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Physical demands in Spanish male and female elite football referees during the competition: a prospective observational study

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ABSTRACT

Objective: The aim of this study was to analyze the physical demands of elite male and female field referees in match play and compare the physical demands between male and female football referees in the competition.

Methods: Match data were collected from 36 elite football referees (19 males and 17 females) during a total of 409 football matches. Electronic performance and tracking systems based on global positioning systems (GPS) were used in this research.

Results: Male referees experienced significantly greater physical demands ($p < 0.05$) in men league than female referees in women league for total distance, explosive distance, high-intensity breaking distance, total of sprints, sprinting distance, high-speed running distance, high-speed running actions, maximal speed, total of accelerations and decelerations, maximal acceleration and deceleration, acceleration/deceleration.

Conclusions: Therefore, strength and conditioning coaches should consider these gender differences in match demands to maximize the fitness-fatigue response of the referees since this may lead to a better performance during the decision-making process in the competition.

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KEYWORDS
Soccer; women; men; monitoring; technology; team sports; fitness

Introduction

In recent years, a number of studies have been published regarding the physical demands of football referees (Schenk et al. 2018; Castillo et al. 2019; Meckel et al. 2020) because the use of electronic performance and tracking systems was allowed for data collection in official matches (Weston 2015). In football, the referees represent the maximum authority during the game so they have to move in all directions on the pitch to ensure optimal positioning and compliance with the laws of the game (Weston et al. 2012). Football is a team sport that requires a high level of fitness (Castagna et al. 2007) since continuous accelerations, decelerations, changes of direction, and other high-intensity actions are performed by the players (Costa et al. 2013; Oliva-Lozano et al. 2021a). For instance, several investigations have reported that referees may cover an average of 11 km per match (Barros et al. 2007; Schmidt et al. 2019), being 18.6% of distance covered at very high-intensity running (Krustrup et al. 2009). Furthermore, authors such as Castillo et al. (2017) analyzed the physical (external load) and physiological (internal load) demands of football referees and assistant referees, reporting disparate data on internal and external match load, assessing the specificity of referee and assistant referee training.

However, previous research observed sex differences in match performance characteristics so this might be a key contextual variable from a training perspective (Bradley et al. 2014). For example, Bradley et al. (2014) concluded that large sex differences existed and that differences at higher speed thresholds were greater in the second half than first half in male players. In addition, a previous study found that female field referees had, on average, lower levels of aerobic fitness and performance compared to male referees (Castagna et al. 2018). Thus, training strategies should be designed for male and female referees in order to have an optimal physical condition (Castagna et al. 2007; Weston et al. 2012) to keep up with play at all times and make key decisions (Weston 2015; Castillo et al. 2017, 2019). Nonetheless, female referees that possess the required skills could be eligible to officiate male football matches even though greater external load demands than female matches are required (Castagna et al. 2007, 2018; Weston et al. 2012).

To date, little research on the match demands of male and female elite football referees is available. The analysis of football referees' physical demands is necessary since it allows a better understanding of match performance and help coaches design adequate training sessions (Weston 2015). Strength and conditioning coaches may wonder what physical demands are required in elite leagues such as the Spanish male and female elite football league. For example, this information is key in order to make decisions about the readiness of each referee to participate in male and/or female matches. If the female league requires 3 sprints, but the male league requires

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10 sprints (or vice versa), coaches need to make sure that the referees have adequate fitness for transitioning from one league to another.

Therefore, the aim of this study was to analyze and compare physical demands of elite male and female field referees during match play. Our hypothesis was that male referees would experience significantly greater physical demands compared to female referees

Methods

Experimental approach

This study followed a prospective observational design during a total of 409 football matches. Global Positioning Systems (GPS) were used for the analysis of physical demands of the men and women football referees. Specifically, data were collected from male and female field referees.

Subjects

A total of 17 female (age: 29.05 ± 5.24 years, height: 163.8 ± 6.77 cm and weight; 54.03 ± 5.19 kg) and 19 male (age: 38.25 ± 4.14 years, height: 182.1 ± 4.73 cm and weight: 74.63 ± 5.89 kg) elite football referees participated in the study. Two male referees and four female referees were excluded due to problems with the performance tracking systems.

