Heart rate and the distance performed by the soccer referees during matches: a systematic review

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Summary

Introduction: The football referee has an important role in the practice of the sport, requiring excellent physical conditioning. The objective of the present study was to analyze the relationship between heart rate and distance covered by field soccer referees during their performances in games.
Material and method: A broad search of articles was carried out, without restriction of dates, in the following electronic databases: Pubmed, Scielo and Google academic, being the last search carried out on 10/09/2017. The following search terms were used: ("heart rate" or "heart rate determination") AND ("distance" or "distance perception" or "vertical dimension") AND
Results: There were 78 articles with potential relevance, 27 articles included all the inclusion and exclusion criteria, totaling 428 soccer referees, analyzed in 2,936 games of the modality.
Conclusion: The referees need a very specific preparation. They travel long distances in games, 10.36 ± 1.11 km per game, but in a very specific way. They vary greatly in direction, intensity, speed and range of heart rate, this happens several times in a non-progressive way. They work in matches with a FC_{med} ranging around 158,88 ± 3,99 bpm and, in most games, they move in low intensity, but high intensity stimuli are very intense and last very little from 2 to 4 seconds, being directly connected to the crucial bids, on these occasions they reach 97%of their $FC_{máx}$. Finally, it is suggested as a practical application a special attention is needed in the preparation and analysis of decision-making processes. Referees need to be trained, evaluated and quantified in circumstances that resemble game conditions, both physically and psychologically. It is necessary to ally physical demands with cognitive, that resemble the environments of the matches, in the trainings and tests.

Key words:
Soccer. Heart rate. Displacement. Review. Physiology. Sport. Movement. Running. Work. Physical education.

Frecuencia cardíaca y la distancia recorrida por los árbitros de fútbol durante los partidos: una revisión sistemática

Resumen

Introducción: El árbitro de fútbol tiene un relevante papel en la práctica de la modalidad y necesita de excelente condición física. El objetivo del presente estudio fue analizar la relación entre la frecuencia cardíaca y la distancia recorrida por los árbitros de fútbol de campo durante sus actuaciones en los juegos.
Material y método: Se realizó una amplia búsqueda de artículos, sin restricción de fechas, en las siguientes bases de datos electrónicas: Pubmed, Scielo y Google académico, siendo la última búsqueda efectuada el día 10/09/2017. Se utilizaron los siguientes términos de búsqueda: ("frecuencia cardíaca" o "heartrate" o "heart rate determination") AND ("distancia" o "distance" o "distance perception" o "vertical dimension") AND (árbitro de fútbol o "soccer referee" or "football referee").
Resultados: Se encontraron 78 artículos con potencial relevancia, 27 artículos contemplaron todos los criterios inclusión, sumando 428 árbitros de fútbol, analizados en 2.936 partidos de la modalidad.
Conclusión: Los árbitros necesitan una preparación muy específica. Recorren grandes distancias en los partidos, 10,36 ± 1,11 km por juego, pero de forma muy específica. Cambian mucho de dirección, de intensidad, de velocidad y rango de frecuencia cardíaca, esto sucede varias veces de forma no progresiva. En la mayoría de los juegos, se desplazan en baja intensidad, pero los estímulos de alta intensidad son muy intensos y duran muy poco de 2 a 4 segundos en su mayoría, estando directamente en los que en esas ocasiones llegan a alcanzar el 97% de su $FC_{máx}$. Se sugiere como una aplicación práctica una atención especial en la preparación y el análisis de los procesos decisivos. Los árbitros deben ser entrenados, evaluados y cuantificados en circunstancias que se asemejen a las condiciones de juego, tanto física, como psicológicamente. Es necesario enlazar las demandas físicas con las cognitivas en los entrenamientos y pruebas que asemejen a los ambientes de los partidos.

Palabras clave:
Fútbol. Frecuencia cardíaca. Desplazamiento. Revisión. Fisiología. Deporte. Movimiento. Carrera. Trabajo. Educación física.

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Introduction

Soccer referees play an important role in the game as they are responsible for applying the match rules, making it possible to take fair and comfortable decisions that are definitive and that validate the outcome of the dispute[1].

