motricidade

ORIGINAL ARTICLE

https://doi.org/10.6063/motricidade.40534

Physical demands and patterns of Portuguese football referees: a case study

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ABSTRACT

This study quantified the match-related external and internal physical demands and activity patterns of Portuguese Football field referees (FRs) and assistant referees (ARs) across different categories. A total of 8 FRs and 7 ARs were monitored during 98 official competitions using GPS with embedded heart rate sensors, and post-match rate of perceived exertion (RPE) was collected. Descriptive statistics and between-group comparisons were applied to examine differences between roles, and the interrelationship between external and internal loads was explored using Pearson's correlation. FRs covered substantially more total distance and distance per minute than ARs (7.49 ± 2.47 vs 5.64 ± 1.25 km; 78.68 ± 14.56 vs 55.88 ± 7.78 m·min-1; both $p < .001$), and accumulated more medium-velocity running, whereas ARs reached higher maximal speeds and performed more high-speed running bouts and decelerations ($p \leq .031$). ARs also reported higher perceived exertion than FRs (6.80 ± .68 vs 4.23 ± 1.65, $p < .001$), and RPE showed strong positive correlations with accelerations ($r = .674$, $p < .001$) and decelerations ($r = .686$, $p < .001$). Heart rate data from FRs showed most match time spent in low-to-moderate intensity zones, with minimal exposure to very high intensities. The referees were exposed to substantial, role-dependent external and internal loads even in a non-professional regional setting. The distinct demands of FRs and ARs support the need for role- and category-specific conditioning, monitoring and recovery strategies used. These findings provide practical benchmarks to inform training prescription, load management and development pathways for football referees.
KEYWORDS: referee role; external load; GPS; internal load; rating of perceived exertion.

INTRODUCTION

Association football is governed by a unified set of Laws of the Game (IFAB, 2025). As a dynamic team sport, it places high technical, tactical, psychosocial and physical demands on both players (Modric et al., 2022; Sarmento et al., 2022) and match officials (Zhang et al., 2025). Matches are conducted under the authority of the field referee (FR), who is responsible for applying the Laws of the Game, supported by a team of officials that may include two assistant referees (ARs), a fourth official, additional assistants, the video assistant referee (VAR), and at least one assistant video assistant referee (AVAR). The performance and decisions of this refereeing team may directly influence match outcomes and the competitive balance of competitions (Spitz et al., 2021; Teixeira da Silva et al., 2024).

Contemporary football is characterised by greater speed, intensity and tactical complexity across men's and women's competitions (Nassis et al., 2020; Norton, 2025; Wallace & Norton, 2014). This evolution has increased the demands imposed on match officials, who typically cover 9–12 km per match and operate at sustained cardiovascular intensities of 85–95% of maximal heart rate (HR_{max}), with repeated high-intensity efforts above 18 km·h^{-1} (Martinho et al., 2023; Weston et al., 2012; Zhang et al., 2025). Refereeing now represents a physically demanding athletic task that requires continuous displacement, accelerations and directional changes

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Conflict of interests: nothing to declare. Funding: nothing to declare.
Received: 28th March 2025. Accepted: 25th April 2026.
Edited by: José Vilaça-Alves Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal.

to maintain effective positioning (Riiser et al., 2019; Weston, 2015). Higher physical fitness levels are associated with greater match running output and improved decision-making accuracy, whereas insufficient capacity may compromise positioning and decision-making performance during competition (Castillo-Rodríguez et al., 2023; Jiang et al., 2022).

