement of the mediated average significantly reduces the possibility of obtain biased results by the highlighted reasons. Using the mediated average, it was estimated that the mean energy consumption of a referee is equal to 5 METs. Based on this result and using the classification proposed by Ainsworth et al. 1993, it is possible to classify the referee's physical activity as moderate energy intensity. This result coincides with the data obtained in the studies that measured the intensity of referee's physical activity by means of heart rate (Catterall et al. 1993; Castagna, 2001; Da Silva and Rodriguez-Añez, 2005; Helsen and Bultynck, 2004; Johnston and Mcnaughton, 1994; Krustrup and Bangsbo, 2001; Rebelo et al., 2002).

The METs system was developed to standardize intensities of physical activities and promote comparison across different studies (Ainsworth et al., 1993). The METs values obtained in the present study, allow us to compare the intensity of a referee's physical activity with the results obtained in soccer players or athletes of other sports, which energy requirements were better establish. This information could be useful in the future to establish a specific nutritional program for soccer referees.

Conclusion

In summary, the present study showed that during official matches, Brazilian referees cover on average, a distance of 9155.47 ± 379 meters with a mean energy consumption of 734.7 ± 65 kcal. This physical activity is, on average, of moderate energy intensity (5 METs) with predominance of the aerobic energy system. However, during 67% of match time the intensity is equal or lower than 3.8 METs and in 32% higher than 9.8 METs. The pattern of movement observed in the present report confirms that soccer referees, like players undertake intermittent type exercise. The high to low-intensity activity ratio may be defined as 1: 7.1. This means that, on average, a high intensity bout occur every 7 low intensity bouts, with an averaged duration of approximately 3.2 seconds. The referee spent 4712 seconds with low-intensity activities and 690 seconds with high-intensity. Although, the distances covered by soccer referees and energy expenditure during the match were very similar to those observed in soccer players, their nutritional strategies should be suitably adapted for the physical demands of the referee. Therefore, the nutritional habits must be adapted to their daily physical activities, short training periods and moderate energy intensity physical activity, on average, during match refereeing.

Acknowledgments

Luiz C. Fernandes was supported by a grant of the Conselho Nacional de Pesquisas (CNPq), Brazil.

References

Ainsworth, B.E., Haskell, W.L., Leon, A.S., Jacobs, Jr.D., Montoye, H.J., Sallis, J.F. and Paffenbarger, Jr.R.S. (1993) Compendium of physical activities: classification of energy costs of human physical activities. *Medicine and Science in Sports and Exercise* **25,** 71-80.

American College of Sport Medicine. (2005) *Guidelines for exercise testing and prescription.* 7th edition. Lippincott Williams & Wilkins, Philadelphia (PA).

American College of Sport Medicine. (1988) *Guidelines for graded exercise testing and exercise prescription.* 2nd. edition. Lippincott Williams & Wilkins, Philadelphia (PA).

Asami, T., Togari, H. and Ohashi, J. (1988) Analysis of movement patterns of referees during soccer matches. In: *Science and Football*. Eds: Reilly T., Lees A., David K., Murphy W.J. London, E& FN. Spon. 341-345.

Bangsbo, J., Norregaard, L. and Thorsoe, F. (1991) Activity profile of competition soccer. *Canadian Journal of Sports Science* **16,** 110-116.

Bangsbo, J. and Lindovist, F. (1992) Comparison of various exercise tests with endurance performance during soccer in professional players**.** *International Journal of Sports Medicine* **13,** 125-132.

Bangsbo, J. (1994) Energy demands in competitive soccer. *Journal of Sports Sciences* **12,** S5-S12.

Bangsbo, J., Mohr, M. and Krustrup, P. (2006) Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences* **24(7),** 665-674.

Bubb, W.J., Martin, A.D. and Howley, E.T. (1985) Predicting oxygen uptake during level walking at speed of 80-130 m/min. *Journal of Cardiopulmonary Rehabilitation* **5(10),** 462-465.

Burke, L., Loucks, A. and Broad, N. (2006) Energy and carbohydrate for training and recovery. *Journal of Sports Sciences* **24(7),** 675-685.

Castagna, C. and D`Ottavio, S. (2001) Effect of maximal aerobic power on match performance in elite soccer referees. *Journal of Strength and Conditioning Research* **15(4),** 420-425.

Castagna, C., Abt, G. and D'Ottavio, S. (2002) The relationship between selected blood lactate thresholds and match performance in elite soccer referees. *Journal of Strength and Conditioning Research* **16,** 623-627.

Castagna, C., Abt, G. and D'Ottavio, S. (2004) Activity profile of international-level soccer referees during competitive matches. *Journal of Strength and Conditioning Research* **18(3),** 486-490.