The referee must be able to follow movements as closely as possible by finding a well-angled view. This enables referees to be impartial and fair, disconnected from any psychological or physical presssure[2-3], a practice that requires good resistance to carry out intermittent and prolonged exercises[4].

Scientific interest for soccer has increased considerably, as the sport is more dynamic. From the 1990s, research – which until that point had been too contingent – became more systematic, yet the change to the game pattern introduced by the W0rld Championship Team in 1994 appears to have been a milestone for both soccer and the academic community dedicated to studying this sport. Numerous relevant studies intensified after that event[4].

Yet the majority of studies focus on the player. Few studies address the physical needs of the football referee, as this person plays a role in the game and reaches very high heart rates. Catteral *et al.*[6] carried out research verifying that during matches, football referees reach average heart rate values (HR) of 165 beats/min^{-1}. Other studies[7-9] discovered equivalent values and in some cases even higher HR values during matches. These values correspond to approximately 85-90% of the maximum heart rate (HRmax)[7,9,10]. It would be reasonable to affirm that a suitable level of physical aptitude is required, principally of the cardio-respiratory system. Blood lactate increased substantially when comparing the pre-game assessment of the referee to the post-game assessment in the study by Castillo *et al.*[11]. Supporting the aforementioned, it is suggested that the anaerobic system is stimulated during matches.

The highest rate of injuries obtained by these professionals occurs during strenuous preparation[12]. The International Federation of Associated Football (FIFA) created a periodical test inspired on the movements carried out by referees during matches[13], which are strenuous in nature, setting another obstacle to attain so that football referees can be considered fit to participate in matches. To do this it is necessary to plan and carry out effective and specific training sessions.

However, until now there have been no systematic reviews analysing the effect of the heart rate of soccer referees, or about the distance covered during matches. In this regard, the aim of this study was to analyse the relationship between heart rate and the distance covered by soccer referees on the pitch during their participation in matches.

Material and method

The literary review was performed in accordance with the PRISMA[14] guidelines for systematic reviews and meta-analyses. A broad search was carried out, with no date restrictions, of the following electronic databases: Pubmed, Scielo and Google Academic, with the latter search carried out on 10/09/2017.

The following descriptions were entered in accordance with DeCS and MASH, highlighting that descriptions with no link or affinity to the focus and objective of the research were excluded: ("heart rate" or "heart rate determination") AND ("distance" or "distance perception" or "vertical dimension") AND ("*arbitro de fútbol*", "soccer referee" or "football referee"). It is worth noting that the last three terms were used to provide a direct connection to the study objective and because they are terms used in the articles available in the databases used in this review in which the focus is the soccer referee, as neither the DeCS or MESH presented descriptions related to these terms nor their possible synonyms. Furthermore, three descriptions were used at the same time, always combining a description of each study variable (HR_{av} and distance covered) with a description related to the target demographic (soccer referees) until all possible combinations had been used.

The inclusion criteria used for the studies were: a) studies performed with central referees on soccer fields; b) studies that analysed and/or quantified the heart rate and distance covered during matches; c) articles in English and Portuguese. The exclusion criteria used were: a) studies that only addressed heart rate and/or distance covered by referees in other activities or settings, that were not carrying out their activities during soccer matches on pitches; b) studies that did not aim to analyse matches in sub 20 and professional categories, as it is a reality within this sport that the athletes in the sub 20 category are frequently bound to the athletes in the category above, and they also compete in matches in the professional category; c) studies published before 1994. After inclusion, the studies were quantified related to the risk of bias according to the Loney scale[15], suitable for crosscutting studies, whose maximum score to be reached in a study is 8 points. As a result, regarding the criteria used, the search was given pursuant to the following flowchart.

