Original Article

Kinematic and physiological analysis of the performance of the referee football and its relationship with decision making

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ABSTRACT

The aim of this study was to examine the cinematic and physiological requirements of referees and assistant referees and their relationship to decision-making in various official competition matches in football. The sample consisted of six referees, one acted as main referee and five as assistant referees (age: 21.2 ± 0.98 years; height: 175.67 ± 4.27 cm, weight: 65.73 ± 4.68 kg). The registration of the data of the subjects participating in the study was conducted with an inertial system called WIMU and the analysis of the data was performed with a software called Quiko (RealTrack Systems, Almeria, Spain). In the study, 4 games of the League Championship Third Division (Group XIII) belonging to the 2014-2015 season were analyzed. The main findings were that the referee runs an average distance of 10124.7 ± 543.2 meters, with an average speed between 7.2 and 13 km/h with a maximum heart rate (HRmax) between 85-95% of his maximum; assistant referees walked an average distance of 5793.4 ± 481.7 meters, with an average speed between 3.6 to 7.2 km/h with a HRmax between 75-85% of their maximum. The aspects which influenced the decision making of the referees and caused the errors were: the part of the pitch, the period of play and the HRmax percentage of the referee. What this research shows is that referees and assistant referees should be considered in terms of training as independent people, and that referees must correct the movements in the field, concentration and work situations where your HRmax is above 85% to improve its success rate. Future studies should pursue this investigation with a greater number of senior officials and higher number of matches to generalize the results to all arbitral establishments and improve its quality. **Key words:** REFEREE, ASSISTANT REFEREE, HEART RATE, VELOCITY, ACCELERATION, HIGH INTENSITY WORK, DISTANCE PERFORMED, DECISION MAKING

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INTRODUCTION

According to the Laws of the Game (FIFA, 2014): "Rule 3: The match is played by two teams which have a maximum of eleven players each one, and one of these players must be a goalkeeper"; and "Rule 5: The match is controlled by a referee who has full authority to enforce the Laws of the Game, in cooperation with the assistant referees who may be designated". Therefore, in a football match converge players decisions with referees decisions to control the different infractions or violations of the laws of the game that happen during total time of the match (Reilly and Gregson, 2006; Reina-Gomez and Hernandez-Mendo, 2012).

Consequently, physiological, kinematical and decision-making referee response during a match is always conditioned by physical and technical conduct which adopted each of the players and the tactic arranged in the pitch in defensive and offensive actions (D'Ottavio and Castagna, 2001; Weston, Drust and Gregson, 2011; Elsworthy et al, 2014.).

For these reasons, there are multiple causes that may influence in the referee both at physiological response and cinematic level during an official competition match. The causes are able to found are the methodology used to record data (Asami, Togari and Ohashi 1988; D'Ottavio and Castagna, 2001; Krustrup and Bangsbo, 2001), the criteria used to classify the physiological and cinematic requirements in scientific publications (Asami et al, 1988; Catterall, Reilly, and Goldewells Atkinson, 1993; Johnston and McNaughton, 1994 ; D'Ottavio and Castagna, 2001; Krustrup and Bangsbo, 2001), the fitness level of referees (Krustrup and Bangsbo, 2001; Castagna and D'Ottavio, 2001; Reilly and Gregson., 2006; Pascual et al, 2014), the competition football division where research is done (Harley, and Doust Tozer, 2001 develops, Castagna, Abt and D'Ottavio, 2004; Mohr, Krustrup and Bangsbo, 2005) or the style of teams play which influences the work done by footballers in the match (Reilly, 1997; Weston et al., 2011).

As for referee decisions can influence other different factors such as public pressure when a team plays at home and the number of fans who witness the match (Page and Page, 2010; Downward and Jones, 2007), the category of the match and training according to referees division analyzed (Rodriguez-Salazar and Salazar-Rojas, 2002; Jones, Paul and Erskine, 2002. Larkin et al, 2011), the period of game produced (Rodriguez-Salazar and Salazar-Rojas, 2002; Unkelbach and Memmert, 2008; Elsworthy et al, 2014.), the correct positioning of referees on the pitch (Mallo and Navarro-Sainz, 2009; Mallo, Frutos Juarez and Navarro, 2012; Elsworthy et al, 2014), social pressure and the nationality of the referees (Dawson and Dobson, 2010), the decisions previously taken during the match (Plessner and Betsch, 2001) and development of referee psychological processes in relation to flash memory volume and attention level (Ortega, Villamizar and Zahir, 2014).

This research will be divided in two parts. In the first part of this study, the objective was to describe kinematical and physiological demands of referees and assistant referees in different matches in Third Division Group XIII (Murcia, Spain) and compare these results with different studies reviewed in the literature. In the second part of this study, we analyzed the relationship between physiological and kinematical variables of a referee in several official competition matches, and decision-making of the different offenses and penalties in the game.

METHOD

Sample

This research was conducted during the 2014-2015 season, between the months of December 2014 and April 2015 in the League Championship Third Division Group XIII, which is located in Region of Murcia, and it is organized by the Royal Spanish Football Federation (RFEF).

In this investigation involved a total of 6 subjects. One of the participating subjects participated in every game as a principal referee, which belonged to the Third Division category (group XIII). Also, five assistant referees are participating in the study. Two of them acted as Assistant Nº1 and they were specific assistants of Third Division. While, the remaining three referees assistants acted as Assistant Nº2, belonging to the category of Regional Preferent as a principal referees, which is organized by the Football Federation of Region of Murcia. Table 1 shows the subjects participation in this research.

Table 1. ***Subjects who participating in this research***

Referees	Main Referee	AA1	AA2
Match 1	Subject 1	Subject 2	Subject 4
Match 2	Subject 1	Subject 3	Subject 5
Match 3	Subject 1	Subject 3	Subject 4
Match 4	Subject 1	Subject 3	Subject 6

Note. AA1: Assistant Referee number 1, AA2: Assistant Referee number 2.

With regard to anthropometric data of the sample: age, height and body mass (mean ± standard deviation) of the test subjects was 21.2 ± 0.98 years; 175.67 ± 4.27 cm and 65.73 ± 4.68 kg. Before starting the research, we reported the project to all the referees and we were obtained written consent of them. Also, we were obtained written consent from the Royal Spanish Football Federation through the Football Federation of the Region of Murcia.

Kinematical analysis

Making data on the participation of the referees in matches was performed using an inertial device (wireless inertial unit movement) called WIMU (RealTrack Systems, Almeria, Spain). This device integrates different sensors (three accelerometers, a gyroscope, a GPS and a magnetometer, among others). This device has a sampling frequency of 100 Hz. To carry out this study, data were recorded on a memory card incorporating the device. To annex the device to referee and assistant referees and it could be used in this research, it was introduced into a specifically designed harness (Figure 1) and then, it put to each referee (Figure 2).

