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Physical demands on professional Spanish football referees during matches

Gemma Martínez-Torremocha[a], Maria Luisa Martin-Sanchez[a,b], Jorge Garcia-Unanue[a], Jose Luis Felipe[b], Víctor Moreno-Pérez[c,d], Víctor Paredes-Hernández[e], Leonor Gallardo[a] and Javier Sanchez-Sanchez[b]

[a]IGOID Research Group, Department of Physical Activity and Sport Sciences, University of Castilla-La Mancha, Toledo, Spain; [b]Faculty of Sport Sciences Universidad Europea de Madrid, Madrid, Spain; [c]Sport Research Center, Miguel Hernandez University of Elche, Alicante, Spain; [d]Center for Translational Research in Physiotherapy, Department of Pathology and Surgery, Miguel Hernandez University of Elche, San Joan, Spain; [e]Department of Sport Sciences, Faculty of Health, Universidad Camilo José Cela, Madrid, Spain

ABSTRACT

Background: Refereeing is a demanding and intermittent activity that combines high-speed and low-intensity action

Objective: The aim of this study is to analyse the external and internal load of professional Spanish football referees during matches, and to compare the physical demands between halves and between referees in different categories

Methods: The physical demands on 40 professional football referees from the first and second divisions were recorded using global positioning system (GPS) technology and heart rate bands. External load (distance covered, speed, acceleration and deceleration) and internal load (perceived exertion [RPE] and heart rate [HR]) were analysed

Results: The referees in the first division reported lower mean HR and RPE results than those in the second division ($p < 0.05$). The total distance covered was similar between the categories ($p > 0.05$), but the distance covered at different speed ranges was different ($p < 0.05$). Finally, greater reductions in performance between the first and the second halves were found in the second division referees ($p < 0.05$)

Conclusions: The results of this study show differences according to the category of referee. This emphasises the need for specific training for professional referees according to their level to ensure optimal performance during matches.

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KEYWORDS
GPS; performance; heart rate; match demands; football; referee

Introduction

Football is one of the most popular and common sports in the world (Fernández-Elías et al. 2017) and imposes great physiological and functional demands (Castagna et al. 2007). However, in football, players are not the only ones on the field: referees are also present in order to make sure that the game develops correctly and with the fewest incidents possible (Schenk et al. 2018). This responsibility means that referees must keep up with the match intensity requirements in order to maintain a good position to detect possible infractions (Fernández-Elías et al. 2017). Therefore, during a match, referees perform repeated short periods of high-speed running interspersed with longer recovery periods of lower intensity (Castagna et al. 2007). The referee's activity during the match is related to the competitive involvement of the players during the playing time (Fernández-Elías et al. 2017). Previous studies have shown a similarity between the activity of professional players and that of referees (Costa et al. 2013) when measured using a GPS device, one of the most commonly-used techniques for the study of physical performance (Suarez Arrones et al. 2014).

There are also studies that show that referees cover between 10 and 12 km per game, with a heart rate (HR) at between 85% and 90% of their maximum HR (HR_{max}), and that they cover about 15% of the total distance (TD) at high speed (> 18 km·h^{-1}) (Castillo et al. 2017, 2019), while referees in Serie A and B matches in the Italian league cover approximately 11 km per game (D'Ottavio and Castagna 2001). In addition, the maximum speed recorded in official matches is around 29 km·h^{-1} (Castillo et al. 2016; Sánchez-García et al. 2018). A referee is subjected to high loads and can therefore become fatigued and/or injured (Riiser et al. 2019). Despite this, there is little information about the physical performance of professional referees in this sport, as only a few researchers have studied this, with studies having been done in the English Premier League and Championship (M. Weston et al. 2011) and in the Danish leagues (Krustrup and Bangsbo 2001).

Authors have reported that football match intensity is correlated with the level of competition (Mohr et al. 2003). Referees have periods of high-intensity running during matches (M. Weston 2015), and as a consequence it is possible that they may experience fatigue, which has been shown to have a negative effect on physical performance (Castillo et al. 2018b; Riiser et al. 2019). It has been shown that the distance covered at high intensity and the total distance covered in the first 15 minutes of the first half of a game are greater than these distances in the first 15 minutes of the second half (M. Weston et al. 2012). Fatigue therefore needs to be tracked by evaluating

CONTACT Maria Luisa Martin-Sanchez marialuisa.martindesanpablo@universidadeuropea.es Faculty of Sport Sciences. Universidad Europea de Madrid, Calle Tajo, s/n, Villaviciosa de Odón, 28670 Madrid, Spain

performance and physiological impact during matches (Krustrup et al. 2010). Nevertheless, referees must be in excellent physical and psychological shape so that they can respond to the demands of the game at each moment of the match (Castillo et al. 2016, 2019).