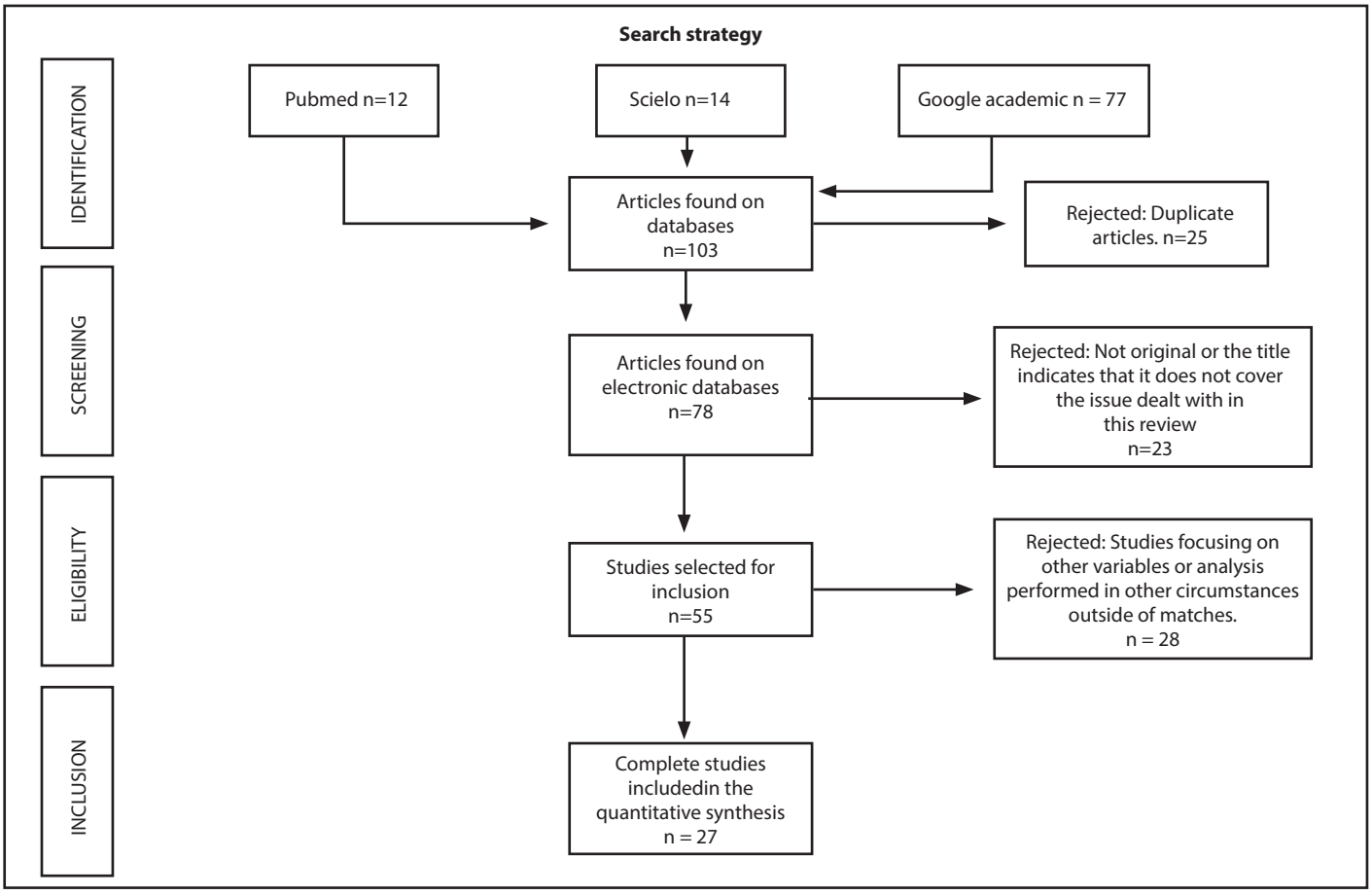
Results

The search of the electronic databases produced 78 potentially relevant articles, 27 articles that met all the inclusion and exclusion criteria, totalling 428 participants, all of which were professional-level central soccer field referees. The studies analysed the referees during their performances in soccer matches, which overall, including the studies found, revealed an analysis of these referees in 2,936 soccer matches. In all the studies, where necessary, a level of significance of $p<0.05$ was employed. The analysed articles were displayed to address the variables of interest in this systematic review. To do this, the studies were separated into two tables: the first with the aim of presenting the articles included in the research, and the second focusing on the variables of interest for this study (Figure 1).

Table 1 displays the descriptive characteristics of the 27 articles included in the review.