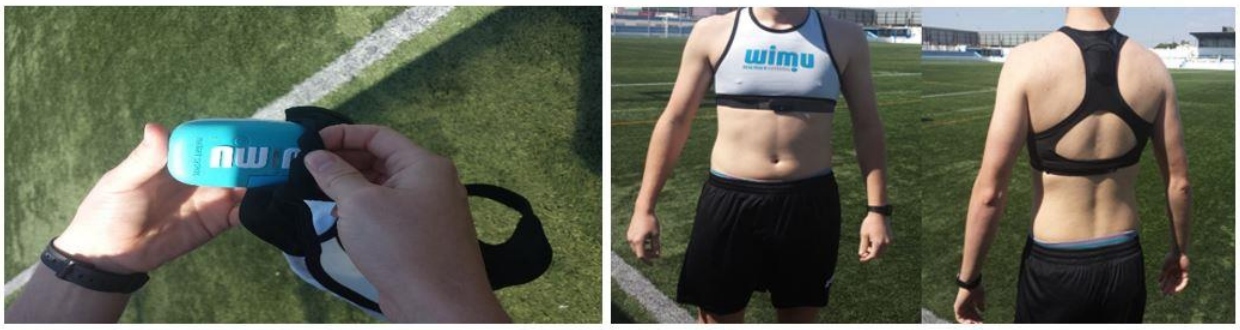

Figure 1 y 2. *Introduction of the WIMU device on specific harness and placing it in one of the participating subjects in this research.*

Linear velocity of the referee and assistant referee movements were grouped into the following ranges according to Mallo, García-Aranda and Navarro (2010): (a) stand (<3.6 km/h); (b) walk (3.61 to 7.20 km/h); (c) jogging (7.21 to 13 km/h); (d) run (13.01 to 18 km/h) and (e) sprint (> 18 km/h). All displacements

exceeding the line speed of 13 km/h were included in "High-intensity exercise" category. Regardless of the running speed, displacement movements of referees were classified into front run and back run, considering the direction of movements used by judges.

Linear accelerations of referee movements performed were acquired by speed varying which provided to the GPS sensor that included WIMU device (RealTrack Systems, Almeria, Spain). At this signal, the derivative was applied to get linear velocity groups which were classified in the following ranges (Table 2).

Table 2. *Categorization of variable acceleration in this research.*

Intensity	Accelerations (m/s-2)	Decelerations (m/s-2)
Low	+ 0 a 2,5	- 0 a 2,5
Medium	+ 2,5 a 4	- 2,5 a 4
High	+ 4 a 100	- 4 a 100

Physiological analysis

Heart rate was recorded by using a GARMIN band (Garmin Ltd., Olathe, Kansas, United States) which sent data to WIMU device through ANT+ technology (RealTrack Systems, Almeria, Spain) in 4 official Third Division (Group XIII) matches with a sampling frequency of 4 Hz. Data were analyzed using Quiko software (RealTrack Systems, Almeria, Spain). The value of maximum heart rate (HRmax) for each judge could be calculated from the files of training sessions, competitive games and physical testing.

Efforts were classified into the following categories according to individual HRmax for each judge (Helsen and Bultynck, 2004): (a) passive recovery (<65% HR max); (b) active recovery (66-75% HR max); (c) medium intensity (76-85% HR max); (d) high intensity (86-95% HRmax) and (e) maximum intensity (> 96% HRmax).

Decision-Making analysis

The acquisition of analysis of decision making data was done through two cameras were installed to registration various infringements sanctioned by referees in the field for. Each camera was oriented to record one half of the field. Then, we merged both video to visualize the arrangement of all elements entirely in the field. In all situations where the referees indicated offenses, the positioning was obtained through GPS data (latitude and longitude) and these were projected in space by Quiko software (RealTrack Systems, Almeria, Spain). Later, video with the physiological and kinematical parameters are synchronized during the match. Violations are classified according to the period of play, beneficiary team of the offense and place where the referee pointed the infringement. To do so, we relied on Krustrup and Bangsbo (2001) model but adding two additional areas. Twenty meters on each side of the center line dividing two different pitches, charted an imaginary line to the attacking zone and the central zone was established. In turn, the whole field was divided longitudinally into two halves, left and right. Thus, every midfield was made up of four zones: right center, left center, left attack, right attack.

To establish the exact time of the intervention of the referee, one of those responsible for the investigation carried a WIMU device. At the time when the referee blew his whistle, he performed a pulse on the device. Subsequently, all kinematic and physiological data of the participating subjects, the data of the marks and the video were synchronized through Quiko software and then all data were analyzed in the different competition matches.

Later, all decisions made by the referee were selected. The sequences of the various infringements incorporating the physiological and kinematic data which were classified according to the following criteria (FIFA, 2014) shown in Table 3.

Table 3. *Description of the variables used in this research and coding them according to FIFA (2014): "Rule 12: Infractions and Sanctions"*

Decisions clasification		Coding decisions
Techniques	Not infraction	0
	Direct Free Kick	1
	Indirect Free Kick	2
	Penalty Kick	3
Disciplinaries	Not Punishable	0
	Yellow Card	1
	Red Card	2

To analyze whether the decision by the arbitrators in each of the matches is correct or not, an expert committee consisting of five arbitrators in categories B and Second Division Third Division was created. A process of training of experts was conducted to ensure intra- and interobserver reliability. For this sequence of situations previously analyzed and distributed by the arbitration department of the International Federation of Football Association (FIFA), which are distributed by the technical direction of the Technical Committee of Referees of the Royal Spanish Football Federation to all umpires they were used national category at the beginning of the season. These sequences are used to improve the capacity to analyze the determinants of the violations occurred during official competition matches (Schweizer, 2011) aspects. On completion of training, inter and intra-observer reliability of the experts of 0.85 it was achieved. Table 4 shows the training plan carried out by the committee of experts to assess the decision of the judges analyzed throughout the research shows.

Table 4. *Committee of experts training planning to evaluate all decisions of the referee analyzed in the investigation (Estero, Iturriaga and Roque, 2009; Anguera and Mendo, 2013).*

Session	Duration	Objective
Session 1	1 hour	Presentation of the study and research objectives. Thanks to reviewers and explanation of the purpose of the observers training.
Session 2	1 hour	Home of the training phase, knowledge and understanding of basic and general concepts of observation and explanation of the steps to be followed in the process.
Session 3	1 hour	Beginning of the training phase. Explain the criteria, sub-criteria and coding system. Explain how to complete the registration form, complete the registration of several bounded analysis units and discuss disagreements.
Session 4 Session 5 Session 6	2-3 hours	Review of criteria and raising doubts. Complete the registration of several units of analysis, discuss disagreements and raise the need to modify criteria and sub-criteria. Finally, distribution of analyzed fragments to establish the reliability of the observers once the training process is completed.
Sesión 7	1 hour	Approval of observers if the inter- and intraobserver reliability is greater than 0.8 and matches sequences distribution to analyze and establishing a deadline thereof. If you miss the reliability of 0.8 was held back the process of formation (Sessions 2-6).