However, refereeing demands are not uniform. Systematic reviews and observational studies indicate that physical and physiological loads vary according to officiating role, competitive category and contextual match characteristics (Martin-Sanchez et al., 2022; Martinho et al., 2023; Zhang et al., 2025). Clear distinctions have been reported between FRs and ARs. Compared with ARs, FRs accumulate greater total distance, higher high-intensity volumes, and elevated internal load markers, whereas ARs cover shorter distances within more spatially constrained lateral corridors (Martinho et al., 2023; Ozaeta et al., 2022). FRs also demonstrated higher mean HR and rate of perceived exertion (RPE), greater acceleration–deceleration loads and more multidirectional running, a pattern attributable to their central positioning and broader spatial responsibilities (Martin-Sanchez et al., 2022). Evidence from amateur competitions in Portugal and Spain confirmed this dichotomy, although with generally lower high-intensity outputs than those reported in elite contexts (Gomes et al., 2024; Ozaeta et al., 2022), supporting the need for role-specific analysis across competitive standards.

Beyond role differences, competitive level further modulates referees' workload profiles. Systematic evidence confirms that match demands vary across competitive categories, with higher-level competitions generally associated with greater high-speed running and cardiovascular strain (Martinho et al., 2023; Zhou et al., 2025). Contextual comparisons showed meaningful differences between confederations, as referees in European competitions covered greater total distances than those in South American tournaments (Birk Preissler et al., 2023). Physiological responses also differed across categories, with national-level referees demonstrating higher HR values and greater physical match outputs than lower-category officials (Castillo-Rodríguez et al., 2022). Further within-country analyses revealed division-dependent patterns: even though total distance remained similar, intensity distribution and physiological responses differed between first- and second-division referees (Martínez-Torremocha et al., 2023). Peak locomotor demands and high-intensity indicators varied substantially across competitive standards, with some sub-elite contexts imposing demands comparable to top-tier competitions (Martínez-Torremocha et al., 2025). Nonetheless, regional-level officials exhibited lower running speeds and reduced acceleration outputs relative to higher categories (Gomes et al., 2024).

Temporal analyses of officiating activity reveal meaningful fluctuations in referees' workload across match periods. Several studies reported reductions in high-intensity running, speed-related metrics and cardiovascular load from the first to the second half, although total distance often remained stable (Martínez-Torremocha et al., 2023; Zhang et al., 2025). Amateur-level investigations in Portugal and Spain described similar trends, with lower high-intensity activity, average speed and HR responses in later phases of play for both FRs and ARs (Gomes et al., 2024; Ozaeta et al., 2022). Short-interval analyses also detected early-match peaks and late-match fluctuations in locomotor and physiological variables, which suggest potential effects of fatigue, pacing strategies and match tempo (Castillo-Rodríguez et al., 2023; Martinho et al., 2023). Altogether, the magnitude and direction of these changes varied across competitive standards and officiating roles, and findings remained inconsistent across methodological approaches and performance levels (Pizzera et al., 2022; Zhang et al., 2025).

Despite advances in tracking technology, important limitations remain in the literature. Global positioning system (GPS)-based systems and effort measures such as RPE allow detailed quantification of referees' external and internal load and together constitute a comprehensive framework for analysing officiating workload (Cummins et al., 2013; Weston et al., 2012). Nevertheless, substantial methodological heterogeneity characterises existing studies, particularly in the definition of speed zones and load thresholds, thereby constraining direct comparisons between competitions and contexts (Birk Preissler et al., 2023; Martinho et al., 2023). Additionally, most evidence derives from elite and international refereeing, whereas amateur and regional contexts remain underrepresented despite their distinct competitive and organisational features (Gomes et al., 2024; Ozaeta et al., 2022; Zhang et al., 2025).

This gap is especially relevant in Portugal, where regional associations serve as the primary pathway for referee development. Context-specific analyses across competitive categories are therefore required to inform training prescription and monitoring strategies. Accordingly, the present study aims to quantify the external and internal match demands of field referees and assistant referees across competitive categories within the Aveiro Football Association (AFA).

MATERIAL AND METHODS

Participants

The study was carried out during the 2024/25 sports season, between October 2024 and January 2025, within the

scope of competitions organised by the AFA, in the Elite Championships (i.e., I Division and II Division), U19, and U23. The study sample consisted voluntarily of 8 referees and 7 assistant referees from the referee panel of the AFA, which referee a total of 98 matches of data collections:

- 1 referee belonged to category C4 Core;
- 2 referee belonged to category C5;
- 2 referee belonged to category C5B;
- 3 referee belonged to category C6 and 7 assistant referee's belonged to category CJ, C6 and C7.