A comprehensive understanding of the physical demands of match-play in referees is necessary in order to apply a systematic approach to training and testing protocols.

However, the physical demands on referees in England and Denmark may be different from the physical demands on referees in Spain because of contextual variables. Taking into account previous research, the outstanding achievement of this study is that it can provide values for the physical performance of professional referees in two categories.

Therefore, the aim of this study is to analyse the external and internal load of professional Spanish football referees during matches, and to compare the physical demands between halves and between referees in different categories.

Methods

Experimental approach

Subjects

Forty professional football referees (age 35.88 ± 4.36 years, body mass 75.15 ± 4.41 kg, height 182.45 ± 4.62 cm) participated voluntarily in this prospective observational study. Among these, 19 refereed in the first division (age 37.80 ± 4.36 years, body mass 75.11 ± 4.49 kg, height 182.74 ± 5.74 cm) and 21 in the second division (age 34.14 ± 3.64 years, body mass 75.18 ± 4.46 kg, height 182.16 ± 4.15 cm). All the participants belonged to the Technical Committee of Referees (CTA) of the Royal Spanish Football Federation (RFEF). All the referees had at least 10 years of refereeing experience, with a minimum of four years in the Spanish national competition. All trained at least five times a week, focusing on strength, endurance and speed, and they normally refereed one match each weekend. All referees working in the first and second divisions participated in the study, but two were excluded from this study because of problems with the GPS devices. Also, matches that were not completed (that did not continue for at least 90 minutes) were excluded from the study. Before starting the study, all the subjects were fully informed about the study procedures, and signed a written informed consent form approved by an Ethics Committee (number CIPI/045/16), in accordance with the recommendations of the Declaration of Helsinki.

Procedures

A descriptive observational study was carried out to analyse the match load demands (internal and external) on referees in professional football during official matches.

The data were collected during 419 official professional matches during the 2019/2020 season. Before recording data during a match, each referee completed a standardised warm-up, consisting of 15 minutes of jogging, active mobility, strength and proprioception exercises, active stretching and high-intensity actions. However, these data were not included in the overall analysis. Also, the between-halves interval data (15 minutes) were excluded from the analysis. The matches were held on different football fields, but the dimensions and surfaces of the pitches were similar. During all the match-play sessions, the referees were monitored using a portable GPS device (Wimu ProTM, RealTrack Systems, Spain), and the data were analysed using SPRO^{TM} software 977 (RealTrack Systems, Almeria, Spain) (Castillo et al. 2018a). To avoid inter-unit error, each referee wore the same GPS device during the whole study period. All referees included in the data analysis officiated for at least 90 minutes per match. At the end of each of the matches, the data were downloaded to a computer in order to carry out the subsequent analysis of the different variables being studied. A week before recording their first match, each referee was familiarised with the GPS device.

Match analysis

External match load

The external measurements were recorded using the GPS device (Mallo et al. 2010; Castellano et al. 2014) operating at a sampling frequency of 18 Hz (Castillo et al. 2018a; Granero-Gil et al. 2020). These devices have shown a good level of accuracy and validity for assessing external load in official competitions (Hernandez-Belmonte et al. 2018).

According to the manufacturer's recommendations, all the devices were activated 15 minutes before data collection to allow the acquisition of satellite signals and synchronisation of the GPS clock with the satellite's atomic clock. For the calculation of the different data based on the GPS signal, SPRO^{TM} software was used.

The participants wore a tight-fitting bib into which the GPS device was inserted, on the upper back, before the match. The variables used were classified according to the following arbitrary categories, similar to those used in previous studies (Castillo et al. 2019): total distance covered (m), distance covered at various speeds (km·h^{-1}), total number of accelerations (ACC) (n) and total number of decelerations (DEC) (n) (where an acceleration or deceleration is deemed to be any increase or reduction in speed that means passing or descending from the zero axis), peaks of ACC and DEC (m·s^{-2}), maximum speed (km·h^{-1}), and total sprint distance (m). The distance covered at different speeds was collected based on different locomotive categories comprising six zones: low-speed walking (0–6 km·h^{-1}); walking (6–12 km·h^{-1}); low-intensity running (12–18 km·h^{-1}); high-intensity running (18–21 km·h^{-1}); high-speed running (21–24 km·h^{-1}); and sprinting (> 24 km·h^{-1}). These zones are similar to those used in other studies (Castagna and Castellano Paulis 2011; McBride et al. 2011; Castillo et al. 2019). Movements at over 18 km·h^{-1} were grouped together and identified as high-intensity running.

