**Physical demands, heart rate response and performance of talent football referees**

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**SUMMARY**

BACKGROUND: To explore the physical and physiological activity demands of talent football referees which belong to the Spanish Referees Technical Committee (CTA-RFFM) in order to understand the need of physical training and prescribe the most adequate exercise.

METHODS: Fourteen semi-professional referees (25.8±3.8 years old; 1.79±0.03 m; 74.4±2.3 kg) from 2nd B Division and 3rd Division of the Spanish Football League were monitored during 2 games (total of 28 games) by wearing a global positioning system (GPS) device and a heart rate monitor in order to assess workload and heart rate.

RESULTS: Total running distance was 8733.6±2238.0 m with no significant differences between first (4385.8±1122.7 m) and second match half (4347.9±1164.9 m). Further, distances covered at different intensity zones were similar between match halves. Average heart rate (HRavg) among matches was 151.2±16.6 bpm. No differences were found among HRavg between match halves (151.9±16.2 and 150.6±17.5 for the 1st and the 2nd half, respectively) and among the different intensity zones during the matches. Also, body load and the number of impacts registered were similar between match halves, with no differences among the intensity zones.

CONCLUSIONS: Data showed, talent referees’ physical fitness should be aerobically trained adequately in order to accomplish performance demands during matches.

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**KEY WORDS:** Physical education and training - Workload - Athletic performance - Soccer.

**RIASSUNTO**

OBIETTIVO: Esplorare la richiesta di attività fisica e fisiologica di giovani e talentuosi arbitri di calcio che appartengono al Comitato Tecnico degli Arbitri Spagnoli (CTA-RFFM) per poter comprendere le necessità di allenamento fisico e prescrivere l’esercizio migliore.

METODI: Quattordici arbitri semi professionali (25.8±3.8 anni; 1.79±0.03 m; 74.4±2.3 kg) che appartengono alle categorie inferiori 2ª Divisione B e 3ª Divisione del Campionato spagnolo di calcio furono monitorati durante 2 partite (28 partite totali) utilizzando dispositivi GPS e di frequenza cardiaca per poter valutare il carico di lavoro fisico e cardio. 

RISULTATI: La distanza percorsa totale media è stata di 8733.6±2238.0 m senza una differenza sostanziale fra il primo (4385.8±1122.7 m) e il secondo tempo della partita (4347.9±1164.9 m). Inoltre, le distanze coperte nelle diverse zone di intensità erano simili fra primo e secondo tempo degli incontri. La frequenza cardiaca media nelle partite era di 151.2±16.6 battiti/min. Non sono state riscontrate differenze nella frequenza cardiaca media fra i due tempi delle partite (151.9±16.2 vs. 150.6±17.5 rispettivamente per primo e secondo tempo) né fra le diverse zone di intensità durante le stesse. Ancora la carica corporea ed il numero di impatti registrati furono simili fra le metà delle partite, senza differenziarsi fra le zone di intensità.

CONCLUSIONI: I dati mostrano che gli arbitri giovani talentuosi necessitano di un allenamento aerobico corretto per poter soddisfare la domanda di rendimento fisico durante le partite.

**Parole chiave:** Allenamento - Carico di lavoro fisico - Prestazione atletica - Calcio.
Football is one of the most common sports worldwide. For this reason, the physical performance of football players has often been analyzed in the scientific literature for decades, and attention has been placed upon the physiological demands of professional football players during competitive matches.1,2 In the other hand, football referees have the obligation of implementing the rules of the match and guaranteeing that players abide by its regulations. Fulfilling this responsibility means that referees must to keep up with play intensity and mobility requirements in order to maintain a good position to detect players' infringements.3 In this way, only a few researches have given importance to referees' performance and physical demands during competition,4,5 being poorly researched the talent referees.6

Previous studies have shown that individual professional football referees cover between 7 and 13 km during a match.8 In the Italian Serie A and Serie B 9,10 and the Danish Superliga 11 referees have shown to cover ~11 km during official matches. In a 2009 study,12 referees in international matches covered ~10 km. Whereas, English football referees covered ~9 km in a study in 1993.15 Approximately 1 km of this distance is covered at high speed (>19.8 km/h).16 According to Reilly,17 referees work rate during matched seems to depend on the competitive component of the players involved. Regarding differences between match halves work rates, D'Ottavio and Castagna 11 found no differences between distance covered in the 1st and 2nd halves when they analyzed referees' performance of Serie A, however they found a 4.1% decrement after analyzing the performance of referees from Serie A and Serie B together.11 This fact was also observed by Catterall et al. in English referees.13 Hence, it seems that referees' performance may also depend on players' level performance.