Castagna, C., Abt, G. and D'Ottavio S. (2007) Physiological aspects of soccer refereeing performance and training. *Sports Medicine* **37(7),** 625-646.

Catterall, C., Reilly. T., Atkinson, G. and Coldwells, A. (1993) Analysis of the work rates and heart rates of association football referees. *British Journal of Sports Medicine* **27(3),** 193-196.

Clark K. (1994) Nutritional guidance to soccer players for training and competition. *Journal of Sports Sciences* **12,** S43-S50.

Coast, J. and Welch, H.G. (1985) Linear increase in optimal pedal rate with increased power output in cycle ergometry. *European Journal of Applied Physiology* **53,** 339-342.

Da Silva, A.I. and Rodriguez-Añez, C.R. (1999) Motor actions of soccer referee during the game. *Treinamento Desportivo* **4(2),** 5-11. (In Portuguese: English abstract).

Da Silva, A.I. and Rodriguez-Añez, C.R. (2001) Energetic expenditure of the referee and the assistant soccer referee. *Journal of Physical Education/UEM* **12(2),** 113-118. (In Portuguese: English abstract).

Da Silva, A.I. and Fernández, R. (2003) Dehydration of football referees during a match. *British Journal of Sports Medicine* **37,** 502-506.

Da Silva, A.I. (2005) *Scientific and methodologist bases for the training of soccer referees.* 1st edition. UFPR Editor, Curitiba, Brasil.

Da Silva, A.I. and Rodriguez-Añez, C.R. (2007) Cardiac responses to the physical activity of the soccer referee during a match. *Cadernos Camilliani* **8(1),** 83-90. (In Portuguese: English abstract).

Daniels J. (1985) A physiologist's view of running economy. *Medicine and Science in Sports and Exercise* **17,** 332-338.

Daniels, J. and Daniels, N. (1992) Running economy of elite male and elite female distance runners. *Medicine and Science in Sports and Exercise* **24,** 483-489.

D'Ottavio, S. and Castagna, C. (2001) Physiological load imposed on elite soccer referees during actual match play. *Journal of Sports Medicine and Physical Fitness* **41,** 27–32.

D'Ottavio, S. and Castagna, C. (2002) Physiological aspects of soccer refereeing. In: *Science and Football IV*. Eds: Spinks W., Reilly T., Murphy A. London, Routledge. 144-150.

Drust, B., Reilly, E. and Rienzi, E. (1998) Analysis of work rate in soccer. *Sports Exercise and Injury* **4,** 151-155.

Durnin, G. B. and Passmore, R. (1967) *Energy, work and leisure.* Heinmann, London.

Ebine, N., Rafamantanantsoa, H., Nayuki, Y., Yamanaka, K., Tashima, K., Ono, T., Saitoh, S. and Jones, P. (2002) Measurement of total energy expenditure by the doubly labeled water method in professional soccer players. *Journal of Sports Sciences* **20(5),** 391-397.

Ekblom, B. (1993) Applied physiology of soccer. *Sports Medicine* **3,** 50-60.

Flynn, T., Connery, S., Smotuk, M., Zeballos, R. and Weisman, I. (1994) Comparison of cardiopulmonary responses to forward and backward walking and running. *Medicine and Science in Sports Exercise* **26(1),** 89-94.

Helsen, W. and Bultynck, J. B. (2004) Physical and perceptual-cognitive demands of top-class refereeing in association football. *Journal of Sports Sciences* **22,** 179-89.

Hopkins, P and Powers, S. (1982) Oxygen uptake during submaximal running in highly trained men and women. *American Corrective Therapy Journal* **36,**130-132.

Johnston, L. and McNaughton, L. (1994) The physiological requirements of soccer refereeing. *Australian Journal of Science and Medicine in Sport* **26 (3-4),** 67-72.

Krustrup, P. and Bangsbo J. (2001) Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. *Journal of Sports Sciences* **19,** 881-891.

Mallo, J., Navarro, E., Garcia-Aranda, J.M., Gilis, B. and Helsen, W. (2007) Activity profile of top-class association football referees in relation to performance in selected physical tests. *Journal of Sports Sciences* **25(7),** 805-813.

Mohr, M., Krustrup, P. and Bangsbo, J. (2003) Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences* **21(7),** 519-528.

National Research Council Food and Nutrition Board. (1996) *Recommended Dietary Allowances.* 10th edition. National Academy Press, Washington (DC).

Rebelo, A., Silva, S., Pereira, N. and Soares, J. (2002) Physical activity of soccer referees uring the match. *Revista Portuguesa de Ciências do Desporto* **2(5),** 24-30.

Reilly, R. and Bowen, T. (1984) Exertional costs of changes in directional modes of running. *Perceptual and Motor Skills* **58,** 149-150.

Reilly, T. (1997) Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *Journal of Sports Science* **15,** 257-263.