Table 2 displays the descriptive characteristics of the 27 articles included in the review. The first two columns identify the study, the first column indicates the bibliographic reference, and the second describes the study authors and year. The others present the average age of the

Figure 1. Flow chart displaying the search criteria, selection of studies included and reasons for excluding studies from the review.



study sample, the distance covered by the referees in the matches, and the HR_{av} and HR_{max}.

In terms of distance covered in the studied matches, the average was 10.36 ± 1.11 km, with 2,917 matches analysed. Only one article mentioned the length of refereeing experience[37], which separated its demographic into two groups: experienced and inexperienced referees.

With regards to the movement pattern during the distance covered in the match, various articles performed analyses whilst considering the type of movement pattern[6,7,9,16-19,26,27,29,33,40,41], where the types of movements described did not vary in terms of naming. In general, the patterns were described as: stopped, walking, jogging, running, running fast, sprinting and moving backwards. In all of these articles, the cut-off speed for the "running fast" mode was >18 km/hr or 5 m/sec.

An interesting fact was revealed in the studies mentioned, which was not thoroughly discussed by any of them: the time and distance covered in the backwards movements were much greater than in "sprint". Silva[40] verified in his results that the "sprints" represented less than 1% of the total playing time.

The other articles[6,7,9,17-19,23-25,29-31,34,35,37-40] performed their analyses based on the intensity of the movement, and, in all of them, the related cut-off point to define high intensity was >18 km/or or >5 m/sec. The results from these studies were very coherent in affirming that the referee, for the most part of the game, moves at low speed, but very intermittently, where the average speed – taken as the base for all the studies – was 5.9 ± 0.26 km/hr, but with short, high-intensity peak lasting an average of 3 ± 1.41 seconds. In these short peaks, the average maximum speed in the studies found was 19.84 ± 1.56 km/h. The highest value of maximum speed of a referee in the studies included in this systematic review was 25.96 km/hr, discussed in the study by Silva[39].

The HR_{av} of the articles found was 158.88 ± 3.99 bpm and the average HR_{av} was 185.02 ± 6.99 bpm. When relating the percentage of HR_{av} and HR_{max}, the HR_{av} of the studies displayed in Table 2 was 85.64 ± 1.94% of the HR_{max}.

Some studies[21,22,37,38] - for analytical purposes - divided the HR_{av} into bands based on the percentage in relation to HR_{max}, and sought to measure the time spent in each band during the game. Roman *et al.*[21] define these phases as follows: phase 1 (<35%), phase 2 (35-59%), phase 3 (60-79%), phase 4 (80-89%) and phase 5 (>90%) of the HR_{max} estimated using the Karvonen formula. Cipriano *et al.*[38] established these phases via absolute intervals of the HR as follows: phase 1 (75-104 bpm), phase 2 (105-125 bpm), phase 3 (126-146 bpm), phase 4 (147-167 bpm) and phase 5 (168-188 bpm), based on a maximum stress test in a laboratory; these authors separated phases 4 and 5 as performance

Table 1. Studies included in the systematic review.

