UEFA RESEARCH GRANT PROGRAMME

FINAL REPORT

Understanding the recovery time course in elite football referees during a congested match schedule

(REFCOVERY PROJECT)

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1. EXECUTIVE SUMMARY

In the last years, the number of matches in the same week has been increased and the time of recovery before the next match is lower. The effects of congested weeks on football players are well-documented; however no studies have presented evidence about such topic on referees. An inadequate recovery can determine the physical, physiological and mental performance of the referees. This problem can influence on decision making during a match and increase the number of mistakes on the field. The Spanish Football Association and European Football in general aim to improve the physical, physiological and mental conditions of the referees with the help of science. Some points for improvement in the last Referee Instructor Development Excellence (RIDE) course from UEFA were to pay more attention to injury prevention, and the use of GPS technology during training and matches for a better education of elite referees on load management and importance of recovery and a better planning of match assignments, in order to avoid overtraining. For this reason, the purpose of this project is to understand the time course of recovery in elite football referees during a congested match schedule. The main hypothesis is that the time course of recovery in physical, physiological and psychological parameters after congested weeks would be longer than after normal weeks. In this study, twenty elite football referees from the Committee of football Referees in Spain were selected. Participants were informed of the procedures, methods, benefits, and possible risks involved in the study before giving their written consent. This investigation is being performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the European University. The monitoring process was carried out since August 2019. Weeks will be classified either as normal (one match per week) or as congested (two matches per week with four or fewer days between matches). Referees' baseline measures will be taken 24 h prior to participation in the match (MD-1). Physical, physiological and psychological variables will also be assessed 30 min (MD), 24 h (MD+1) and 48 h (MD+2) into the post-match recovery period. On the other hand, movement patterns (with GPS devices) and heart rate parameters are being monitored during the match. On the other hand, individual perceptions (muscle soreness (DOMS), fatigue, stress, and sleep), physical performance (Countermovement jump) and physiological parameters (plasma creatine kinase

concentration) will be assessed 24 h pre-match and 30 min, 24 h and 48 h post-match. Between-type of weeks (normal vs. congested) and between-training days (MD-1 vs. MD+1 vs. MD+2) variations will be analysed using standardized differences of effect size (ES) with a 90% CI. The results of this study could suggest that specific activities during the match are associated with post-match muscle damage and with decreased performance. The analysis and review of this information may therefore help coaches to design and adjust individual referee's recovery strategies.

2. CONTEXT OF THE RESEARCH AND ITS RELEVANCE FOR UEFA

The effects of congested weeks on football players are well-documented, however no study has presented evidence about such topic on referees. Field and assistant referees combine high-speed running actions with low-intensity activity periods during matches. To ensure an appropriate fitness level of match officials, the Union of European Football Associations (UEFA), and continental, national and regional associations have designed a battery of fitness tests that referees must pass. However, in the last years, the number of matches in the same week has been increased and the time of recovery before the next match is lower. An inadequate recovery can determine the physical, physiological and mental performance of the referees. This problem can influence on decision making during a match and increase the number of mistakes on the field. In this way, no study has evidenced the effect of recovery processes or the fatigue time course after a match in referees. For this reason, the understanding of recovery time of physical, physiological and mental parameters during a congested match schedule would allow the fitness instructor to design better recovery strategies to improve the match performance of the referees. In this sense, the research question is: does a congested match schedule influence on the time course of recovery in elite football referees?

3. OBJECTIVES AND HYPOTHESIS OF THE PROJECT

General Objective

To understand the time course of recovery in elite football referees during a congested match schedule.

Specific Objectives

1. To determine the influence of internal and external load in a match on biochemical markers related to fatigue in elite football referees.
2. To identify the effect of congested weeks (two matches in a week) on the physical performance and time course of recovery in comparison to normal weeks (one match in a week) in elite football referees.
3. To analyse the evolution of stress, well-being, mental and neuromuscular fatigue after congested weeks in elite football referees.

Hypothesis

1. A higher number of activities with a high eccentric component and congested weeks would be associated with larger alterations in biochemical markers related to fatigue and muscle damage.
2. The time course of recovery in physical parameters after congested weeks would be longer than after normal weeks.
3. Mental fatigue in congested weeks would impair referees' decision-making speed and accuracy, and alter muscle soreness (DOMS), fatigue, stress, and sleep perception.

4. LITERATURE REVIEW

Physical demands

In this sense, to ensure the proper course of play, elite referees combine high-speed running actions with periods of low intensity activity during matches (Castagna, Abt and D'Ottavio, 2007). This pattern of activity characterizes football refereeing as an intermittent activity (Castagna et al., 2007). Elite referees cover approximately 10–12 km (Castillo, Yanci, Cámara and Weston, 2016), with a corresponding average heart rate (HRmean) of 85–90% of their maximum heart rate (HRmax), with lactate concentrations in blood that occasionally can reach 14 mM · l -1 Max (Castagna et al., 2007). In addition, they perform around 70 high-intensity accelerations during matches (Barbero-Alvarez, Boullosa, Nakamura, Andrin and Castagna, 2012) and also cover almost 15% of the total distance (TD) running at high speed (Mallo, Navarro , García-Aranda and Helsen, 2009). In order to achieve the best positioning on the football field and, consequently, to ensure the correct course of the game (Castillo, Cámara, Castellano and Yanci, 2016), the football referee performs an activity, covering up to 1539 ± 115 m at speeds above

18 km · h and performing 38 ± 17 sprint actions per game (Barbero-Alvarez, Boullosa, Nakamura, Andrin and Weston, 2014). In addition, elite levels of male RF were reported to sustain 73 ± 28 high intensity accelerations (698 ± 288 m) at more than 1.5 m · s during games. High intensity decelerations are up to 2.9 times more frequent than high intensity accelerations (Hoyo et al., 2016). Presumably, this discrepancy is a feature of competitive play, accelerations to higher running speeds can occur with a more gradual frequency without crossing the high intensity threshold, however, a higher proportion of decelerations are suddenly imposed above the threshold (Jaspers et al., 2018; Hoyo et al., 2016). Therefore, the physical demands of a match for a referee, including sprints, accelerations, decelerations, or changes of direction, cause disturbances in the musculoskeletal, nervous, immune, and metabolic systems (Reilly and Ekblom, 2005).

Variations of physical demands between assistant and field referees

In contrast, the physical demands of an assistant referee during matches, compared to field referee is significantly lower since their activity is limited to half the distance of the field (Weston et al., 2012). Specifically, assistants referees cover a total distance of 5–6 km per game (Mallo, Navarro, García-Aranda and Helsen, 2009), compared to a field referee covering approximately 10–12 km, twice the distance (Castillo et al., 2016). Furthermore, their high intensity accelerations during games have been shown to be ~ 29% lower than those reported by the field officials (Barbero-Alvarez et al., 2012). On the other hand, taking into account the different physical demands that the field umpires and the assistants have, in total distance traveled, accelerations and decelerations, it would be appropriate to design specific training to improve running capacity and cardiovascular capacity (Castillo, Cámara, Lozano, Berzosa and Yanci, 2019).

Physical demands depending on the competitive level

Weston, Drust and Gregson (2011) reported that the external load of field referees covariated with the activities of the team, which suggests a physical preparation of game field referees differentiated according to the competitive level of the team and style of play. The physical performance (endurance ability [yo-yo intermittent recovery test, 12-minute running test] and change of direction ability [modified agility test]) of the top-level umpires were significantly better than those of lower level levels (Bartha et al., 2009; Yanci, Arcos, Grande and Casajús, 2016). Interestingly, the internal FR match burden considered as heart rate (HR) was affected by the league's competitive level. In fact, literature reported variations of internal load and external due to competitive levels, age and refereeing experience (Castagna et al., 2007; Weston et al., 2012). Ultimately, the physical demands of referees vary depending on the competitive level of the teams. (Weston, 2015; Castillo, Yanci, Cámara and Weston, 2016).

Physical fitness tests

To ensure an adequate level of physical fitness for official matches, the International Federation of Football Association (FIFA), and the continental, national and provincial associations designed a battery of physical fitness tests that must be passed by match officials (FIFA, 2016). Certification of a certain level of fitness is a fundamental prerequisite for officiating at each level of competition and promoting higher standards of play (CTA, 2016; FIFA, 2016).

Congested calendar and its influence on performance

With the aim of understanding the effects of a congested game schedule on performance parameters in professional football, which represents a broad problem explored in literature for football players but a lesser extent for referees. Modern elite football involves many tournaments and matches throughout the season, and it is not unusual for a team to play 2 matches in a single week (Thorpe and Sunderland, 2012). For elite referees, the same is true, including national and international matches, which have increased markedly in the last decade. Elite referees often have to play competition matches with only 2-3 days of recovery (Lago-Peñas et al., 2011). There are reasons to believe that too many games can lead to lack of motivation and concentration can deteriorate, which can affect coordination, leading to poor performance and increased risk of injury (Ekstrand, Walden, & Hägglund, 2004). Existing research analysing fatigue and the schedule of congested matches has generally focused on football players (Arruda et al., 2015; Moreira et al., 2016).

Previous studies have found evidence that congested agendas did not affect running performance in football competitions (Carling, Gall and Dupont, 2012; Dellal, Lago-Penas, Rey, Chamari and Orhant, 2015; Lago-Peñas, Rey, Lago -Ballesteros, Casais and Dominguez, 2011), such as the total distance covered (TD) (Carling and Dupont, 2011; Andrzejewski, Konarski, Chmura and Pluta, 2014), absolute frequency of sprints (Andrzejewski et al., 2014) and high intensity running distance. Furthermore, contextual factors that can potentially affect performance, such as the location of the match, the state of the match, the quality of the opponent and environmental conditions, can modulate the physical performance of a football match. (Nassis, Brito, Dvorak, Chalabi, and Racinais (2015); Dellal, Lago-Peñas, Rey, Chamari and Orhant, 2015). Many physical trainers argue that the level of preparation of a player or referee is also raised by participation in matches. Participation in competitions helps to achieve a high state of readiness for the next competition. During games, umpires have the opportunity to test all training factors in the most specific way. However, the correct peak cannot be achieved through competition alone. Considering competition as the only means of improvement weakens the entire philosophy of training and, consequently, disrupts the main cycle of activity: training, competition and regeneration (Lago-Peñas et al., 2011). As a consequence of a limited recovery in the available time between matches, it sometimes leads to residual fatigue (Lago-Peñas et al., 2011), and increases the stress imposed on the players and referees, which increases the risk of injury and decreases their performance (Ispirlidis et al., 2008; Rey, Lago-Peña, Lago-Ballesteros, Casais, Dellal, 2010). However, it is necessary to delve further into the effects of a congested schedule on the physical, physiological and mental performance of elite football referees.

Recovery and fatigue

For the above reasons, participation in football match-play leads to acute and transient subjective, biochemical, metabolic and physical disturbances in referees over subsequent hours and days (Nédélec et al., 2012). Inadequate time for rest and regeneration between matches can expose referees to the risk of training and competing whilst not entirely recovered. Accordingly, it is important to monitor post-match fatigue (PMF) using a variety of methods and tools in an attempt to evaluate recovery in referees and determine their readiness status for ensuing training and competition (Carling et al., 2018). The physical demands of a match for a referee, including sprints, accelerations, decelerations or changes of direction, lead to disturbances in the musculoskeletal, nervous, immune and metabolic systems (Reilly & Ekblom, 2005). Participation in a single match leads to acute and residual fatigue, characterised by a decline in physical performance over the following hours and days (Ispirlidis et al., 2008). The magnitude of these disturbances increases within the first 24 h after exercise, peaks between 24 and 48 h, and thereafter subsides and returns to baseline after 72 to 96 h (Magalhães et al., 2010). Together with a decline in performance, muscle damage and increased levels of intramuscular enzymes such as creatine kinase (CK) and inflammatory markers are reported following football competition (Magalhães et al., 2010). Magalhães et al. (2010) observed increased plasma CK up to 72 h post-match, and found significant reductions in sprint performance, and in isokinetic knee extension and flexion peak torques in football players. According to the neuromuscular effect, Brownstein et al., (2017) revealed that competitive football match-play elicits substantial impairments in central nervous system and muscle function, requiring up to 48 h to resolve in elite football players. Previous studies suggest that match GPS-accelerometry parameters may predict muscle damage and changes in components of neuromuscular performance immediately and 24–48 h post-match in football players (Del Hoyo et al., 2016).

For these reasons, this project could have important implications for fixture scheduling, optimal management of training processes, referee rotation during congested competitive schedules and the implementation of appropriate recovery interventions.

Synthesis to evidence

- Referees achieve similar physical demands to football players, in distance completed (10-12 km), accelerations (70) and sprint actions (38 at> 18km / h).
- There are differences in these demands between field and assistant referees, therefore specific training is recommended based on the demands of each one.
- The competitive level of each match affects the physical demands of the referees, the higher the competitive level, the greater the capacity to face the development of the match.

- The Federation International Football Association (FIFA) has developed a battery of physical fitness tests that match those which must be passed as a prerequisite at each level of competition.
- Currently, elite referees face a high number of matches played due to national and international competitions.
- In football players, research shows that performance and fatigue are not affected by calendar congestion.
- Contextual factors such as the location of the match, the state of the match, the quality of the opponent and environmental conditions, can modulate the physical performance of the football match.
- Literature shows that a peak performance cannot be acquired only with competitions.
- There are no researches on the influence of a congested schedule on elite referees.
- Football matches lead to acute and transient subjective, biochemical, metabolic and physical disorders in referees during the hours and days that follow.
- The magnitude of these disturbances increases within the first 24 h after exercise, peaks between 24 and 48 h, and then disappears and returns to baseline after 72 to 96h.
- Muscle damage and increased levels of intramuscular enzymes such as creatine kinase (CK) and inflammatory markers occur after the competition.
- Competition causes substantial deficiencies in the central nervous system and muscle function
- Match GPS accelerometry parameters can predict muscle damage and changes in components of neuromuscular performance.

5. A REVIEW OF THE PROPOSED RESEARCH DESIGN AND STRATEGY

5.1. Justification of the design

A longitudinal (the physical demands of a Spanish professional football league season) and quasi-experimental study (data collection of weekly periods with various matches) was analyzed and carried out. Weeks are being classified either as normal (one match per week) or as congested (two matches per week with four or fewer days between matches). The post-match recovery strategies used are those traditionally used with football referees. The day after each match, all referees perform static stretching (involving three bilateral sets of 30 s held stretches of the hamstring, quadriceps, gastrocnemius and adductor muscles), receive a whole-body manual massage and immerse their lower body in an alternating cold and hot bath. For diet monitoring, each referee get a meal plan (food and hydration). Referees' baseline measures will be taken 24 h prior to participation in the match (MD-1). Physical, physiological and psychological variables are assessed 30 min (MD) and 24 h (MD+1) during the post-match recovery period. On the other hand, external and internal load are monitored during the match.

Fitness Tests

The Fitness Tests were performed in February according to the Spanish member association rules. The referees and assistant referees were divided in two groups for the statistical analysis to check the influence of fatigue on the results in these tests. All the referees and assistant referees performed the fitness tests at the same time and our research compared the physical performance according to the recovery days regarding the pervious match.

Repeated Sprint Ability Test (RSA)

Referees carried out the RSA test (6 x 40 m). The test consisted of six 40-m sprints. Participants sprinted 40 m at maximum intensity. The deceleration took place one metre after passing the line. After 60 s of active recovery, referees repeated the same procedure. There had to be a gap of 5 seconds before the start of the next sprint, and the researcher carried out the countdown. A system of two pairs of photocells (Microgate, Bolzano, Italy) was placed along the sprint zone, which collected time at 40 m with a sensibility of 0.001 s.

On the other hand, the RSA test of the assistant referees consisted of five 30-m sprints. Participants sprinted 30 m at maximum intensity. After 30 s of active recovery, assistant referees repeated the same procedure. The best time of sprint (RSA_{BEST}) and the mean time (RSA_{MEAN}) were calculated.

Yo-Yo intermittent recovery test

Referees completed a Yo-Yo intermittent recovery test. Individuals wore a heart rate monitor attached to the participants' chest (Polar Team System, Kempele, Finland) and a GPS device on their back. The Yo-Yo intermittent recovery test consists of repeated 2 x 20-m runs back and forth between the starting, turning, and finishing line at a progressively increased speed controlled by audio bleeps from a tape recorder (Krustrup et al., 2003). Between each running bout, the subjects have a 10-s active rest period, consisting of 2 x 5 m of jogging. When the subjects failed to reach the finishing line in time twice, the distance covered is recorded and represents the test result. All the referees had to cover 1800 m (level 18.2) to pass the test.

5.2. Justification of the measurement approach and assumptions about the research topic

This study reveals that specific activities during the match are associated with post-match muscle damage and with decreased performance. These results showed that GPS-accelerometry derived match time–motion parameters (high intensity running, sprint, accelerations, decelerations and impacts) which may predict the likelihood of muscle damage and decreased performance in the 24–48 h after a football match. The results of the study have important implications for fixture scheduling, optimal management of training processes in elite referees and the implementation of appropriate recovery interventions. The results suggested that mental fatigue impairs accuracy and speed of football-specific decision-making during congested match schedules.