Reilly, T. and Gregson, W. (2006) Special populations: the referee and assistant referee. *Journal of Sports Science* **24(7),** 795-801.

Rico-Sanz, J., Frontera, W.R., Molé, P.A., Rivera, M.A., Rivera-Brown, A. and Meredith, C.N. (1998) Dietary and performance assessment of elite soccer players during a period of intense training. *International Journal of Sports Nutrition* **8,** 230-240.

Rico-Sanz, J. (1998a) Body composition and nutritional assessments in soccer. *International Journal of Sports Nutrition* **8,** 113-123.

Rienzi, E., Drust, B., Reilly, T., Carter, J. E. and Martin, A. (2000) Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *Journal of Sports Medicine and Physical Fitness* **40(2),** 162-169.

Roman, E.R., Arruda, M., Gasperin, C.E., Fernandez, R. and Da Silva, A.I. (2004) Study of the dehydration, intensity of the physical activity and distance covered for the soccer referee during the game. Revista Brasileira de Fisiologia do Exercício **3(2),** 160-71. (In Portuguese: English abstract).

Rontoyannis, G.P., Stalikas, A., Sarros, G. and Vlastaris, A. (1988) Medical, morphological and functional aspects of Greek football referees. *Journal of Sports Medicine and Physical Fitness* **38(3),** 208-214.

Shephard, R. (1992) The energy needs of the soccer player. *Clinical Journal of Sport Medicine* **2(1),** 62-70.

Tumilty, D. (1993) Physiological characteristics of elite soccer players. *Sports Medicine* **16,** 80-96.

Weston. M., Helsen, W., Macmahon, C. and Kirkendall, D. (2004) The impact of specific high-intensity training sessions on football referees' fitness levels. *American Journal of Sports Medicine* **32(1),** 54s-61s.

Weston. M. and Brewer, J. (2002) A study of the physiological demands of soccer refeering. *Journal of Sports Sciences* **20,** 59-60.

Weston, M., Bird, S., Helsen, W., Nevill, A. and Castagna, C. (2006) The effect of match standard and referee experience on the objective and subjective match workload of English Premier League referees. *Journal of Science and Medicine in Sport* **9,** 256-262.

Weston, M., Castagna, C., Impellizzeri, F.M., Rampinini, E. and Abt, G. (2007) Analysis of physical match performance in English premier league soccer referees with particular reference to first half and player work rates. *Journal of Science and Medicine in Sport* **10(6),** 390-397.

Wilmore, J.H. and Costill, D.L. (2005) *Physiology of Sport and Exercise.* 3th. edition. Human Kinetics Publishers, Idaho.

Williford, H.N., Olson, M.S., Gauger, S., Duey, W. and Blessing, D.L. (1998) Cardiovascular and metabolic costs of forward, backward, and lateral motion. *Medicine and Science in Sports and Exercise* **30(9),** 1419-1423.

Wolinsky, I. (1997) *Nutrition in Exercise and Sport*. 3th. edition. CRC Press, Boca Raton (FL).

Key points

- In order to elaborate a diet that sufficiently restores the athlete's energy expenditure during training and/or competition, the first step would be to measure energy expenditure during activity.
- We observed that during officials matches soccer referees perform physical aerobic activities of low and moderate intensity, and present a significant decline in energy expenditure between the first and second half.
- The pattern of movement observed in the present report confirms that soccer referees, like players undertake intermittent type exercise.
- Nutritional habits of soccer referees must be adapted to their daily physical activities, short training periods and moderate energy intensity physical activity, on average, during match refereeing.

AUTHORS BIOGRAPHY

Alberto Inácio DA SILVA
Employment
Asistant professor. Physical Education Department, State University of Ponta Grossa – UEPG, Paraná, Brasil
Degree
PhD
Research interests
Physical performance and training of soccer referees.
E-mail: albertoinacio@bol.com.br

Luiz Cláudio FERNANDES
Employment
Associated Professor. Physiology Department, Biological Science Building, Federal University of Paraná (UFPR), Paraná, Brasil
Degree
PhD
Research interests
Effect of fish oil supplementation and physical activity on metabolism of normal and cachectic subjects.
E-mail: lcfer@ufpr.br

Ricardo Fernandez PEREZ
Employment
Associated Professor. Physiology Department, Biological Science Building, Federal University of Paraná (UFPR), Paraná, Brasil
Degree
PhD, MD
Research interests
Regulation of renal proton transport. Physical performance of soccer referees.
E-mail: ricfer@ufpr.br

✉ **Alberto Inácio da Silva, PhD**
Universidade Estadual de Ponta Grossa, Campus Uvaranas - Av. General Carlos Cavalcanti, 4748, CEP 84.030-900, Ponta Grossa - Paraná - Brasil