Internal match load

Internal load measurements were collected using the heart rate (HR) (HR_{max}, HR_{mean} and HR_{rel}) (bpm) during the matches, using a Garmin band (Garmin Ltd., Olathe, Kansas, USA) that was synchronised with the GPS device via Ant+ technology. The rated perceived exertion (RPE) was also recorded (Losnegard et al. 2013) on a scale from 1 to 10 (1 being no effort and 10 maximum effort).

Statistical analyses

For the statistical analysis, the IBM SPSS Statistics version 25.0 software for Windows (SPSS Inc., IL, USA) was used. The results are presented in the form of text, tables and figures, presenting the mean ± standard deviation. To test the normality distribution and the homogeneity of variance, the Kolmogorov–Smirnov and Levene test, respectively, were used. The results showed that the data were normally distributed and displayed homogeneous variance. All the analyses were performed using linear mixed models to analyse the differences in the performance variables between the first and the second halves (for both the first and the second divisions) and between the first and second division. The referee identity was introduced and modelled as a random effect to control the repeated measurements. The confidence level was established at 95%, with values of $p < 0.05$ considered to be statistically significant. Furthermore, differences were also studied using the standardised effect size differences (ES) using Cohen's coefficient (Cohen 1992). The ES was interpreted as follows: < 0.2 = negligible; 0.2–0.6 = small; 0.6–1.2 = moderate; > 1.2 = large.

Results

A total of 419 games were recorded, with 181 first division games and 238 second division games. The analysis of the variance between the physical and physiological demands for the first and second division referees during the matches indicates that there was a lower mean HR (−7.07 bpm; 95% CI: −9.86 to −4.29; ES: 0.59) and lower RPE (−0.60; 95 CI: −0.94 to −0.26; ES: 0.45) in the first division referees ($p < 0.05$) (Table 1).

Table 1. Distance covered, heart rate and load indicators during the match in first and second division referees.

	First division			Second division			p value	ES
Total distance (m)	10,417.50	±	860.09	10,420.36	±	729.10	0.786	0.00
Accelerations (n)	2813.02	±	274.66	2738.89	±	265.56	0.123	0.27
Decelerations (n)	2813.16	±	274.49	2738.85	±	265.83	0.122	0.28
Accelerations ($n \cdot min^{-1}$)	57.20	±	4.74	56.62	±	5.00	0.540	0.12
Decelerations ($n \cdot min^{-1}$)	57.21	±	4.73	56.62	±	5.01	0.536	0.12
ACC_{max} ($m \cdot s^{-2}$)	4.63	±	0.94	4.43	±	0.65	0.070	0.25
DEC_{max} ($m \cdot s^{-2}$)	−5.36	±	0.80	−5.19	±	0.64	0.122	0.24
Sprint distance (m)	212.98	±	121.08	209.07	±	105.51	0.856	0.03
Sprint distance (n)	10.01	±	5.43	9.88	±	4.57	0.887	0.03
V_{max} ($km \cdot h^{-1}$)	28.76	±	2.06	28.56	±	1.82	0.517	0.10
HR_{max} (bpm)	171.60	±	9.15	179.59	±	8.91	0.057	0.89
HR_{mean} (bpm)	146.63	±	11.79	153.70	±	12.00*	0.045	0.59
HR_{mean} (%)	83.26	±	5.34	82.96	±	5.85	0.859	0.05
RPE	7.22	±	1.38	7.82	±	1.27*	<0.001	0.45

* Significant differences between first and second division referees ($p < 0.05$); ACC_{max}: Maximum accelerations; DEC_{max}: Maximum decelerations; HR: Heart rate; V_{max}: Maximum speed; RPE: Rated of perceived exertion.

No significant differences were identified between the first and second division referees in the rest of the variables ($p > 0.05$).

The total distance covered was similar between the categories ($p > 0.05$). However, the distance covered in the different speed ranges was significantly different between the first and the second division referees ($p < 0.05$). Specifically, the second division referees covered a greater distance during the matches during low-intensity running (12–18 $km \cdot h^{-1}$) (+211.70 m; 95% CI: 103.25 to 320.16; ES: 0.42) and running at high intensity (18–21 km□h^{-1}) (+63.38 m; 95% CI: 30.99 to 95.78; ES: 0.42) than the first division referees. However, the first division referees had lower results than the second division referees for walking distance (+373.07 m; 95% CI: 259.15 to 486.99; ES: 0.70). Walking (6–12 $km \cdot h^{-1}$), high-speed running (21–24 $km \cdot h^{-1}$) and sprint distances (+24 $km \cdot h^{-1}$) were similar between the first and second divisions ($p > 0.05$) (Figure 1).