The monitoring of heart rate has been adopted as a means of indicating the referees' physiological strain during a match. Despite the irregular fluctuations in exercise intensity, the average heart rate (HR$_{avg}$) during a match can provide a reasonable estimate of the energy expended.2,17 The HR$_{avg}$ of referees has shown an outstanding agreement between studies, within a range 162-165 bpm 8 and 85-90% of HR$_{max}$.18,19 Furthermore, HR$_{avg}$ between halves have not shown significant differences in previous studies, despite some have shown a decline in the work rate. This consistency in heart rate

Football è uno dei più comuni sport in tutto il mondo. Per questo, la prestazione fisiica dei giocatori di calcio è spesso analizzata dalla letteratura scientifica, con un particolare interesse per le sollecitazioni fisciche dei giocatori professionalisti di tale disciplina durante le parti-te.1-7 Dall’altro lato, gli arbitri hanno l’obbligo di applicare le regole del match e di garantire che i giocatori si attengano ad esse. Onorare questa responsabilità significa stare al passo con l’intensità del gioco e le esigenze di mobilità per mantenere una buona posizione che permetta all’arbitro di notare le infrazioni dei giocatori.8 Solo poche ricercche hanno dato importanza alla prestazione e alle sollecitazioni fisciche degli arbitri durante la competizione 8,9 essendo pochi gli arbitrì di talento studiati.10

Precedenti studi hanno mostrato che i singoli arbitri di calcio professionalisti coprono dai 7 ai 13 km durante una partita.8 Nella Serie A e Serie B italiane 11,12 e nella Superliga 13 danese gli arbitri coprono ~11 km durante le competizioni ufficiali. In uno studio del 2009,14 è emerso che durante gli incontri internazionali la distanza coperta era di ~10 km. Invece, in uno studio del 1993 15 gli arbitri inglesi di calcio coprivano ~9 km. Circa 1 km di questa distanza veniva percorsa ad alta velocità (>19.8 km/h).16 Secondo Reilly,17 il ritmo di lavoro degli arbitri durante i match sembra dipendere dalla componente competitiva dei giocatori coinvolti. Analizzando le differenze tra i ritmi di lavoro durante i due tempi, D’Ottavio e Castagna 11 non hanno riscontrato differenze tra la distanza coperta nel primo e nel secondo tempo quando hanno preso in esame la prestazione degli arbitri di Serie A, mentre hanno osservato un calo del 4,1% nell’analisi della prestazione dei professionisti di Serie A e Serie B messi insieme.11 Ciò è stato notato anche da Catterall et al. negli arbitri inglesi.13 Quindi, sembra che la prestazione degli arbitri dipenda anche dal livello di prestazione dei giocatori.

Il monitoraggio della frequenza cardiaca è stato adottato come mezzo per indicare lo sforzo fisiologico degli arbitri durante una partita. Nonostante le oscillazioni irregolari di intensità dell’esercizio, la frequenza cardiaca media (FC$_{media}$) durante un match può fornire una stima sensata dell’energia consumata.2,17 In termini di FC$_{media}$ degli arbitri, gli studi si sono mostrati notevolmente in linea, con valori che hanno oscillato tra 162 e 165 bpm 8 e rappresentanti l’85-90% della FC$_{max}$.18,19 Inoltre, la FC$_{media}$ tra i due tempi non ha fatto registrare differenze significative negli studi precedenti, anche se alcuni hanno rilevato un calo nel ritmo di lavoro. Questa
throughout the game accompanied by a fall in work rate has been attributed to the cardiovascular drift that occurs with prolonged exercise. This physical strain has been shown to be smaller in lower division in a study that analyzed referees from the English Premier League and the Football League. In consequence, referees’ fitness level need has been established to match aerobic endurance requirements. Thus, scientific literature has proposed different training methods.

According to Krstrup and Bangsbo and Castagna and D’Ottavio, the fitness level of referees clearly affects the distance they cover during a match. Obviously, besides the distance covered, the speed used to cover the distance is influenced by play rhythm and/or accumulated fatigue. In this way, Krstrup and Bangsbo reported that referees were further away from infringements in the second half than in the first, suggesting that the fall in work rate manifests as true fatigue. Most of the activity of referees is conducted at a low intensity, comprising walking and jogging (41.4 and 15.6%, respectively). However, low, moderate and high speed running and sprinting are also activity intensities performed by football referees, this changes performance intensity have implications in the body load (i.e. acceleration forces that the referees generate during the sport action), and number of impacts performed during football matches that would need to be considered in order to properly adequate referees training and fitness needs, as it has been reported in other sports such as rugby or ice-hockey and in the military training. On the other hand, although the above exposed wide evidence supporting the importance of heart rate in referee performance, to our knowledge, there is no literature on its importance in the case of talent referees, as it exists on other sports. In this framework, it is essential to know their response levels in order to make appropriate training programs that increase their chances of reaching professional football level since during their formation the competition level of the players is much lower than professional football. In this line non-professional football training protocol are usually design less carefully, which is logical attending to economic and social issues, being strength training the main careless physical parameter, as observed in previous studies in amateur Spanish and in Greek level referees performing at similar levels.

