Hemodynamic and motion demands of soccer referees: a comparison between series A and B of the State Championship of Rio de Janeiro, Brazil

Leandro de Lima e Silva[1,2,3], Rodrigo Gomes de Souza Vale[1,2], Eduardo Borba Neves[1,4], Juliana Brandão Pinto de Castro[1,2], Erik Salum de Godoy[1,2], Jurandir Baptista da Silva[1,2], Magna Leilane Silva[3], Rodolfo de Alkmim Moreira Nunes[1,2]

[1]Laboratory of Exercise and Sport. Institute of Physical Education and Sports. Rio de Janeiro State University. Rio de Janeiro. Brazil. [2]Postgraduate Program in Exercise and Sport Sciences, Rio de Janeiro State University. Rio de Janeiro. Brazil. [3]Research Group in Sport, Education and Health. Federal Institute of Education. Science and Technology of Ceará. CE. Brazil. [4]Brazilian Army Sports Commission. Rio de Janeiro. RJ. Brazil.

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Summary

Introduction: Soccer referees need excellent conditioning to withstand the physical and psychological demands of games.
Objective: To compare the hemodynamic variables, speed, cadence, and distance coursed of referees during soccer games of series A and B in Rio de Janeiro, Brazil.
Material and method: The total number of decisions made during the 10 soccer matches evaluated was 1,224 observable decisions of 10 professional Soccer referees (one per soccer match: 5 in series A and 5 in series B). We used a frequency meter (Polar, model V800, PolarFlow software) and video footage of the games (Sony, model PXW-Z150, 4K). The moments considered were: the decision, 15 seconds that preceded it, and the period from the beginning of each stage to each decision. Were studied the hemodynamic [average heat rate (mean HR), maximum heart rate (HR_{max}), and minimum heart rate (HR_{min})] and motion variables [average speed (V_{med}), maximum speed (V_{max}), average cadence ($cadence_{med}$), maximum cadence ($cadence_{max}$), minimum cadence ($cadence_{min}$), and distance covered]. Descriptive measures were used to present the results of the variables studied and the Student's T-Test for independent samples to test the study hypotheses. The significance level was set at 95% (P <0.05).
Results: The matches of series A had a greater number of interventions and greater hemodynamic load at the exact moment of the decision than those of series B. significantly (P <0.05): mean HR, HR_{max}, HR_{min}, V_{max}, $Cadence_{med}$, and $Cadence_{max}$ in series A were higher compared to series B. In the 15 seconds before the decisions: mean HR, HR_{max}, and HR_{min} in series A were higher than in series B, and V_{med} in series B was higher in relation to series A. At the exact moment of the decisions: mean HR in series A was higher in relation to series B.
Conclusion: Referees' interventions are generally carried out under high hemodynamic pressure. The matches played in the A series require a higher number of interventions and hemodynamic intensity than the matches in the series B under high hemodynamic pressure, other psychological factors may play a role; however, this needs to be studied in greater depth.

Key words:
Heart rate. Intensity. Decision. Referee. Soccer.

Las demandas hemodinámicas y de movimiento de los árbitros de fútbol: una comparación entre las series A y B del Campeonato Estatal de Río de Janeiro, Brasil

Resumen

Introducción: Los árbitros de fútbol necesitan un excelente acondicionamiento para soportar las exigencias físicas y psicológicas de los partidos.
Objetivo: Comparar las variables hemodinámicas [frecuencia cardíaca media (mean HR), frecuencia cardíaca máxima (HR_{max}) y frecuencia cardíaca mínima (HR_{min})] y desplazamiento [velocidad media (V_{med}), velocidad máxima (V_{max}), cadencia media ($cadence_{med}$), cadencia máxima ($cadence_{max}$), cadencia mínima ($cadence_{min}$) y distancia recorrida] durante intervenciones arbitrales en partidos entre las series A y B en Río de Janeiro, Brasil.
Material y método: Se analizaron 1.224 decisiones observables de 10 árbitros profesionales de fútbol cada uno en 1 partido (10 partidos del Campeonato Carioca: 5 en la serie A y 5 en la B). Se utilizaron frecuencímetros (Polar, modelo V800, software PolarFlow) y secuencias de video de los juegos (Sony, modelo PXW-Z150, 4K). Los momentos considerados fueron: la decisión, los 15 segundos que la precedieron y el tiempo desde el inicio de cada etapa hasta cada decisión.