Statistical analysis

In this investigation has used a descriptive statistical analysis where the data are shown as average and standard deviations (average ± SD) to describe all requirements were obtained by under study subjects. For all, we used the Microsoft Office Excel 2007 software for the Windows 8 OS (operating system).

RESULTS

Heart rate

The main referee reached a maximum heart rate of 207 beats/min including all matches, which was recorded in the first half of one of the matches that were investigated. The average heart rate was 179,4 ± 2,02 beats per minute (bpm), being higher in the first half of the matches (181,8 ± 3.59 bpm) than the second part of the game (177, 3 ± 2.63 bpm). The average percentage of the referee´s high intensity work was 68,38% ± 7.57, being higher in the first half (76,28% ± 12.23) than the second half of the matches recorded (60.69% ± 3.96). Figure 3 shows the time distribution of heart rate intervals analyzed, based on his maximum heart rate.

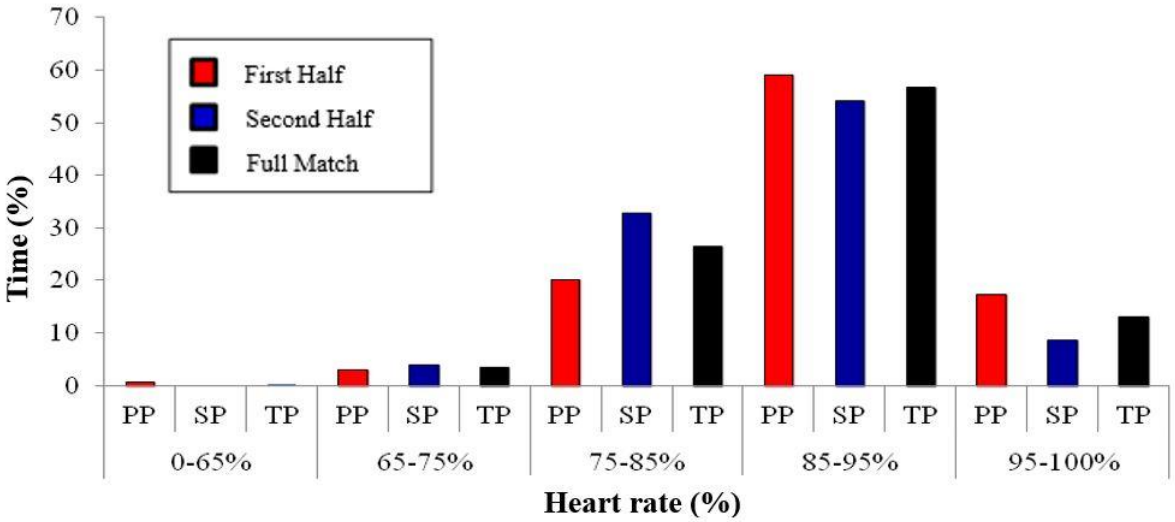

Figure 3. *Distribution of percentages of maximum heart rate in relation to the referee working time during first half, second half and full match.*

The referee spends most of the match between 85% and 95% of his maximum heart rate (56,27% ± 4,28), with the percentages over 85% being more frequent in the first 45 minutes of the match (76,41% ± 7,65) than the second half (62,78% ± 3,72). Finally, the study also shows that the values between 65% and 85% of the maximum heart rate are displayed more often in the second half of the matches (36,55% ± 3,72) than the first (22,93% ± 7,41).

The assistant referee reaches a maximum heart rate during the game of 174 beats/minute registered in the first half of one of the matches. The average heart rate of this assistant was 139,1% ± 2,29 beats per minute, again being higher in the opening 45 minutes (141,7 ± 2,08 bpm) than the second half (137,2 ± 2,13 ppm). Regarding the high intensity work rate of the assistant referee we find that the average of all the games was of 23,29%± 2,96, being higher in the first half (32,16%± 10,36) than in the second (21,31%± 8,49). In figure 4 the time distribution by intervals based on the maximum heart rate of the assistant referee is described.

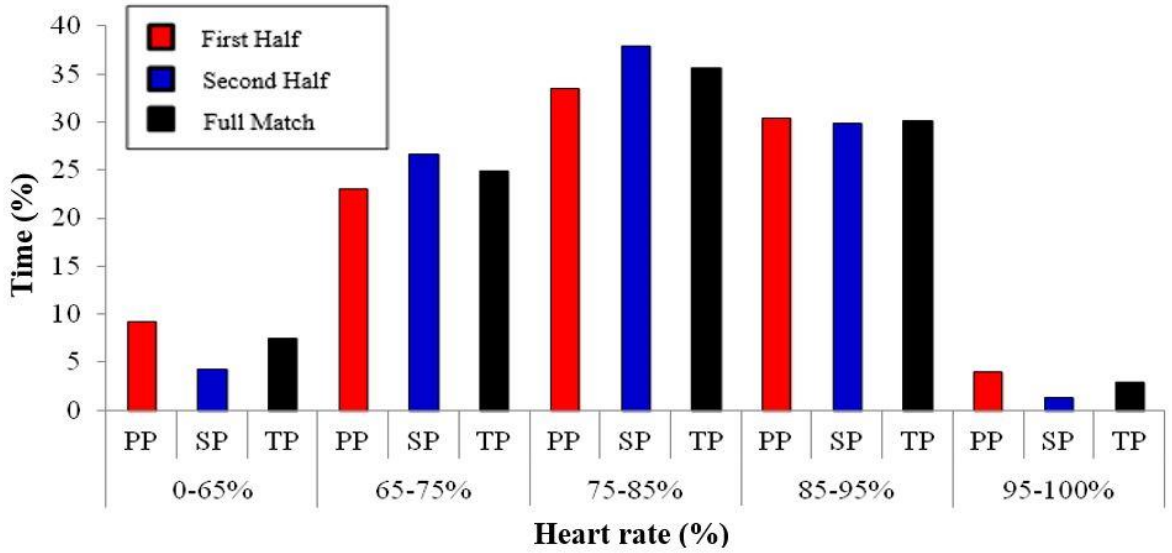

Figure 4. *Distribution of percentages of maximum heart rate in relation to assistant referee working time during first half, second half and full match.*

The assistant referee spends most of the match between 65% and 95% of his maximum heart rate (67,82%± 10,16), with the percentages between 75% and 85% being more frequent in the second half of the match (37,88%± 7,71) than in the opening half (33,43%± 12,60)

Travel speed and distance covered

The main referee covered an average distance of 10124,7 ± 543,2 meters with a maximum speed of 10574,3 meters. Regarding the distance covered in the different parts of the match, they were higher in the first half of the games (5233,9 ± 293,8 meters) than the second half (49437,7± 390,1). The percentages of travel speed in relation to the work time of the main referee are displayed in figure 5.