Therefore, the purpose of this study was to uniformità della frequenza cardiaca durante la competizione, accompagnata da una riduzione del ritmo di lavoro, è stata attribuita alla derivazione cardiovascolare che si verifica con un esercizio fisico prolungato. In uno studio che ha analizzato gli arbitri della Premier League e della Football League inglesi, questo sforzo fisico si è dimostrato minore in una divisione di categoria inferiore. Di conseguenza, è stato stabilito che il livello di forma fisica deve combaciare con le esigenze di resistenza aerobica. Per questo, la letteratura scientifica ha proposto diversi metodi di allenamento.

Secondo Krstrup e Bangsbo e Castagna e D’Ottavio, il livello di forma fisica degli arbitri influenza chiaramente sulla distanza che coprono durante un match. Ovviamente, oltre alla distanza coperta, la velocità impiegata per coprire tale distanza è influenzata dal ritmo di gioco e/o dall’affaticamento accumulato. In questo modo, Krstrup e Bangsbo hanno osservato che gli arbitri erano più distanti dalle infrazioni nel secondo tempo che nel primo, suggerendo che il calo nel ritmo di lavoro si manifesta come uno affaticamento. La maggior parte dell’attività degli arbitri viene condotta a una bassa intensità, tra cui camminata e jogging (rispettivamente 41,4% e 15,6%). Tuttavia, corsa e sprint a bassa, moderata e alta velocità sono altre intensità a cui gli arbitri di calcio eseguono le loro attività e tali cambiamenti nell’intensità della performance hanno implicazioni sul carico fisico (cioè le forze di accelerazione che gli arbitri generano durante l’azione sportiva) e sul numero di contatti durante le partite, che andrebbero considerati per adeguare appropriatamente l’allenamento degli arbitri alle necessità fisiche, come notato in altri sport come rugby, hockey su ghiaccio e addestramento militare. Dall’altro lato, anche se le ampie evidenze illustrate sopra sostengono l’importanza della frequenza cardiaca nella prestazione degli arbitri, a quanto sappiamo non vi sono opere in letteratura dedicate all’importanza di questo elemento nel caso degli arbitri talentuosi, come accade per altri sport. In questo contesto, è essenziale conoscere i loro livelli di risposta per strutturare programmi di formazione adeguati che aumentino le loro possibilità di raggiungere il livello dei professionisti del calcio, poiché durante la formazione il livello di competizione dei giocatori è molto inferiore rispetto a quanto accade nelle partite dei calciatori professionisti. Su questa linea, i protocolli di addestramento nel calcio dilettantistico sono solitamente concepiti in maniera meno attenta, una cosa logica se ci si deve occupare di questioni economi-
analyze physical, mechanical, and physiological parameters of football talent referees in terms of physical strain distance covered, speed, sprints, impacts, body load and heart rate, and to analyze the differences in these responses between the first and the second half during football matches in semi-professional Spanish 2nd Division B and 3rd Division. The hypothesis of the present research was that global positioning satellite (GPS) will confirm previous studies data and further, will report a high mechanical stress. In consequence, data will justify the implementation of strength training in referees’ fitness programs allowing referees to performance adequately into an elite environment. Also, data will aim to improve the referee’s talent detection and preparation to reach the elite football referees level.

Materials and methods

Fourteen referees (all men) from 2nd División B and 3rd Division of the Spanish Football League volunteered to participate in the study. All of them are participating into the Talent Referees Develop Program (Referees Technical Committee CTA-RFFM-RFEF). This program selects the referees of greater talent of Madrid, and we counted on the participation of all the group. Their mean age, height, body weight and Body Mass Index (BMI) were 25.8±3.8 years old; 1.79±0.03 m; 74.4±2.3 kg. All participants had between 4 and 9 years of experience on officiating football matches. Referees dressed up with the official uniform (T-shirt, short pants, and cleats) besides they wore the experimental instruments during the matches. Prior to participation, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent in accordance with the Declaration of Helsinki. The present study emerged out in a collaboration with the Royal Madrid Football Federation (RFFM) and the Royal Spanish Football Federation (RFEF).