Correspondencia: Leandro de Lima e Silva
E-mail: l.limaesilva@gmail.com

Resultados: Los partidos de la serie A tuvieron mayor número de intervenciones y mayor carga hemodinámica en el momento exacto de la decisión que los de la serie B. significativamente (p <0,05): mean HR, HR_{max}, HR_{min}, V_{max}, $cadence_{med}$ y $cadence_{max}$ in la serie A fueron mayores que en la serie B. En los 15 segundos previos a las decisiones: mean HR, HR_{max} y HR_{min} en la serie A fueron mayores con relación a la serie B, la V_{med} en la serie B fue mayor en relación a la serie A.
Conclusión: Las intervenciones de los árbitros generalmente se realizan bajo presión hemodinámica elevada. Los partidos disputados en la serie A requieren un número de intervenciones e intensidad hemodinámica superior a los partidos de la serie B. En el momento exacto de las decisiones, la FC de los árbitros aumentó en relación a los 15 s que la precedieron, demostrando que, además de las intervenciones que se realizan bajo una presión hemodinámica elevada, pueden influir otros factores psicológicos; sin embargo, esto necesita ser estudiado con mayor profundidad.

Palabras clave:
Frecuencia cardíaca. Intensidad. Decisión. Árbitro. Fútbol.

Introduction

Soccer referees play an important role in the practice of the sport, as they analyze the game and apply the rules. Among the demands of the match, it is necessary to be well-positioned to make decisions with greater tranquility[1], follow the bids as closely as possible, with a well-angled optic, which allows it to be as correct as possible, mitigating the influence of psychological or physical pressures[2,3]. Therefore, referees need good physical conditioning to perform intermittent and prolonged exercises[4,5].

A systematic review[6] analyzed 2936 matches and described that Soccer referees move in a very peculiar way, covering an average distance of 10.36 ± 1.11 km per match. Additionally, it revealed that these displacements have types of movements that have been described as: standing, walking, running, running fast, and running moving backward. Thus, it was found that the referees sprinted for less than 1% of the game time and moved most of the time intermittently and with a low average speed of 5.9 ± 0.26 km/h, with high-speed peaks of 3 ± 1.41 seconds. At these times, the average maximum speed (V_{max}) was 19.84 ± 1.56 km/h. It was also found that the maximum heart rate (HR_{max}) of the referees was, on average, 185.02 ± 6.99 beats per minute (bpm). However, the authors emphasize that there is still considerable progress to be made in the cognitive aspect.

For the referees to be able to act in matches, the Brazilian Soccer Confederation (CBF) periodically performs physical tests, which are recommended by the legislation of the *Fédération Internationale de Soccer Association* (FIFA)[7]. This test is divided into two phases, both of which are extremely exhaustive[8].

Helsen and Bultynck[9] point out that referees make, on average, 137 observable decisions during the game. This was measured through the referees' body language in the video replay of the matches and ranged from 104 to 162 observable decisions per game. This study[9] states that training and visual assessments are still very limited because they are generally performed in static environments.

Therefore, it is clear that it is necessary to plan and execute effective training, based on the heart rate (HR) zone that will be used in matches, the distances covered in the games, and the average and maximum speeds required to prepare the referee to meet game displacement and positioning needs[10,11], as well as the FIFA physical test.

However, there is a gap in knowledge regarding the physiological and environmental circumstances in which referees make their decisions in the bids of Soccer matches. In this context, the present study aimed to compare the hemodynamic variables, speed, cadence, and distance coursed of referees during soccer games of series A and B in Rio de Janeiro, Brazil.

Material and method

Study design

This study was characterized as an analysis of results collected in field research, of a quantitative, transversal, and observational nature[12].

Participants

The total number of decisions made during the 10 soccer matches evaluated was 1,224 observable decisions of 10 professional Soccer referees (one per soccer match: 5 in series A and 5 in series B). The inclusion criteria were: being a Soccer referee registered with the Soccer Federation of the State of Rio de Janeiro (FERJ) and playing in official professional games of the series A and B of state championships. The exclusion criteria were: the referee not having correctly performed the protocol standardized by the study for the start of the match, starting the stopwatch with his arm outstretched, which would make it impossible to synchronize the time of the filming of the game with that of the frequency meter; or the match footage suffers interruptions.