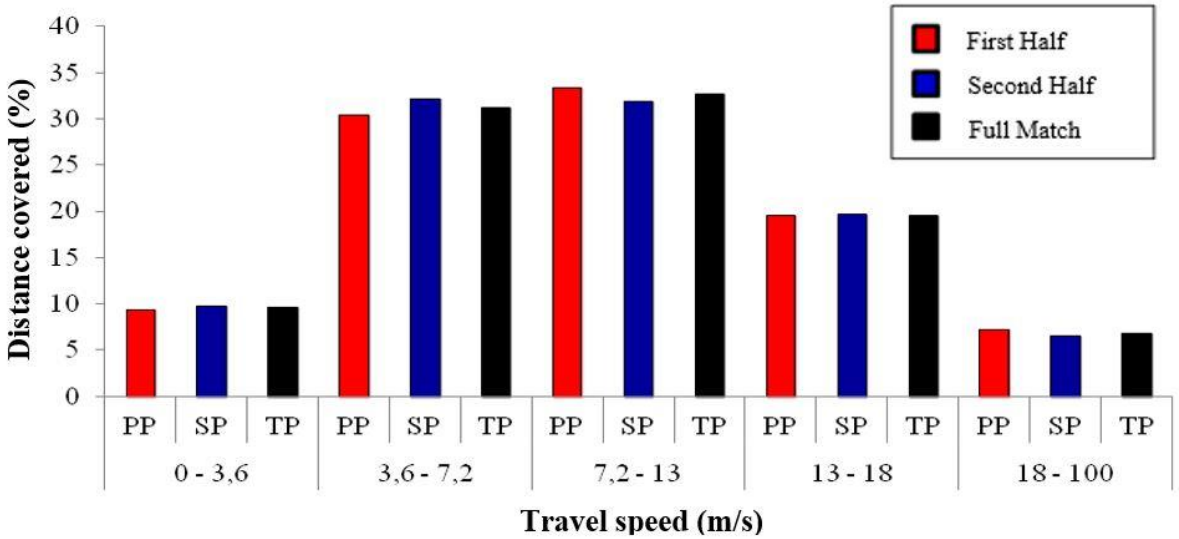

Figure 5. *Distribution of the percentages of the travel speed in relation to the referee distance covered during first half, second half and full match.*

The referee spends most of the match within travel speeds of 3,6-7,2 km/h (walking) and 7,2-13 km/h (jogging) in relation to the total distance covered during the whole game (64,75%± 4,35 being 6331,3± 308 meters). If we discard the two main travel speed intervals (walking and jogging), the referee spends one fifth of the distance covered in a match running between 13-18 km/h (19,55%± 2,00 being 1951,1± 310,5 meters) and the least distance sprinting at over 18 km/h (6,8 %± 0,7 % equaling 680,2 ± 102,6 meters). Finally, the main referee only finds himself below a speed of 3,6 km/h (paused) throughout a distance of 9.6%± 1,5 of the whole distance covered in a game. Regarding the differences between the travel speeds of the first and second half, we don´t find any.

The assistant referee covers an average distance of 6176,7 ± 443,1 meters and a maximum distance in one of the matches of 6649,1 meters. Regarding the distances covered in the different parts of the game, they were higher in the second half of the matches (3289,8 ± 389,1 meters) than the first half (2933,6± 250,4 meters). The percentages of the travel speed in relation to the work time of the assistant referee are displayed in figure 6.

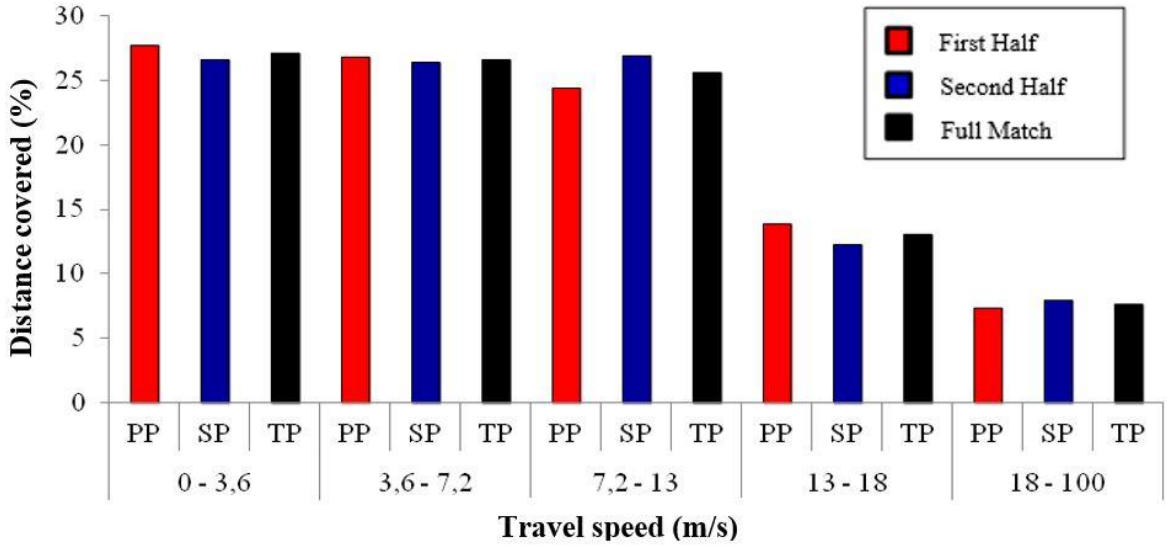

Figure 6. *Distribution of the percentages of the travel speed in relation to the assistant referee distance covered during first half, second half and full match.*

The assistant referee spends most of the game with a travel speed of between 0-3,6 km/h (paused) in 27,0%± 5,0, between 3,6-7,2 km/h (walking) in 26,5%± 2,4 and between 7,2-13 km/h (jogging) in 25,9%± 2,6 of the total of the distance covered in the match. With this being said, the assistant referees are within 0-13 km/h in 79,4%± 3,83 of the total of the distance covered during the match (4347,2 ± 308,0 meters). If we eliminate the most frequent intervals, the assistant is only running between 13-18 km/h in 13,1% ± 3,03 and sprinting at over 18 km/h in 7,5% ± 3,5 of the total distance covered once the game is finished. Regarding the difference between the travel speed of the first half and the second half, we don´t find any differences.