The physical performance of the referees was reduced during the second halves of the matches ($p < 0.05$) (Table 2). However, the first division referees showed an increase in the number of accelerations (+84.01; 95% CI: 48.09 to 119.94; ES: 0.57) and the number of decelerations (+84.30; 95% CI: 48.37 to 120.24; ES: 0.57) in the second halves. Similar results were demonstrated for the second division referees ($p < 0.05$). The main reductions in physical performance between the first and the second halves were shown in the second division referees ($p < 0.05$). Maximum deceleration (−0.17 $m \cdot s^{-2}$; 95% CI: −0.30 to −0.03; ES: 0.25), sprint distance per minute (−0.53 $m \cdot min^{-1}$; 95% CI: −1.08 to 0.02; ES: 0.19), V_{max} ($km \cdot h^{-1}$) (−0.36 $km \cdot h^{-1}$; 95% CI: −0.75 to 0.03; ES: 0.18), HR_{mean} (−3.22 bpm; 95% CI: −5.85 to −0.59; ES: 0.25) and HR_{mean} (−1.71%; 95% CI: −2.99 to −0.43; ES: 0.27) were significantly lower in the second halves of the matches ($p < 0.05$).

No significant differences were identified between the first and second halves for the distances covered in the different speed zones ($p > 0.05$) (Figure 2). Only the walking distance (0–6 $km \cdot h^{-1}$) was significantly greater in the second half, in both the first (+76.92 m; 95% CI: 7.80 to 146.05; ES: 0.22) and the second (+66.27 m; 95% CI: 13.22 to 119.32; ES: 0.29) divisions ($p < 0.05$).

Discussion

The aim of this study was to analyse the external and internal load of professional Spanish football referees during matches. Referees of different categories (in the first and second divisions) were included to analyse the influence of these categories on the physical demands. This is the first study to quantify the physical performance of Spanish football referees from the first and second divisions. The main findings were that referees from the first division had higher physical demands with a lower RPE during the matches. Regarding the influence of fatigue, the second division referees revealed a lower number of high-intensity actions in the second halves of the matches.

In relation to the external load, the results of this study showed that referees from the first and second divisions covered a similar total distance during matches. This agrees with another study (Castillo et al. 2019) of 44 football match officials

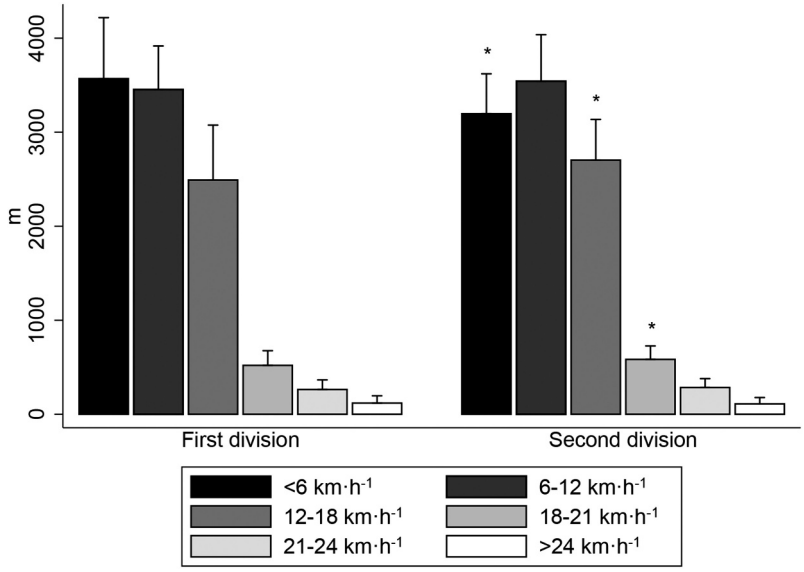

Figure 1. Activity profile during the match in first and second division referees, expressed as the total distance covered in different speed zones, including low walking (<6 km.h-1), walking (6–12 km.h-1), low intensity running (12–18 km.h-1), high intensity running (18–21 km.h-1), high speed running (21–24 km.h-1), and sprinting (> 24 km.h-1). *Significant differences between first and second division referees for a given variable ($p < 0.05$).

from the Spanish national third division that reported a total distance of 10,091.12 ± 794.06 m, which is comparable to the distances recorded in this study. Furthermore, this study showed that the distance covered in the two halves is similar for both first and second division referees. Recently, Costa et al. (2013) and Krustrup et al. (2009) demonstrated a similarity in the distances covered in both halves, while Weston et al. found that referees covered less TD during the second half of the match (Krustrup et al. 2009; M. Weston et al. 2007).

Although the match time is very similar in both halves, there is usually longer added time in the second half. Thus, it would have been convenient to have calculated the total distance per minute to investigate the effect of the additional time on the physical performance of the referees (Costa et al. 2013; Fernández-Elías et al. 2017; Castillo et al. 2019).