Procedures

Referees movement patterns (mechanical and physical) and physiological demands were analyzed during 2 different games for each referee (total of 28 games) during the 2015-16 season. Before starting each match, the referees have a 30-minute warmup consisting of 10 min-

che e social. Come osservato in precedenti studi su arbitri amatoriali spagnoli e greci con prestazioni di livello simile, l’allenamento di forza è il principale parametro fisico impreciso.

Quindi, lo scopo del presente studio era analizzare i parametri fisici, meccanici e fisiologici di talentuosi arbitri di calcio in termini di sforzo fisico, distanza coperta, velocità, sprints, contatti, carico fisico e frequenza cardiaca e studiare le differenze in queste risposte tra il primo e il secondo tempo delle partite di calcio nell’ambito della seconda divisione B e terza divisione spagnole semi-professionistiche. L’ipotesi della presente ricerca era che il sistema di posizionamento globale (GPS) avrebbe confermato i dati dei precedenti studi e avrebbe segnalato un elevato stress meccanico. Di conseguenza, i dati avrebbero giustificato l’implementazione dell’allenamento di forza nei programmi di fitness degli arbitri, permettendo loro di avere una prestazione adeguata a un ambiente di élite. Inoltre, i dati miravano a migliorare la scoperta del talento degli arbitri e la loro preparazione per raggiungere il livello di quelli di élite nel calcio.

Materiali e metodi

Quattordici arbitri (tutti uomini) della seconda e terza divisione del campionato di calcio spagnolo hanno scelto volontariamente di partecipare allo studio. Tutti facevano parte del Programma di sviluppo di arbitri talentuosi (Comitato tecnico arbitri CTA-RFFM-RFEF). Questo programma seleziona gli arbitri di maggior talento di Madrid, e abbiamo potuto contare sulla partecipazione di tutto il gruppo. L’età, l’altezza, il peso e l’indice di massa corporea (IMC) medi erano 25.8±3.8 anni; 1.79±0.03 m; 74.4±2.3 kg. Ogni partecipante aveva dai quattro ai nove anni di esperienza nel calcio. Durante i match, gli arbitri indossavano la divisa ufficiale (maglietta, pantaloncini e scarpe da calcio) e gli strumenti sperimentali. Prima della partecipazione, i partecipanti hanno ricevuto una spiegazione delle procedure sperimentali, a cui hanno fornito il loro volontario consenso in conformità con la Dichiarazione di Helsinki. Il presente studio è nato in una collaborazione con la Reale Federazione di Calcio di Madrid (RFFM) e la Reale Federazione di Calcio Spagnola (RFEF).

Procedure

I patterni di movimento (meccanici e fisici) e le sollecitazioni fisiologiche degli arbitri sono stati
utes of continuous running and joint mobility, 5 minutes of running with different types of displacement, and 5 minutes of stretching. All matches were played in stadiums with official dimensions and similar characteristics (100×70 m). Participants wore a GPS device (SPI Elite, GPSports Systems, Canberra, Australia) inserted in a purpose-built backpack that recorded speed and distance. Also, they wore a HR transmitter belt (Polar Electro, Kempele, Finland) to incorporate the HR data. Referees’ accelerations were also recorded using a triaxial built-in accelerometer with an operational sampling rate of 100 Hz. The GPS system was switched on before starting the match, switched off at the end of the first half, again switched on before the beginning of the second half, and switched off immediately at the end of the match. Data stored included velocity, distance, body load, HR, and number and intensity of impacts. After collection, data were downloaded into a personal computer where further analysis was carried out with Team AMS software (v. 1.2; GPSports Systems).

Football matches were held during the same competition season and in the center area of Spain, thus physiological differences because of geographical locations were discarded. However, time-of-day schedule was either in the morning or in the evening, thus circadian rhythm interactions could be present.30 Also, weather issues could be present.