Research ethics

This study is part of a project approved by the Research Ethics Committee CAAE Nº 06805512.9.0000.5291, with protocol Nº 223412. All study procedures followed the current legislation of the Brazilian National Health Council for research with human beings[13]. All participants voluntarily signed an informed consent form before entering the study.

Procedures

Before the start of the warm-up for the matches and in an appropriate place, the referees underwent a test offered by the HR monitor

model V800, made by Polar, to verify the maximum oxygen volume (VO_{2max}). They were instructed not to speak and to remain relaxed in the supine position for about 1 to 3 minutes when the frequency meter measurement was started. For anthropometric assessment, we used an anthropometric body control scale with portable digital bioimpedance OMRON (USA), model HBF-514C, a hand-held sensor for portable digital bioimpedance OMRON, and a Sanny tape measure (Brazil).

For the quantitative analysis of the data, all the referees were instructed that they could use the Polar brand V800 GPS frequency meter, the same used to perform the VO_{2max} test. The equipment was adjusted to the physical and physiological characteristics of the participant before the games and was activated at the beginning of each half and turned off shortly after the end of each stage by the referee. Silva *et al.*[14] validated the reliability and reproducibility of the data obtained by the frequency meter used in this study.

To identify decisions during the matches, the games were filmed with a professional Sony camera, model PXW-Z150, with 4K resolution quality. To synchronize the time of the frequency meter with the time of decisions in the games, the referees were instructed to start recording the frequency meter so that it was visible in the replay of the match, extending the arm in front of the body. It was necessary to segment the replay of the match so that the initial time of the filming was the exact moment in which the frequency meter was triggered by the referee and, thus, the time of the filming and the frequency meter were synchronized.

To identify the referees' decisions during the game, the exact moment when the referee gestured or whistled, whichever happened first, was considered, to demonstrate the decision during the match.

The decisions taken during the games were: direct free kick in favor of the attack; direct free kick in favor of the defense; direct free kick in favor of the attack, with application of a yellow card; direct free kick in favor of the defense, with application of a yellow card; direct free kick in favor of the attack, with application of the second yellow card and, consequently, the red card; direct free kick in favor of the defense, with application of the second yellow card and, consequently, the red card; direct free kick in favor of the attack, with application of the direct red card; direct free kick in favor of the defense, with application of the direct red card; throw-in in favor of the attack; throw-in for the defense; application of the yellow card; application of the red card; goal kick; corner kick; technical time; end of the game period; ball to the ground; goal; off-side; penalty; penalty with application of a yellow card; goal with the application of a yellow card.

For the analysis of hemodynamic variables (mean HR, HR_{max}, HR_{min}, and HR amplitude) and variables related to displacement (V_{med}, V_{max}, and V_{min}, in km/h; $cadence_{med}$, $cadence_{max}$, and $cadence_{min}$, in steps/min; distance covered, in km), the Polar Flow program was used. In addition to the exact moment of decision making in each observed decision, the period of 15 seconds that preceded it, as well as the period from the beginning of the match to the decision, were considered.

The most used movement pattern was verified in the periods: a) between the beginning of the match and each decision taken; b) the 15 seconds preceding the decision; c) the moment of the decision. The patterns considered were based on the V_{med} of the period and, to compare this data, the amplitude between the V_{max} and V_{min} of this interval was analyzed. The standards used followed those described by Di Salvo *et al.*[15] and are described in Table 1.

Table 1. Categorization of referee displacements regarding the speed.

Movement pattern	Speed (km/h)
Walking	0 – 7.2
Jogging	7.3 – 14.4
Running	14.5 – 19.8
High intensity running	19.9 – 25.2
Sprint (running at maximum intensity)	>25.2

Matches are divided into two 45-minute stages, plus extras that the referee deems relevant to make up for a lost time, according to the rules of the sport[1]. All games had a technical time-out, which is a two-minute stoppage that takes place in Rio de Janeiro games, at the first opportunity in which the game is interrupted by a game marking, from the twentieth minute played of each stage.