The results for RPE shown in this study were similar to those in other research such as the values reported by referees during Premier League matches (7.8 ± 0.8) (Weston et al. 2006). The results for the mean HR and RPE were lower in the first division, since the second division referees probably have a lower mean age, and these data are different from other studies (Costa et al. 2013).

Comparing the distance covered whilst in the different speed zones, this study showed that the second division referees covered a greater distance in low-intensity running (12–18 km·h^{-1}) and high-intensity running (18–21 km·h^{-1}) compared to the first division referees. However, other studies have shown that referees who officiated in matches in the Spanish national third division cover shorter distances at high intensity (>18 km·h^{-1}) (Castillo et al. 2019). This finding suggests that the physical requirements of first division games are different from those of second division games. Meanwhile, few differences were found when comparing the halves in each category, with a difference seen only in walking distance (0–6 km·h^{-1}), which was higher in the second half of both the first and the second division matches. Other studies have not shown differences in the first and second halves based on the distances covered at different speeds (Fernández-Elías et al. 2017), possibly due to the fatigue caused by the game. However, Fernández-Elías et al. used different speed zones from those used in this study, so these results must be interpreted cautiously.

Likewise, in the present study, the accelerations and decelerations were analysed based on the total numbers and peaks, while in other studies they have been analysed based on a range of degrees (low, moderate, high, and very high ACC and DEC) (Castillo et al. 2019). In this study, we found that there were higher numbers of ACC and DEC, both total and peak, in the first division referees, but these differences were not significant. Previous studies have shown that there are no differences in very high ACC and DEC between field and assistant referees (Castillo et al. 2019). Furthermore, looking at ACC and DEC in the first and second halves shows that an increase is only found in the ACC and DEC of the second halves for the first and second division referees, perhaps due to the contextual variables of the match. These results suggest that the longer duration of the second halves, caused by substitutions, could be the reason for the greater numbers of ACC and DEC. There are no studies that have studied ACC and DEC in referees in this way; however, Akenhead et al. observed the distance covered by football players in defined ACC and DEC during elite match-play (Akenhead et al. 2013), and Russell et al. showed the total number of high-intensity ACC and DEC for each half in football players (Russell et al. 2016).

Finally, speed has been studied in other areas of research, in which it has been shown that there are no differences in the maximum speed between the first (26.0 ± 2.6) and the second half (26.5 ± 3.2) (Fernández-Elías et al. 2017). Similar results are seen in this study, since there are no differences between the halves in the first and second divisions, nor between the categories, but the maximum deceleration, V_{max} and sprint distance per minute was lower in the second half for the second division referees.

Table 2. Distance travelled, heart rate and load indicator values in the first and second half of the match for first and second division referees.

	First division								Second division							
	First half			Second half			p value	ES	First half			Second half			p value	ES
Total distance (m)	5182.11	±	449.06	5264.91	±	454.62	0.068	0.18	5219.56	±	370.49	5215.10	±	462.99	0.921	0.01
Accelerations (n)	1367.66	±	161.88	1451.67	±	134.59*	<0.001	0.57	1333.00	±	132.59	1410.12	±	155.35*	<0.001	0.54
Decelerations (n)	1367.58	±	161.69	1451.88	±	134.51*	<0.001	0.57	1332.94	±	132.50	1410.11	±	155.73*	<0.001	0.54
Accelerations (n·min^{-1})	28.27	±	2.69	28.85	±	2.35	0.051	0.23	28.09	±	2.60	28.53	±	2.70*	0.017	0.17
Decelerations (n·min^{-1})	28.27	±	2.69	28.86	±	2.35*	0.049	0.23	28.09	±	2.60	28.53	±	2.71*	0.017	0.17
ACC_{max}(m·s^{-2})	4.26	±	0.70	4.25	±	0.96	0.928	0.01	4.18	±	0.56	4.11	±	0.64	0.178	0.13
DEC_{max} (m·s^{-2})	−5.02	±	0.79	−4.93	±	0.81	0.335	0.11	−4.93	±	0.72	−4.76	±	0.61*	0.007	0.25
Sprint distance (m)	107.62	±	71.22	106.18	±	72.13	0.826	0.02	108.23	±	66.01	101.20	±	62.42	0.205	0.11
Sprint distance (n)	5.02	±	3.14	5.03	±	3.09	0.999	0.01	5.21	±	2.96	4.68	±	2.61*	0.030	0.19
V_{max} (km·h^{-1})	27.79	±	2.21	27.71	±	2.21	0.732	0.04	27.85	±	1.96	27.49	±	2.02*	0.041	0.18
HR_{max} (bpm)	170.18	±	9.42	169.41	±	9.15	0.221	0.08	178.35	±	9.15	176.69	±	13.03	0.074	0.15
HR_{mean} (bpm)	147.12	±	11.75	146.23	±	14.30	0.360	0.07	155.28	±	11.64	152.06	±	14.14*	0.001	0.25
HR_{mean} (%)	83.57	±	5.68	83.03	±	6.66	0.439	0.09	83.83	±	5.76	82.12	±	7.00*	0.004	0.27

* Significant differences between the first and second half; ACC_{max}: Maximum accelerations; DEC_{max}: Maximum decelerations; HR: Heart rate; V_{max}: Maximum speed.