Analyses of referees’ movement during the match were categorized as follows, based on previous studies analyzing football performance.31, 32 Standing (Z1: 0-0.4 km/h); walking (Z2: 0.5-3.0 km/h); jogging (Z3: 3.1-8.0 km/h); medium-intensity running (Z4: 8.1-13.0 km/h); high-intensity running (Z5: 13.1-18.0 km/h); and sprinting (Z6: running speed higher than 18.0 km/h). The impact data of the referees were gathered from accelerometer data, expressed as g force. Minimum impact intensity was 5xg. We analyzed the number of impact higher than 5xg. Computation of soldier body load during exercise also involved use of the above-mentioned acceleration zone forces. All the data analyses were performed with a specific software package (Team AMS software v. R1.2011.6, GPSports). Recorded HR during matches were grouped into 6 HR zones based on each subject known maximum HR (HRmax).25, 27 HR zones were as follows: Z1: 0-59.9% HRmax; Z2: 60-69.9% HRmax; Z3: 70-79.9% HRmax; Z4: 80-89.9% HRmax; Z5: 90-94.9% HRmax; and analizati nell’ambito di due partite per ciascun professionista (per un totale di 28 partite) durante la stagione 2015-2016. Prima dell’inizio dei match, gli arbitri si riscaldavano per 30 minuti, con dieci minuti di corsa continua e mobilità articolare, cinque minuti di corsa con diversi tipi di spostamento e cinque minuti di stretching. Tutte le partite sono state giocate in stadi con dimensioni ufficiali e caratteristiche analoghe (100×70 m). I partecipanti indossavano un dispositivo GPS (SPI Elite, GPSports Systems, Canberra, Australia) che registrava velocità e distanza inserito in uno zaino appositamente costruito. Inoltre, portavano un trasmettitore di HR da cintura (Polar Electro, Kempele, Finlandia) per registrare i dati sulla HR. Sono state annotate anche le accelerazioni degli arbitri tramite un accelerometro triassiale incorporato con un tasso di campionamento di 100 Hz. Il sistema GPS è stato acceso prima dell’inizio della competizione, spesso alla fine del primo tempo, accesso di nuovo prima dell’inizio del secondo tempo e rispetto subito dopo la fine della partita. I dati raccolti includevano velocità, distanza, carico fisico, HR e numero e intensità dei contatti. Dopo la raccolta, i dati sono stati scaricati su un computer personal dove è stata condotta un’ulteriore analisi con il software Team AMS (v. 1.2; GPSports Systems).

Le partite di calcio hanno avuto luogo durante la stessa stagione di campionato e nell’area centrale della Spagna, quindi le differenze fisiologiche a causa delle posizioni geografiche sono state scartate. Tuttavia, le competizioni si sono svolte di mattina o di sera, quindi potrebbero essersi verificate interazioni dei ritmi circadiani.30 Inoltre, potrebbero essere state presenti questioni legate al meteo.

Le analisi del movimento degli arbitri durante il match sono state classificate come segue sulla base di precedenti studi che hanno analizzato le prestazioni nel calcio:31, 32 posizione eretta con assenza di movimento (Z1: 0-0.4 km/h); camminata (Z2: 0.5-3.0 km/h); jogging (Z3: 3.1-8.0 km/h); corsa a media intensità (Z4: 8.1-13.0 km/h); corsa ad alta intensità (Z5: 13.1-18.0 km/h) ed esecuzione di sprint (Z6: velocità di corsa superiore a 18.0 km/h). I dati sui contatti degli arbitri sono stati dedotti da quelli dell’accelerometro, espressi come forza g. La minima intensità di contatto corrispondeva a 5xg. Abbiamo analizzato il numero di contatti superiori a 5xg. Il calcolo del carico fisico durante l’esercizio ha previsto anche l’uso delle forze delle zone di accelerazione sopra citate. Tutte le analisi dei dati sono state condotte con uno specifico pacchetto software (software Team AMS v. R1.2011.6, GP-
Z6: >95% HRmax. The HRmax was estimated using the formula proposed by Tanaka et al.33

Statistical analysis

Results are presented as mean and standard deviation. Shapiro-Wilks test revealed that data were normally distributed. A paired t-test was used to compare mean values. Data variability between halves for distance covered and HRavg was calculated using the coefficient of variation (CV).34 The data were analyzed with the statistical package SPSS v. 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Distance covered and running speed

The total distance covered by the referees during football matches was 8733.6±2238.0 m, with no significant differences between match halves (4385.8±1122.7 vs. 4347.9±1164.9 m for 1st and 2nd half, respectively; CV 6.6±8.3%). Figure 1 illustrates the distance covered at different speeds, ranging from standing (Z1) to sprinting (Z6). No significant differences were noticed among distances covered at the different intensity zones between the 1st and the 2nd half of Sports. L’HR registrata durante le partite è stata raggruppata in sei zone sulla base della frequenza cardiaca massima nota di ogni soggetto (FCmax).25, 27 Le zone erano le seguenti: Z1: 0-59.9% FCmax; Z2: 60-69.9% FCmax; Z3: 70-79.9% FCmax; Z4: 80-89.9% FCmax; Z5: 90-94.9% FCmax and Z6: >95% FCmax. L’FCmax è stata stimata utilizzando la formula proposta da Tanaka et al.33

Analisi statistica

I risultati sono presentati come media e deviazione standard. Il test di Shapiro-Wilks ha rivelato che i dati erano normalmente distribuiti. Per confrontare i valori medi è stato utilizzato il test t per dati appaiati. La variabilità dei dati tra i due tempi per la distanza coperta e la FCmedio è stata calcolata tramite il coefficiente di variazione (CV).34 I dati sono stati analizzati con il pacchetto statistico SPSS v. 18.0 (SPSS Inc., Chicago, IL, USA).