All the referees had more than 10 years of experience refereeing and a minimum of 4 years in the top Spanish football leagues (i.e., Liga Santander, which is the male league, and Liga Iberdrola, which is the female league). Male referees trained an average of five sessions a week, while the females in a total of four sessions (i.e., strength, endurance, and speed). They usually officiated one match during the week and weekend. As an inclusion criterion, referees had to be free of injuries. An injury was defined as: *'Any physical complaint sustained by a referee that results from match or training'* and led to an absence of the next training session or match (Fuller et al. 2006).

Each referee was informed about the study, and they provided informed consent to participate. The project was approved by the Bioethics Committee for Clinical Research of Virgen de la Salud Hospital in Toledo (Ref.: 2551;17/02/2021). All subjects belonged to the Technical Committee of Referees (TCR), and Real Federación Española de Fútbol and TCR authorized this investigation.

Procedure

Data were collected from 409 competitive matches (male matches: 223; female matches: 186) during the 2020–2021 season. The matches were held on different football fields, but the dimensions and surfaces of the pitches were similar. Referees' physical demands were monitored using WIMU PRO^{TM} (RealTrack System SL, Almería, Spain). Each device collected data at 10 Hz, and has its own internal microprocessor, with a high-speed USB interface, to record, store and upload data, with an authorized computer protocol (Bastida Castillo et al. 2018). This technology is valid and reliable for the collection of time-motion variables (e.g., total bias in distance and mean velocity measurements: 2.32–4.32 m and 1.18–1.32 km/h, respectively (Bastida Castillo et al. 2018); intra-class correlation coefficients >0.93). In addition, these devices have been approved by the FIFA Quality Program (Oliva-Lozano and Muyor 2022; FIFA 2022). All devices were activated 30 minutes before data collection to allow acquisition of satellite signals, and synchronization of the GPS clock with the satellite's atomic clock (Maddison and Mhurchu 2009). All referees developed a standard warm-up before the match for 15 minutes. However, warm-up data were excluded. Only data collected during the first and second half was considered for the analysis.

The physical demands were represented by external load variables, which were downloaded from the intervals pro report on SPro (Realtrack Systems SL, Almería, Spain). Specifically, the following variables were included: total distance (m), explosive distance (total distance covered with an acceleration above 1.12 m/s^2; m), high-intensity breaking distance (HIBD: distance decelerating >2 m/s^2), total of sprints (n), sprinting distance (m), high-speed running distance (HSRD in *m* >15.1 km/h), high-speed running actions (HSRA, n) (Mara et al. 2017; Pons et al. 2021), maximal speed (km/h), distance covered in different speed zones (Z1: 0–6 km/h; Z2: 6–12 km/h; Z3: 12–18 km/h; Z4: 18–21 km/h; Z5: 21–24 km/h; and Z6: >24 km/h), total of accelerations (*n*), total of decelerations (*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), maximal acceleration (ACC_{MAX}: m/s^2), maximal deceleration (DEC_{MAX}: m/s^2), acceleration/deceleration ratio (Acc/Dec), mean acceleration (ACC_{MEAN}: m/s^2), mean deceleration (DEC_{MEAN}: m/s^2), total of accelerations and distance covered accelerating by zones (Z1: 0–1 m/s^2; Z2: 1–2 m/s^2; Z3: 2–3 m/s^2; Z4: >3 m/s^2), and total of decelerations and distance covered decelerating by zones (Z1: 0–1 m/s^2; Z2: 1–2 m/s^2; Z3: 2–3 m/s^2; Z4: >3 m/s^2) (Oliva-Lozano et al. 2021).

Statistical analysis

The descriptive statistics were presented as mean ± standard deviations. Firstly, a Kolmogorov-Smirnov test was used to test the normality of the data ($p > 0.05$). In order to explore the differences in physical demands between male and female field referees, an independent samples T-test was performed. Effect size (ES) was also calculated by Cohen's d and defined as follows: trivial (ES < 0.19); small (ES = 0.2–0.49); medium (ES = 0.50–0.79) and large (ES > 0.8) (Cohen 1992). The confidence level was established at 95%, with values of $p < 0.05$ considered to be statistically significant.

The level of significance was set at $p < 0.05$ and all analyses were performed using the SPSS package (v24, SPSS Inc., Chicago, USA).

Results

The differences between male and female field referees are outlined in Tables 1 and 2 for distance- and speed-related variables. The results showed that the men league was significantly more demanding than the women league for distance- and speed-related variables ($p < 0.05$). Specifically, the physical

Table 1. External load variables related to distance covered in elite football matches by male and female field referees.