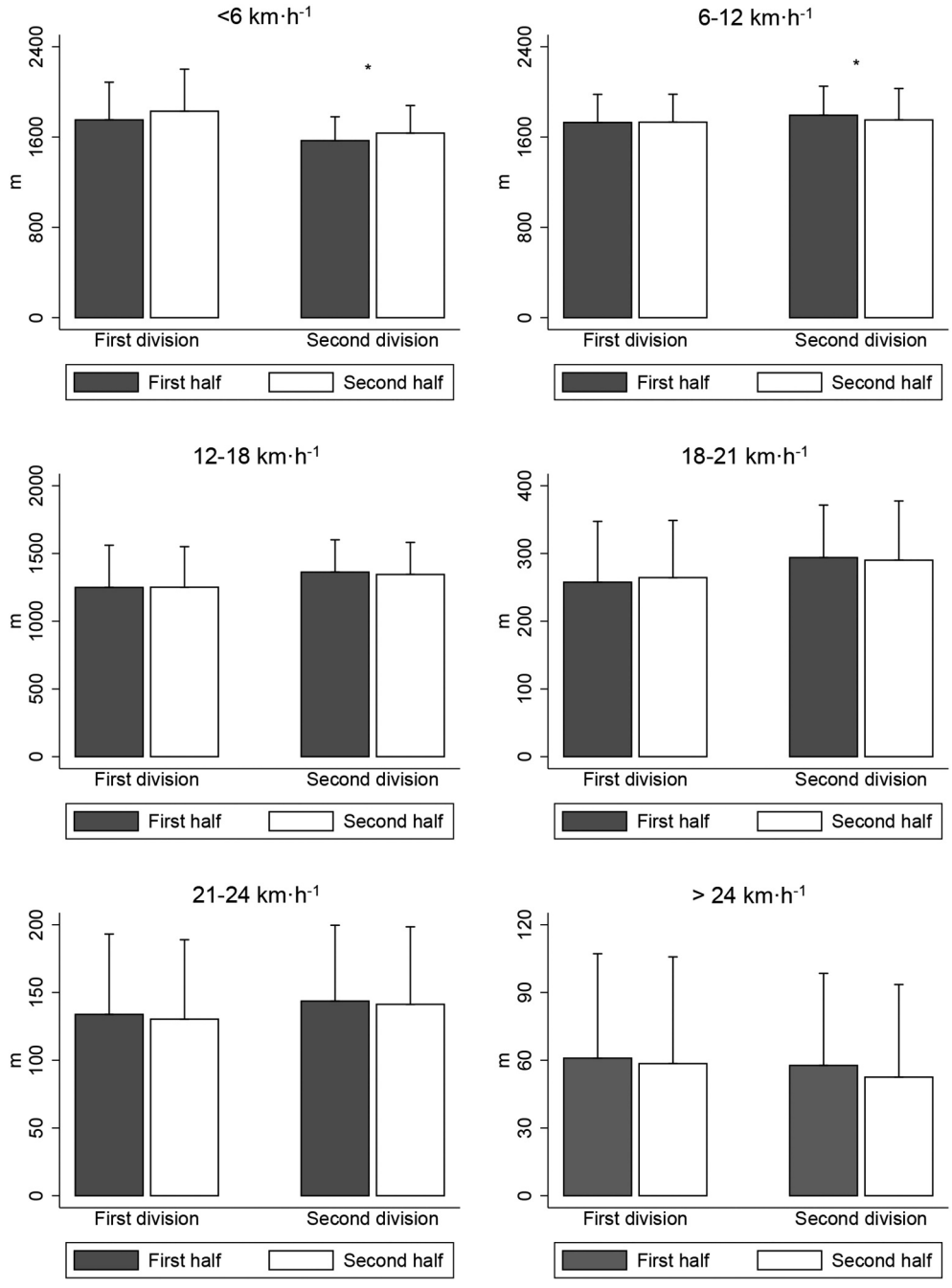

Figure 2. Activity profiles of the referees, expressed as the total distance by speed zone during the first and second half of the match. *Significant differences between referees and for each variable in the first and second half of the match. ($p < 0.05$).