5.3. Key variables for quantitative work

- ***Movement Patterns—External Load.*** The GPSs attached to the referees provided information about the total covered distance during the game (DT), the maximum speed (V_{max}), average speed (V_{mean}) and repeated sprint ability (RSA) reached in the 45 and 5-minute intervals, and the distance covered in each 1 of the 6 locomotor categories with speed ranges adapted from previous studies: standing (0–6 km·h^{-1}), walking (6–12 km·h^{-1}), easy running (12–18 km·h^{-1}), fast running (18–21 km·h^{-1}), high-speed running (21–24 km·h^{-1}), and sprinting (>24 km·h^{-1}). The actions above 18 km·h^{-1} (fast running, high-speed running, and sprinting) were grouped and defined as high intensity running. The absolute (m) and relative (%) distances with respect to the total covered distances were selected for analysis. The GPS software also provided information about the number, distance average, and maximum speed average of the sprints. In the same way, the GPS devices registered the maximum acceleration peaks and the number of accelerations of the players in different ranges of intensity used in previous research: 1.5–2; 2–2.5; 2.5–2.75; and >2.75 $m \cdot s^{-2}$. The data of reaction time jumps and maximum peak and number of impacts during the game were obtained using a 3D accelerometer 100G recording at 1000 Hz incorporated to each one of the GPSs. Finally, this study included the positional data (events with XY coordinates of referees) with the Geographical Information System (GIS) and work:rest ratio, which results from the quotient between the covered distance at speeds above 4 $km \cdot h^{-1}$ (work phase) and the covered distance by the player at speeds below 4 $km \cdot h^{-1}$ (rest phase).

- ***Heart Rate Parameters—Internal Load.*** The HR_{max} value obtained in the intermittent recovery Yo-Yo test was taken as a reference value to establish different categories of intensity defined in previous research: 50-60 % HR_{max}, 60-70 % HR_{max}, 70-80 % HR_{max} 80–90% HR_{max}, 90–95% HR_{max}, and >95% HR_{max}. The GPS software synchronized with the HR bands registered the time used by referees in each one of the zones described. The data was presented as relative percentages in relation to the total played time. Differently, the peak and average values of heart rate reached during the game and 5-minute intervals was presented in absolute ($b \cdot min^{-1}$) and relative (% HR_{max}) terms.
- ***Psychological parameters.*** The Hooper questionnaire is being used to monitor the well-being status of referees. The 7-point scale version of the questionnaire was used to analyse four categories: (i) muscle soreness (DOMS), (ii) fatigue, (iii) stress, and (iv) sleep. On this scale, 1 means ‘very, very low,’ and 7 means ‘very, very high’ for the DOMS, fatigue, and stress variables. For the variable of sleep, a rating of 1 means ‘very, very good,’ and a rating of 7 means ‘very, very bad.’ After obtaining the ratings, the Hooper index was calculated based on the sum of the ratings given for all four categories.
- ***Physical parameters.*** Countermovement jump (CMJ) height and kinetic parameters were assessed using a force platform (NMP Technologies Ltd., ForceDecks model FD4000a, London, UK) with a sampling rate of 1000 Hz. Referees performed five CMJ’s with 60 s rest between each jump. The variables included within the analysis were: average concentric force (CMJ_{CON}), average eccentric force (CMJ_{ECC}) and jump

height (CMJ_H). The best and the worst scores (according to concentric peak velocity) were removed and the mean of the remaining three CMJ's was used in subsequent analysis.

- ***Physiological parameters:*** Plasma CK was taken 24 h pre-match and 30 min and 24 h post-match from 30 µl capillarised whole-blood samples collected via fingertip puncture made using a spring-loaded single use disposable lancet. Samples were centrifuged (Hereaus Function Line, Labofuge 400, Kendro Laboratory Products, Hanau, Germany) at 3000 rpm for 10 min and analysed using a Reflotron spectrophotometer (Abbott Architect, Abbott Park, IL, USA) via an optimised UV test. Cortical arousal activity was measured using the Critical Flicker Fusion Threshold (CFFT). Referees were seated in front of a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12021), which was constructed to control extraneous factors that might distort CFFT values. Two light-emitting diodes (58 cd/m^2) were presented simultaneously in the viewing chamber, one for the left eye and one for the right eye. The stimuli was separated by 2.75 cm (centre to centre) with a stimulus-to-eye distance of 15 cm and a viewing angle of 1.9°. The inside of the viewing chamber was painted matte black to minimize reflection. After a fovea binocular fixation, referees were required to respond by pressing a button upon identifying the visual flicker (descending frequency) and the fusion (ascending frequency) thresholds. Referees carried out the test three times with an interval of five seconds. CFFT was considered the average of values obtained in the ascending and descending tests. An increase in CFFT suggested an increase in cortical arousal and information processing; a decrease in CFFT values below the baseline reflected a reduction in the efficiency of information processing and central nervous system fatigue. Lower body muscular strength manifestation was evaluated employing a horizontal jump test; referees performed two maximal horizontal jumps as a previous report informed, and the best attempt was used for the statistical analysis (Clemente-Suárez & Díaz-Manzano, 2019); Isometric Hand Strength (IHS) was measured using a grip dynamometer (Takei Kiki Koyo, Tokyo, Japan); and spirometry variables of forced vital capacity (FVC), volume exhaled at the end of the first second of forced expiration (FEV1) and the peak expiratory flow (PEF) using a QM-SP100

(Quirumed, Spain) spirometer in a maximum inhale−exhale cycle, according to previous research

5.4. Sample frame and size

Forty-two (n=42) elite football referees and eighty-four (n=84) assistant referees from the Committee of football Referees in Spain (35.88 ± 4.36 years; 182.4 ± 5.02 cm; 75.15 ± 4.42 kg) have been selected for the study (Spanish first and second division). The referees have at least 10 years of officiating experience, with a minimum of 6 years at national competition level in Spain. All referees are training at least three times a week focusing on strength, endurance and speed capacities and will be involved in refereeing in first division.

5.5. An outline of the hypothesis addressed, the analysis strategy and techniques used, and the strength and significance of the results

Results have been presented in form of text, tables, and figures as either means with standard deviation (SD) or means with a 90% confidence interval (90% CI) where specified. A two way analysis of the variance (ANOVA) has been applied to analyze the differences between first and second division and the different competitions (national and international). The purpose of this analysis has been to know the physical demands of the referees to analyse the effect of fatigue in the second part of the project. The differences were analysed using standardized differences of effect size (ES) with a 90% CI. The following interpretation of ES was used: <0.2 = trivial; 0.2-0.6 = small; 0.6-1.2 = moderate; >1.2 = large. Probabilities were calculated considering the smallest worthwhile changes (SWC, 0.2 × between-subjects SD). The scale for qualitative probabilities were as follows: 25-75% = possible; 75-95% = likely; 95-99% = very likely; >99% = almost certain. Pearson's correlation analysis was used to assess the associations between GPS-accelerometry parameters and heart rate variables. The criteria adopted to categorize the magnitude of the correlation (r) between the different measures were: ≤0.1, trivial; >0.1–0.3, small; >0.3–0.5, moderate; >0.5–0.7, large; >0.7–0.9, very large; and >0.9–1.0, almost perfect (Hopkins et al., 2009).

5.6. The validity and reliability of the instruments

Global Positioning System (GPS)

This system is considered a valid instrument to collect physiological parameters in elite football (Mallo, Mena, Nevado, & Paredes, 2015) during training and matches, with computerized semi-automatic tracking systems also being used to collect physical performance variables (Castellano, Álvarez-Pastor, & Bradley, 2014). Recently, a validation of a semi-automatic tracking system to analyse the physical demands during matches in the Spanish League was published by the research team of this project (Felipe et al., 2019).

Hooper questionnaire (RPE-Scale)

RPE (Rating of Perceived Exertion) scale from 1 to 10 was validated previously to quantify internal training load in professional football (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004).

Force platform to assess horizontal jump

This system was validated previously to analyse the distance in horizontal jumps (Aladro Gonzalvo, Esparza Yanez, Tricás Moreno, Lucha López, 2017).

5.7. An overview of any ethical issues and how they are addressed

Participants have been informed of the procedures, methods, benefits, and possible risks involved in the study before giving their written consent. This investigation is being performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the European University (CIPI17/19).

6. MAIN RESEARCH FINDINGS

Influence of the category and competition

- <u>Fitness Tests</u>

No differences were found between first and second division referees in the physical and physiological variables during the RSA and YoYo Test ($p>0.05$; Table 1).

Table 1. Physical and physiological demands of Repeated Sprint Ability and YY Intermittent Endurance Test in first and second division referees

	RSA Test (6 x 40 m)		YY Intermittent Test	
	First division	Second division	First Division	Second Division
Acceleration (n)	265.25 ± 57.41	266.00 ± 23.56	344.63 ± 36.96	358.74 ± 40.82
Decelerations (n)	265.75 ± 57.09	265.89 ± 23.59	344.75 ± 36.97	359.05 ± 40.95
ACC_{MAX} ($m·s^{-2}$)	4.72 ± 0.54	4.97 ± 0.46	4.46 ± 0.32	4.48 ± 0.31
DEC_{MAX} ($m·s^{-2}$)	-2.94 ± 0.53	-3.41 ± 0.56	-5.42 ± 0.54	-5.27 ± 0.60
V_{MAX} ($km·h^{-1}$)	32.69 ± 2.66	32.20 ± 1.59	21.94 ± 1.19	22.73 ± 1.54
HR_{MAX} (b.p.m)	161.33 ± 4.03	160.89 ± 10.84	173.33 ± 6.53	179.05 ± 9.55
HR_{MEAN} (b.p.m)	142.50 ± 6.28	144.37 ± 12.25	163.17 ± 5.04	166.21 ± 10.46
HR_{MEAN} (%)	71.25 ± 3.14	72.18 ± 6.13	81.58 ± 2.52	83.11 ± 5.23
$HR_{50-60\%}$ (%)	6.39 ± 5.84	7.96 ± 16.18	1.57 ± 1.40	1.37 ± 1.51
$HR_{60-70\%}$ (%)	31.88 ± 15.92	30.66 ± 21.00	4.71 ± 1.61	5.10 ± 5.74
$HR_{70-80\%}$ (%)	55.39 ± 18.57	45.64 ± 21.12	20.83 ± 14.08	20.59 ± 18.53
$HR_{80-90\%}$ (%)	5.57 ± 8.62	15.07 ± 18.94	71.55 ± 11.96	58.53 ± 26.00
$HR_{90-95\%}$ (%)	-	-	1.33 ± 3.26	10.47 ± 17.88
$HR_{95-100\%}$ (%)	-	-	-	3.60 ± 15.13
Player Load (a.u.)	10.14 ± 4.44	9.76 ± 3.42	37.14 ± 13.16	37.73 ± 13.06
Player Load (a.u. · min^{-1})	1.74 ± 0.61	1.63 ± 0.57	2.48 ± 0.88	2.51 ± 0.87
Power Metabolic ($W·kg^{-1}$)	1935.64 ± 499.21	2021.18 ± 106.00	6909.84 ± 440.76	6764.01 ± 409.87
Power Metabolic mean ($W·kg^{-1}$)	12.46 ± 0.71	12.20 ± 0.59	16.45 ± 1.07	15.74 ± 1.04
Power Metabolic ($W·kg^{-1}·min^{-1}$)	330.37 ± 29.36	338.71 ± 17.39	461.16 ± 29.87	449.82 ± 28.69
HMLD (m)	253.80 ± 62.90	268.19 ± 10.77	912.62 ± 147.77	914.15 ± 153.02
Energy_Expenditure (kcal)	61.18 ± 16.68	61.37 ± 9.81	274.50 ± 24.21	267.89 ± 27.33
Energy_Expenditure ($kcal·min^{-1}$)	10.52 ± 1.44	10.28 ± 1.65	18.32 ± 1.62	17.82 ± 1.85
DSL (a.u.)	192.08 ± 238.03	108.92 ± 149.85	357.74 ± 538.36	373.64 ± 560.19
DSL (a.u. · min^{-1})	32.17 ± 37.72	18.22 ± 24.93	23.88 ± 35.92	24.91 ± 37.40

HR: Heart Rate; HMLD: High Metabolic Load Distance; DSL: Dynamic Stress Load

The average of the RSA times (6 x 40 m) revealed significant differences between first and second division referees. First division referees showed lower mean times in the test in comparison to second division referees (- 0.09 s; CI 95%: -0.18 to 0.01; ES: 0.65; $p<0.05$; Figure 1).

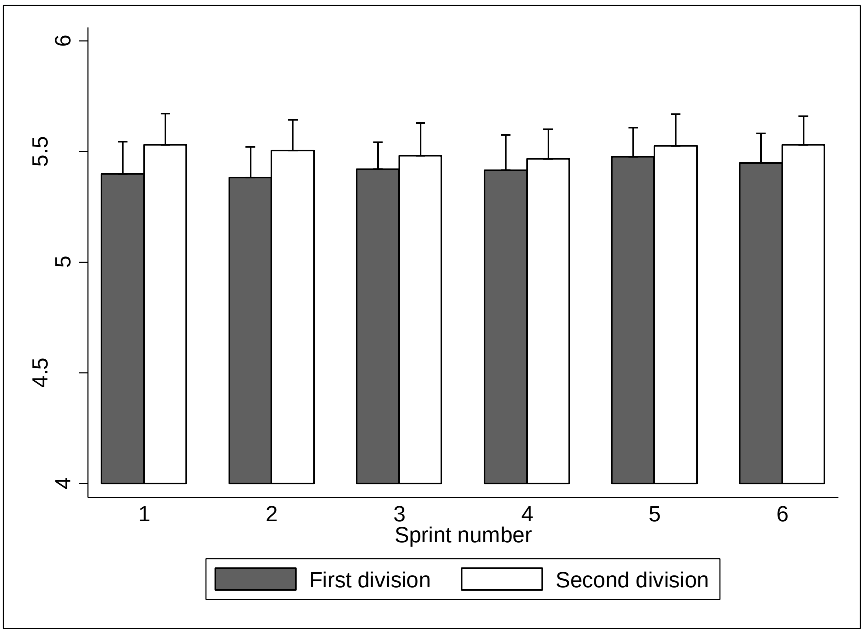

Figure 1. Sprint times of the RSA test (6×40 m) in first and second division referees.

No significant differences were found between first and second division assistant referees in the RSA test (5 x 30 m). Sprint times were similar between both categories ($p>0.05$; Figure 2).

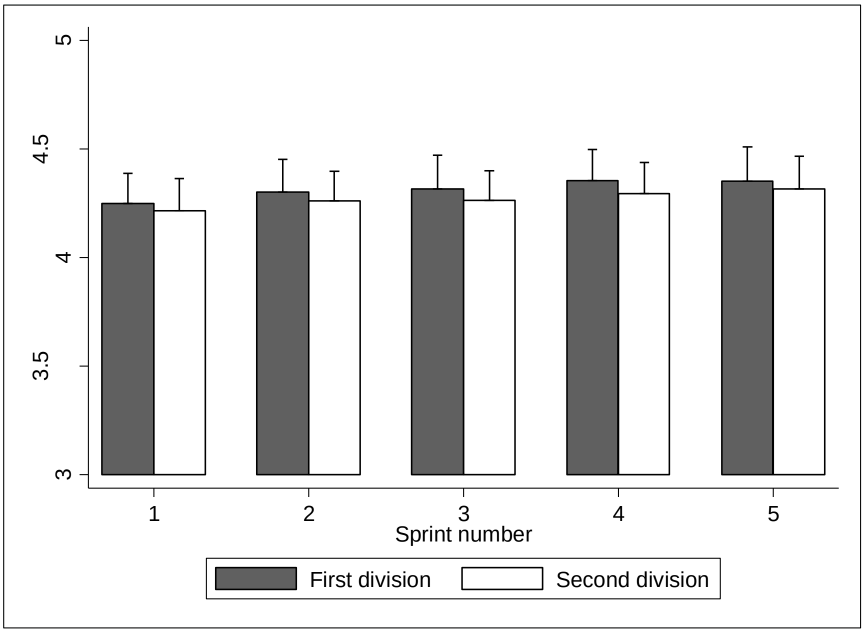

Figure 2. Sprint times of the RSA test (5×30 m) in first and second division referees.

- <u>Competition</u>

The analysis of the variance between the physical and physiological demands of first and second division referees during the match revealed significant differences in some parameters ($p<0.05$; Table 2). First division referees showed a higher number of accelerations (+74.12; CI95%: 15.11 to 133.13; ES: 0.27) and deceleration (+74.31; CI95%: 15.27 to 133.34; ES: 0.28). Also, the peak of acceleration (+0.19 $m \cdot s^{-2}$; CI95%: 0.03 to 0.37; ES: 0.25) and deceleration (+0.17 $m \cdot s^{-2}$; CI95%: 0.02 to 0.33; ES: 0.24) was higher in the first division referees. However, first division referees evidenced a lower HR_{MAX} (-7.99 b.p.m; CI95%: -10.10 to -5.89; ES: 0.89), HR_{MEAN} (-7.07 b.p.m; CI95%: -9.86 to -4.29; ES: 0.59) and RPE (-0.60; CI95%: -0.94 to -0.26; ES: 0.45) during the match in comparison to second division referees ($p<0.05$).

Table 2. Covered distance, heart rate and load indicators values during the match in first and second division referees

	First Division	Second Division
Total Distance (m)	10417.50 ± 860.09	10420.36 ± 729.10
Accelerations (n)	2813.02 ± 274.66*	2738.89 ± 265.56
Decelerations (n)	2813.16 ± 274.49*	2738.85 ± 265.83
Accelerations ($n \cdot min^{-1}$)	57.20 ± 4.74	56.62 ± 5.00
Decelerations ($n \cdot min^{-1}$)	57.21 ± 4.73	56.62 ± 5.01
ACC_{MAX} ($m \cdot s^{-2}$)	4.63 ± 0.94*	4.43 ± 0.65
DEC_{MAX} ($m \cdot s^{-2}$)	-5.36 ± 0.80*	-5.19 ± 0.64
Sprint Distance (m)	212.98 ± 121.08	209.07 ± 105.51
Sprint Distance ($m \cdot min^{-1}$)	10.01 ± 5.43	9.88 ± 4.57
V_{MAX} ($km \cdot h^{-1}$)	28.76 ± 2.06	28.56 ± 1.82
HR_{MAX} (b.p.m)	171.60 ± 9.15*	179.59 ± 8.91
HR_{MEAN} (b.p.m)	146.63 ± 11.79*	153.70 ± 12.00
HR_{MEAN} (%)	83.26 ± 5.34	82.96 ± 5.85
RPE (a.u.)	7.22 ± 1.38*	7.82 ± 1.27

* Significant differences between first and second division referees ($p<0.05$); HR: Heart Rate; $V_{MAX:}$ Maximum Speed; RPE: Rating of Perceived Exertion

The total distance was similar between categories ($p>0.05$). However, the distance covered in the different speed ranges was significantly different between first and second division referees ($p<0.05$). Second division referees covered higher easy [12-18 $km \cdot h^{-1}$] (+ 211.70 m; CI95%: 103.25 to 320.16; ES: 0.42), fast [18-21 $km \cdot h^{-1}$] (+ 63.38 m; CI95%: 30.99 to 95.78; ES: 0.42) and high-speed running [21-24 $km \cdot h^{-1}$] (+ 21.45 m; CI95%: 0.08 to 82.41; ES: 0.22) during the match. The sprint distance [+24 $km \cdot h^{-1}$] was similar between first and second division ($p>0.05$).