This categorical stratification helps clarify the influence of Competitive Category on physical demands, a concept central to the intensity-driven progression across categories.

A post hoc power analysis was conducted using G*Power (version 3.1) after data collection to evaluate the sensitivity of the design for the primary between-group comparisons. The analysis was based on the sample sizes achieved for field referees (FR; N = 83) and assistant referees (AR; N = 15), using a two-tailed independent-samples t-test with an alpha level of 0.05 and the observed effect sizes for the main outcomes. For the key external and internal load variables, the achieved statistical power ranged from .78 to .92 for effects of the magnitude observed in the present data, indicating that the study was adequately powered to detect small-to-moderate between-role differences for the primary comparisons.

Ethical considerations guided the study design; formal ethical approval was obtained from both the AFA and its Refereeing Committee, reinforcing adherence to human subjects' research guidelines. These safeguards ensure the study's integrity and respect for participant autonomy, and all participants provided written informed consent after receiving comprehensive information on the study's procedures, potential benefits, discomforts, and associated risks.

Measures

A questionnaire was used to collect sociodemographic data (i.e., age, height, BMI, injuries, category, years of experience, and years in the respective category). Body weight was measured using a TANITA bioimpedance scale (TANITA Corporation, Tokyo, Japan). The referees' game activity was recorded using a portable GPS (INSIDERS, Lausanne, Switzerland), officially approved by FIFA. All referees included in the sample officiated matches with a duration of at least 90 minutes, 2 assistant referees (AR) were eliminated for not providing complete data.

One week before recording their first match, each referee was familiarised with the GPS device. The data collected during the games was then analysed by specific software called UBIKO SPORTS (UBIKO SORTS, Murcia, Spain). These devices have demonstrated an excellent level of accuracy and validity for evaluating external load in official competitions. This high-resolution data collection identifies the activity patterns of referees, distinguishing between linear and lateral movements, and quantifies the explosive efforts of modern officiating demands. The variables used were classified according to the following categories: total distance travelled (km); total distance travelled divided by time ($m.min^{-1}$); total high speed running distance (km); total sprint distance (km); total distance covered in sprint divided by time ($m.min^{-1}$); total number of ACC (n); total number of DEC (n). Distance covered and time were further categorised into distinct speed zones, offering a granular breakdown of movement patterns throughout a match: Walking-1 $km{\cdot}h^{-1}$, Jogging- 4 $km{\cdot}h^{-1}$, Low- 7 $km{\cdot}h^{-1}$, Medium- 14 $km{\cdot}h^{-1}$, High- 21 $km{\cdot}h^{-1}$, Sprint- 24 $km{\cdot}h^{-1}$.

Internal load measurement variables quantify the psychophysiological stress experienced by the referee in response to external demands. These measures complement external load data by quantifying the body's physiological response to work performed. They were collected during games using the same GPS device that has heart rate (HR) sensors embedded in the vest on the chest area. Heart rate data offers an objective physiological marker of cardiovascular strain, while the 0-10 Borg RPE scale provides a subjective assessment of effort, ranging from 0 ("no effort") to 10 ("maximum effort"). Integrating these measures is crucial for a holistic understanding of the workload and fatigue experienced by referees.

Statistical analysis

This study employed initial data processing that involved calculating descriptive statistics. The mean and standard deviation (SD) were computed for all external and internal load variables, providing a foundational summary of central tendency and variability. This was stratified by referee role (FR versus AR) to understand the physical and physiological demands. Before inferential analyses, assumptions regarding data distribution and variance were assessed. The Shapiro–Wilk test verified data normality, and Levene's test evaluated homogeneity of variances. Non-parametric alternatives were considered if assumptions were violated, ensuring robust statistical inferences.