Acceleration

The main referee has an average of total accelerations of 1217,5 ± 361,4 and an average of total decelerations of 1092,5 ± 258,3. If we relate the amount of changes in speed with the time, the referee has an average of 13,0 ± 3,8 accelerations per minute and an average of 11,7 ± 2,7 decelerations per minute. Divided by the halves of the match, the referee accelerates and decelerates in the first half, both in total (first

half: 627,0 ± 179,3 and second half: 559,3 ± 123,6) and per minute (first half: 13,6 ± 3,8 and second half: 12,1 ± 2,6). The percentages of accelerations and decelerations in relation to the work time of the referee are displayed in figure 7.

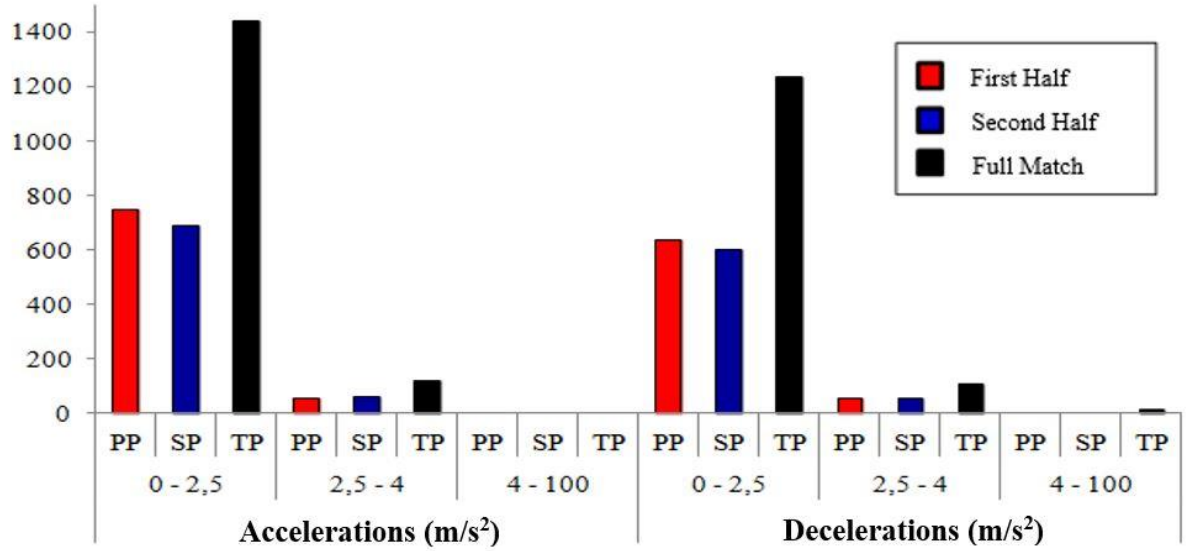

Figure 7. *Distribution of the percentages of accelerations and decelerations in relation to referee working time during first half, second half and full match.*

The most frequent acceleration groups are the ones realized between 0-2,5 m/s2, including accelerations (1439± 321,3) and decelerations (1232 ± 220,9). In second place we find the interval between 2,5-4 m/s2, also affecting both accelerations (118± 38,5) and decelerations (109 ± 34,6). Finally we have the interval between 4-100 m/s2, which are unusual during a match (accelerations: 3,8 ± 4,2 and decelerations: 7,0 ± 4,4).

The assistant referee has an average of 1231,8 ± 253,5 total accelerations and an average of 1169,5 ± 298,4 total decelerations. If we relate the total of changes of speed with the time, the assistant has an average of 15,7 ± 3,5 accelerations per minute and an average of 14,8 ± 3,4 decelerations per minute. Depending on the part of the match, the assistant referee accelerates and decelerates more in the first half, both in total (first half:637, 4 ± 138,0 and second half: 594,0 ± 117,4) and per minute (first half :13,8 ± 3,0 and second half: 12,5 ± 2,4). The percentages of accelerations and decelerations in relation to the work time of the assistant referee are displayed in figure 8.

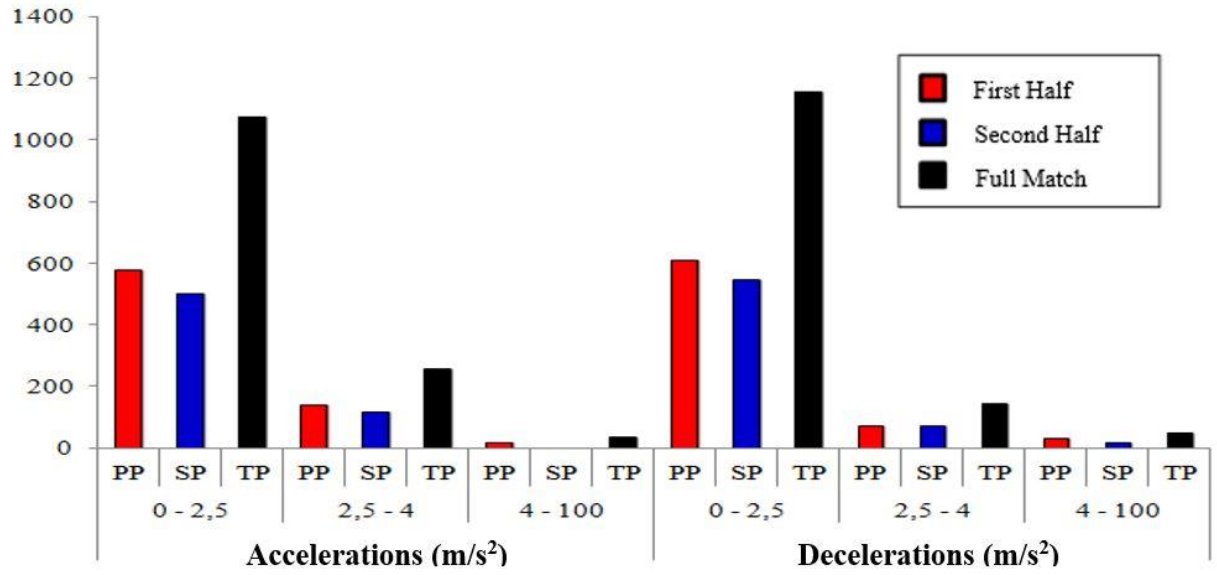

Figure 8. *Distribution of the percentages of accelerations and decelerations in relation to assistant referee working time during first half, second half and full match.*

The most recurring group of accelerations in relation to the travel speed is the one between 0-2,5 m/s2, for accelerations (1075 ± 165,8) and decelerations (1153 ± 232,4). Regarding the rest of the intervals, the most frequent are the ones between 2,5-4 m/s2 for accelerations (257 ± 93,5) and decelerations (143 ± 51,6), and finally the ones between 4-100 m/s2 (A: 34 ± 22,3 and D: 47 ± 21,9), which are very superior to those completed by the main referee in this group.