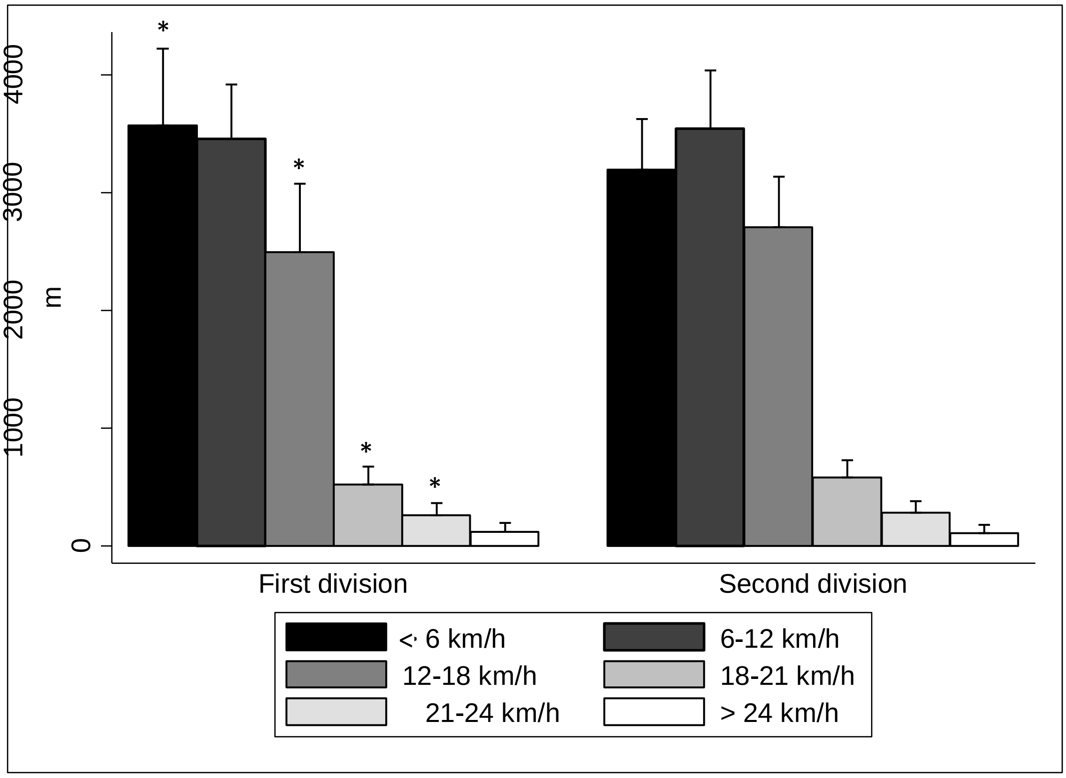

Figure 3. Activity profile during the match in first and second division referees, expressed as the total distance covered in different locomotor categories including standing (St;<6 km·h^{-1}), walking (W; 6-12 km·h^{-1}), easy running (ER; 12-18 km·h^{-1}), fast running (FR; 18-21 km·h^{-1}), high-speed running (HSR; 21-24 km·h^{-1}) and sprinting (Sp; >24 km·h^{-1})

On the other hand, first division referees showed differences in the distance covered according to the competition (p<0.05; Figure 4). The most important result was a lower high-speed distance covered in the national competitions (Spanish League and Cup) in comparison to UEFA Champions League and national team matches (p<0.05). The first division referees covered less sprint distance (>24 km·h^{-1}) in the Spanish league games in comparison to UCL (-78.28 m; CI95%: -134.03 to -22.52; ES: 0.92) and national team matches (-103.41 m; CI95%: -159.16 to -47.66; ES: 0.83). In the same way, the sprint distance during the Spanish Cup matches was lower than the distance covered in the UEFA Champions League (-99.43 m; CI95%: -163.34 to -35.53; ES: 1.14; p<0.001) and the national team matches (-124.57 m; CI95%: -188.48 to -60.66; ES: 0.98; p<0.001). The comparison between international competitions revealed higher sprint distance in UCL (+ 85.48 m; CI95%: 7.46 to 163.49; ES: 1.01) and national team matches (+ 110.61 m; CI95%: 32.60 to 188.63; ES: 0.89) in comparison to UEFA Europa League (p<0.05).

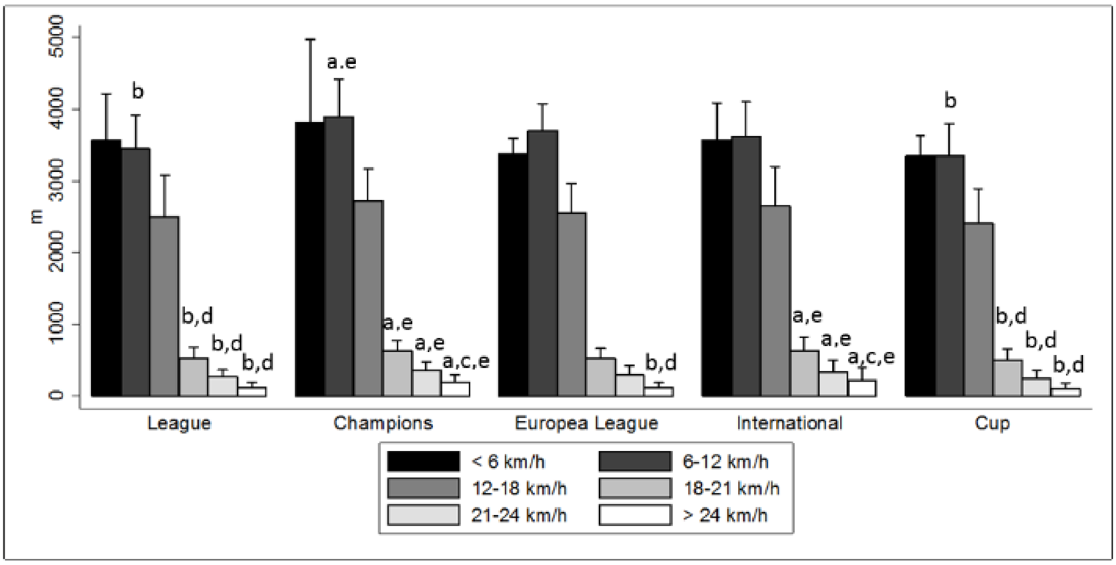

Figure 4. Activity profile during the match in different competitions (Spanish League [a], UEFA Champions League [b], UEFA Europa League [c], National-team matches [d] and Spanish Cup [e]), expressed as the total distance covered in different locomotor categories including standing (St;<6 km·h^{-1}), walking (W; 6-12 km·h^{-1}), easy running (ER; 12-18 km·h^{-1}), fast running (FR; 18-21 km·h^{-1}), high-speed running (HSR; 21-24 km·h^{-1}) and sprinting (Sp; >24 km·h^{-1}). [a,b,c,d,e] Significant differences between competitions

The results evidenced a higher total distance covered in the UEFA Champions League matches in comparison to Spanish League (+ 1186.52 m; CI95%: 614.16 to 1758.89; ES: 1.05), UEFA Europa League (+ 1054.25 m; CI95%: 253.32 to 1855.19; ES: 0.94) and Spanish Cup (+ 1646.24 m; CI95%: 990.13 to 2302.35; ES: 1.53) matches. Similar evidences were found in the matches between national teams (11045.10 ± 867.35 m). On the other hand, the number of accelerations and decelerations performed by the referees were similar in all the competitions (p>0.05; Table 3). However, the highest acceleration peak was found in UEFA Champions League (5.08 ± 1.05 m·s^{-2}). On the contrary, the lowest acceleration peak was evidenced in the Spanish Cup matches (4.13 ± 0.52 m·s^{-2}). In the same way, the maximum speed revealed during the matches was higher in the UEFA Champions League than in the Europa League (+ 2.13 km·h^{-1}; CI95%: 0.29 to 3.98; ES: 1.16; p<0.05) and Spanish Cup (+ 1.97 km·h^{-1}; CI95%: 0.46 to 3.49; ES: 0.92; p<0.05) games. The Heart Rate values of the referees showed a lower internal load (%HR_{MEAN}) in the national-team matches in comparison to Spanish League (-5.21 %; CI95%: -8.06 to -2.36; ES: 0.70), UEFA Champions League (-8.45 %; CI95%: -13.41 to -3.49; ES: 1.07) and UEFA Europa League (-5.81 %; CI95%: -10.78 to -0.85; ES: 0.69) games (p<0.05). However, the referees indicated a lower Rating of Perceived Exertion (RPE) after the Spanish Cup matches (6.48 ± 1.29).

Table 3. Covered distance, heart rate and load indicator values during the match in Spanish League (a), UEFA Champions League (b), UEFA Europa League (c), National-Team games (d) and Spanish Cup (e).

	League (a)	Champions (b)	Europa League (c)	National-Team (d)	Spanish Cup (e)
Total Distance (m)	10417.50 ± 860.09[b,d,e]	11604.02 ± 1401.71[a,c,e]	10549.77 ± 852.80[b,e]	11045.10 ± 867.35[a,e]	9957.78 ± 754.43[a,b,d]
Accelerations (n)	2813.02 ± 274.66	2847.30 ± 200.21	2702.67 ± 130.12	2805.70 ± 286.73	2814.25 ± 132.17
Decelerations (n)	2813.16 ± 274.49	2848.40 ± 199.26	2703.56 ± 130.08	2805.60 ± 285.98	2814.00 ± 131.63
Accelerations ($n·min^{-1}$)	57.20 ± 4.74	56.91 ± 3.08	55.68 ± 2.77	56.41 ± 5.39	58.51 ± 2.73
Decelerations ($n·min^{-1}$)	57.21 ± 4.73	56.93 ± 3.07	55.70 ± 2.76	56.40 ± 5.37	58.50 ± 2.71
ACC_{MAX} ($m·s^{-2}$)	4.63 ± 0.94[e]	5.08 ± 1.05[e]	4.44 ± 0.73	4.83 ± 0.96[e]	4.13 ± 0.52[a,b,d]
DEC_{MAX} ($m·s^{-2}$)	-5.36 ± 0.80[e]	-5.34 ± 0.61	-5.69 ± 1.40[e]	-5.63 ± 1.26	-5.04 ± 0.64[a,c]
Sprint Distance (m)	212.98 ± 121.08[b,d]	334.26 ± 144.89[a,c,e]	201.24 ± 116.95[b,d]	367.96 ± 248.81[a,c,e]	174.58 ± 118.63[b,d]
Sprint Distance ($m·min^{-1}$)	10.01 ± 5.43[b,d]	16.60 ± 6.92[a,c,e]	10.56 ± 5.17[b,d]	16.40 ± 9.62[a,c,e]	8.08 ± 5.43[b,d]
V_{MAX} ($km·h^{-1}$)	28.76 ± 2.06	30.00 ± 2.24[c,e]	27.86 ± 1.45[b]	29.12 ± 1.97	28.03 ± 2.05[b]
HR_{MAX} (b.p.m)	171.60 ± 9.15[d]	173.56 ± 5.64[d]	178.00 ± 9.38[d,e]	157.80 ± 25.90[a,b,c,e]	168.33 ± 10.09[c,d]
HR_{MEAN} (b.p.m)	146.63 ± 11.79[d,e]	150.61 ± 10.16[d,e]	152.17 ± 15.02[d,e]	134.00 ± 26.23[a,b,c]	138.77 ± 13.35[a,b,c]
HR_{MEAN} (%)	83.26 ± 5.34[d,e]	86.50 ± 4.12[d,e]	83.86 ± 7.29[d,e]	76.03 ± 15.42[a,b,c]	78.05 ± 5.64[a,b,c]
RPE (a.u.)	7.22 ± 1.38[b,e]	8.57 ± 0.79[a,e]	8.00 ± 1.00	7.80 ± 0.92[e]	6.48 ± 1.29[a,b,d]

[a,b,c,d,e] Significant differences between competitions; HR: Heart Rate; $V_{MAX:}$ Maximum Speed; RPE: Rating of Perceived Exertion

Influence of fatigue (First vs Second Half)

- <u>Category</u>

The influence of fatigue on the physical variables can reduce the performance of the referees during the second half of the match (p<0.05; Table 4). However, first division referees only showed an increment in the number of accelerations (+ 84.01; CI95%: 48.09 to 119.94; ES: 0.57) and decelerations (+ 84.30; CI95%: 48.37 to 120.24; ES: 0.57) in the second half, probably due to the contextual variables of the game. Similar results were revealed in second division referees (p<0.05). The main decrements found between the first and second half in the physical performance were evidenced in the second division referees (p<0.05). The maximum deceleration (-0.17 $m \cdot s^{-2}$; CI95%: -0.30 to -0.03; ES: 0.25), the sprint distance per minute (-0.53 $m \cdot min^{-1}$; CI95%: -1.08 to 0.02; ES: 0.19) and the HR_{MEAN} (-1.71 %; CI95%: -2.99 to -0.43; ES: 0.27) were significantly lower in the second half *(p*<0.05).

Table 4. Covered distance, heart rate and load indicator values in the first and second half of both first and second division referees.

	First division		Second division	
	First half	Second half	First half	Second half
Total Distance (m)	5182.11 ± 449.06	5264.91 ± 454.62	5219.56 ± 370.49	5215.10 ± 462.99
Accelerations (n)	1367.66 ± 161.88*	1451.67 ± 134.59	1333.00 ± 132.59*	1410.12 ± 155.35
Decelerations (n)	1367.58 ± 161.69*	1451.88 ± 134.51	1332.94 ± 132.50*	1410.11 ± 155.73
Accelerations ($n \cdot min^{-1}$)	28.27 ± 2.69	28.85 ± 2.35	28.09 ± 2.60	28.53 ± 2.70
Decelerations ($n \cdot min^{-1}$)	28.27 ± 2.69	28.86 ± 2.35	28.09 ± 2.60	28.53 ± 2.71
ACC_{MAX} ($m \cdot s^{-2}$)	4.26 ± 0.70	4.25 ± 0.96	4.18 ± 0.56	4.11 ± 0.64
DEC_{MAX} ($m \cdot s^{-2}$)	-5.02 ± 0.79	-4.93 ± 0.81	-4.93 ± 0.72*	-4.76 ± 0.61
Sprint Distance (m)	107.62 ± 71.22	106.18 ± 72.13	108.23 ± 66.01	101.20 ± 62.42
Sprint Distance ($m \cdot min^{-1}$)	5.02 ± 3.14	5.03 ± 3.09	5.21 ± 2.96*	4.68 ± 2.61
V_{MAX} ($km \cdot h^{-1}$)	27.79 ± 2.21	27.71 ± 2.21	27.85 ± 1.96	27.49 ± 2.02
HR_{MAX} (b.p.m)	170.18 ± 9.42	169.41 ± 9.15	178.35 ± 9.15	176.69 ± 13.03
HR_{MEAN} (b.p.m)	147.12 ± 11.75	146.23 ± 14.30	155.28 ± 11.64*	152.06 ± 14.14
HR_{MEAN} (%)	83.57 ± 5.68	83.03 ± 6.66	83.83 ± 5.76*	82.12 ± 7.00

*Significant differences between first and second half; HR: Heart Rate; V_{MAX}: Maximum Speed

No significant differences were identified between the first and second half in the distances covered in the different speed zones (p>0.05; Figure 5), only the walking distance [0-6 $km \cdot h^{-1}$] was significantly higher in the second half in first (+76.92 m; CI95%:

7.80 to 146.05; ES: 0.22) and second (+66.27 m; CI95%: 13.22 to 119.32; ES: 0.29) division referees (p<0.05).