Ref.	Author/Year	Competition	Sample (n) (Referees / No. of Matches)	Score on the Loney Scale
(8)	Johnston, McNaughton (1994)	Tasmania State League	10/10	5
(16)	Da Silva, Rodriguez-Añez (1999)	Paranaense Championship series A	9/9	4
(17)	D'ottavio, Castagna (2001)	Italian Championship series A	33/96	7
(7)	D'ottavio, Castagna (2001)	Italian Championship series A	18/18	6
(9)	Krustrup, Bangsbo (2001)	Denmark League 1st and 2nd Div.	27/43	8
(18)	Castagna (2002)	Italian Championship A and B	22/22	7
(19)	Rebelo *et al.* (2002)	Portuguese Championship	8/8	4
(20)	Roman *et al.* (2004)	Paranaense Championship 1998	12/15	4
(21)	Roman *et al.* (2004)	Paranaense Championship 1st Div.	12/12	4
(22)	Helsen, Bultynck (2004)	Euro Cup 2000	17/31	6
(23)	Castagna C *et al.* (2004)	Italian Championship Series A and European Cup	13/13	6
(24)	Mallo *et al.* (2007)	World Cup sub-17	12/12	5
(25)	Weston *et al.* (2007)	English Premier League 1st Div.	19/254	7
(26)	Oliveira *et al.* (2008)	Paulista Championship Sub 20	8/8	5
(27)	Da Silva *et al.* (2008)	Paranaense Championship series A and B	29/29	5
(28)	Silva (2008)	Paranaense Championship A and B 2005 and 2006	10/30	7
(29)	Da Silva *et al.* (2010)	Paranaense and Paulista Championships	16 (PN=9+SP=7)/16	6
(30)	Vieira *et al.* (2010)	Potiguar Championship 2009	11/21	4
(31)	Weston *et al.* (2010)	English Premier League 1st Div	22/778	7
(32)	Ardigò (2010)	Italian Championship 6th and 7th Divisions	6/20	5
(33)	Da Silva *et al.* (2011)	Paranaense Championship Series A	10/30	6
(34)	Weston *et al.* (2011)	English Premier League	59/1269	7
(35)	Dos Santos V *et al*. (2012)	Bahiano Championship 2012	30/138	6
(36)	Roman *et al.* (2012)	Paranaense Championship	12/12	4
(37)	Silva (2014)	Cearense Championship 3rd Division, Sub 20 and UNIMED Cup	28/28	6
(38)	Cipriani (2015)	Portuguese League 2013 and 2014	1/11	5
(39)	Silva (2016)	Goiano Championship 2016	2/3	5

Ref.: bibliographic reference; Author/Year: author and year the study was created; Competition: competition used to gather data; PN: referee from the state of Paraná in Brazil; SP: referee from the state of Sao Paulo in Brazil.

categories, but these bands are those in which the intensities are above the anaerobic threshold and below the VO_2max value, and it is expected that only trained individuals display this kind of performance. Furthermore, if efforts are made to study their results, it should be affirmed that the referees spent 50-69% of the match time in phase 4, above the anaerobic threshold.

Discussion

The aim of this systematic review was to identify studies in literature that address the physical demands of central soccer referees during matches. The studies analysed in this systematic review support Reilly and Gregson[42], who affirm that the distance covered by referees during soccer matches varies from 9 to 13 km. Despite the major advances made in soccer in terms of physical foundations, already in 1988 the work by Asami *et al.* - pioneering in their description of the motor actions performed by soccer referees and considered a classic in this field[41] – related their results that back up this distance. In this study the authors analysed the distance covered in a match by two classes of referees: one with those from the Japanese league, i.e. national referees, and the other international referees. The average movement of the national referees was 10.168 ± 756 metres, whilst international referees revealed an average movement of 9.736 ± 1.077 metres.

A large part of the studies found mention the distance covered, measuring this distance in each motor action carried out by these professionals during games. The referee spends a large amount of time performing low-intensity activities: walking or jogging. Some studies affirm that they walk more, whilst others claim that referees jog more during the game. This will depend in great measure on the intensity of the game. The percentage related to walking in the articles was between 30 and 60% during the match. This large variation in the walking percentage in matches seems to be influenced on the region where the match takes place. In the case of Brazilian referees, they walked 58% of the total time of the match, whilst another study of Danish referees[9], revealed a game time of 40% walking, and Japanese and Portuguese referees walked for 33% of the match[19,41]. The difference in game style

Table 2. Distance covered, HR_{av} and HR_{max} of the soccer referees during the matches.