In the games played by the series A, the central referees had the help of two additional referees (positioned on the goal line close to the goal), in addition to the conventional ones, two assistant referees, and a fourth referee, unlike in the series B, where there is no figure of the additional referee, positioned at the goal line.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 25. Descriptive measures were used to present the results of the variables studied and the Student's T-Test for independent samples to test the study hypotheses. We opted for parametric statistics, based on the central limit theorem[16], which refers to the convergence of sums of random variables for a normal distribution in large samples (>30) since a dataset with 1,224 events was analyzed. The level of significance was set at 95% (P <0.05).

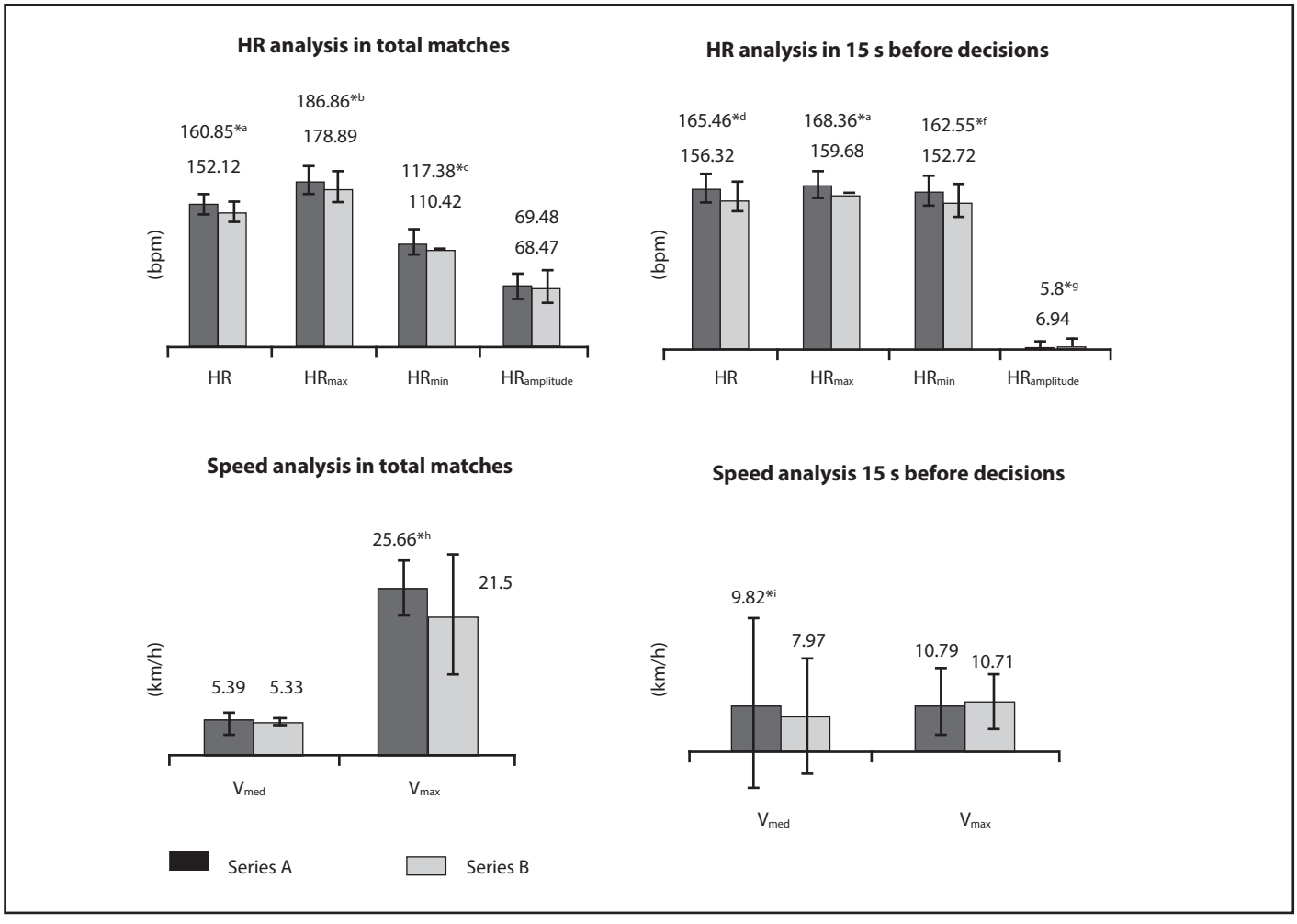
Results

The mean age of the referees involved in the study was 37.20 ± 5.05 years; mean height was 1.84 ± 0.06 m; mean body mass of 84.53 ± 7.14 kg; the mean fat percentage measured was 14.83 ± 3.4%, and they had a mean VO_2 of 48.90 ± 3.66 mL/kg/min. It was collect to characterize the simple.

The 1,224 decisions analyzed, in the total of matches, generated an average of 124 ± 11.24 decisions per game, where the game in which the referees showed the highest number of decisions totaled 142 and the lowest number of decisions observed in a game was 108. In series A games, the average of decisions was 131.8 ± 8.37 (124 -142) per game, in series B, this average was 116 ± 7.88 (108 -125).

All decisions in which the referee whistled and/or gestured demonstrating his interference in the game were analyzed, which generated a total of 1224 analyses, 650 in games played by series A and 574 in games played by series B.

Figure 1. Analysis of HR and speed in total matches and 15 seconds before decisions.



HR: heart rate; bpm: beats per minute; s: seconds; HR_{max}: maximum heart rate; HR_{min}: minimum heart rate; V_{med}: average speed; V_{max}: maximum speed; $P<0.05$ in Student's t-test for independent samples ([a]: $P<0.001$; [b]: $P<0.001$; [c]: $P<0.001$; [d]: $P<0.001$; [e]: $P<0.001$; [f]: $P<0.001$; [g]: $P=0.001$; [h]: $P<0.001$; [i]: $P=0.025$).

The hemodynamic variables, as well as those related to displacement, were verified during the referees' observable decision-making, in the matches, and were compared considering the possibility of being influenced by the level of competition. Figure 1 and Table 2 demonstrate which variables have significantly changed depending on the level of competition.