To investigate differences in physical and physiological parameters between groups (FR versus AR), independent-samples t tests were conducted across all external and internal load variables. The interrelationship between external and internal loads was explored using Pearson's correlation coefficients (r). This analysis quantified the strength and direction of linear associations between key GPS-derived metrics (e.g., total distance, sprint distance, accelerations) and physiological or

perceptual responses (e.g., max HR, RPE). Such correlations illuminate how mechanical work translates into physiological and perceived stress. Statistical significance for all analyses was set at $p < .05$. Cohen's d and the Mann–Whitney U test were used, respectively, for effect size estimation and as a non-parametric alternative to the t-test when assumptions were not met. All statistical computations, including the main inferential analyses and the post hoc power analysis, were performed using JAMOVI (Version 2.7.11.0, The JAMOVI project, 2025, https://www.jamovi.org).

RESULTS

Participant characteristics

Participant demographics and anthropometrics offer crucial context for interpreting physical performance data. Table 1 details the mean (± SD) sociodemographic and anthropometric characteristics of the study participants, categorised by referee role (FR versus AR). FRs had a higher mean age, a significantly higher average height, and a slightly lower mean weight, resulting in a lower BMI, than the ARs. Also, their experience averaged a significantly higher value, at 10.38 ± 7.50 years overall. ARs' experience levels were lower, at 3.60 ± 3.71 years overall. Participant Characteristics provides the foundational human element of the study. This data underpins the analysis of external and internal loads, offering a demographic lens through which to interpret the physiological and kinematic responses observed during match play.

External load demands by referee role

Analysis of external load variables revealed significant differences in physical output between FRs and ARs within the AFA. These disparities highlight the distinct athletic profiles required for each officiating role, supporting the notion that referees' workload is role-specific. FR consistently exhibited greater distances covered and performed more distance-intensity activities across external load metrics compared to the ARs. Specifically, FRs covered an average total distance (TD) of 7.49 ± 2.47 km per match, reflecting their dynamic positioning requirements across the entire pitch. In contrast, ARs registered a mean TD of 5.64 ± 1.25 km, presenting a highly significant difference ($p < .001$). This indicates a profound practical difference in the volume of ground covered. When normalised by time, FRs maintained a total distance per minute (TD.min^{-1}) of 78.68 ± 14.56 m·min^{-1}, also significantly higher than the 55.88 ± 7.78 m·min^{-1} observed for ARs ($p < .001$).

High-intensity efforts, essential for optimal positioning in modern football, also demonstrated significant divergence. High-intensity running results were significantly higher for the ARs. Similarly, sprint running (SR) for ARs was more than double that of the FRs. There were differences in movement patterns, with FRs engaging in more frequent and longer medium-speed events. On the other hand, ARs had higher values in the extreme velocity range, with higher values in the walking category, higher speeds, and sprints (Figure 1). The number of accelerations (ACC) and decelerations (DEC), crucial indicators of intermittent high-intensity activity, also showed interesting differences. FRs executed 64.60 ± 37.84 ACC and 44.39 ± 38.18 DEC per match, while ARs performed 74.13 ± 17.88 ACC and 66.27 ± 19.19 DEC, with significant differences only in the DEC ($p = .003$). These data confirm that ARs perform a greater number of explosive, high-force movements.

The magnitude of these differences supports the observation that modern refereeing has become a highly demanding athletic task, even within an amateur context. ARs, while covering less total ground, still engage in significant high-intensity actions, albeit with a distinct kinematic profile emphasising lateral movements, which requires specific conditioning. Empirical evidence for these distinct external load

Table 1. Participant Characteristics (Mean ± SD).