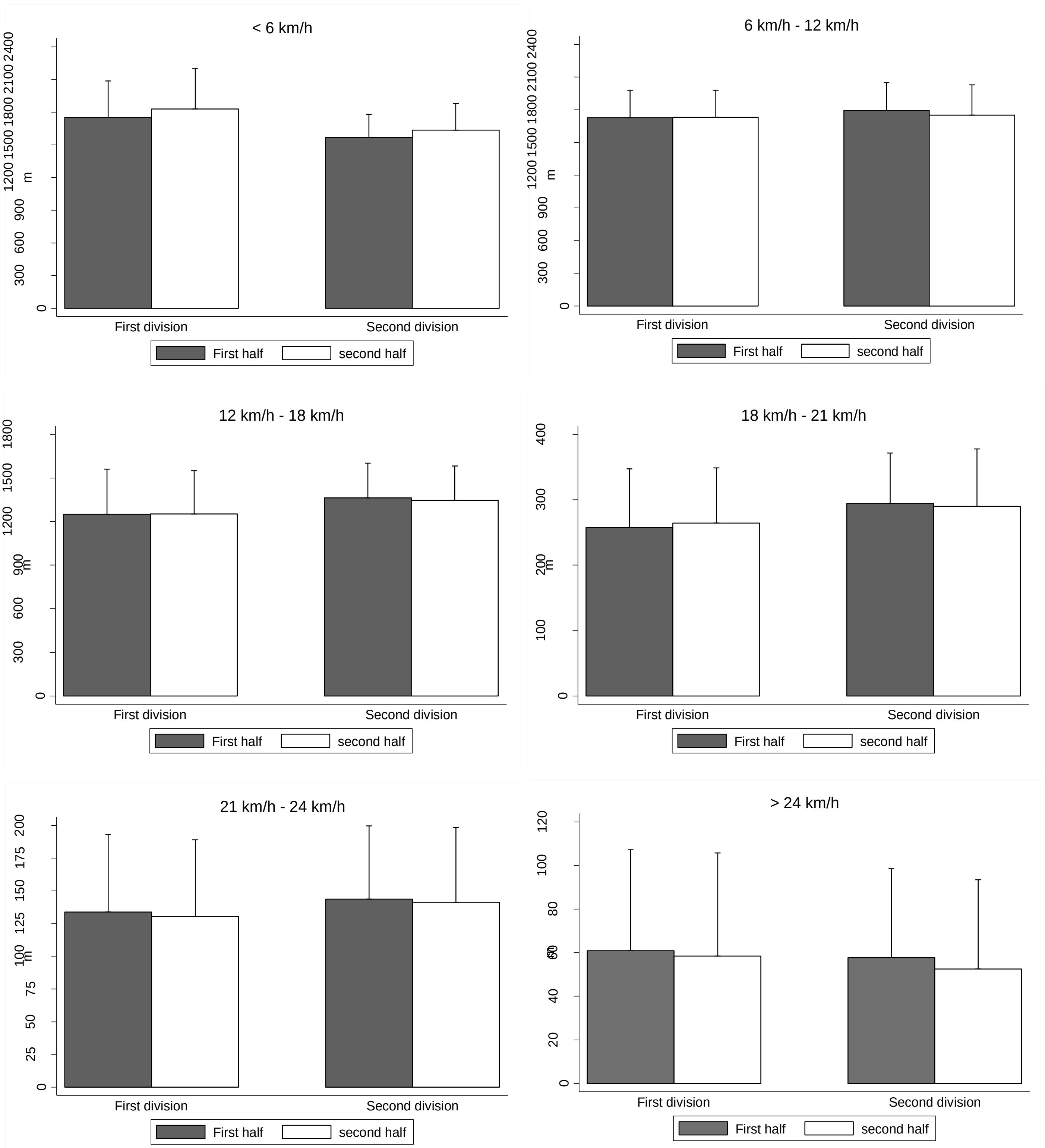

Figure 5. Activity profile of first and second division referees, expressed as the total distance covered in different locomotor categories during the first and the second half of the match.

- Competition

Regarding the competition, the referees performed a higher number of accelerations in the second half during Spanish League (+ 84.01; CI95%: 49.69 to 118.34; ES: 0.56; Table 5), UEFA Champions League (+ 128.90; CI95%: 6.34 to 251.46; ES: 1.05) and national-team (+ 128.50; CI95%: 5.94 to 251.06; ES: 0.84) games. However, the relative number of accelerations and decelerations per minute was only higher in the second half during the Spanish League matches (ACC: + 0.59; CI95%: 0.004 to 1.17; ES: 0.23; DEC: + 0.59; CI95%: 0.01 to 1.17; ES: 0.23). These results suggest that the higher duration of the second half, caused by substitutions could be the reason of a higher number of accelerations and decelerations.

The internal load did not reveal differences in most of the analysed competitions ($p>0.05$). The referees showed a significant decrement in the heart rate peak (-13.43 b.p.m; CI95%: -23.20 to -3.66; ES: 0.74) and the heart rate mean in absolute terms (-12.98 b.p.m; ; CI95%: -25.81 to -0.14; ES: 0.62) and relative (-7.95 %; CI95%: -14.11 to -1.79; ES: 0.69) during the second half in the National-team matches, probably related to fatigue in these kind of matches ($p<0.05$). The referees did not evidence any significant decrement of the internal load during the second half in the rest of the competitions ($p>0.05$).

Table 5. Covered distance, heart rate and load indicator values in the first and second half of first division referees according to the competition

	League	Champions	Europa League	National-Team	Spanish Cup
First half					
Total Distance (m)	5182.11 ± 449.06	5814.78 ± 1009.34	5317.75 ± 467.21	5583.22 ± 466.59	5013.46 ± 408.57
Accelerations (n)	1367.66 ± 161.88*	1359.20 ± 132.45*	1321.56 ± 74.76	1338.60 ± 170.08*	1383.79 ± 76.81
Decelerations (n)	1367.58 ± 161.69*	1359.20 ± 131.47*	1322.44 ± 75.17	1339.10 ± 169.73*	1383.88 ± 76.55
Accelerations ($n \cdot min^{-1}$)	28.27 ± 2.69	27.87 ± 2.01	27.69 ± 1.52	27.60 ± 3.04	29.10 ± 1.38
Decelerations ($n \cdot min^{-1}$)	28.27 ± 2.69*	27.87 ± 1.99	27.72 ± 1.53	27.61 ± 3.04	29.10 ± 1.37
ACC_{MAX} ($m \cdot s^{-2}$)	4.26 ± 0.70	4.77 ± 1.11	4.25 ± 0.39	4.16 ± 0.43	3.96 ± 0.53
DEC_{MAX} ($m \cdot s^{-2}$)	-5.02 ± 0.79	-5.03 ± 0.45	-4.93 ± 0.37	-5.30 ± 1.18	-4.78 ± 0.77
Sprint Distance (m)	107.62 ± 71.22	181.91 ± 73.31	103.99 ± 79.41	187.72 ± 139.62	88.01 ± 63.62
Sprint Distance ($m \cdot min^{-1}$)	5.02 ± 3.14	9.20 ± 3.58	5.44 ± 3.91	8.30 ± 5.12	3.92 ± 2.80
V_{MAX} ($km \cdot h^{-1}$)	27.79 ± 2.21	29.39 ± 2.57	27.60 ± 1.47	28.64 ± 2.00	27.42 ± 2.25
HR_{MAX} (b.p.m)	170.18 ± 9.42	173.00 ± 5.77	177.67 ± 9.03	168.63 ± 11.16*	167.21 ± 11.45
HR_{MEAN} (b.p.m)	147.12 ± 11.75	153.89 ± 9.48	151.56 ± 12.25	145.88 ± 15.38*	140.21 ± 12.37
HR_{MEAN} (%)	83.57 ± 5.68	88.40 ± 3.46	83.54 ± 5.95	83.34 ± 7.48*	78.89 ± 5.28
Second half					
Total Distance (m)	5264.91 ± 454.62	5789.24 ± 601.05	5232.01 ± 441.65	5461.88 ± 462.71	4944.33 ± 436.19
Accelerations (n)	1451.67 ± 134.59	1488.10 ± 113.16	1381.11 ± 77.93	1467.10 ± 137.64	1430.46 ± 108.70
Decelerations (n)	1451.88 ± 134.51	1489.20 ± 113.28	1381.11 ± 78.16	1466.50 ± 136.87	1430.13 ± 108.73
Accelerations ($n \cdot min^{-1}$)	28.85 ± 2.35	29.03 ± 1.42	27.98 ± 1.32	28.81 ± 2.62	29.41 ± 1.67
Decelerations ($n \cdot min^{-1}$)	28.86 ± 2.35	29.06 ± 1.43	27.98 ± 1.31	28.79 ± 2.60	29.40 ± 1.67
ACC_{MAX} ($m \cdot s^{-2}$)	4.25 ± 0.96	4.55 ± 0.87	4.10 ± 0.78	4.55 ± 1.12	3.98 ± 0.49
DEC_{MAX} ($m \cdot s^{-2}$)	-4.93 ± 0.81	-4.93 ± 0.80	-5.36 ± 1.61	-5.29 ± 0.94	-4.65 ± 0.61
Sprint Distance (m)	106.18 ± 72.13	152.34 ± 94.17	97.25 ± 68.55	180.25 ± 123.29	86.57 ± 71.92
Sprint Distance ($m \cdot min^{-1}$)	5.03 ± 3.09	7.40 ± 4.33	5.11 ± 3.41	8.10 ± 5.00	4.17 ± 3.57
V_{MAX} ($km \cdot h^{-1}$)	27.71 ± 2.21	28.56 ± 1.97	26.71 ± 1.74	28.35 ± 1.79	26.94 ± 2.22
HR_{MAX} (b.p.m)	169.41 ± 9.15	169.44 ± 8.89	173.78 ± 13.68	155.20 ± 25.08	164.96 ± 11.23
HR_{MEAN} (b.p.m)	146.23 ± 14.30	147.33 ± 11.08	152.78 ± 18.40	132.90 ± 26.04	137.33 ± 14.69
HR_{MEAN} (%)	83.03 ± 6.66	84.60 ± 4.91	84.18 ± 9.01	75.39 ± 15.26	77.21 ± 6.31

*Significant differences between the first and second half; HR: Heart Rate; $V_{MAX:}$ Maximum Speed

There were no differences between the distances covered in the different speed zones for the referees in the analysed competitions ($p>0.05$; Figure 6). Nonetheless, the highest decrement in the sprint distance (+24 km·h^{-1}) was identified in the UEFA Champions League during the second half (-26.35 m).

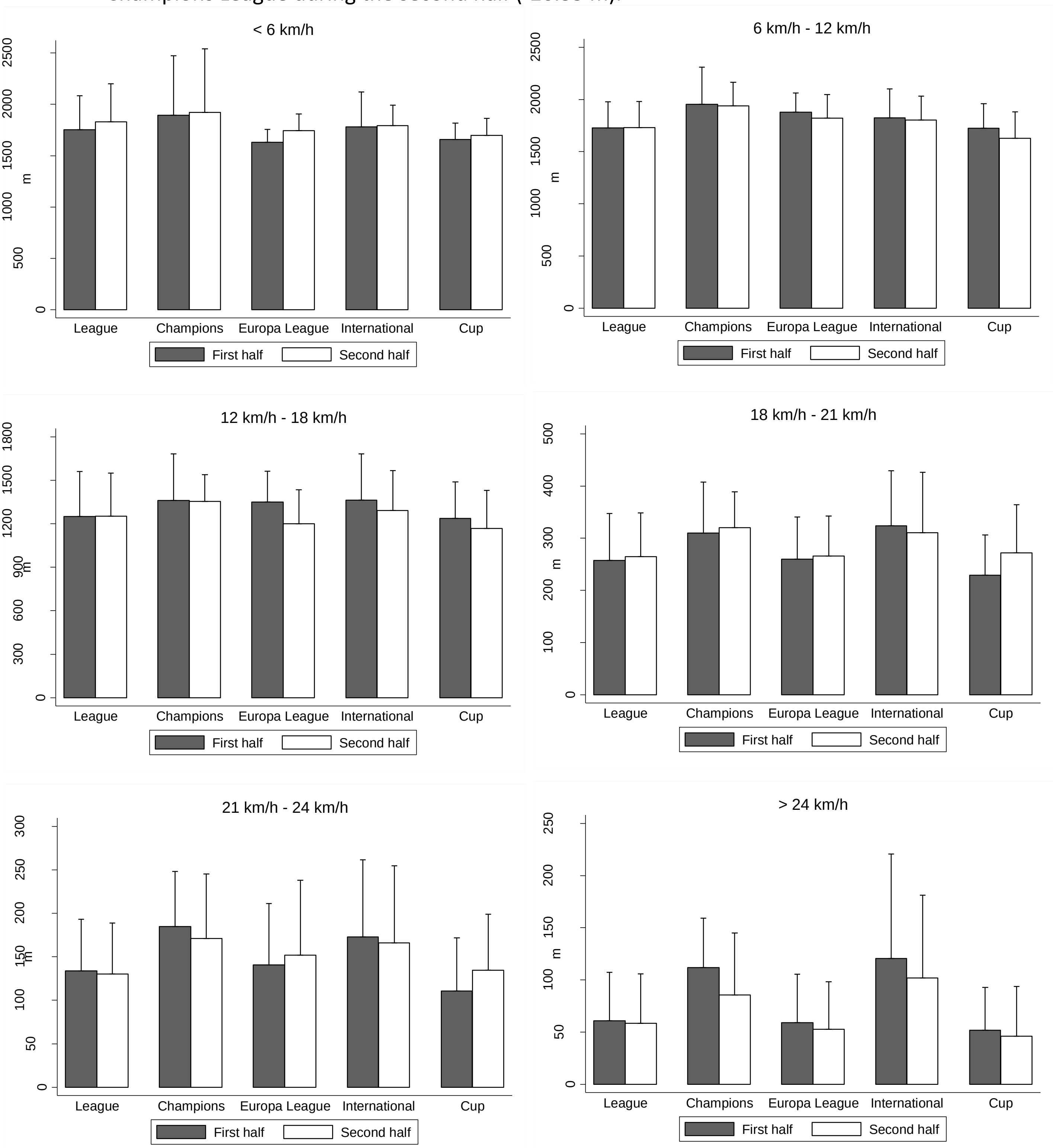

Figure 6. Activity profile of first division referees, expressed as the total distance covered in six locomotor categories during the first and the second half in different competitions.

Time course of recovery

➢ <u>Fitness Tests</u>

The results of the fitness test did not evidence differences between the referees who had a match the same week of the tests (2-3 recovery days) and the referees without a match (p>0.05; Figure 7). A higher sprint time in the last part of the Repeated Sprint Ability Test (6 x 40 m) could reveal the effect of fatigue on the referees with a lower number of recovery days, but it is important to know that this difference was not significant.

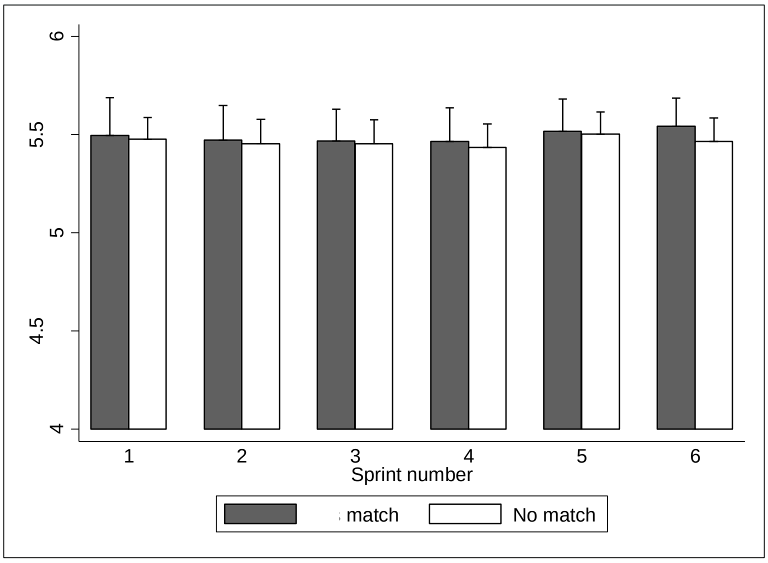

Figure 7. Comparison of the sprint times of the RSA test (6×40 m) between referees with and without a match the same week of the test.

The same results were found in the assistant referees with and without a match during the same week of the fitness tests in the RSA test (5 x 30 m; Figure 8).

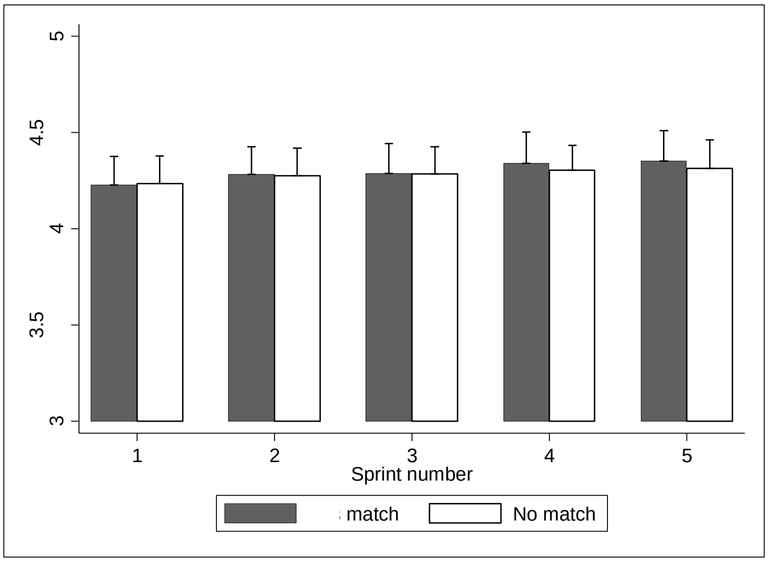

Figure 8. Comparison of the sprint times of the RSA test (5×30 m) between assistant referees with and without a match the same week of the test.

➢ Competition

The physiological responses to two matches in 1 week did not evidence any significant difference in comparison to the referees and weeks with more recovery days (*p*>0.05; Table 6). Probably because in most of the cases, the referees had more than 72h between matches. However, the muscle damage was slightly higher when the referees had two matches in a week, especially 24 h post-match (715.80 ± 349.25 IU·L^{-1}).

Table 6. Effect of a congested match schedule on attention, RPE, physical, respiratory and biomarker parameters in Spanish referees

		Pre-match	Post-match	Post-24h
No Match	CFFT (Hz)	36.25 ± 3.48	35.54 ± 3.94	
	RPE (u.a.)	4.00 ± 0.68	8.87 ± 1.65	
	Hand force (N)	47.02 ± 7.40	47.27 ± 8.69	
	Horizontal Jump (cm)	176.23 ± 20.60	179.00 ± 18.24	
	FVC	5.75 ± 1.27	5.21 ± 1.59	
	FEV1	4.25 ± 0.98	3.79 ± 1.32	
	PEF	11.95 ± 3.75	10.51 ± 3.41	
	CK (IU·L^{-1})	90.73 ± 51.355	195.31 ± 124.68	643.23 ± 269.94
Match	CFFT (Hz)	35.46 ± 2.84	35.20 ± 2.46	
	RPE (u.a.)	4.75 ± 0.94	8.91 ± 1.25	
	Hand force (N)	43.56 ± 6.94	42.95 ± 7.63	
	Horizontal Jump (cm)	173.66 ± 16.89	175.27 ± 14.71	
	FVC	5.18 ± 0.79	5.02 ± 0.85	
	FEV1	4.32 ± 0.72	3.95 ± 1.28	
	PEF	11.80 ± 2.78	10.65 ± 1.81	
	CK (IU·L^{-1})	115.85 ± 58.10	240.69 ± 167.80	715.80 ± 349.25

CFFT: critical flicker fusion threshold; RPE: rated of perceived exertion; FVC: forced vital capacity; FEV1: volume exhaled at the end of the first second of forced expiration; PEF: peak expiratory flow; CK: creatinkinase.