Decision making

The referee indicated a total of 99 infractions (n=4) in the matches analyzed in group XIII of the Third Division. The distribution of these infractions are displayed in table 5.

Table 5. *Distribution of the infringements indicated by the referee in matches analyzed in this research.*

	TMI	Direct Free Kick				Indirect Free Kick				Penalty Kick			
		Nº	DD			Nº	DD			Nº	DD		
			N	Y	R		N	Y	R		N	Y	R
Match 1	27	26	20	6	0	0	0	0	0	1	0	1	0
Match 2	27	26	25	1	0	1	1	0	0	0	0	0	0
Match 3	30	30	24	6	0	0	0	0	0	0	0	0	0
Match 4	15	13	9	4	0	1	1	0	0	1	1	0	0
Average	24,75	23,75	19,50	4,25	0,00	0,50	0,50	0,00	0,00	0,50	0,25	0,25	0,00
SD	6,65	7,41	7,33	2,36	0,00	0,58	0,58	0,00	0,00	0,58	0,50	0,50	0,00

Nota. TMI: Total Match Infractions; DD: Disciplinary Decisions; N: Not Disciplinary Sanctions; Y: Yellow Card; R: Red Card. SD: Standard Deviation.

The committee of experts carefully analyzed every decision taken, with a reliability of interobservers of 95,75%, indicating that at least 4 of the 5 participating experts were in agreement. In table 6 we can see the decisions made by the referee during the investigated matches in relation to the decisions made after the analysis by the experts, both at a technical and a disciplinary level.

Table 6. *Comparative analysis between decisions taken by the referee and the decisions taken by the committee of experts at technical and disciplinary level.*

				Committee of Experts			
				Technical Decision		Disciplinary Decision	
				W	R	W	R
Main Referee	DFK	TD	I	0,17	0,78		
		DD	N			0,07	0,72
			Y			0,03	0,13
			R			0,00	0,00
	IFK	TD	I	0,01	0,01		
		DD	N			0,00	0,03
			Y				
			R				
	PK	TD	I	0,00	0,03		
		DD	N			0,01	
			Y				0,01
			R				
		TOTAL		0,18	0,82	0,11	0,89

Nota. W: Wrong; R: Right; DFK: Direct Free Kick; IFK: Indirect Free Kick; PK: Penalty Kick; TD: Technical Decision; I: Infractions; DD: Disciplinary Decision; N: Not Disciplinary Sanction; A: Yellow Card; R: Red Card.

This table shows that the referee has a success level penalizing infractions on a technical level of 0,82, with the committee of experts disagreeing with 0,18 (0,17 direct free kicks and 0,01 indirect free kicks). Also at a technical level, all penalty kicks are agreed upon. At the disciplinary level the referee has a success rate of 0,89, leaving 0,11 as errors. Most of these errors are found in infractions where the referee does not show any cards, but the committee considers he should have (0,07).

After analyzing the data, we observe 18% of technical errors and 11% of disciplinary errors, which lead to an analysis of the errors to determine the main causes of these mistakes. For this we analyze many variables to see how they influence the decisions made by the referee, which are: part of the pitch, minute of the match, heart rate, travel speed and the team favored by the mistake.

In figure 9 we observe a comparison between the percentage of errors made by the referee and his heart rate at said moment. The referee commits his mistakes when his heart rate is over 75%, especially when his heart rate is between 85-95% (67,7%) and over 95% (26,7%).

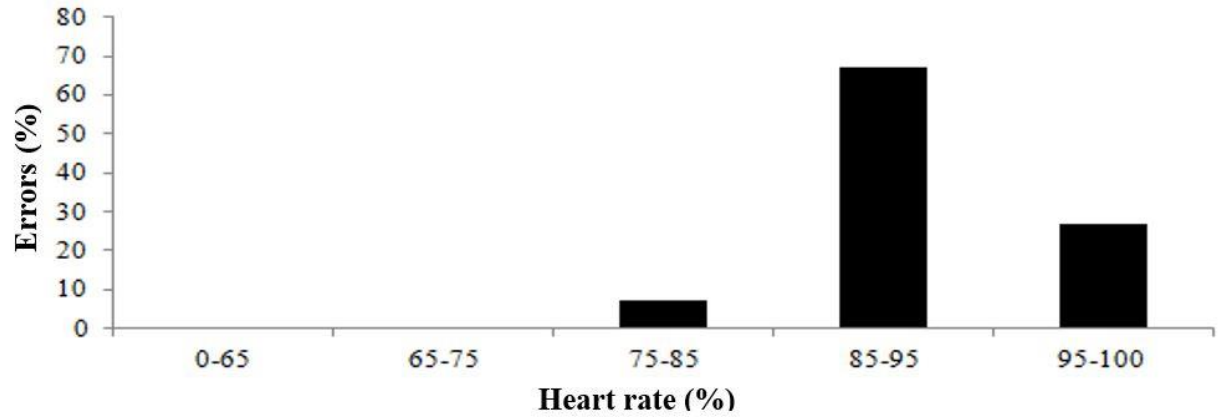

Figure 9. *Distribution of error rate in signaling infractions by the referee in relation to heart rate.*

Figure 10 shows a comparison between the percentage of errors and it´s relation with the travel speed at said moment. The referee makes a larger amount of errors when his travel speed is lowest, between 0-3,6% km/h (35,2). The number of mistakes decreases as the travel speed of the referee rises.

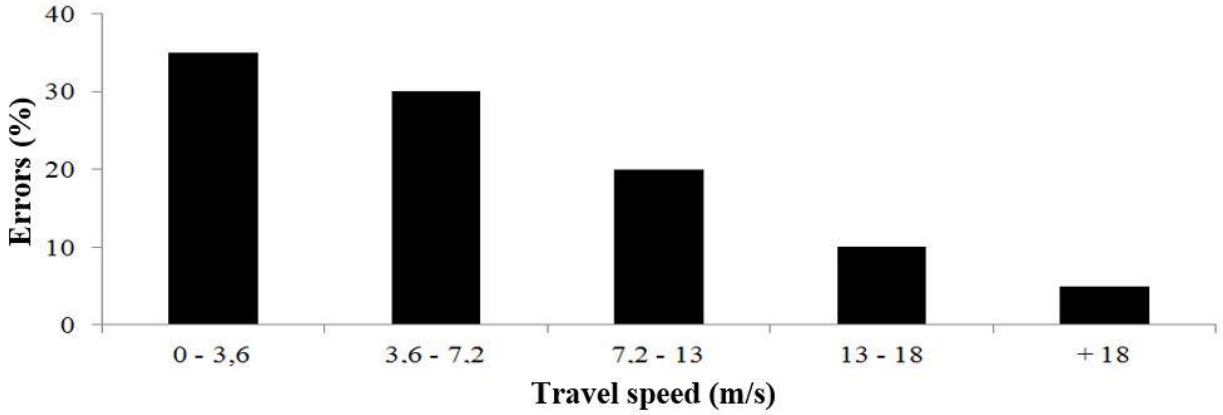

Figure 10. *Distribution of error rate in signaling infractions by the referee in relation to travel speed.*

In figure 11 we can observe a comparison between the percentage of errors and it´s relation with the part of the match in which these mistakes are made. Most of them (69%) take place in the first half of the match. To be more concrete, we can see that in the first 15 minutes the mistake rate is 54%, and between minute 30-45 the mistake rate is 31%, the lowest being found between minute 15 and minute 30 (15%).