	Role	N	Mean	SD	*p*-value
Age	AR	5	25.74	9.6434	.272
	FR	8	31.19	8.3164	
Height (m)	AR	5	1.71	.0241	**.001**
	FR	8	1.80	.0402	
Weight (kg)	AR	5	77.38	13.0316	.872
	FR	8	78.31	7.5543	
BMI (kg/m2)	AR	5	26.38	4.7802	.285
	FR	8	24.21	2.2470	
Activity years	AR	5	3.60	3.7148	**.039**
	FR	8	10.38	7.5012	

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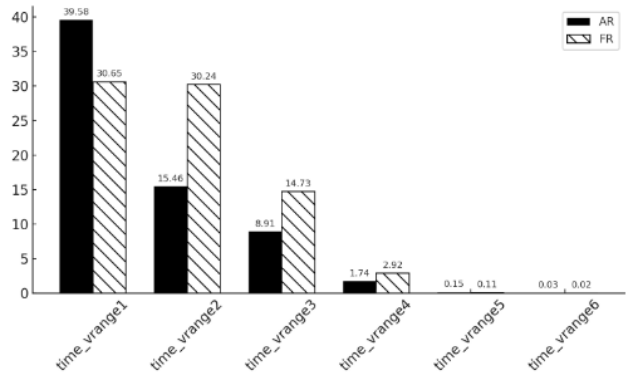


Figure 1. Comparison of time (minutes) in different velocity ranges by Referee Role.

profiles is presented in Table 2: Comparison of External Load Variables by Referee Role; findings establish a clear empirical distinction between roles.

Internal load demands by referee role

Internal load indicators, which capture referees' physiological and perceptual strain, were assessed subjectively by RPE and objectively with HR sensors. For FRs, the mean RPE was 4.23 ± 1.65, and the ARs' mean RPE score was 6.80 ± 0.68 on a 0–10 scale, indicating a higher perceived effort for the ARs with a significant difference (Table 3), in tune with the higher external load values in terms of ACC and DEC. Considering HR measures, the variation between roles could not be presented, since the vests with the HR sensors were used only by the FRs; therefore, HR data were available for 48 match observations from FRs only. Hence, the data presented in Table 4 are concerning HR scores of FRs in terms of maximum HR, mean HR, and percentage of time in 4 HR zones: Very Soft: 62; Soft: 70; Moderate: 80; Intense: 90. The average HR max was 157 ± 27.7 bpm and HR mean was 111 ± 34.9 bpm. Considering HR intensity zones, it is notable that RFs spent the majority of time in HR zones 1 and 2, interestingly with no accounts on zone 4—Intense. This also aligns with the external load findings concerning the velocity zones of the RFs.

These internal load findings offer crucial physiological context to the external demands previously discussed. The Fatigue-Induced Decoupling phenomenon establishes a foundation for further discussion on fatigue accumulation and its profound implications for referee performance, well-being, and the necessity of targeted recovery strategies. Table 4 summarises these internal load variables, providing an empirical view of AFA referees' physiological and perceptual responses.

Distance covered across speed categories

The Table 2 illustrates the breakdown of total distance covered by FRs and ARs across distinct speed zones: Walking 1 $km \cdot h^{-1}$, Jogging 4 $km \cdot h^{-1}$, Low 7 $km \cdot h^{-1}$, Medium 14 $km \cdot h^{-1}$, High 21 $km \cdot h^{-1}$, Sprint 24 $km \cdot h^{-1}$.

The visual pattern clearly indicates that FRs dedicate a greater proportion of their match distance to middle-speed zones - Jogging 4 $km \cdot h^{-1}$, Low 7 $km \cdot h^{-1}$. In the profile, FRs also spend a considerable amount of time and distance of their total distance walking. Conversely, ARs exhibit a contrasting distribution: the majority of their distance is covered in walking and medium-intensity running, with medium-intensity running accounting for a smaller fraction, and high-intensity and sprint zones contributing minimally, although these higher-intensity zones present higher values than RFs. This distribution confirms that the difference between referee roles is qualitative as well as quantitative. RFs cover a larger proportion of distance at velocities that engage aerobic pathways and necessitate repeated accelerations. ARs, however, concentrate their movement in higher-speed bands, characterised by intermittent short bursts of speed rather than sustained lower-intensity segments.