The analysis of the physical performance according to the congested match schedule revealed differences related to the number of matches in a week (*p*<0.05; Table 7). The referees evidenced a higher distance above 24 km·h^{-1} (+ 11.04 m; CI95%: 0.83 to 21.24; ES: 0.28), sprint distance (+ 16.05 m; CI95%: 0.45 to 31.64; ES: 0.27) and peak of acceleration (+ 0.16 m·s^{-2}; CI95%: 0.01 to 0.31; ES: 0.21) in the first half when they had one match in a week in comparison to two matches in the same week (*p*<0.05). This result suggests a lower capacity to perform high intensity actions because of a congested match schedule.

Table 7. Effect of a congested match schedule on GPS and Heart Rate parameters during the first and second half in Spanish elite referees.

	No Match		Match	
	First Half	Second Half	First Half	Second Half
Total Distance (m)	5215.94 ± 397.75	5211.71 ± 473.70	5202.82 ± 538.31	5242.79 ± 492.65
Distance Zone 1 (m)	1628.72 ± 214.96	1687.14 ± 215.23	1682.26 ± 394.43	1772.10 ± 452.14
Distance Zone 2 (m)	1762.37 ± 248.65	1733.23 ± 265.02	1793.94 ± 278.65	1754.36 ± 269.60
Distance Zone 3 (m)	1333.83 ± 258.02	1311.47 ± 253.29	1279.17 ± 294.75	1259.04 ± 291.21
Distance Zone 4 (m)	284.21 ± 82.42	283.50 ± 87.58	265.95 ± 91.34	271.58 ± 86.17
Distance Zone 5 (m)	143.23 ± 58.93	139.49 ± 61.02	130.20 ± 61.11	135.28 ± 57.42
Distance Zone 6 (m)	63.58 ± 48.19*	56.89 ± 47.81	51.30 ± 40.46	50.43 ± 39.74
Accelerations (n)	1349.82 ± 131.34	1425.54 ± 147.09	1344.48 ± 160.19	1430.64 ± 138.09
Decelerations (n)	1349.73 ± 131.17	1425.68 ± 147.27	1344.59 ± 160.14	1430.48 ± 138.40
Accelerations ($n \cdot min^{-1}$)	28.25 ± 2.46	28.71 ± 2.46	28.15 ± 2.84	28.71 ± 2.62
Decelerations ($n \cdot min^{-1}$)	28.24 ± 2.45	28.72 ± 2.46	28.15 ± 2.84	28.71 ± 2.62
ACC_{MAX} ($m \cdot s^{-2}$)	4.25 ± 0.61*	4.15 ± 0.74	4.12 ± 0.64	4.22 ± 0.84
DEC_{MAX} ($m \cdot s^{-2}$)	-4.97 ± 0.74	-4.83 ± 0.70	-4.91 ± 0.74	-4.78 ± 0.81
Sprint Distance (m)	114.40 ± 73.54*	106.13 ± 72.94	95.24 ± 66.16	97.22 ± 61.91
Sprint Distance ($m \cdot min^{-1}$)	5.38 ± 3.19	4.96 ± 3.12	4.78 ± 3.18	4.63 ± 2.76
V_{MAX} ($km \cdot h^{-1}$)	27.94 ± 2.04	27.54 ± 2.03	27.52 ± 2.22	27.40 ± 2.28
HR_{MAX} (b.p.m)	174.99 ± 9.81	173.27 ± 12.85	173.57 ± 11.25	171.52 ± 13.34
HR_{MEAN} (b.p.m)	151.59 ± 12.03	148.80 ± 15.10	149.92 ± 13.80	147.23 ± 15.70
HR_{MEAN} (%)	83.63 ± 5.81	82.00 ± 7.48	82.76 ± 5.73	81.44 ± 6.85

*Significant differences between one (no match) and two (match) matches in a week; HR: Heart Rate; $V_{MAX:}$ Maximum Speed. ; Zone 1: <6 $km \cdot h^{-1}$, Zone 2: 6-12 $km \cdot h^{-1}$; Zone 3: 12-18 $km \cdot h^{-1}$; Zone 4: 18-21 $km \cdot h^{-1}$; Zone 5: 21-24 $km \cdot h^{-1}$; Zone 6: >24 $km \cdot h^{-1}$.

Conclusions

- *Category*

1. First Division referees revealed a higher repeated sprint ability in comparison to second division referees.
2. Assistant referees did not show any difference according to the category during the fitness test.
3. First division referees evidenced higher high intensity physical demands and lower internal load and perceived exertion during competition compared to second division referees.

- Competitions

4. High intensity physical demands were higher in the international competitions (UEFA Champions League and national-team matches).

- Fatigue

5. Second division referees showed a lower number of high intensity actions in the second half of the matches.
6. First division referees only evidenced a lower internal load in the second half during the national-team matches.

- Congested Match Schedule

7. The referees and assistant referees who had a match just before the fitness tests did not reveal a lower performance in the RSA test.
8. A congested match schedule did not influence on the physiological parameters of the referees before and after the match. However, higher 24h post-match CK levels were evidenced when the referees had two matches in a week.
9. A congested match schedule showed a lower sprint distance and peak of acceleration in Spanish referees.

7. THE LIMITATIONS OF THE CURRENT STUDY

The main limitation of this study was the availability of the referees. Given their level of professional athlete, the referees, at the end of the game or the morning after, take a plane to their home to rest, making it difficult to monitor the recovery of physiological variables 24 and 48 h after the match. On the other hand, the number of matches of referees in different competitions were not the same. I have included all the matches of the referees in the international competitions, but the number of these matches was lower in comparison to league matches. However, the number of matches in all the competitions was enough to do the comparison according to the statistical power of the sample.

With respect to data, all referees' matches were evaluated, and physical and physiological variables were assessed. There was no breaks or limitations in this sense.

8. THE IMPACT OF THE RESEARCH

To analyse the impact of this project we will have to wait a while. A priori, this project will be useful for different stakeholders in next terms:

Football federations and regulatory bodies:

Promotion of results: The applicability of the results obtained in this study and the technologies used will contribute to the development of a new and more precise line in the research of optimization of the overall performance of elite football referees.

Availability of information on the determinants of physical, physiological and psychological performance in elite referees: UEFA will have relevant results on the influence of congested match schedule in elite referees.

Physical coaches:

Understanding the multifactorial character of physical performance of elite football referees: Factor analysis will make it possible for emphasizing the most important variables in the physical performance of elite referees, improving the efficiency of training tasks and providing a new approach to physical and also psychological training within elite referees.

Universities and training centers:

Developing a more effective training system. Based on the data of this research, the results would be applied as new contents for training subjects at sport science schools. In addition, this knowledge will be shared with elite referees.

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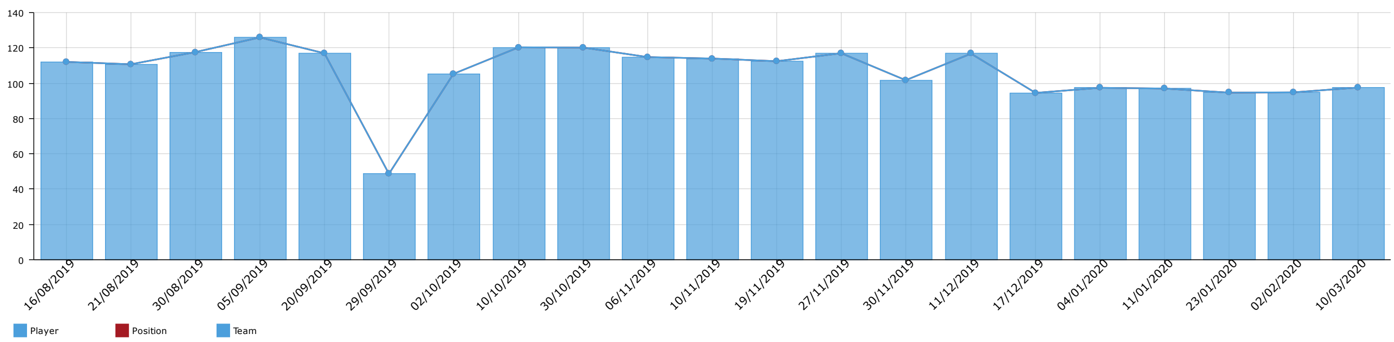
Appendix 1. Evolution report sended to the referee

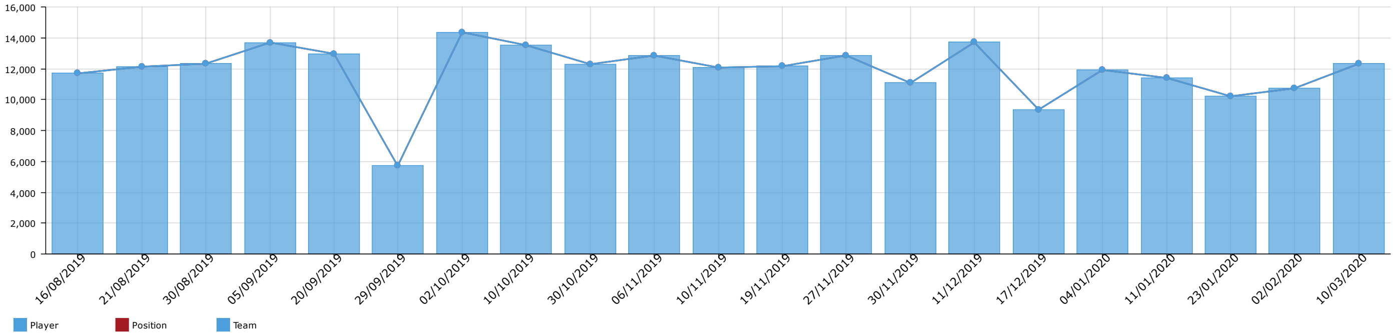
Evolution Report

Field	MAX	AVG	16/08/2019 MD	21/08/2019 MD	30/08/2019 MD	05/09/2019 MD	20/09/2019 MD	29/09/2019 MD	02/10/2019 MD	10/10/2019 MD	30/10/2019 MD	06/11/2019 MD	10/11/2019 MD	19/11/2019 MD	27/11/2019 MD	30/11/2019 MD	11/12/2019 MD	17/12/2019 MD	04/01/2020 MD	11/01/2020 MD	23/01/2020 MD	02/02/2020 MD	10/03/2020 MD
Duration (min)	125.96	106.21	112.09	110.73	117.63	125.96	116.96	48.68	105.29	120.34	120.19	114.81	113.98	112.47	116.98	101.70	116.75	94.52	97.39	96.98	94.67	94.83	97.54
Distance (m)	14357.17	11873.47	11693	12132	12324	13697	12967	5707	14357	13524	12290	12853	12073	12159	12861	11073	13704	9348	11919	11400	10213	10729	12320
Distance/min (m/min)	136.44	112.27	104.3	109.6	105.1	109.3	110.9	117.3	136.4	113.4	102.7	112.1	105.9	108.3	109.9	109.0	117.4	98.9	122.4	117.6	107.9	113.1	126.3
HSR Rel (m)	613.20	154.26	178	467	76	483	224	0	42	613	16	128	26	81	61	87	270	53	53	152	59	0	172
HSR Rel/min (m/min)	5.11	1.36	1.58	4.22	0.64	3.66	1.91	0.00	0.41	5.11	0.13	1.11	0.23	0.72	0.52	0.86	2.32	0.56	0.54	1.57	0.62	0.00	1.77
HSR + Sprints (count)	145.00	67.62	47	70	46	91	76	27	29	105	40	78	74	82	82	85	95	41	55	71	40	41	145
Sprints/min	1.49	0.64	0.42	0.63	0.39	0.73	0.65	0.55	0.28	0.87	0.33	0.68	0.65	0.73	0.70	0.84	0.81	0.43	0.56	0.73	0.42	0.43	1.49
HMLD (m)	3380.33	2465.45	1967	2663	2409	3340	2883	1328	1603	3380	2254	2454	2483	2447	2804	2759	3217	1714	2138	2552	2357	1925	3095
HMLD/min (m/min)	31.73	23.32	17.55	24.06	20.48	26.70	24.65	27.28	15.24	28.10	18.76	21.37	21.79	21.76	23.97	27.13	27.55	18.13	21.95	26.32	24.90	20.30	31.73
Accelerations +3 (count)	68.00	33.40	46	26	14	30	28	7	60	38	24	33	26	68	54	30	33	21	36	23	34	25	45
Decelerations +3 (count)	90.00	50.10	62	34	41	66	32	18	56	52	37	39	41	76	90	77	69	28	61	36	44	26	67
Accelerations +3/min (count/min)	0.61	0.31	0.41	0.23	0.12	0.24	0.24	0.14	0.57	0.32	0.20	0.29	0.23	0.61	0.46	0.30	0.28	0.22	0.37	0.24	0.36	0.26	0.46
Decelerations +3/min (count/min)	0.77	0.47	0.56	0.31	0.35	0.52	0.27	0.37	0.53	0.44	0.31	0.34	0.36	0.68	0.77	0.76	0.59	0.30	0.63	0.37	0.46	0.27	0.69
Distance Acceleration (m)	558.08	339.01	357	341	143	370	407	88	525	494	240	399	221	558	426	343	278	239	335	275	323	261	496
Distance Deceleration (m)	510.57	284.42	252	192	254	430	237	123	291	327	175	232	225	380	408	430	511	144	294	261	205	175	429
Max Speed (km/h)	34.40	30.23	31.4	34.4	33.2	31.3	30.4	26.3	28.5	32.2	27.9	29.6	28.3	32.4	30.1	30.3	31.8	30.1	30.1	30.0	29.1	26.8	30.6
Avg Speed (km/h)	7.73	7.18	6.6	7.2	7.2	7.6	7.5	7.6	5.7	7.5	7.1	7.4	7.2	6.7	7.1	7.1	7.7	6.6	6.9	7.7	7.3	7.2	7.7
Max Acceleration (m/s²)	7.49	4.90	5.04	4.75	4.50	4.09	4.18	3.50	7.49	4.54	4.99	4.42	3.94	6.25	5.98	5.65	4.47	3.96	6.37	4.01	4.27	4.47	6.14
Max Deceleration (m/s²)	-4.27	-5.65	-5.07	-5.02	-5.34	-6.45	-4.92	-4.61	-5.44	-6.37	-5.64	-5.82	-5.63	-7.97	-6.15	-6.32	-5.00	-5.45	-6.00	-5.16	-5.85	-4.27	-6.26
High Intensity Actions (count)	392.00	238.71	375.00	250.00	210.00	242.50	298.00	96.00	362.50	392.00	197.00	236.00	137.00	281.00	322.00	229.00	286.00	115.00	205.00	172.00	187.00	111.00	309.00
High Intensity Actions/min (count/min)	3.45	2.23	3.35	2.26	1.79	1.93	2.55	1.97	3.45	3.26	1.64	2.06	1.20	2.50	2.75	2.25	2.45	1.22	2.10	1.77	1.98	1.17	3.17
Power Metabolic AVG (W/kg)	41994.63	31719.02	31162.3	32891.7	33054.5	41994.6	34692.7	15382.2	25195.0	37010.6	33806.7	35445.6	33463.4	33004.9	35209.0	30339.9	38474.1	25721.4	28548.1	31177.7	28641.0	28726.8	32157.1
Player Load (a.u.)	201.70	158.27	158.29	155.61	154.91	190.11	162.34	70.87	173.94	168.08	183.22	181.14	157.05	176.96	187.54	149.48	201.70	116.42	152.56	142.53	134.52	138.25	168.20
Player Load/min (a.u./min)	1.73	1.49	1.41	1.41	1.32	1.51	1.39	1.46	1.65	1.40	1.52	1.58	1.38	1.57	1.60	1.47	1.73	1.23	1.57	1.47	1.42	1.46	1.72
High G Actions (count)	278.00	147.74	256	167	150	126	229	71	243	278	135	157	69	131	175	117	173	63	105	104	106	60	187
High G Actions/min (count/min)	2.31	1.38	2.28	1.51	1.28	1.01	1.96	1.46	2.31	2.31	1.12	1.37	0.61	1.16	1.50	1.15	1.48	0.67	1.08	1.07	1.12	0.63	1.92
DSL (u.a.)	816.76	537.56	529.9	491.4	455.4	602.8	577.9	222.5	688.8	671.8	583.9	610.6	366.2	657.3	816.8	563.9	743.3	331.2	497.0	440.2	477.3	316.8	644.1
DSL/min (u.a./min)	6.98	5.04	4.73	4.44	3.87	4.82	4.94	4.57	6.55	5.59	4.86	5.32	3.21	5.84	6.98	5.54	6.37	3.50	5.10	4.54	5.04	3.34	6.60
Jumps +3G (count)	14.00	4.14	5.00	0.00	0.00	5.00	0.00	1.00	0.00	3.00	7.00	7.00	1.00	3.00	14.00	0.00	9.00	1.00	9.00	5.00	9.00	3.00	5.00
Landing +5G (count)	3.00	0.71	0.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00	0.00	3.00	1.00	1.00	0.00	0.00	1.00	2.00	0.00	2.00
Jumps +3G/min (count/min)	0.12	0.04	0.04	0.00	0.00	0.04	0.00	0.02	0.00	0.02	0.06	0.06	0.01	0.03	0.12	0.00	0.08	0.01	0.09	0.05	0.10	0.03	0.05
Landing +5/min (count/min)	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.02
AVG Take Off (G)	3.44	2.36	2.22	1.16	1.96	2.64	0.00	2.52	1.55	3.40	2.72	2.82	1.43	2.57	2.77	1.33	3.20	2.36	2.63	3.44	3.06	3.08	2.67
AVG Landing (G)	4.22	3.56	3.53	4.22	4.13	3.52	0.00	3.42	3.77	3.69	3.69	3.59	3.35	3.82	3.97	4.06	3.69	3.27	3.65	3.74	4.07	3.73	3.87
Impacts +8G/min (count/min)	2.30	1.34	2.24	1.50	1.28	0.97	1.96	1.44	2.30	2.28	1.06	1.30	0.60	1.14	1.35	1.14	1.40	0.66	0.99	1.01	1.00	0.60	1.85
Impacts +8G (count)	274.00	142.88	251	166	150	122	229	70	242	274	127	149	68	128	158	116	163	62	96	98	95	57	180
HSR Absolute (m)	2361.02	945.40	569	1108	762	1366	1260	419	293	1726	526	1013	953	872	847	1087	1301	550	659	1072	567	542	2361
HSR Absolute/min (m/min)	24.21	8.91	5.07	10.02	6.50	10.92	10.78	8.61	2.78	14.48	4.40	8.83	8.36	7.77	7.24	10.70	11.15	5.82	6.76	11.06	5.99	5.71	24.21
HSR Absolute Count (count)	124.00	50.10	39	50	34	62	51	22	21	66	32	57	55	60	64	58	68	32	41	51	33	31	124
Energy Expend (kcal)	1568.90	1231.77	1136	1261	1278	1504	1413	619	1083	1461	1297	1406	1283	1199	1349	1127	1569	873	1180	1274	1094	1138	1324
Energy Expend/min (kcal/min)	13.58	11.63	10.14	11.38	10.87	11.99	12.08	12.72	10.29	12.14	10.79	12.25	11.25	10.66	11.53	11.08	13.44	9.23	12.11	13.13	11.56	12.00	13.58
Step Balance (%)	0.04	0.01	0.01	0.03	-0.00	0.01	0.01	-0.02	-0.01	-0.02	0.00	0.00	0.01	-0.00	0.01	-0.01	0.03	0.04	0.03	0.01	0.04	0.00	0.01