Variables	Female referees	Male referees	Sig. (*p*)	ES	95 % CI	
Total distance (m)	9945.36±706.14	10396.48±898.67*	0.000	0.56	−610.52	−291.70
Explosive distance (m)	1086.92±232.77	1189.84±252.24*	0.000	0.42	−150.49	−55.36
HIBD (m)	156.59±80.44	211.88±112.48*	0.000	0.57	−74.64	−35.93
Total of sprints (n)	3.78±3.92	8.74±5.29*	0.000	1.08	−5.88	−4.04
Sprinting distance (m)	67.57±75.19	179.93±118.44*	0.000	1.16	−132.07	−92.64
HSR (n)	17.43±9.57	27.68±11.80*	0.000	0.96	−12.36	−8.13
HSR (m)	308.28±175.11	514.86±232.32*	0.000	1.01	−247.22	−165.94
Maximal Speed (km/h)	26.18±2.14	28.42±2.32*	0.000	1.00	−2.68	−1.80

* Significant differences between male and female elite referees (p <0.05); ES, effect size; CI, confidence interval; HIBD, High Intensity Break Distance; HSR, High Speed Running; MAX, maximal.

Table 2. Distance covered in elite football matches by male and female field referees in different speed zones.

	Female referees	Male referees	Sig. (*p*)	ES	95 % CI	
Distance Zone 1 (<6 km/h) (m)	3523,51±541,16	3870,76±828,93*	0,000	0,51	−486,26	−208,24
Distance Zone 2 (6–12 km/h) (m)	3505,73±501,06	3392,23±481,38*	0,020	0,23	17,70	209,31
Distance Zone 3 (12–18 km/h) (m)	2328,18±522,08	2311,12±614,01	0,765	0,03	−95,01	129,12
Distance Zone 4 (18–21 km/h) (m)	410,05±141,26	486,73±161,28*	0,000	0,51	−106,45	−46,90
Distance Zone 5 (21–24 km/h) (m)	146,81±88,99	236,25±104,23*	0,000	0,93	−108,49	−70,39
Distance Zone 6 (>24 km/h) (m)	31,08±42,63	99,39±79,91*	0,000	1,11	−81,11	−55,52

* Significant differences between male and female field referees (p <0.05).

demands were significantly lower in female referees compared to the male referees in the total distance covered (−451.11 m; ES = 0.56; $p < 0.05$), explosive distance (−102.92 m; ES = 0.42; $p < 0.05$), HIBD (−55.29 m; ES = 0.57; $p < 0.05$), total of sprints (−4.96 actions; ES = 1.08; $p < 0.05$), sprinting distance (−112.35 m; ES = 1.16; $p < 0.05$), HSRA (−10.25 actions; $p < 0.05$), HSRD (−206.58 m; ES = 1.01; $p < 0.05$), maximal speed (−2.24 km/h; ES = 1.00; $p < 0.05$), Z1 (−347.25 m; ES = 0.51; $p < 0.05$), Z4 (−76.67 m; ES = 0.51; $p < 0.05$), Z5 (−89.44 m; ES = 0.93; $p < 0.05$), and Z6 (−68.31 m; ES = 1.11; $p < 0.05$). In addition, Z2 scores were higher in female referees compared to male referees (113.51 m; ES = 0.23; $p < 0.05$). However, no significant differences ($p >$ 0.05) were found in Z3 between female and male field referees.

The physical demands related to the acceleration and deceleration variables are shown in Table 3. The results showed that women league was significantly less demanding than men league ($p < 0.05$) for the referees in the total of accelerations (−100.35; ES = 0.42; $p < 0.05$), total of decelerations (−100.96; ES = 0.42; $p < 0.05$), ACC_{MAX} (−0.36 m/s^2; ES = 0.41; $p < 0.05$), DEC_{MAX} (0.39 m/s^2; ES = 0.46; $p < 0.05$), and ACC/DEC ratio (2.27; ES = 0.22; $p < 0.05$). In addition, the total of accelerations by zones were significantly lower in female referees than male referees in Z1 (−107.88; ES = 0.47; $p < 0.05$) and Z4 (−5.11; ES = 0.53; $p < 0.05$). Regarding the total of decelerations, similar findings were observed in Z1 (−87.37; ES = 0.39; $p < 0.05$), Z3 (−9.53; ES = 0.28; $p < 0.05$), and Z4 (−7.39; ES = 0.49; $p < 0.05$). Also, lower physical demands were observed for the females in terms of distance covered accelerating in Z1 (−183.53; ES = 0.53; $p < 0.05$), Z2 (71.02; ES = 0.23; $p < 0.05$), Z3 (−61.51; ES = 0.25; $p < 0.05$), and Z4 (−55.37; ES = 0.44; $p < 0.05$) in addition to

Table 3. Acceleration and deceleration demands of referees in match play.