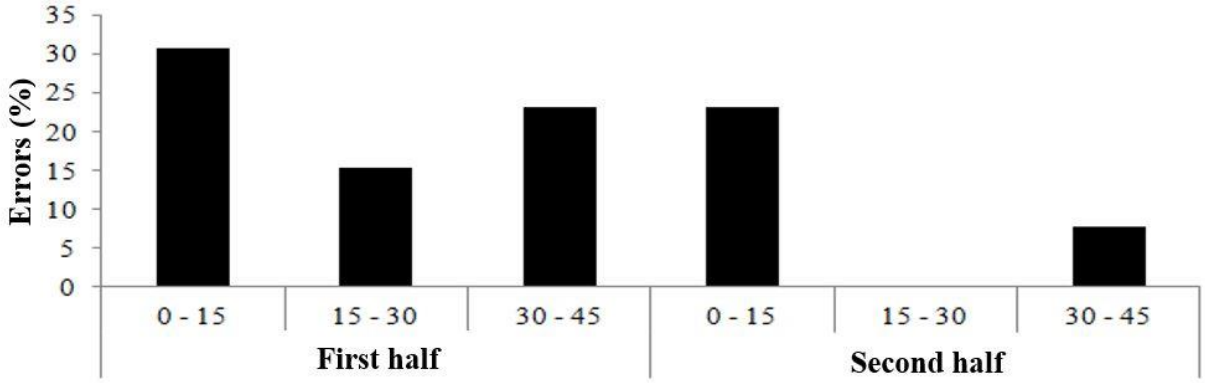

Figure 11. *Distribution of error rate in signaling infractions by the referee in relation to period of match (in minutes).*

Figure 12 shows the relation between the percentage of errors and the part of the pitch where the action takes place, bearing in mind the diagonal run made by the referee described in the Rules of the Game (FIFA, 2014). From this we observe that whether the action takes place in an attacking, central of defensive position makes no difference, but it´s the laterality that matters. The referee makes many more mistakes on the right side of the pitch (79%) than on the left side (21%), caused by the diagonal movement of the referee described in Figure 1 to leave the ball to his right and have a better view of the assistant referees.

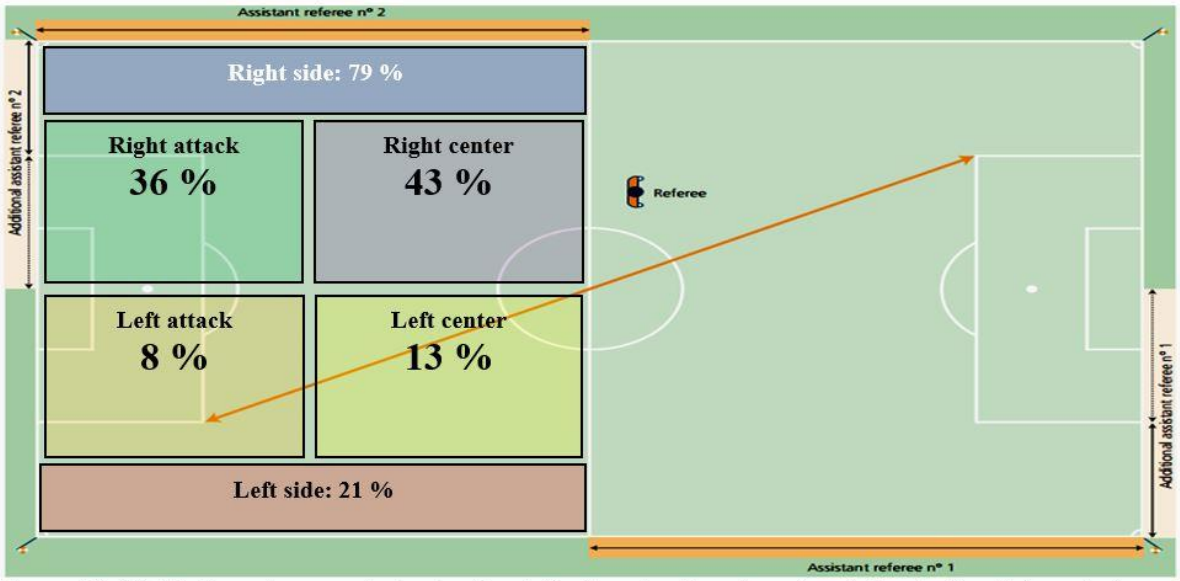

Figure 12. *Distribution of error rate in signaling infractions by the referee in relation to the pitch part where is produced infractions and diagonal movement which is performed by the referee in the field of play (FIFA, 2014).*

Figure 13 shows the relation between the percentage of mistakes made by the referee and the team favored by these errors. As we can see, there are no significant differences regarding the teams affected by the mistakes (home team: 53%, away team: 47%).

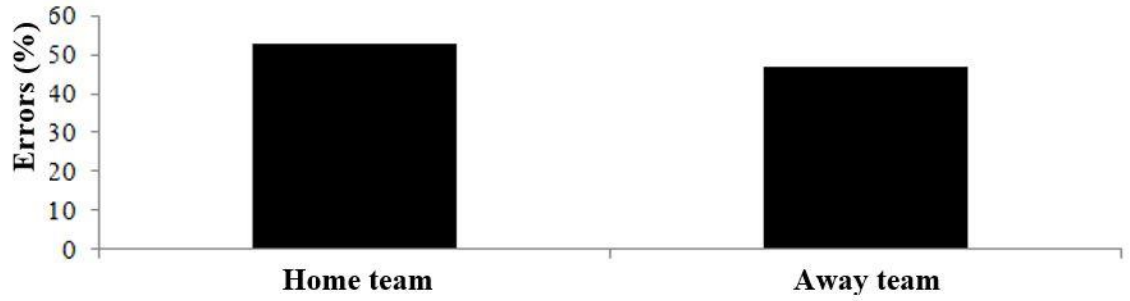

Figure 13. *Distribution of error rate in signaling infractions by the referee in relation to the team that benefits from the decision.*

DISCUSSION

Cinematic and physiological analysis

With the results obtained from this research, we have been able to determine that both referees and assistant referees should be considered as independent groups when it comes to planning training sessions for official competition matches (Mallo, 2006; Krustrup et al, 2009; Mallo and Navarro, 2009). For this we´ve decided to analyze, step by step, every possible cinematic and physiological variable that affects the physical performance of referees and assistant referees in the games studied in this investigation.