Risultati

Distanza coperta e velocità di corsa

La distanza totale coperta dagli arbitri durante le partite di calcio è stata di 8733.6±2238.0 m, senza alcuna differenza significativa tra i due tempi del match (rispettivamente 4385.8±1122.7 nel primo tempo vs. 4347.9±1164.9 m nel secondo; CV 6.6±8.3%). La Figura 1 illustra la distanza coperta a diverse velocità, dalla posizione eretta con assenza di movimento (Z1) all’esecuzione di sprint (Z6). Non sono state notate differenze significative tra le distanze coperte alle diverse zone di intensità tra il primo e il secondo tempo delle partite. Infine, anche il numero di sessioni di sprint registrate era simile tra i due tempi del match (rispettivamente 6,9±5,6 sessioni nel primo tempo vs. 7,1±5,7 nel secondo).

Frequenza cardiaca durante l’esercizio

FCmedio FCmax e FCmin sono risultate simili tra i due tempi durante le partite di calcio (Tabella I). Inoltre, anche la percentuale di metri coperti alle diverse intensità si è rivelata simile (Tabella I). Pertanto, durante gli incontri calcistici lo stress fisiologico era affine tra i due tempi. Il CV della frequenza cardiaca tra i tempi era di 2,4±2,5%.

Prestazione meccanica

I dati meccanici sono mostrati nella Tabella II. La velocità massima raggiunta dagli arbitri du-
Physiological Demands of Talent Football Referees

FERNÁNDEZ-ELÍAS

Exercise heart rate

HR_{avg}, HR_{max}, and HR_{min} heart rates were similar between halves during the football matches (Table I). Also, the percentage of meters covered at the different intensities (Z1 to Z6) was similar (Table I). Thus, physiological stress was similar between halves during the football matches. Heart rate CV between halves was 2.4±2.5%.

Mechanical performance

Mechanical data is shown in Table II. Maximum speed reached by referees during the matches was 26.0±2.6 and 26.5±3.2 km/h for the 1st and the 2nd half, respectively. Besides, total body load and total body impacts were similar during match halves. Further, body load and impact at different intensity zones were not significantly different.

Discussion

The aim of the present study was to analyze physical, mechanical, and physiological parameters and to analyze the differences in these responses between the first and the second half of football talent referees during official matches in semi-professional Spanish 2nd Division B and 3rd Division. Data obtained from GPS and the matches. Finally, the number of sprint bouts registered was also similar between match halves (6.9±5.6 vs. 7.1±5.7 bouts for the 1st and the 2nd half, respectively).

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<table>
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<th>Parameters</th>
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<th>Second half</th>
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<td>9.5±19.6</td>
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<td>% Time in HR Z2</td>
<td>14.6±14.2</td>
<td>16.6±16.1</td>
</tr>
<tr>
<td>% Time in HR Z3</td>
<td>32.2±16.6</td>
<td>32.5±13.8</td>
</tr>
<tr>
<td>% Time in HR Z4</td>
<td>33.7±20.9</td>
<td>34.2±21.7</td>
</tr>
<tr>
<td>% Time in HR Z5</td>
<td>6.6±11.2</td>
<td>6.2±8.6</td>
</tr>
<tr>
<td>% Time in HR Z6</td>
<td>1.3±4.0</td>
<td>0.7±1.6</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD.