The internal load in this study was recorded using HR_{max} and HR_{mean}, while other articles have analysed it by grouping it into zones (Costa et al. 2013; Fernández-Elías et al. 2017; Castillo et al. 2019). In our study, we found that HR_{mean} (bpm) is lower in the first division than in the second, while, as seen from other areas of research, third division referees show even higher values than those in the second division. This is probably due to the mean age of the referees in each division, since the mean age of first division referees is higher than that of other referees. HR_{mean} (bpm) and HR_{mean} (%) were lower in the second division referees in the second halves. Some authors have found that HR_{max} does not vary between the first and second halves (Costa et al. 2013), and other researchers have shown that HR_{max} decreases in the second half of the match (Fernández-Elías et al. 2017). Looking at the HR_{mean}, there are studies in which this variable is reduced (Costa et al. 2013) and others in which it is increased (Fernández-Elías et al. 2017) in the second half of the match.

The main limitation of this study was that no contextual variables were included in the analysis. The age of the referee, the kind of match, and the moment in the season could influence the physical demands on the referee, so more research is necessary to analyse these variables. However, the number of games was sufficient to perform statistical comparisons of the sample, and this is the first research that includes referees in different divisions. In addition, all the matches were studied and both physical and physiological variables were evaluated, with no limitations in this regard.

Conclusion

In conclusion, the results of this study reveal that referees from the first division had higher physical demands, with lower RPE values, during matches than referees officiating in the second division. In addition, the second division referees showed a decrease in the number of high-intensity actions in the second halves of their matches. Based on the present findings, professional referees require specific training.

Practical applications

All this information could be useful for training staff when trying to manage the load for professional referees in a systematic way. Specifically, these results can help to adjust training loads and to establish tasks during training according to the evolution of the physical requirements of each match and referee category. Our data also provide useful and practical information for training staff when planning tournament schedules, as well as for preparing match and recovery strategies.

Disclosure statement

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ORCID

Maria Luisa Martin-Sanchez http://orcid.org/0000-0003-0392-157X
Jorge Garcia-Unanue http://orcid.org/0000-0002-1741-5566
Jose Luis Felipe http://orcid.org/0000-0002-2029-1277
Víctor Moreno-Pérez http://orcid.org/0000-0003-3357-0045
Leonor Gallardo http://orcid.org/0000-0002-6296-6121
Javier Sanchez-Sanchez http://orcid.org/0000-0003-0017-0184

Ethical approval

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments, or comparable ethical standards.

Informed consent

The participants gave verbal and written informed consent.

References

Akenhead R, Hayes PR, Thompson KG, French D. 2013. Diminutions of acceleration and deceleration output during professional football match play. J Sci Med Sport. 16(6):556–561. doi:10.1016/j.jsams.2012.12.005.

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

Castagna C, Castellano Paulis J. 2011. Relationship between indicators of training load in soccer players. J Strength Conditioning Res. 2–7. doi:10.1519/JSC.0b013e3182548af1

Castellano J, Alvarez-Pastor D, Bradley PS. 2014. Evaluation of research using computerised tracking systems (Amisco® and Prozone®) to analyse physical performance in elite soccer: a systematic review. Sports Med. 44(5):701–712.

Castillo D, Cámara J, Castellano J, Yanci J. 2016. Football match officials do not attain maximal sprinting speed during matches. Kinesiology. 48(2):207–212. doi:10.26582/k.48.2.10.

Castillo D, Cámara J, Lozano D, Berzosa C, Yanci J. 2019. The association between physical performance and match-play activities of field and assistants soccer referees. Res Sports Med. 27(3):283–297. doi:10.1080/15438627.2018.1534117.

Castillo D, Gómez-Carmona CD, Reche P, Ortega JP, Gil PG. 2018a. Trunk stability assessment using an inertial device. Retos Nuevas Tendencias en Educación Física, Deporte y Recreación. (33):199–203.

Castillo D, Weston M, McLaren SJ, Cámara J, Yanci J. 2017. Relationships between internal and external match-load indicators in soccer match officials. Int J Sports Physiol Perform. 12(7):922–927. doi:10.1123/ijspp.2016-0392.

Castillo D, Yanci J, Cámara J. 2018b. Impact of official matches on soccer referees' power performance. J Hum Kinet. 61:131. doi:10.1515/hukin-2017-0116

Cohen J. 1992. A power primer. Psychol Bull. 112(1):155. doi:10.1037/0033-2909.112.1.155.

Costa EC, Vieira CMA, Moreira A, Ugrinowitsch C, Castagna C, Aoki MS. 2013. Monitoring external and internal loads of Brazilian soccer referees during official matches. J Sports Sci Med. 12(3):559.

D'Ottavio S, Castagna C. 2001. Analysis of match activities in elite soccer referees during actual match play. J Strength Conditioning Res. 15(2):167–171.