Ref.	Author/Year	Average age of the sample	Distance covered	HR_{av}	HR_{max}
(8)	Johnston, McNaughton (1994)	---	9.40±0.83	1st half: 163 2nd half: 162	191.76
(16)	Da Silva, Rodriguez-Añez (1999)	---	9.29±0.62	---	---
(17)	D'ottavio, Castagna (2001)	37.8±2.1	11.49±0.98	---	---
(7)	D'ottavio, Castagna (2001)	37.5±2.14	11.17±1.69	163±5	183.5
(9)	Krustrup, Bangsbo (2001)	38 (from 29 to 47)	10.07±0.13	162±2	190.5
(18)	Castagna (2002)	37.0±2.4	11.63±0.9	---	---
(19)	Rebelo *et al.* (2002)	37±6.6	----	150±21,9	176±17
(20)	Roman *et al.* (2004)	37.1±6.8	10.71±0.89	---	---
(21)	Roman *et al.* (2004)	35.5±6.7	10.71±0.89	156.5±13.2	179.5±12.1
(22)	Helsen, Bultynck (2004)	40.2±3.9	---	155±16	182.35
(23)	Castagna *et al.* (2004)	37±3	12.95±0.54	---	---
(24)	Mallo *et al.* (2007)	33.4±3.8	11.05±0.93	161±8	187
(25)	Weston *et al*. (2007)	40.1± 4.9	11.62±0.73	---	---
(26)	Oliveira *et al.* (2008)	26.79.73±4.13	9.35±1.02	160.51±2	---
(27)	Da Silva *et al.* (2008)	38.9±3.8	9.15±0.07	---	---
(40)	Silva (2008)	38.89±3.79	9.18±0.39	---	---
(29)	Da Silva *et al.* (2010)	PN=38.44±4.0 SP=27.29±4.7	9.13±0.25 10.03±0.84	---	---
(30)	Vieira *et al.* (2010)	36.36 ± 6.34	10.50 ± 0.35	162.77 ± 7.44	182.22 ± 7.72
(31)	Weston *et al.* (2010)	(31-48)	11.53±0.74	---	---
(32)	Ardigò (2010)	22.6±2.4	11.39±0.69	163±8	201
(33)	Da Silva *et al.* (2011)	38±1.1	9.18±0.12	---	---
(34)	Weston *et al.* (2011)	(22-49)	11.77±0.80	---	---
(35)	Dos Santos *et al*. (2012)	---	10.05	---	---
(36)	Roman *et al*. (2012)	35.5±6.7	10.71±0.89	156.5±13.2	179.5±12.1
(37)	Silva (2014)	Ref. Exp. 31.17±5.18 No Exp. 28.60±5.06	Ref. Exp. 9.3±0.7 No Exp. 8.8±0.9	1st half: 157.23 ±12.92 2nd half: 155.31 ±12.43	1st half: 180.46±9.31 2nd half: 181.62 ±15.84
(38)	Cipriani (2015)	(one referee) 39	---	159	191
(39)	Silva (2016)	37.6±4.39	9.2±0.65	---	---

Ref. Exp.: referee with experience; No Exp.: inexperienced referee; PN: Paraná; SP: São Paulo; 1st half: first part of 45 minutes of play; 2nd half: second part of 45 minutes of play; PN: referee from the state of Paraná in Brazil; SP: referee from the state of Sao Paulo in Brazil.

(between countries) should also be taken into account when the results found are compared.

It is agreed that the most used motor actions by referees are jogging and walking[6-9,16-19,24,26,29,34,40,41], but it is also unanimous that the intensity of the game has a major influence on this aspect. The distance covered by the ball in the game directly influences the profile of referee behaviour[24]. The study by Weston *et al*.[25] performed with 19 referees, analysed 254 games in England during the Premier League. They studied a positive correlation of the physical performance of the referees with that of the players, and they also observed that the physical performance of the referees revealed a negative correlation between the first and second half of the matches; whereas the first half is very intense, this intensity tends to lessen in the second half, implying that referees may adopt more energy-saving behaviour. The study by Costa *et al*.[43], despite not being included in the articles of this systematic review, did not find any significant differences in the distance covered, nor in the maximum speed between the first and second halves of the match. Despite this, the average speed and the time that was spent at between 90-100% of the HR_{max} were greater in the first half of the matches. This alternation of intensity between the match halves was also verified in other studies[8,9,17,20,26,27].

Heart rate is another relevant factor. The HR_{max} during play represents on average 70 to 85% of the estimated HR_{max}. The study by Krustrup and Bangsbo[9] observed that the highest heart rate value reached by a referee in a match corresponded to almost 97% of his HR_{max}. This information could be linked to the literary data for soccer players. In this respect, it has been observed that the heart rate of a player during a match varies between 80 and 90% of the HR_{max} [44-46]; values similar to those displayed by football referees.