Figure 1 presents the variables mean HR, HR_{max}, HR_{min}, HR amplitude, V_{med}, and V_{max}, descriptively, in the time between the beginning of each match time until the moment of each decision and in the period of 15 s that precedes the referees' decisions.

Table 2 presents, in a descriptive way, the study variables related to displacement, in two periods: between the beginning of each match time until the moment of each decision and in the period between the decision and the 15 seconds that precede it. Based on the period between the making of each decision and the 15 seconds that precede it, the *N* remains the same because they are the same decisions.

Table 3 presents the study variables at the exact moment of each decision.

Based on the exact moment of decision making, only four variables are described, because, as it is not a time interval, but a single moment for each decision, only the variables mean HR, V_{med}, cadence, and movement pattern are possible to measure. The mean HR in the decisions taken in the series A games surpassed the result of the series B ($P<0.001$). We observed that, at the moment of the decision, the referees stop to gesture and/or whistle. Both actions influenced the values of the variables V_{med}, cadence, and movement pattern, which presented low values in all the analyzed games.

Discussion

This study aimed to analyze the hemodynamic variables and those related to the displacement of Soccer referees from series A and B

Table 2. Variables related to displacement in the periods: between the beginning of each stage of the match until each decision and 15 s before the decisions.

Variable	N	Mean	SD	*P*-value
(Period: from the beginning of each stage to each decision)				
Covered distance A (km)	650	1.99	1.32	0.211
Covered distance B (km)	574	1.89	1.34	
Cadence A (steps/min)	650	72.84	3.46	<0.001*
Cadence B (steps/min)	574	71.06	4.05	.
$Cadence_{max}$ A (steps/min)	650	109.39	6.8	<0.001*
$Cadence_{max}$ B (steps/min)	574	103.67	8.77	
$Cadence_{min}$ A (steps/min)	650	24.92	7.04	0.001*
$Cadence_{min}$ A (steps/min)	574	23.73	5.93	
Movement pattern A (km/h)	650	1.01 (walking)	0.1	0.008*
Movement pattern B (km/h)	574	1.00 (walking)	0	
(Period: 15 s before decisions)				
Covered distance A (km)	650	0.02	0.01	0.317
Covered distance B (km)	574	0.02	0.01	
Cadence A (steps/min)	650	71.49	14.74	0.125
Cadence B (steps/min)	574	70.24	13.58	
$Cadence_{max}$ A (steps/min)	650	81.24	17.24	0.023
$Cadence_{max}$ B (steps/min)	574	79.06	16.16	
$Cadence_{min}$ A (steps/min)	650	60.76	15.69	0.744
$Cadence_{min}$ B (steps/min)	574	60.46	15.9	
Movement pattern A (km/h)	650	1.59 (walking)	0.96	0.013*
Movement pattern B (km/h)	574	1.46 (walking)	0.83	