Regarding the maximum heart rate (HRmax), the main referee finds himself between 85-95%. The first studies determined that referees had an average of 95% of the HRmax (Caterall et al, 1993). As time has gone past until today this percentage has lowered to the 85-95% region, as described by the following studies

(Weston, Helsen, MacMahon and Kirkendall, 2004; Helsen and Bultnick, 2004; Krustrup et al, 2009; Mallo and Navarro, 2009), also being higher in the first half than the second half , like in this study (Mallo et al, 2009). To achieve these results intermittent methods have been used, with training frequencies higher than 85% of the HRmax (Krustup and Bangsbo, 2001; Weston et al, 2004). On the other hand, the assistant referees have a lower maximum heart rate (75-85%) throughout the whole match, as determined by different articles (Mallo, 2006, Mallo and Navarro, 2009, Krustup et al, 2009).

Apart from the HRmax we should bear in mind the time the referee spends doing high intensity work. In this study the average is 68,8%, and in the literature it´s between 45% and 50% (Mallo, Navarro, Garcia-Aranda and Helsen, 2009).

Regarding the distance covered, our referees cover an average of 10,2 km. In past studies, this amount is reduced to 9 km (Caterall et al, 1993), but recent studies frequent between 10 and 11 km (Krustrup and Bansgbo, 2001; Krustrup et al, 2009; Mallo et al, 2009). As for the assistant referees this distances are reduced to 6 km (Krustrup et al, 2009; Mallo, Navarro, García-Aranda and Helsen, 2009), similar to results obtained in this investigation.

If we look at the travel speeds on the pitch, in this study the referee moves above all in the interval between 7,2-13 km/h (32,3%). In other studies this group was also the most frequent but with lower percentages (25%), with the interval rising between 3,6-7,2 km/h (30%) in the 2003 sub-17 world cup (Mallo et al, 2010). Regarding the assistant referees, they travel most distance in the interval between 0-7,2 km/h (Assistant number 1: 53,5% and assistant number 2: 64,4%) although this can´t be compared with data obtained in other studies, because they relate the time the referees travel at that speed and not the distance of these runs.

No studies were found on the accelerations, so no comparison could be made. The most important conclusions that should be investigated in the future, are that the accelerations and decelerations over 2,5 m/s2, which are more frequent in assistant referees, are determinant for the competition.

Analysis of the decision making

In this category, the referee in this study has a percentage of correct decisions of 82% in the technical infractions and 88% in the disciplinary infractions, and different studies support these results in national competitions (Mascarenhas, Button, O´Hara and Dicks, 209; Elsworthy et al, 2014) and in international competitions (Mallo et al, 2012). This shows that the error percentage of referees is worrying, so the causes of these mistakes were investigated with the following results.

Regarding the heart rate in the moment of the decision, the mistakes have been more frequent when the heart rate is over 85%, although there is a study which found no significant differences between errors and right decisions in relation to the maximum heart rate (Mascarenhas et al, 2009).

Depending on the period in which the mistakes are made, more errors have been found in the first half than the second half, as well as more errors being found in the first 15 minutes of each half as proved by previous investigations (Mascarenhas et al, 2009; Elsworthy et al, 2014), although there are studies that show more mistakes in the second half of matches (Mallo et al, 2012).

The referees travel speed doesn´t appear to be important, because more mistakes are made when the referee is travelling at a low speed (Mascarenhas et al, 2009; Elsworthy et al, 2014). Regarding the cinematic

variables, it´s proven in the literature but couldn´t be analyzed in this study, that the distance between the referee and where the infraction occurs affects the final decision. The optimum distance has been proven to be 11-15 meters, and the percentage of the errors grows at both a closer and a further distance (Mallo et al., 2012).

If we take into account the positioning on the pitch in relation to the mistakes made, we find that the right side of the pitch is where most errors occur (71%), especially in the more central zone of the right side (43%). This is due to this zone being further away from the referee than the left central position, and the left and right attacking zone (Mallo, García-Aranda and Navarro, 2010).

Finally, regarding the team favored by the errors, no differences were found, which is described in the literature (Mascarenhas et al., 2009; Elsworthy et al., 2014).

CONCLUSIONS

The main conclusions that me can extract from this investigation are:

1. Main referees and assistant referees should be considered as totally different work groups because at a cinematic and physiologic level we find the following differences:

    - **Heart rate:** The average heart rate of the main referee during the match is between 85-95% of the maximum heart rate, while the assistants find themselves between 75-85% of the maximum heart rate.
    - **Travel speed:** The most frequent average travel speed of the main referee is between 7,2 and 13 km/h (jogging) while the average of the assistant is between 3,6-7,2 km/h (walking).
    - **Distance covered:** The referee covers an average of 4125,7 ± 467,2 meters more than the assistants.
    - **Accelerations:** The assistant referee makes more accelerations and decelerations than the main referee, especially in the acceleration groups of 2,5-4 m/s2 and when these are over 4 m/s2.

2. Regarding the decisions made by the main referee when punishing different infractions during the matches we obtain:

    - **Aspects that influence the decision making**

        - ✓ **Heart rate:** Most of the mistakes made by the referee (94,4%) take place when it´s over 85% of the maximum heart rate.
        - ✓ **Part of the pitch:** The referee makes wrong decisions in the right part of the pitch more than any other part, due to the diagonal run established in the rules of the game.
        - ✓ **Period of the match:** Most of the errors occur in the first half of the games, especially in the first 15 minutes.

    - **Aspects that don´t affect decision making.**

- ✓ **Speed:** The referee makes more mistakes in the lowest speed group 0-3,6 km/h, which shows that they don't make more mistakes at a higher speed.
- ✓ **Team that benefits from the decision:** The referee makes mistakes favoring both the home team and the away team equally, dismounting one of footballs most talked about theories.

PROPOSAL FOR FUTURE INVESTIGATIONS

Throughout the realization of this study we obtained important conclusions for the improvement of the quality at a technical-tactical and physical level of football referees to optimize the accuracy in official matches, but because of the category and limited amount of the officials that we have studied, these conclusions can´t be generalized to the total population of referees. Due to this, we propose that in the future this study should be applied to more referees of a higher category and over a more numerous amount of matches to make the results more reliable.

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