Correlation between external and internal load

The strong positive correlations observed confirm that greater physical output directly translates into increased physiological and perceived strain in AFA referees, underscoring the interconnectedness of these two load dimensions. Table 5 presents Pearson's correlation coefficients (r) between total distance (TD), distance per minute, high speed running (HSR), sprint running (SR), accelerations (ACC), decelerations (DEC), and perceived exertion (RPE). This indicates that referees need higher intensity scores to better perceive the game load. Similarly, the Total distance and Distance/Minute external load variables did not significantly correlate with the internal RPE, emphasising the physiological lower perceived cost of sustained lower-speed movements. These relationships highlight the direct impact of higher mechanical work on RPE.

Sprint running (SR) exhibited a moderate positive correlation with RPE ($r = 0.308$, $p < .05$), suggesting that referees' subjective perception of effort increases with the volume of maximal speed efforts. This is further supported by the strong positive correlation between accelerations (ACC) and decelerations (DEC) with RPE ($r = .674$ and .686, respectively, both $p < .001$), reinforcing that explosive, intermittent actions contribute significantly to overall perceived exertion.

The strong positive correlations between external and internal load RPE variables provide a crucial empirical link between the "work done" and the "body's response" in AFA referees. This subsection concludes the Results by demonstrating the integrated nature of referee workload. It provides a crucial link between the external demands of officiating and the internal physiological and perceptual responses.

Table 2. Comparison of External Load Variables by Referee Role (Mean ± SD).

	Role	N	Mean	SD	p-value
Total distance km	AR	15	5.6421	1.2527	< .001
	FR	83	7.4940	2.4699	
Distance per minute $m.min^{-1}$	AR	15	55.8755	7.7821	< .001
	FR	83	78.6753	14.5624	
Max speed $km{\cdot}h^{-1}$	AR	15	23.9695	2.1056	.031
	FR	83	22.3694	2.6792	
Hid intervals	AR	15	7.3493	7.4423	.005
	FR	83	3.4917	5.3279	
High speed runs	AR	15	.0651	.0616	.019
	FR	83	.0488	.0969	
Sprints	AR	15	.9333	1.7915	.460
	FR	83	.6627	2.2267	
Accelerations m/s2	AR	15	74.1333	17.8800	.068
	FR	83	64.6024	37.8356	
Decelerations m/s2	AR	15	66.2667	19.1851	.003
	FR	83	44.3855	38.1818	

N: refers to match observations, not individual referees.

Table 3. Comparison of Internal Load Variable (Rate of Perceived Exertion - RPE) by Referee Role (Mean ± SD)

	Role	N	Mean	SD	p-value
Borg CR-10	AR	15	6.80	.676	< .001
	FR	35	4.23	1.65	

N: refers to match observations, not individual referees.

Table 4. Internal Load Variables Heart Rate (bpm) of Main Referees (FRs).

	HR max	HR mean	HR Z1 (%)	HR Z2 (%)	HR Z3 (%)	HR Z4 (%)
N	48	48	26	26	23	0
Missing	35	35	57	57	60	83
Mean	157	111	33.2	33.8	17.6	NaN
SD	27.7	34.9	18.0	17.2	15.7	NaN
Minimum	67	15.4	1.75	1.15	2.58	NaN
Maximum	208	159	59.4	63.4	59.5	NaN

N: refers to match observations, not individual referees.

Table 5. Correlation Matrix of Key External and Internal Load Variables.

	Total distance	Distance/ Minute	Max speed	High speed running	Sprints	ACC	DEC	Borg CR-10
Total distance	—							
Distance/ minute	.734***	—						
Max speed	.244	.079	—					
High speed running	.464**	.267	.798***	—				
Sprints	.431**	.269	.707***	.847***	—			
ACC	.603***	.268	.716***	.706***	.540***	—		
DEC	.301	-.030	.719***	.712***	.497***	.857***	—	
Borg CR-10	.161	.176	.605***	.484**	.308*	.674***	.686***	—

*p < .05; ** p < .01; *** p < .001.