Fernández-Elías VE, Gomez-Lopez M, De La Vega Marcos R, Clemente Suárez VJ. 2017. Physical demands, heart rate response and performance of talent football referees. Med Sport. 70:2–4. doi:10.23736/S0025-7826.17.03076-9

Granero-Gil P, Bastida-Castillo A, Rojas-Valverde D, Gómez-Carmona CD, de la Cruz Sánchez E, Pino-Ortega J. 2020. Influence of contextual variables in the changes of direction and centripetal force generated during an elite-level soccer team season. Int J Environ Res Public Health. 17(3):967. doi:10.3390/ijerph17030967.

Hernandez-Belmonte A, Bastida-Castillo A, Gomez-Carmona CD, Pino-Ortega J. 2018. Validity and reliability of an inertial device (WIMU PROTM) to quantify physical activity level through steps measurement. J Sports Med Phys Fitness. 59(4):587–592. doi:10.23736/s0022-4707.18.08059-3.

Krustrup P, Bangsbo J. 2001. Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. J Sports Sci. 19(11):881–891. doi:10.1080/026404101753113831.

Krustrup P, Helsen W, Randers MB, Christensen JF, Macdonald C, Rebelo AN, Bangsbo J. 2009. Activity profile and physical demands of football referees and assistant referees in international games. J Sports Sci. 27 (11):1167–1176.

Krustrup P, Zebis M, Jensen JM, Mohr M. 2010. Game-induced fatigue patterns in elite female soccer. J Strength Conditioning Res. 24 (2):437–441.

Losnegard T, Myklebust H, Spencer M, Hallén J. 2013. Seasonal variations in V [combining dot above] O2max, O2-cost, O2-deficit, and performance in elite cross-country skiers. J Strength Conditioning Res. 27 (7):1780–1790.

Mallo J, Veiga S, Lopez De Subijana C, Navarro E. 2010. Activity profile of top-class female soccer refereeing in relation to the position of the ball. J Sci Med Sport. 13(1):129–132. doi:10.1016/j.jsams.2008.09.006.

McBride JM, Haines TL, Kirby TJ. 2011. Effect of loading on peak power of the bar, body, and system during power cleans, squats, and jump squats. J Sports Sci. 29(11):1215–1221.

Mohr M, Krustrup P, Bangsbo J. 2003. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci. 21(7):519–528. doi:10.1080/0264041031000071182.

Riiser A, Andersen V, Sæterbakken A, Ylvisaker E, Fusche Moe V. 2019. Running performance and position is not related to decision-making accuracy in referees. Sports Med Int Open. 3(2):E66. doi:10.1055/a-0958-8608.

Russell M, Sparkes W, Northeast J, Cook CJ, Love TD, Bracken RM, Kilduff LP. 2016. Changes in acceleration and deceleration capacity throughout professional soccer match-play. J Strength Conditioning Res. 30 (10):2839–2844. doi:10.1519/JSC.0000000000000805.

Sánchez-García M, Sánchez-Sánchez J, Rodríguez-Fernández A, Solano D, Castillo D. 2018. Relationships between sprint ability and endurance capacity in soccer referees. Sports. 6(2):28. doi:10.3390/sports6020028.

Schenk K, Bizzini M, Gatterer H. 2018. Exercise physiology and nutritional perspectives of elite soccer refereeing. Scand J Med Sci Sports. 28 (3):782–793. doi:10.1111/sms.12989.

Suarez Arrones L, Torreno N, Requena B, Sáez De Villarreal E, Casamichana D, Barvero-Alvarez JC, Munguia-Izquierdo D. 2014. Match-play activity profile in professional soccer players during official games and the relationship between external and internal load. J Sports Med Phys Fitness. 55:1417–1422.

Weston B, Helsen S, Nevill W, Castagna C. 2006. The effect of match standard and referee experience on the objective and subjective match workload of English Premier League referees. J Sci Med Sport. 9 (3):256–262.

Weston M. 2015. Match performances of soccer referees: the role of sports science. Mov Sport Sci Motricité. 87:113–117. doi:10.1051/sm/2014011

Weston M, Castagna C, Impellizzeri FM, Bizzini M, Williams AM, Gregson W. 2012. Science and medicine applied to soccer refereeing. Sports Med. 42 (7):615–631.

Weston M, Castagna C, Impellizzeri FM, Rampinini E, Abt G. 2007. Analysis of physical match performance in English Premier League soccer referees with particular reference to first half and player work rates. J Sci Med Sport. 10(6):390–397. doi:10.1016/j.jsams.2006.09.001.

Weston M, Drust B, Atkinson G, Gregson W. 2011. Variability of soccer referees' match performances. Int J Sports Med. 32(3):190–194. doi:10.1055/s-0030-1269843.