SD: standard deviation; A: related to series A games; B: related to series B games; Covered distance: covered distance until the decisions in the period; Cadence: average cadence of the referees in each period; $Cadence_{max}$: maximum cadence of the referees in the period; $Cadence_{min}$: minimum cadence of the referees in each period; Movement pattern: predominant movement pattern in each period; *: $P<0.05$ in Student's t-test for independent samples.

Table 3. Hemodynamic variables and movement pattern at the exact moment of decision making.

Variable	Serie	N	Mean	SD	*P*-value
Mean HR (bpm)	A	650	166.03	14.14	<0.001*
	B	574	157.04	14.70	
V_{med} (km/h)	A	650	8.24	7.77	0.177
	B	574	7.73	5.70	
Cadence (steps/min)	A	650	70.59	19.83	0.414
	B	574	69.65	20.28	
Movement pattern (km/h)	A	650	1.54 (walking)	0.93	0.444
	B	574	1.51 (walking)	0.85	

SD: standard deviation; mean HR: average heart rate of the referee at the exact moment of each decision making; V_{med}: average speed at the exact moment of each decision making; Cadence: average cadence of the referee at the exact moment of each decision making; Movement pattern: movement pattern at the exact moment of each decision making.

of the State Championship in Rio de Janeiro, Brazil, based on the moments in which the referees intervene in the games. The number of interventions comprised 1,224 observable decisions in 10 matches. In terms of cognitive demand, games in the main category (series A) outperformed those in series B, with an average of 132 decisions per game. This average is close to the study by Helsen and Bultynck[9], who observed an average of 137 decisions per game, in an analysis of 31 games, during the second phase of Euro 2000. These findings suggest that, in terms of the number of interventions, the referees in this study are similar to Europeans.

These data also suggest that the game has a lot of interruptions and that the ball time in dispute seems to be greatly reduced in Soccer since a match lasts 90 minutes, plus stoppage time. This suggests a value greater than one game interruption per minute. In the present study, the number of game interruptions in series A exceeded that of series B, even considering that in series B the stadiums are usually more modest and with smaller fields, which would favor a greater number of interruptions. This may have happened because, in series A, the games were played with greater intensity as the results were presented, which will be discussed below.

Mean HR seems to be a good indicator of the physical effort imposed on the referee in matches. The HR increases to supply oxygen to the muscles required during the effort. However, this rate can also be affected by other reasons, including stress[17]. In our study, it seemed that the decisions made in the games of the series A demanded more from the referees than the games of the series B since the averages of mean HR, HR_{max}, and HR_{min} in the games of the series A significantly surpassed the values presented in the games of the series B. These factors indicate that the games played in the superior category are more intense, since, corroborating these findings, in our study, the averages of V_{max}, cadence, and $cadence_{max}$ were also higher in the A series games.

Concerning mean HR, the series A games were more intense and/or more stressful, showing an average value of 160 bpm. D'Ottavio and Castagna[18] carried out a study with referees from the Italian Soccer Federation in the main series, who had an average age of 37.5 years, very close to the referees in our study. The authors found a mean HR of 163 bpm in the matches. Still dealing with the main series, the study of Krustrup and Bangsbo[19] found results that corroborate these findings, as the sample had an average age of 38 years and presented a mean HR in games of 162 bpm.