HR_{avg}: average heart rate; HR_{max}: maximum heart rate; HR_{min}: minimum heart rate; HR Z: heart rate zone intensity; Z1: 0-59.9% HR_{max}; Z2: 60-69.9% HR_{max}; Z3: 70-79.9% HR_{max}; Z4: 80-89.9% HR_{max}; Z5: 90-94.9% HR_{max}; Z6: >95% HR_{max}.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>First half</th>
<th>Second half</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed, km/h</td>
<td>26.0±2.6</td>
<td>26.5±3.2</td>
</tr>
<tr>
<td>Total body load, au</td>
<td>62,042.8±69,287.7</td>
<td>68,752.5±86,348.6</td>
</tr>
<tr>
<td>Body load Z1, au</td>
<td>12,740.8±10,977.2</td>
<td>14,274.7±13,254.4</td>
</tr>
<tr>
<td>Body load Z2, au</td>
<td>17,342.6±19,052.7</td>
<td>18,361.8±22,538.7</td>
</tr>
<tr>
<td>Body load Z3, au</td>
<td>28,713.9±37,149.3</td>
<td>32,212.2±47,162.2</td>
</tr>
<tr>
<td>Body load Z4, au</td>
<td>2669.3±5124.5</td>
<td>3443.7±10,047.1</td>
</tr>
<tr>
<td>Body load Z5, au</td>
<td>459.9±1960.7</td>
<td>419.7±1336.8</td>
</tr>
<tr>
<td>Body load Z6, au</td>
<td>116.3±347.6</td>
<td>40.5±241.4</td>
</tr>
<tr>
<td>Total impacts, N.</td>
<td>605.9±222.6</td>
<td>600.4±219.3</td>
</tr>
<tr>
<td>Impacts Z1, N.</td>
<td>197.7±107.9</td>
<td>205.3±84.7</td>
</tr>
<tr>
<td>Impacts Z2, N.</td>
<td>133.5±80.4</td>
<td>144.9±80.3</td>
</tr>
<tr>
<td>Impacts Z3, N.</td>
<td>154.6±118.9</td>
<td>176.8±141.6</td>
</tr>
<tr>
<td>Impacts Z4, N.</td>
<td>91.9±115.3</td>
<td>107.0±150.4</td>
</tr>
<tr>
<td>Impacts Z5, N.</td>
<td>25.0±36.7</td>
<td>25.5±42.9</td>
</tr>
<tr>
<td>Impacts Z6, N.</td>
<td>3.1±12.7</td>
<td>2.8±8.5</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD.

Z1: standing, 0-0.4 km/h; Z2: walking, 0.5-3.0 km/h; Z3: jogging, 3.1-8.0 km/h; Z4: medium-intensity running, 8.1-13.0 km/h; Z5: high-intensity running, 13.1-18.0 km/h; Z6: sprinting, running speed >18.0 km/h.
HR devices confirms findings in previous studies\(^\text{11,15}\) that in low competitions levels, referees' activity and physiological strain are at the low edge of the activity range.\(^\text{8}\) Furthermore, body load and impacts analysis showed mechanical stress information that provided very useful information on braking and changes of direction that evidences the need of implementing strength training on referees' fitness programs.

The mean distance covered by referees in the present study was 8.7±2.2 km, which is within the range of 7 to 13 km shown in previously studies.\(^\text{8}\) Nevertheless, the mean 8.7 km covered during matches by the referees in this study are near to the low edge of the range distances, which is in accordance with data reported in previous studies.\(^\text{11,15}\) As in these previous researches, the referees monitored in our study belonged to a lower competition level (i.e. semiprofessional Spanish football). Regarding match halves differences, our data shows similar outcomes between 1\(^{\text{st}}\) and 2\(^{\text{nd}}\) half. This fact is in accordance with previous studies performed in high levels competition referees,\(^\text{2,4,11-13}\) but disagrees with data from studies with similar levels referees.\(^\text{11,15,35,36}\) A possible explanation of this circumstance is the implementation and improvement of referees' aerobic physical training programs as a consequence of scientific researches and its considerations.\(^\text{6,37}\) Distance covered at different speed zones reported in our data is in accordance with previous studies,\(^\text{2,4,11-13}\) with ~60% of the distance covered by walking and jogging and ~40% covered at speeds higher than 13 km/h, with a mean maximum sprint velocity of 26.5±3.2 km/h reported in this study (Table II). And with no significant differences in speed zones between halves, as shown in previous studies with similar distances covered between halves, despite some reported higher total distances covered during matches.

Referees physical strain reported in our study by HR analysis showed a HR\(_{\text{avg}}\) in accordance with the distance covered during matches. Also, the percentage of time spent at different intensities is similar to speed zones (Figure 1). In this way, our data is in accordance with the literature.\(^\text{11-13}\) However, referees in our study reported a HR\(_{\text{avg}}\) ~10 bpm lower than previous researches.\(^\text{9,13}\) This difference may lie on the lower competition level,\(^\text{8}\) but HR\(_{\text{avg}}\) in this study is similar to that shown by international-elite referees.\(^\text{14}\) Thus, the improvements of referees training programs in the last decade, and their implementation in referees from lower level

namento di forza nei programmi di fitness degli arbitri.