Variables	Female referees	Male referees	Sig. (*p*)	ES	95 % CI	
ACC (n)	2694.40±207.91	2794.76±272.31*	0.000	0.42	−148.19	−52.52
DEC (n)	2700.72±205.32	2801.68±272.47*	0.000	0.42	−148.62	−53.29
DEC_{MAX} (m/s^2)	−4.95±0.79	−5.34±0.89*	0.000	0.46	0.22	0.56
ACC_{MAX} (m/s^2)	4.36±0.85	4.72±0.90*	0.000	0.41	−0.53	−0.19
ACC/DEC ratio	−10.75±10.82	−13.02±10.28*	0.030	0.22	0.22	4.33
ACC Z1 (n)	2113.59±222.85	2221.48±236.38*	0.000	0.47	−152.86	−62.90
ACC Z2 (n)	438.89±73.00	424.88±81.75	0.071	0.18	−1.20	29.22
ACC Z3 (n)	121.76±33.59	123.14±33.42	0.681	0.04	−7.91	5.17
ACC Z4 (n)	20.15±13.65	25.26±12.15*	0.000	0.40	−7.62	−2.60
ACC Z1 (m)	2292.40±290.92	2475.94±404.11*	0.000	0.53	−253.22	−113.85
ACC Z2 (m)	2267.45±320.91	2196.44±303.77*	0.022	0.23	10.12	131.91
ACC Z3 (m)	956.21±241.38	1017.73±245.66*	0.011	0.25	−109.12	−13.91
ACC Z4 (m)	185.79±127.36	241.16±121.57*	0.000	0.44	−79.64	−31.10
DEC Z1 (n)	2128.35±217.31	2215.72±229.27*	0.000	0.39	−131.10	−43.64
DEC Z2 (n)	423.91±69.25	420.59±78.19	0.652	0.05	−11.17	17.82
DEC Z3 (n)	117.56±31.56	127.08±37.57*	0.006	0.28	−16.35	−2.70
DEC Z4 (n)	30.90±15.48	38.29±14.66*	0.000	0.49	−10.32	−4.45
DEC Z1 (m)	2147.10±267.74	2280.02±371.11*	0.000	0.42	−196.95	−68.88
DEC Z2 (m)	1470.99±179.75	1460.59±203.79	0.588	0.05	−27.32	48.13
DEC Z3 (m)	545.87±136.50	618.71±152.56*	0.000	0.50	−101.24	−44.43
DEC Z4 (m)	155.67±81.11	204.10±85.02*	0.000	0.58	−64.70	−32.18

*Significant differences between male and female elite referees (p < 0.05); CI, confidence interval; ES, effect size; ACC, Accelerations; DEC: Decelerations.

the distance covered decelerating in Z1 (−132.91; ES = 0.42; $p < 0.05$), Z3 (−72.83; ES = 0.50; $p < 0.05$), and Z4 (−48.44; ES = 0.58; $p < 0.05$).

Discussion

The purpose of this study was to analyze and compare the physical demands of male and female football referees. The main finding was that Spanish male referees in men's football matches experienced greater physical demands than female referees in women's football matches.

To the best of the authors' knowledge, this is the first study analyzing the physical demands in both male and female field referees from elite football leagues. Previous studies have focused on the independent analysis of male or female samples (Barros et al. 2007; Castillo et al. 2016a; Mallo et al. 2010; Weston et al. 2010). Based on the results of our study and previous research, it has been observed that field football referees cover similar total distance than the players (Rampinini et al. 2007; Bradley et al. 2014; Mara et al. 2017). For instance, a previous study found that male players covered 11142 m and female players 10754 m (Bradley et al. 2014) while our male referees covered 10396 m and female referees covered 9945 m. These results are also in line with previous studies that analyzed the distance covered of male football referees in the America's Cup (10138 m) (Barbero-Álvarez et al. 2012). Brazilian first division (10449 m) (Costa et al. 2013) and Spanish third division (9991 m) (Castillo et al. 2017). Regarding the female referees, a previous study observed that they covered 10032 m in the FIFA female under-20 World Championships (Mallo et al. 2010). However, these differences may be related to the pace of the game, which implies that other contextual variables may have a significant impact on physical performance (e.g., match outcome or level of the competition) (Aquino et al. 2017; Oliva-Lozano et al. 2021).