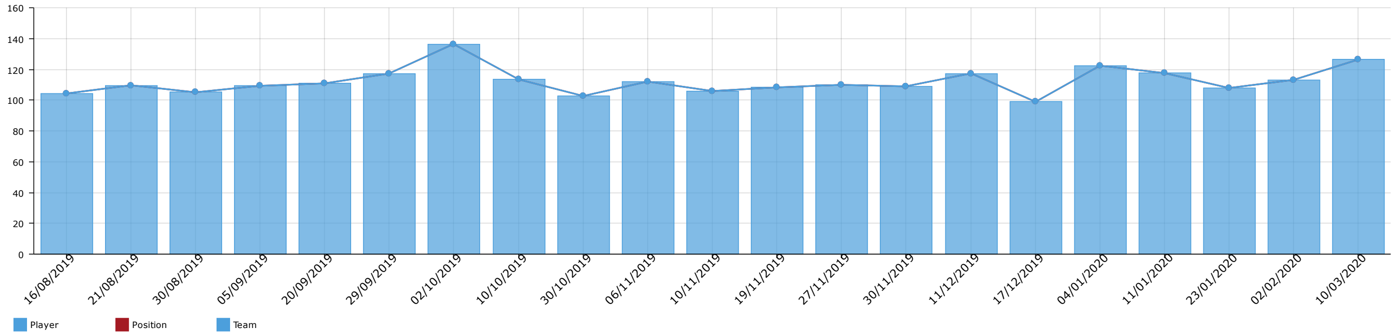
Duration (min)



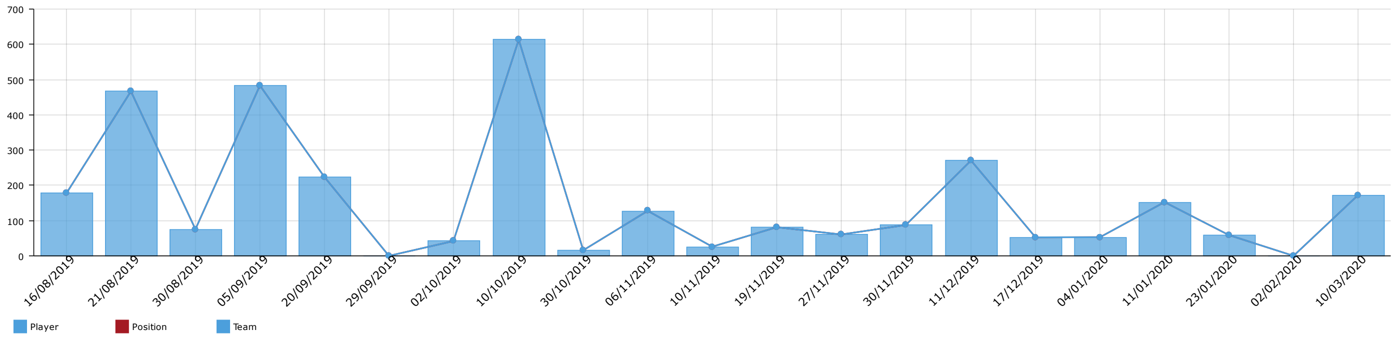
Distance (m)



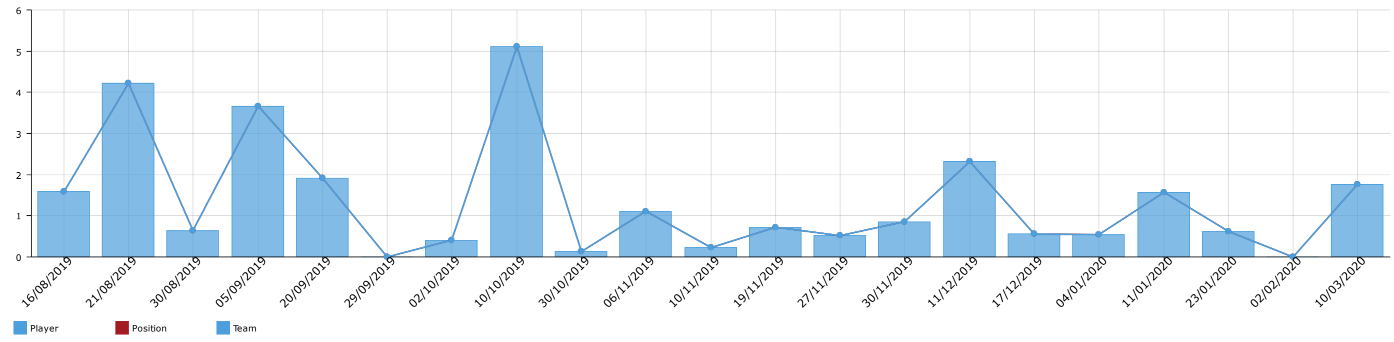
Distance/min (m/min)



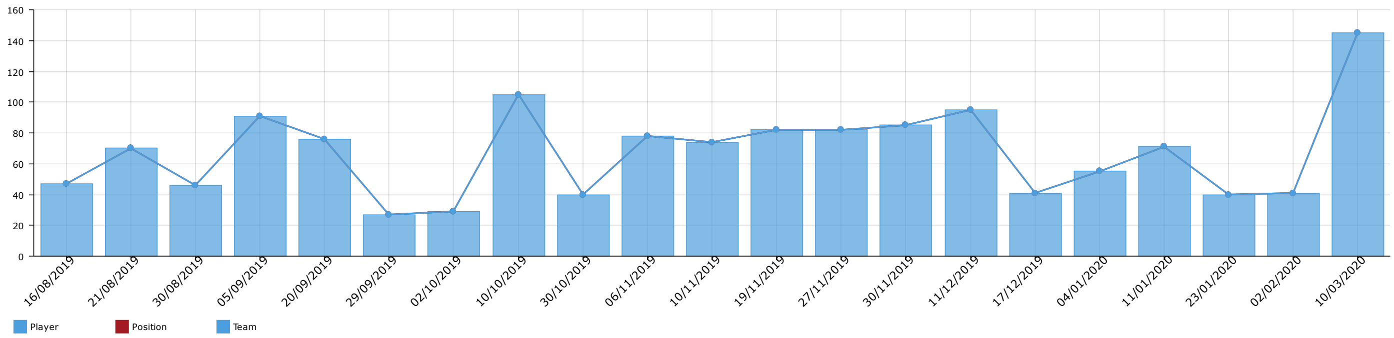
HSR Rel (m)



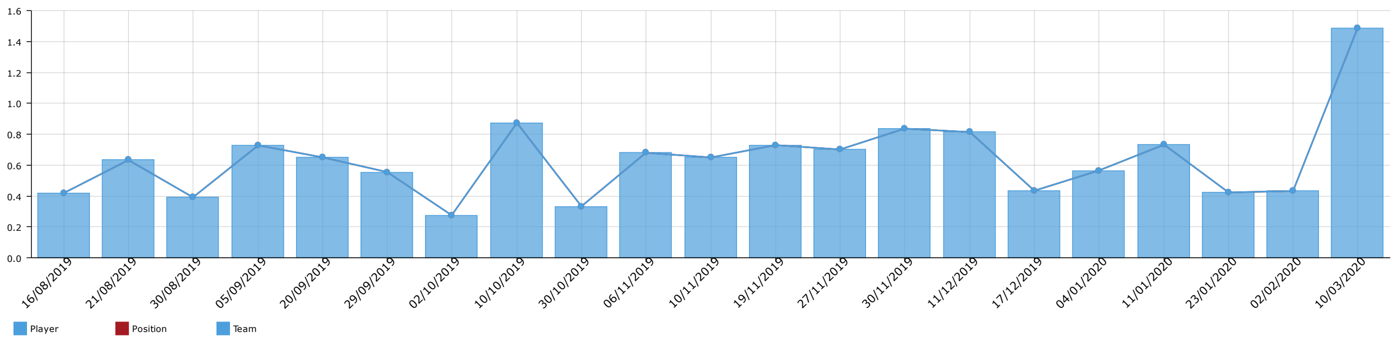
HSR Rel/min (m/min)



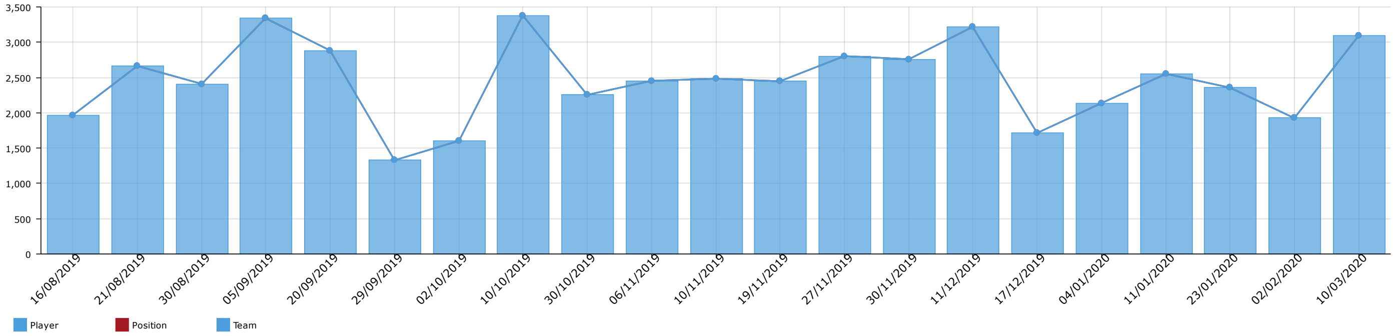
HSR + Sprints (count)



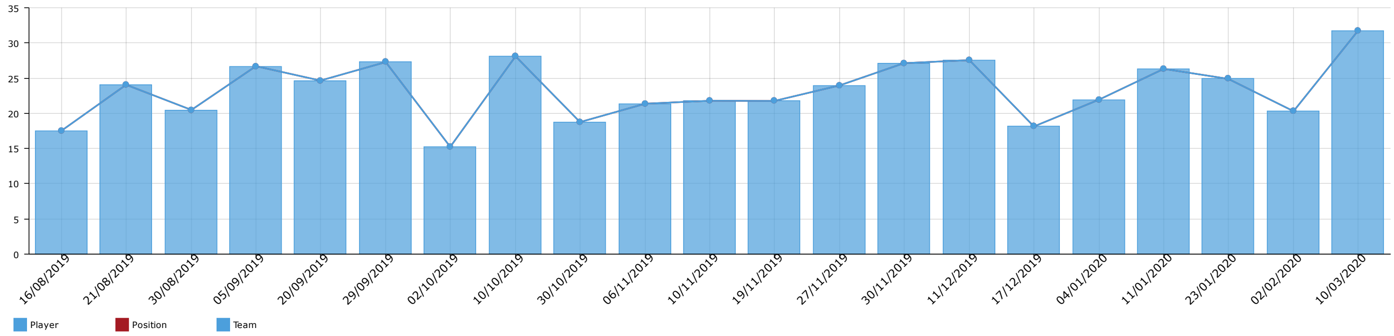
Sprints/min



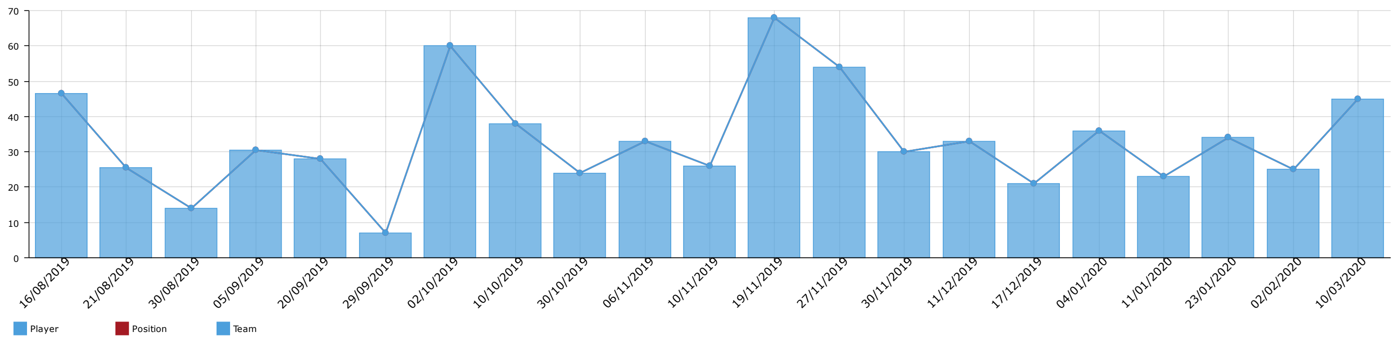
HMLD (m)



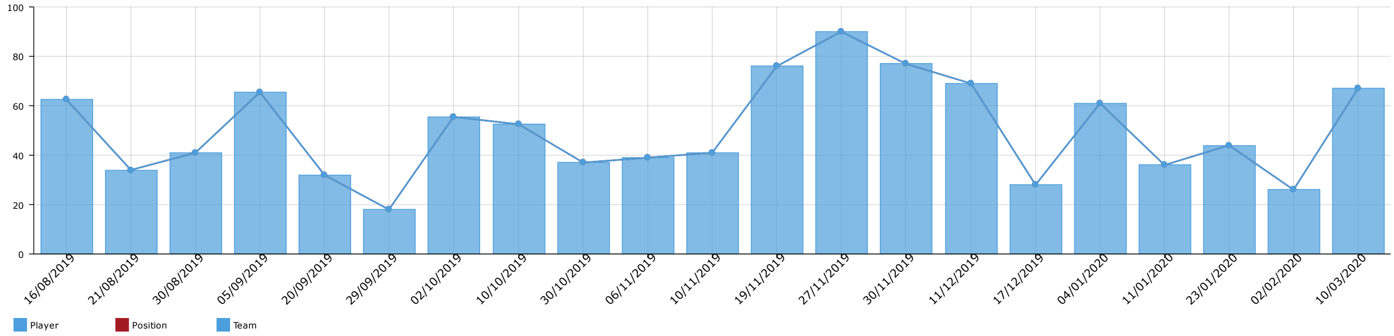
HMLD/min (m/min)



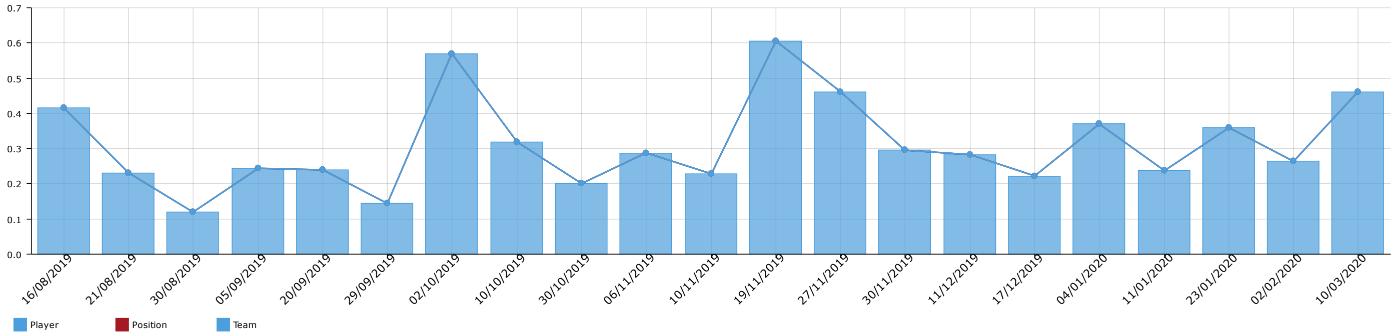
Accelerations +3 (count)