La distanza media coperta dagli arbitri nel presente studio è stata di 8.7±2.2 km e si trova all'interno del range che oscilla tra i 7 e i 13 km emerso negli studi precedenti.\(^\text{8}\) Ciò nonostante, gli 8,7 km medi coperti durante le partite dagli arbitri in questo studio sono vicini al margine inferiore del range delle distanze, elemento in linea con i dati riportati in studi precedenti.\(^\text{11,15}\) Come avvenuto in tali ricerche precedenti, gli arbitri monitorati nello studio operavano nell'ambito di un livello agonistico basso (cioè, il calcio semiprofessionistico spagnolo). Per quanto riguarda le differenze tra i tempi del match, i nostri dati mostrano risultati simili tra il primo e il secondo tempo. Ciò risultava in linea con gli studi precedenti condotti su arbitri che dirigevano partite di alto livello.\(^\text{9,12-14}\) Tuttavia, se si discosta dai dati di studi con arbitri di livello simile.\(^\text{11,15}\) Una possibile spiegazione risiede nell'implementazione, e nel miglioramento, dell'allenamento fisico aerobico degli arbitri con conseguenza di ricerche scientifiche e delle loro considerazioni.\(^\text{6,37}\) I nostri dati relativi alla distanza coperta a diverse zone di velocità risultano in linea con le ricerche precedenti,\(^\text{8,2,4,11-13}\) con ~60% della distanza coperta camminando e ~40% coperta a velocità superiori a 13 km/h, con una velocità massima di sprint media di 26,5±3,2 km/h (Tabella II). Come mostrato in studi precedenti con distanze simili coperte tra i due tempi, non sono state riscontrate differenze significative nelle zone di velocità tra i due tempi, nonostante alcune ricerche abbiano segnalato la copertura di distanze totali maggiori durante le partite.

Lo sforzo fisico degli arbitri osservato nel nostro studio tramite l'analisi dell'HR ha mostrato una FC\(_{\text{media}}\) conforme alla distanza coperta durante gli incontri. Inoltre, la percentuale di tempo speso a diverse intensità è risultata simile alle zone di velocità (Figura 1). In questo modo, i nostri dati sono in linea con quelli riportati in letteratura.\(^\text{11-13}\) Tuttavia, gli arbitri che abbiamo studiato avevano una FC\(_{\text{media}}\) minore di ~10 bpm rispetto alle ricerche precedenti.\(^\text{9,13}\) Tale differenza potrebbe risiedere nel minor livello di agonismo,\(^\text{8}\) ma la FC\(_{\text{media}}\) risultava simile a quello degli arbitri di élite internazionali.\(^\text{14}\) Quindi, i miglioramenti nei programmi di allenamento degli arbitri nell’ultimo decennio e la loro implementazione in arbitri che dirigono competizioni di minor livello potrebbero spiegare tale riduzione della FC\(_{\text{media}}\) rispetto agli studi precedenti.

Per ciò che riguarda il carico fisico e i contatti riferiti durante le partite, a quanto sappia-
interest in determining the characteristics that referees must have to participate in elite sport is without doubt growing. Taking into account that experience is developed by a complex interaction of factors (physiological, technical, tactical, psychological), we presented empirical great value physiological characteristics that must comply talent football referees. Talent football referees presented a predominant aerobic intensity and a body load that suggest the combination of aerobic and resistance training to improve their fitness levels and performance in matches. Also, no significant differences between cardiovascular, speed, body load and number of impacts between the half of the match were found. The data obtained in the present research allow us to have a standardized index to the previous literature in professional football referees to improve the referees’ talent recruitment. New talent recruitment strategies must comply talent football referees. Talent football referees presented a predominant aerobic intensity and a body load that suggest the combination of aerobic and resistance training to improve their fitness levels and performance during the match would be better.

Conclusions

Interest in determining the characteristics that referees must have to participate in elite sport is without doubt growing. Taking into account that experience is developed by a complex interaction of factors (physiological, technical, tactical, psychological), we presented empirical great value physiological characteristics that must comply talent football referees. Talent football referees presented a predominant aerobic intensity and a body load that suggest the combination of aerobic and resistance training to improve their fitness levels and performance in matches. Also, no significant differences between cardiovascular, speed, body load and number of impacts between the half of the match were found. The data obtained in the present research allow us to have a standardized index to the previous literature in professional football referees to improve the referees’ talent recruitment. New talent recruitment strategies must comply talent football referees. Talent football referees presented a predominant aerobic intensity and a body load that suggest the combination of aerobic and resistance training to improve their fitness levels and performance during the match would be better.

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egies, ought to update the training programs focusing on referee’s explosive strength needs. In this way, referees’ associations could use the reported data discriminant marks in the recruitment and training process until they join the professional status.

References/Bibliografia