When it comes to the performance in higher intensity actions, there were significant differences in all variables as well. In this regard, a recent study found that distance covered by male players in higher speed zones was greater than female players during training sessions and matches (McFadden et al. 2020). This may be due to the context of male and female football matches but also to the relative sex differences in the force-velocity profile (Haugen et al. 2020). In addition, a recent study concluded that the relative sex differences in sprint performance usually increased along with sprinting distance (Haugen et al. 2020). Also, this might be explained by the fact that men may generate explosive distance over short distances due to an improved stride rate and based on a reduced contact time (Murphy et al. 2003). Nonetheless, the fact that our male football referees covered more HSRD (515 m) than football players in match (e.g., 461 m) (Oliva-Lozano et al. 2020a) may be also due to the fast game pace and the fact that the referees need to pay attention to the laws of the game and they should have as few errors as possible (Schmidt et al. 2019), therefore, they have to cover as much HSR as possible. Also, the football players may have higher total sprints and maximal speed (11 sprints, 30 km/h) (Oliva-Lozano et al. 2020) than male football referees (9 sprints, 28 km/h) respectively. However, different contextual variables may be related to physical performance in professional soccer matches (e.g., match-to-match variability, length of the microcycle, match location, etc.) (Carling et al. 2016; Oliva-Lozano et al. 2021; Oliva-Lozano et al. 2021; Oliva-Lozano et al. 2021).

Nonetheless, football is defined as an intermittent aerobic sport (Mohr et al. 2008) so male and female field referees need to train not only high-intensity actions but the ability to perform repeated sprints (Mohr et al. 2003; Mujika et al. 2009) and keep explosive power during these actions (McCormack et al. 2014). A high cardiovascular capacity could be the reason why male referees cover a greater distance at high intensity. In this regard, a previous research concluded that maximal oxygen uptake (VO_2max) and muscle architecture were key components of fitness that predicted high-intensity running (McCormack et al. 2014).

Regarding the variables related to the accelerations and decelerations, this study presents novel findings since, to the best of our knowledge, this is the first study to report the acceleration profile of elite football referees. These actions are very physically demanding (Oliva-Lozano et al. 2020) because of the mechanical load that leads to an increase in the neuromuscular fatigue and perceived exertion (Gaudino et al. 2015; Harper et al. 2019). Therefore, although female referees had lower physical demands in acceleration-related variables than male referees, coaches need to train the acceleration profile regardless of the sex differences. The significant differences were mainly with a small effect size, which implies that these differences are low (apart from distance in ACC Z1, DEC 3, and DEC Z4, which had a moderate effect size). However, these results were also analyzed from a practical perspective and these differences need to be considered by coaches. In this regard, it has been suggested by previous researchers that the repeated acceleration ability is trained since referees experience a decline in this ability when comparing the first to the second half of the match, which may be associated to the effects of fatigue (Barberó-Álvarez et al. 2014).

Also, this study has some limitations. The main limitation was the interruption of the season due to COVID-19. Also, many matches were postponed because female team players tested positive. Therefore, the match had to be played on a different date, so there were weeks without matches and in other weeks, they had a congested calendar (i.e., more than one match per week). There is an average age difference of 9 years between male and female referees, and male referees train on average one more session per week than female referees. It is also implicit in the fact that male referees are professionals and are dedicated exclusively to refereeing. Future research should consider the limitations of this study and analyze not only match demands but also training load to check if an adequate training plan is being carried out. Furthermore, this study focuses on the comparison between female referees in women's matches and male referees in men's matches, therefore, future research will focus on the analysis of the physical demands of female football referees officiating matches in men's competition would allow a comparison of the differences in fitness requirements.

Conclusions

The results of this investigation may serve as a profile of the physical demands required by Spanish field referees in elite football matches. Male field referees experienced greater physical demands than female referees in terms of speed, distance covered, accelerations, and decelerations.

Disclosure statement

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Ethical approval

All procedures performed in studies 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 their verbally and written informed consent.

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