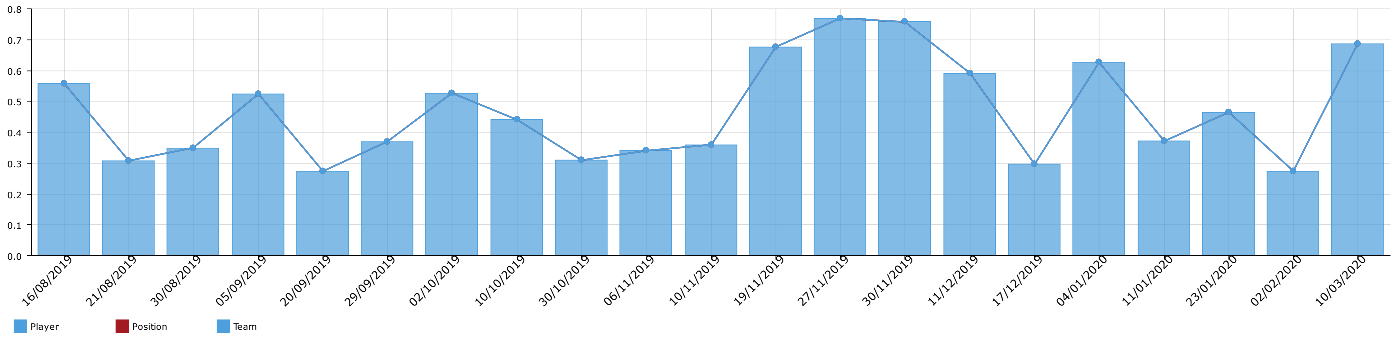
Decelerations +3 (count)



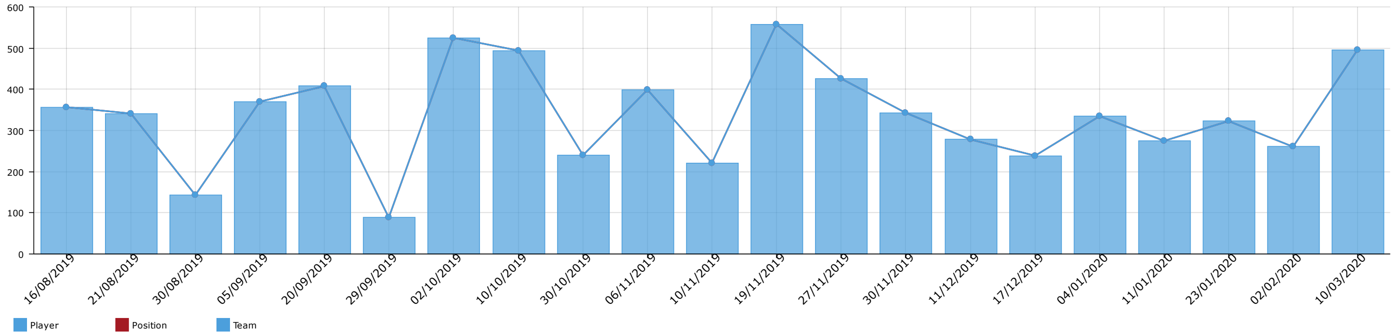
Accelerations +3/min (count/min)



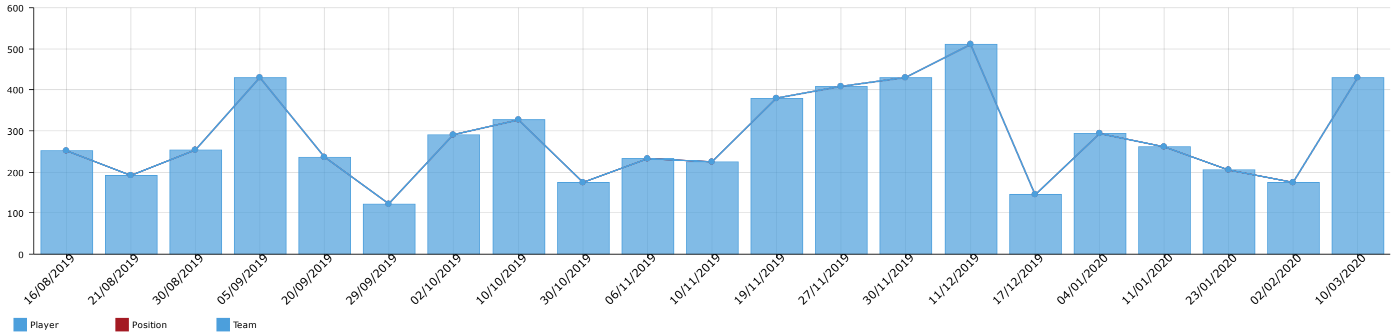
Decelerations +3/min (count/min)



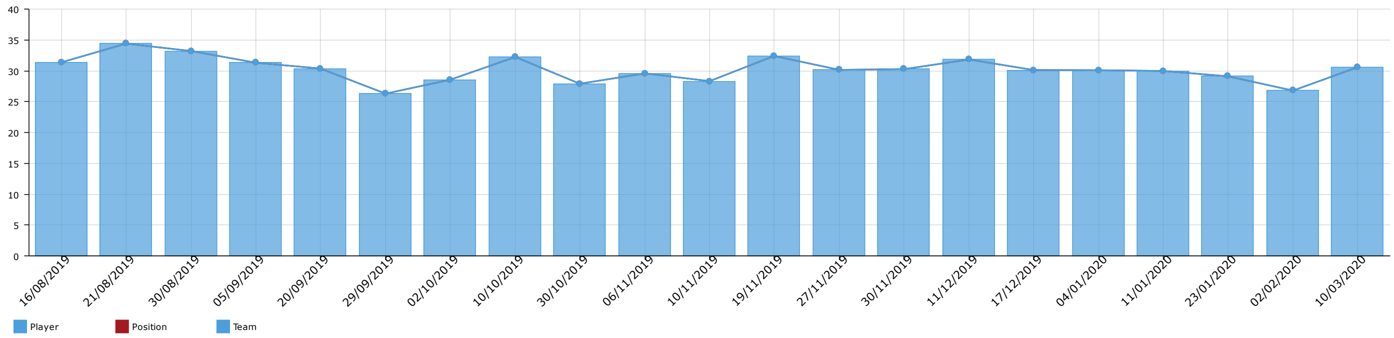
Distance Acceleration (m)



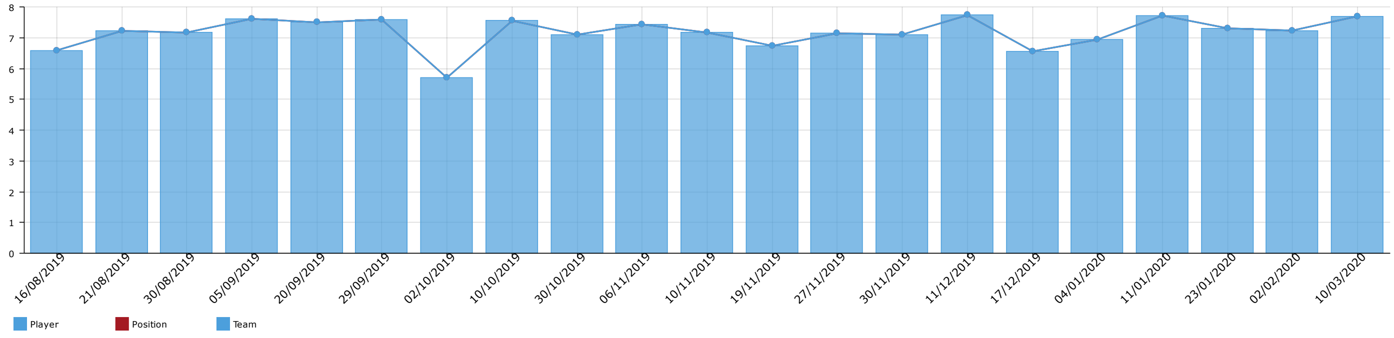
Distance Deceleration (m)



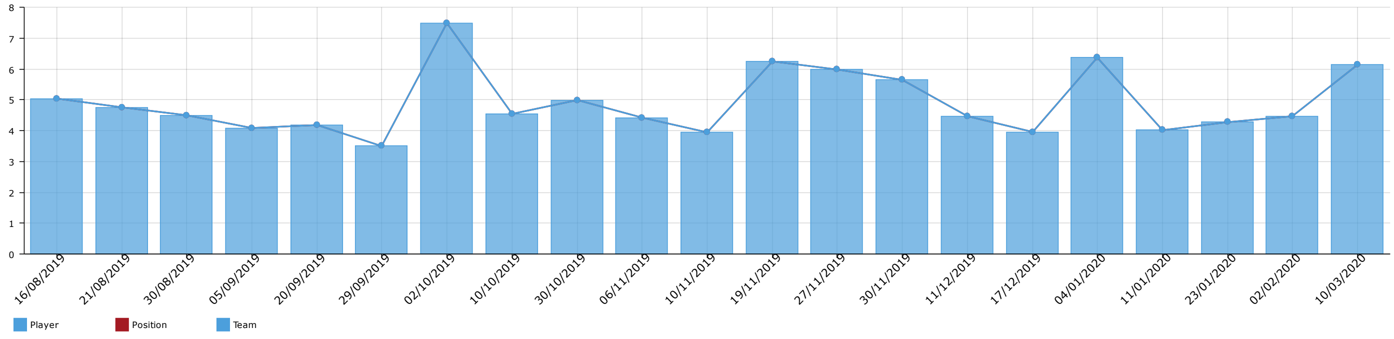
Max Speed (km/h)



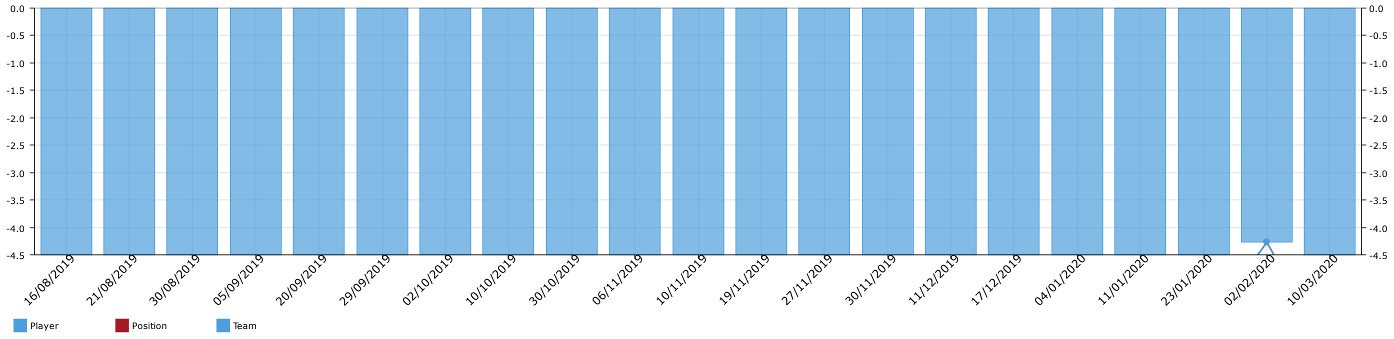
Avg Speed (km/h)



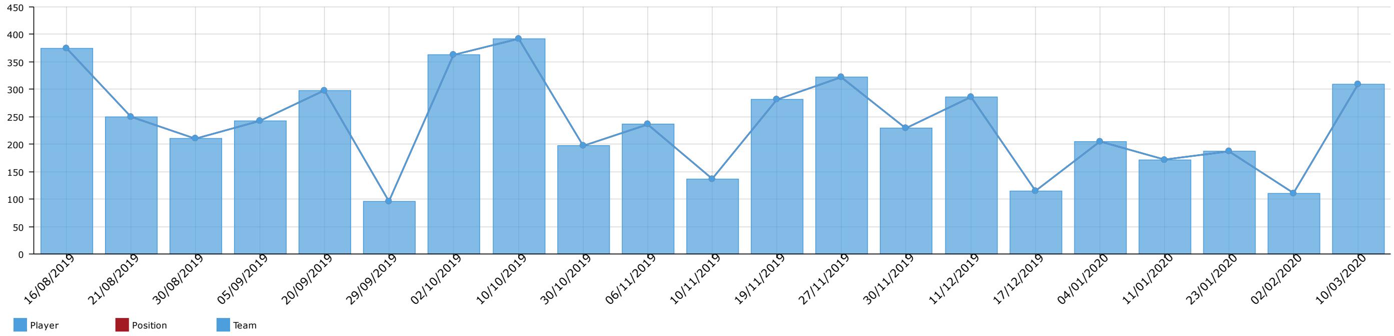
Max Acceleration (m/s²)



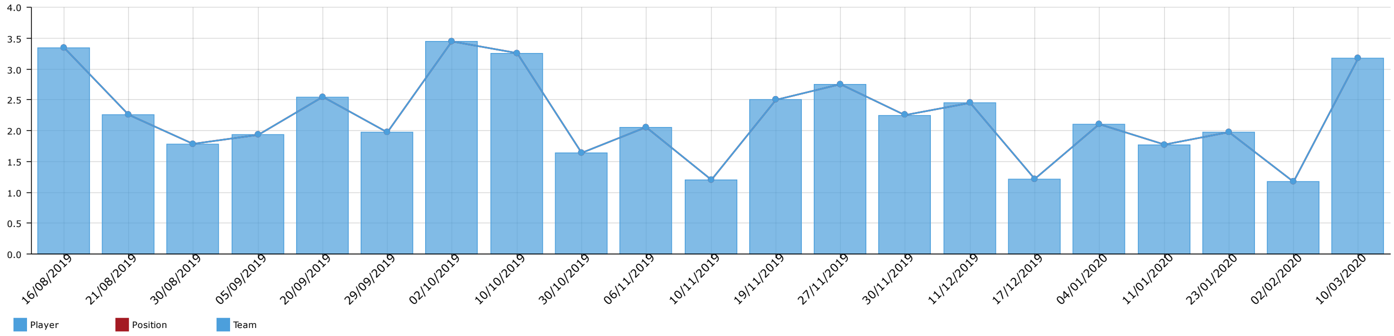
Max Deceleration (m/s²)



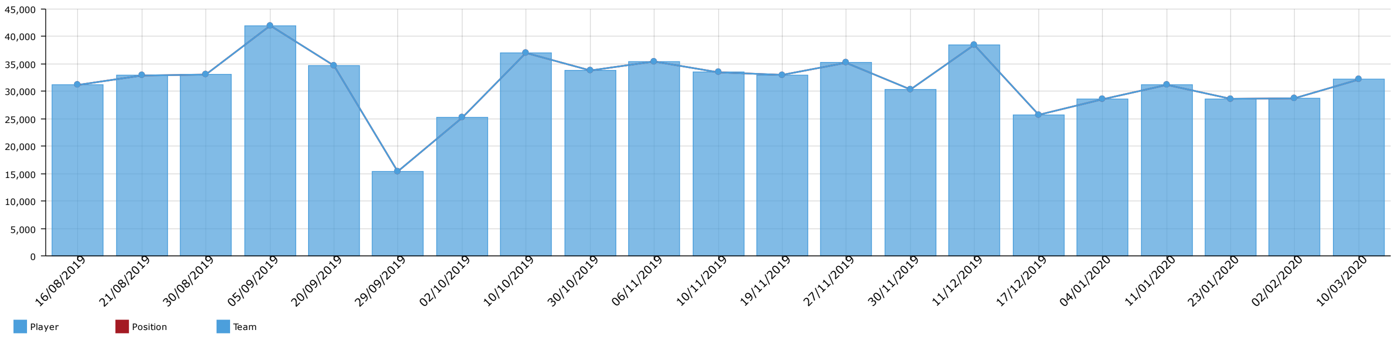
High Intensity Actions (count)



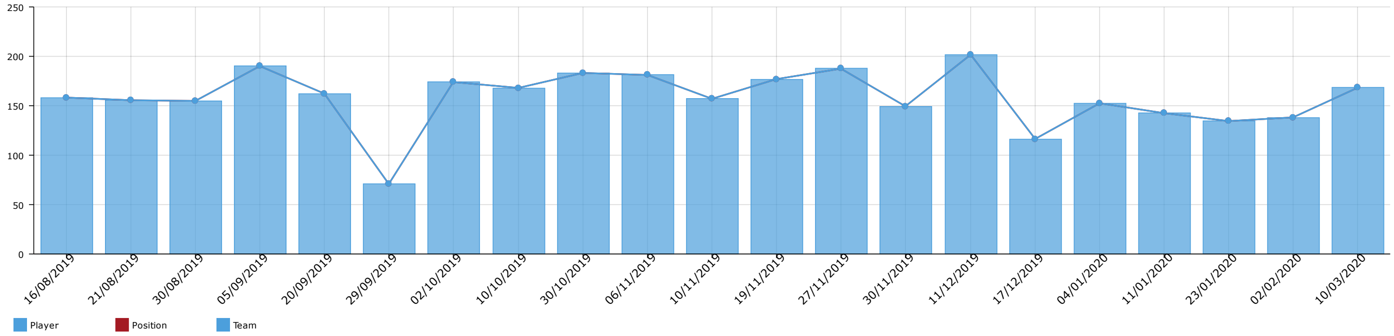
High Intensity Actions/min (count/min)



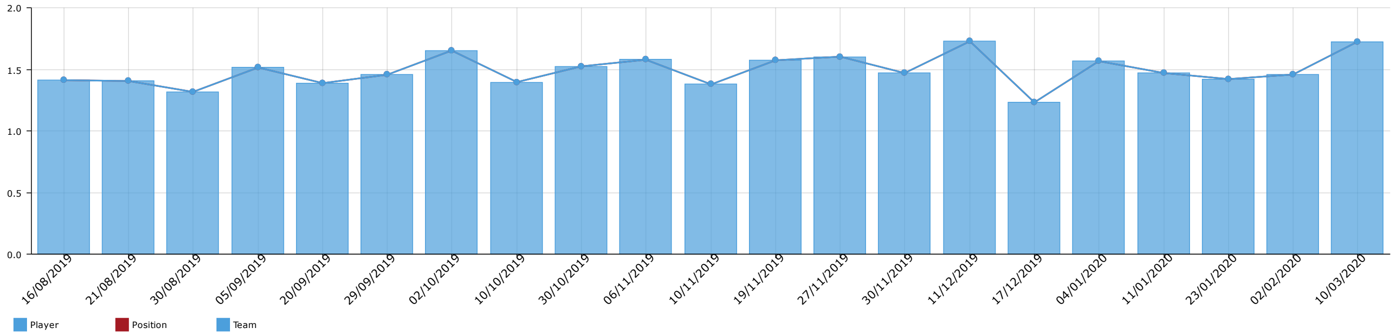
Power Metabolic AVG (W/kg)



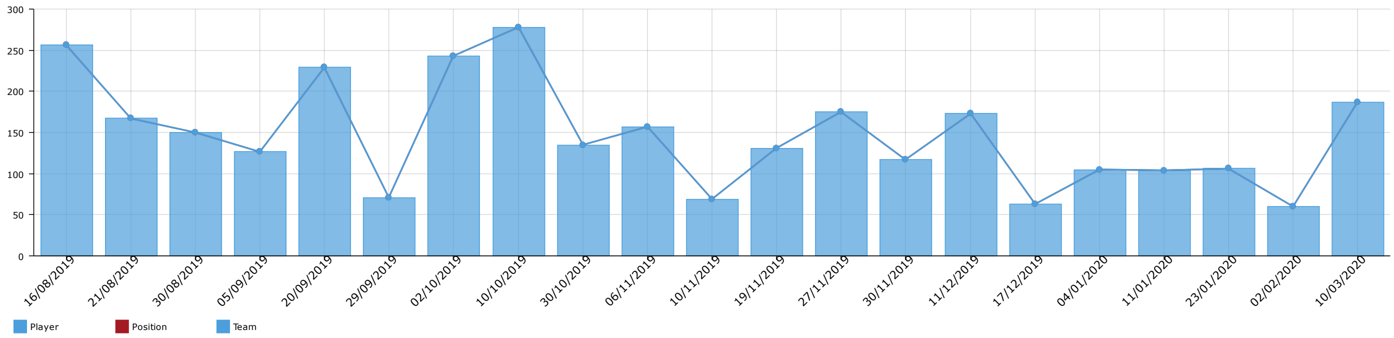
Player Load (a.u.)