The study by Oliveira *et al.*[20], although it had a sample with a mean age of 36.36 and the referees had a mean HR of 160.51 bpm, differed from the others because they analyzed the under-20 category of the Paulista Championship, Brazil. This suggests that, apparently in this pre-professional category, the game has the same intensity as the A series of our study and exceeds the intensity of the series B games of our study, which presented a mean HR of 152.12 ± 9 bpm. In general, referees exercise arbitration with a very high mean HR, when compared to referees from other modalities who also exercise their function in movement, for example in basketball, in the study by Vaquera *et al.*[21], in which basketball referees, during the main European tournament, presented a mean HR of 140.3 bpm.

In terms of HR_{max}, the results showed that the referees, during the matches, make decisions, several times, with a very altered hemodynamic state and, in our study, the games played in the superior category were more intense for the referees. The intensity of matches in series A was higher than in series B since, in our study, there was a significant overcoming in relation to V_{max}, which in series A was 26.66 km/h against 21.50 km/h in series B games.

The $cadence_{med}$ and $cadence_{max}$ were also significantly higher in series A, reaching 109.39 steps/min. This high intensity in games is compatible with the study of Mallo *et al.*[22]. The authors, although not comparing different categories, found an average mean HR of 187 bpm, showing that the referees' heart in matches is quite demanded. Additionally, the referee needs to be conditioned to ratiocinate in some moments of the game with very high HR. Furthermore, this study[22] found that time spent performing high-intensity activities correlated with the distance traveled by the ball during games.

These results demonstrate that there is a high hemodynamic load imposed on the referees during games, including a high level of the aerobic system, as well as anaerobic capacities to meet the demands of the game. Therefore, the referee must be prepared in a very specific way. The results of this study support the adoption of intensive and intermittent training, which should, in the first place, prioritize high-intensity aerobic exercise, aiming to support and maintain high HR during the game. Also, it develops the anaerobic system because, although involved to a lesser extent, it plays an important role, with short and several periods of high-intensity activities during decisions in the game.

Cognitive factors, related to referees' interventions during matches, must be involved in the training of these professionals. Weston *et al.*[23] found a relationship between the intensity of the referees and that of the players and emphasize that the most important thing for arbitration is the decision-making process. Similarly, the games in the A series of the present study are more intense than those in the B series and the level of competition interferes with the hemodynamic response presented by the referees.

In the total period that precedes the decisions cumulatively in this study, the "walk" movement pattern prevailed, which confirms that the most used system in the game is the aerobic one, corroborating with the study of Johnston and McNaughton[24]. However, the V_{max} reached by the referees in the present study was quite high, 25.66 ± 4.27 km/h, in series A, and 21.50 ± 8.88 km/h, in series B. Although this value is a little lower than that measured by Silva[25], who verified 25.96 km/h demonstrated by a referee in a match of the Campeonato Goiano, in 2016. The value found in the present study is very high and this leads us to state that these professionals need to severely change their pace of travel during matches. Still about V_{max}, the A series of the present study surpassed the results of the study by Santos *et al.*[26], carried out with 30 referees from Bahia, where the highest speed reached in the game was 24 km/h, and although, according to D'ottavio and Castagna[18], sprints last from 2 to 4 seconds only, they can be crucial when making decisions in the game and can completely change the referee's optics at decision time, making him manage to be close or not to the throw, in a long throw for example, or a crucial move in the game.

It was found that the cadence behaved in the same way as the variable V_{max}, as there was a considerable difference between the $cadence_{med}$ and the $cadence_{max}$, which corroborates the previous paragraph, with the great intermittence and sudden change in intensity during decisions, throughout the game, but in the search for greater depth. Regarding the variables of this study, in the moments closest to when the referees showed to have taken the decisions, the analysis of the moment of the decision and the 15 s that precede it, revealed interesting data.

Although a comparison was not made between the 15 s that precede the decisions with the exact moment in which they are taken, the data revealed a tendency that in the 15 seconds before the decision, the mean HR is greater than in the total period of the stage, from the start of the match to the referee's intervention in the game. Apparently, in this short period of 15 s before the referee's intervention in the game, the mean HR increases with the other moments of the match and, perhaps, for this reason, FIFA has reduced the stimulus time in the physical assessment test from 30 s to 15 s, because, currently, the referees cover 75 m in this short time interval, for 40 times[27]. This fact cannot be confirmed because the literature has not presented any justification for this change in the test distance. The results of the present study show that the average distance in this period was 20 m. According to Krustrup and Bangsbo[19] and Castagna *et al.*[28], who stated that the longest distance traveled in a straight line (without changing direction) is around 35–40 m. This information alone already demonstrates that there is a lack of specificity (running without change of direction) in the aptitude test carried out by the referees.