The match requires referees to perform very unusual movements, of an excessively intermittent nature, with many very quick and unexpected pace changes. The most demanded energy-producing system is aerobic, but anaerobic interventions seem to be the most important for soccer referee performance. Despite this, these interventions occur less throughout a match. The studies in this systematic review support this lesser amount of high-intensity actions (sprints) and even relate that they are less used than backward movements of referees in matches[6,8,9,17-19,24,25,29,40, 41].

On the other hand, despite physical condition being important, decision-making power is the crucial key to the game[29]. In this respect, some studies indicate that the most experienced referees tend to make more correct decisions[22,25,30,31,34,36,37]. Silva[37] concludes in his study that as well as tending to make more correct decisions, more experienced referees performed better in HC checks, even keeping up the pace between match halves. The study by Aoba *et al.*[47] revealed a significant difference between international and national level referees from the Japanese Football Association (JFA) in relation to the distance of the points in which fouls occurred to the place where the referees were positioned. In this study, the referees were assessed for distance of movement, distance from the points where fouls occurred to the place where the referees were positioned and heart rate. For all of these indicators, it seems that experience benefits referees in decision-making and in administrating physical effort during the game, a fact that requires further study, as it is necessary to analyse the distance at which the game actions occurred to where the referees were positioned at the decision-making instant. This can vary considerably and not alter the distance covered by the referee, and it is agreed that increased distance with relation to a game action makes it more difficult to evaluate. Perhaps this has occurred because more experienced referees tend to have better spatial evaluation of the field of play, and are able to alter their movement during the match, using less energy and reaching a comfortable distance at which to make assessments of the game.

In the case of referees from the Paranaense Soccer Federation[36], this line of reasoning is backed up; the study performed with soccer referees relates that those with more years of experience are more secure and do not need to be so close to analyse the game actions, and that the younger referees run more during matches. Although there is a protocol that orientates this game movement suggested by FIFA and its affiliated entities[1,48,49], it appears that refereeing experience can improve this movement, reaching correct decisions with less effort. The most important aspect for a successful soccer referee is clearly the power to make decisions, taken quickly and in a good metabolic state, modified depending on the instant of the game[31].

Cognitive issues are essential for this sporting modality. Some of these issues, such as self-esteem and anxiety for example, are associated to the risk of the players injuring themselves during disputes[50]. For soccer referees, cognitive factors are also important, and these can be influenced by aspects related to the game atmosphere, as well as by physiological factors. The study by Gomez-Carmona *et al.* [51] verifies that the aspects that influenced referees' decisions and that caused errors were: the part of the pitch, the period of the game, and the referee's HR_{max} percentage.

Helsen and Bultynck[22], performed a study about referees' decisions during matches. In this study, they indicate that these professionals make an average of 137 observable decisions in a match. This was measured through the body language of referees in video replays of matches, and the number varied from 104 to 162. The authors related that 64% of these decisions were taken in communication with assistant referees and with the fourth referee. They also affirm that it is important for referees to train on video, watching game actions, but it is not possible to take a referee to a specialist level simply using visual imitation. The training sessions and visual assessments are still very limited because they are generally carried out in static settings, which is understandable due to the complexity of simulating a decisive setting such as football referees in controlled game settings.

Conclusion

The results indicate that soccer referees cover large distances during games (10.36 ± 1.11 km), but they do so very specifically and there are a considerable number of direction, intensity, speed and heart rate changes. This occurs various times in a non-progressive way. The HR_{av} is de 158.88 ± 3.99 bpm during matches, and in the majority of matches the referees move at low intensity. However, the high-intensity stimuli are both very intense and very brief – around 2 to 4 seconds, linked directly to crucial moves within the game. On these occasions they reach 97% of their HR_{max}.

For practical advice, particular attention should be paid to preparation, as well as to analysing decisive processes performed by these professionals. Studies indicate that there is still considerable progress to be made in the cognitive aspect. Referees should be trained, assessed and classified in circumstances that are similar to match conditions. A better understanding of the conditions at these critical decision-making instants is necessary, both physically and psychologically, so that training sessions can be developed and fine-tuned more effectively.

Studies that research the connections between the physical and cognitive demands of this position and that compare the atmospheres of matches during training and official matches are recommended. This could help advance the practice of refereeing, and promote the success of soccer.

Conflict of interest

There is no conflict of interest in this study.

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