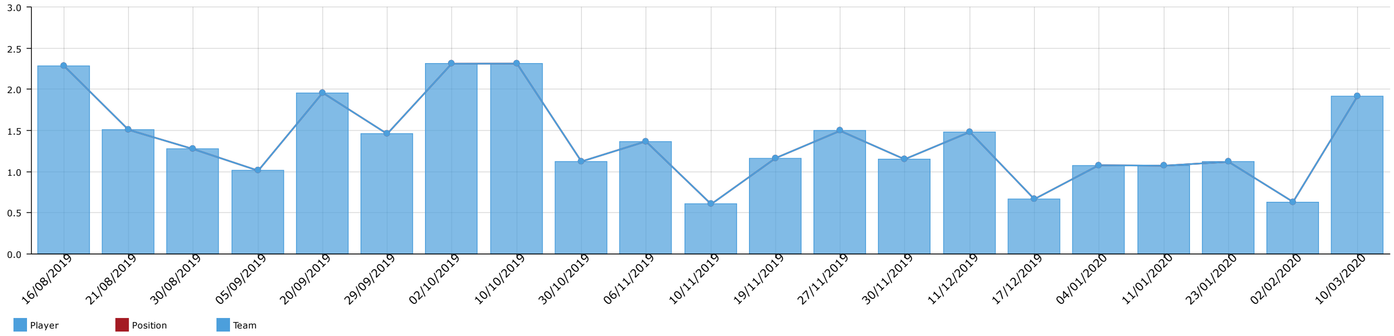
Player Load/min (a.u./min)



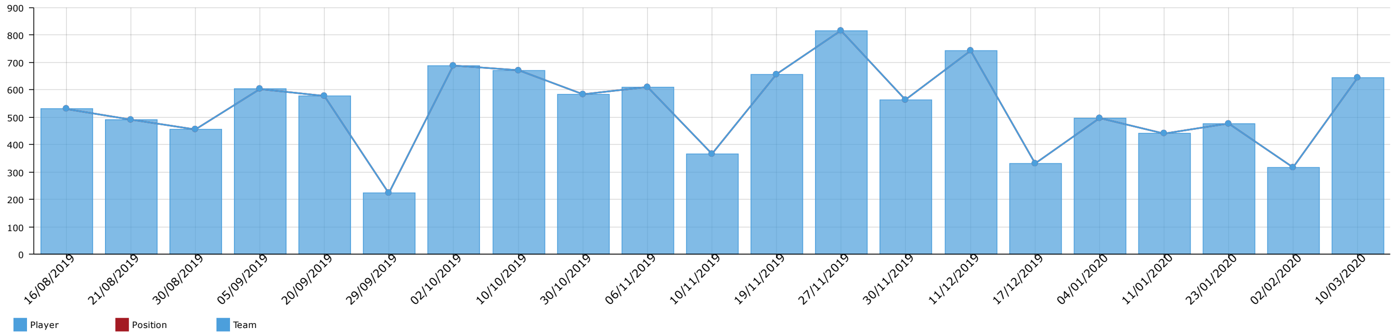
High G Actions (count)



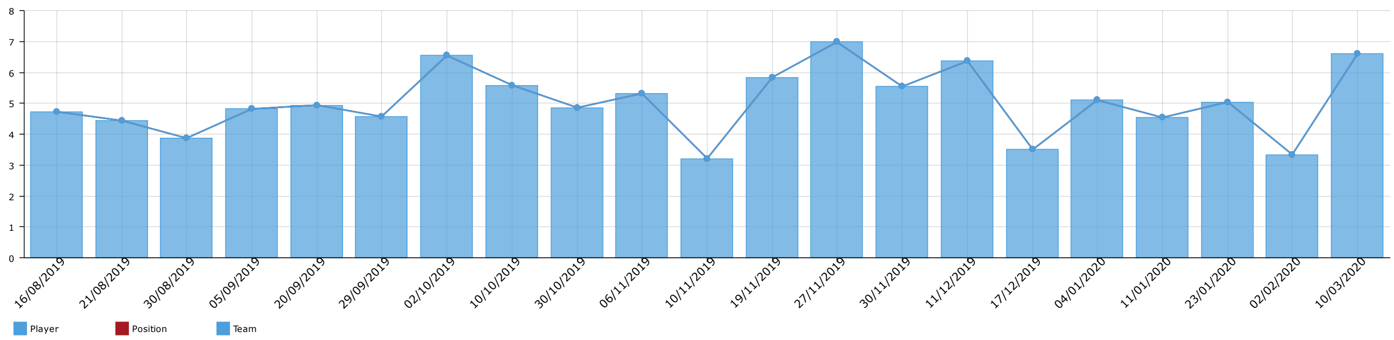
High G Actions/min (count/min)



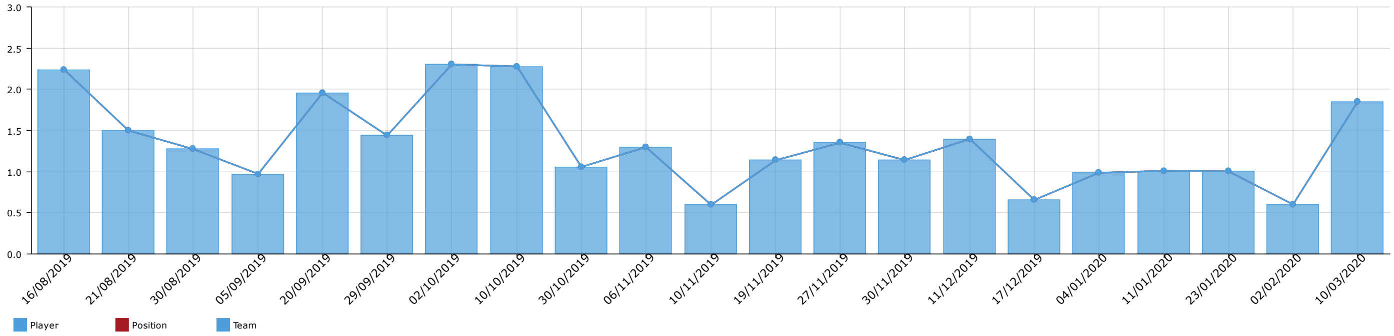
DSL (u.a.)



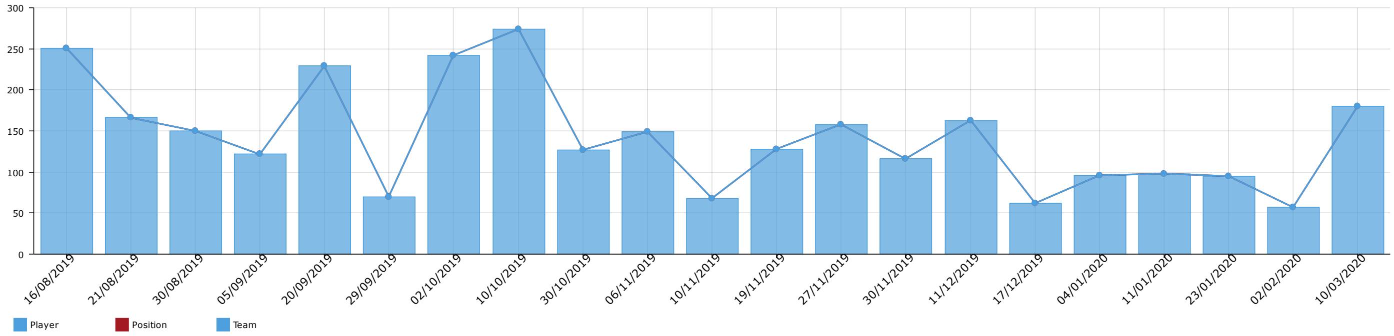
DSL/min (u.a./min)



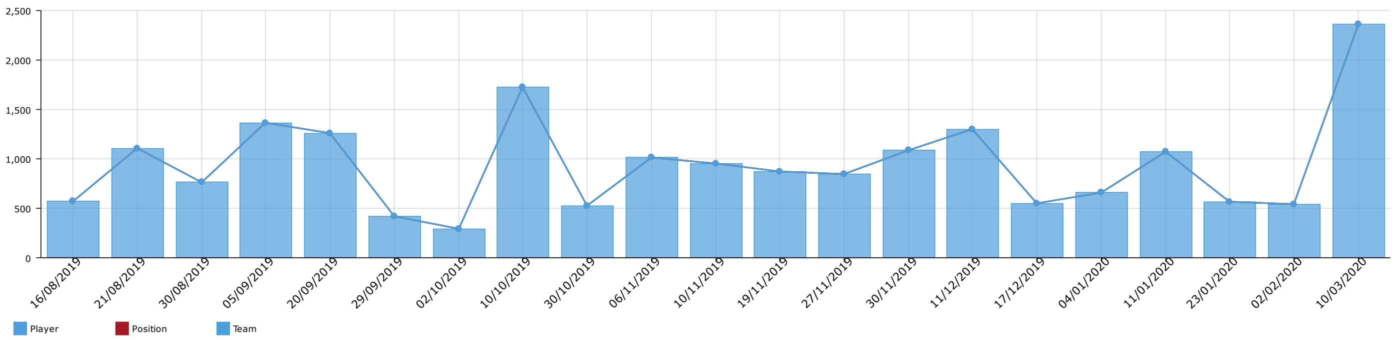
Impacts +8G/min (count/min)



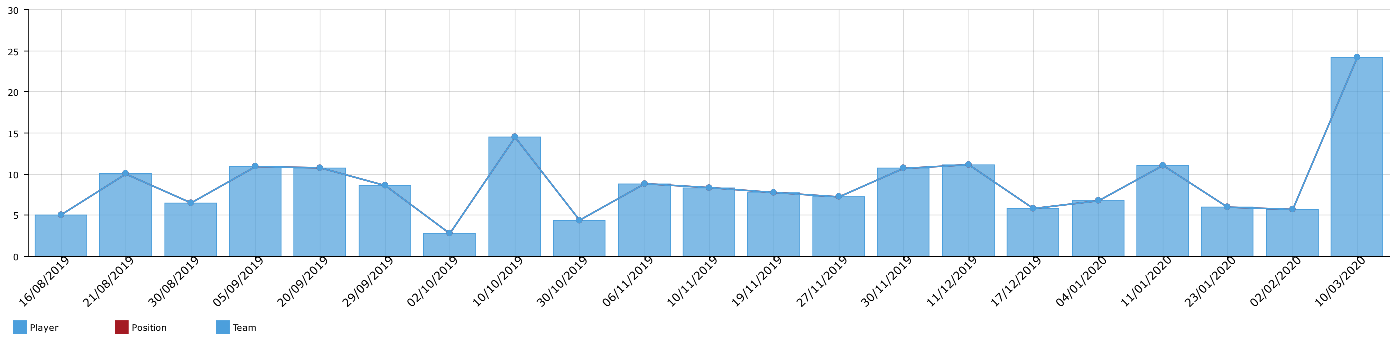
Impacts +8G (count)



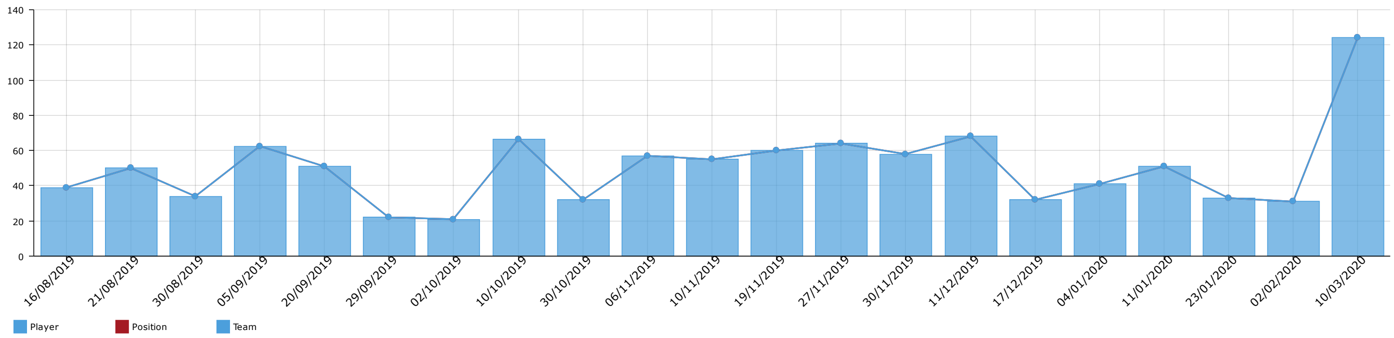
HSR Absolute (m)



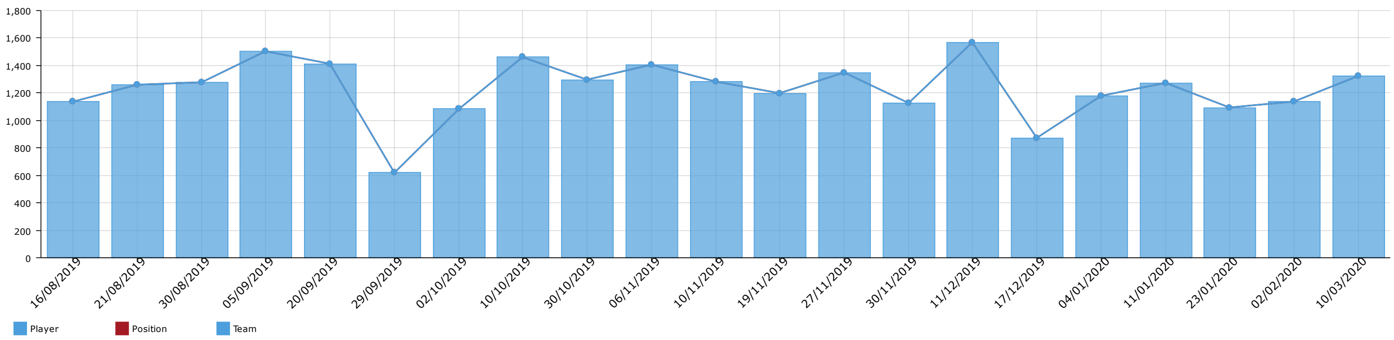
HSR Absolute/min (m/min)



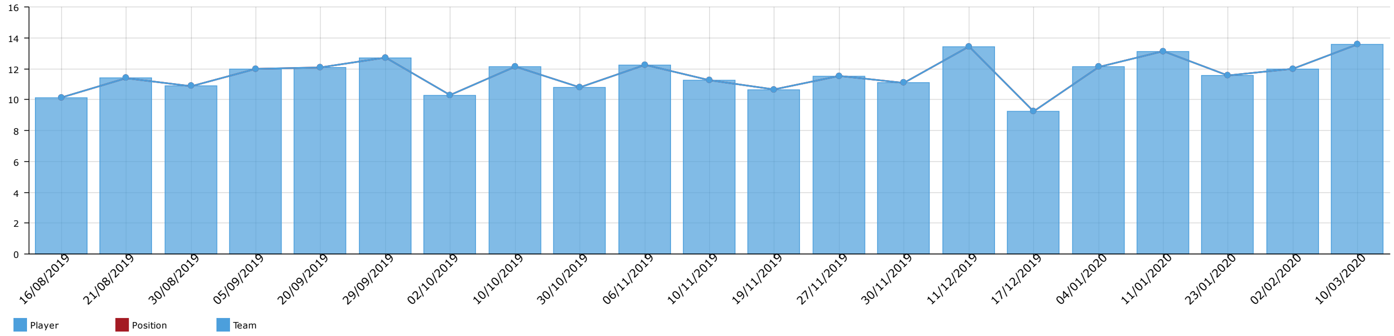
HSR Absolute Count (count)



Energy Expend (kcal)



Energy Expend/min (kcal/min)



Step Balance (%)