Still concerning the period of 15 s before each intervention in the game, the HR_{max} was also significantly higher in series A (165.46 ± 14.44 bpm) and series B (156.32 ± 14.86 bpm). A factor that ratifies and justifies this superiority, in relation to FC in the total period of the match, is that the FC_{min} was significantly higher in the A series matches. Therefore, in the superior category, as the game is more intense, the referees already start from a higher HR than in the series B games and, perhaps, for this reason, the hemodynamic variables mean HR and HR_{max} reached higher averages in the A series of this study, both in this short period of 15 s and in the period from the beginning of each stage of the game until the intervention of the referees in the games.

The HR amplitude in this period was 5.80 ± 5.91 bpm, in the A series against 6.94 ± 6.10 bpm in the B series. These low values suggest that the HR does not change abruptly in relation to the average of the match, in the eminence of decision making. Perhaps for this reason, in the study of Silva[29], the more experienced referees were more correct in decisions, as she states that the more experienced referees controlled the intensity better during the match, obtaining less variation than the less experienced referees. However, psychological factors and the current mental state can interfere with decisions. This same study claims that watching videos before matches minimizes the mistakes of these professionals. Thus, in the present study, the analyzes regarding the exact moment of the referees' interventions revealed that the mean HR was also higher in the series A, which seems to be a consequence of the superiority of the HR-related variables in the 15-second periods preceding the interventions of the arbitrators, a fact already discussed in the previous paragraph.

It has been observed that referees often demonstrate decisions by standing still or slowing down. This made the analysis shown in Figure 1 present low average values in relation to the standards of each variable, except for the referee's mean HR, at the exact moment of each decision making (Table 3); because the deceleration or stop time is very short and the heart rate gradually drops.

According to Oliveira *et al.*[30], if, at the time of the decision, there is some psychological pressure, it can raise the referee's HR. However, none of the results of the present study can corroborate this assertion, as it did

not analyze the psychological factor. The aforementioned authors[30] state that referees tend to increase their attention span during the match and that the increase in the level of anxiety reduces the focus of attention. In this way, he justified in his study the improvement in the speed of concentration of the referees at the end of the games, since, at this moment, the level of tension decreases. These authors also state that activation is a multisensory phenomenon, consisting of physiological arousal and the interpretation of a referee, for example, the elevation of HR in the heart, and confidence and anxiety in the brain. This need for activation may have contributed to a trend towards an increase in mean HR at the exact moment of the interventions in relation to the 15 s that precede them, both in the results of series A and B. However, as discussed earlier, this can also be a consequence of the change in intensity in this short period.

This study has a limitation regarding the variables related to cadence since the instrument used does not present validation in relation to this item, where the step is considered by an estimate related to the data entered by the user (height, body mass, and age).

Conclusion

The results show that soccer referees intervene in soccer matches, about 137 times, and under strong hemodynamic and psychological stress. The matches played in the highest category (series A) require a greater demand from the referees for interventions, surpassing in hemodynamic intensity the interventions carried out in the games of the lower category (series B).

Due to the particularities verified about the hemodynamic factors to which the referees are exposed in the games, they need to be trained in an environment as close as possible to the reality of the matches, where they can make decisions based on a high HR, value around 160 bpm. and need to increase the intensity for 15 s, culminating with a moment of intervention in the game of a cognitive nature.

At the exact moment the decision is made, the HR of the referees tended to increase in relation to the 15 seconds that preceded it, demonstrating that interventions are usually carried out under high hemodynamic pressure, in addition to suggesting that other psychological factors can have a big influence at this time. However, this needs to be studied in greater depth. Studies are suggested with the moments of decision-making intervention of the referees with a greater focus on psychological factors, which take into account the level of the opposing teams in the confrontations, as well as analyze the result of the matches and the team that is acting in their stadium.

Conflict of interest

The authors do not declare a conflict of interest.

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