DISCUSSION

This study examined the external and internal match demands of field referees and assistant referees from a Portuguese regional football association (AFA) across multiple competitive categories. FRs covered greater total distance and distance per minute and spent a larger proportion of time in medium-speed zones, whereas ARs reached higher maximal speeds and performed more high-speed efforts, accelerations and decelerations. ARs also reported higher perceived exertion than FRs, and RPE was strongly associated with high-intensity external load indicators, particularly ACC and DEC. These findings confirm that referee workload is both role- and category-dependent, even in a non-professional regional context, and underline the relevance of integrated monitoring of external and internal load for referee development and support.

The non-professional status of these referees, a common feature in regional football, constrains their availability for structured training and recovery and helps explain the heterogeneity observed in their physical profiles. Their demographic and experience characteristics provide important context for interpreting the external and internal load results, as they reflect distinct career trajectories and physical development opportunities for each role. In practice, AFA referees must frequently balance officiating with work or study commitments, which amplifies the relevance of quantifying their match demands in real competitive settings. The present data, collected across multiple official competitions within the Aveiro Football Association, therefore captures the reality of regional officiating rather than idealised laboratory conditions.

The inclusion of several competitive tiers (Elite Championships, I Division, II Division, U19, and U23) allows a nuanced view of how demands may scale with level of play. Higher divisions typically feature faster tempo, greater technical quality and more intense tactical actions, which translate into higher physical loads for the officiating team. Conversely, lower divisions and youth competitions may exhibit different activity patterns, with more variability in game control and match rhythm, influencing both movement profiles and physiological responses of referees. Although the present sample size prevents detailed between-division comparisons, this competitive context is essential to frame the observed external and internal load patterns and to interpret their practical significance for amateur referee development.

Interpretation of role-specific demands

The results clearly support the notion that referees' workload is role specific. FRs and ARs exhibited distinct athletic profiles. FRs covered greater total distance and distance per minute and accumulated more medium-intensity running, whereas ARs reached higher maximal speeds and performed more high-speed running, accelerations and decelerations, alongside higher RPE scores. These differences are consistent with their positional tasks, as FRs must cover the entire pitch to maintain appropriate proximity to play, while ARs operate in a more confined lateral corridor and rely on short, high-intensity bursts to track offsides and transitions (Gomes et al., 2024; Ozaeta et al., 2022).

In several metrics, particularly total distance, AFA FRs resemble elite referees reported in international competitions (Barbero-Álvarez et al., 2012; Mallo et al., 2009; Weston et al., 2012). However, their high-intensity running and sprint distances remain below elite values described in recent systematic reviews and meta-analyses (Birk Preissler et al., 2023; Martinho et al., 2023; Zhang et al., 2025). This gap suggests that while non-professional FRs sustain substantial work volume, their ability to repeatedly perform very high-intensity efforts is comparatively limited. The movement profiles further highlight that ARs carry a disproportionate share of explosive actions, supporting the view that each role imposes specific energy-system and neuromuscular demands that should be reflected in conditioning programmes (Martin-Sanchez et al., 2022).

These role-dependent patterns have direct implications for training load management. Monitoring GPS-derived variables such as high-intensity running, sprint distance, accelerations and decelerations, together with simple internal load measures like post-match RPE, provides a practical framework to estimate physiological and perceptual strain (Cummins et al., 2013; Weston et al., 2012). For example, a match characterised by high sprint distance and frequent accelerations/decelerations is likely to impose greater mechanical and perceptual load, signalling the need for more targeted recovery strategies in subsequent days. This integrated, data-informed approach moves beyond subjective impressions of fitness and offers concrete information to support decisions about training prescription, recovery and match appointments.

From a development perspective, generic endurance-focused programmes that mainly target total distance are unlikely to prepare referees for the qualitative demands of higher tiers (Martinho et al., 2023; Zhang et al., 2025). Instead, role- and category-specific training is warranted. FRs may benefit from high-intensity interval training and repeated-sprint protocols that mimic their intermittent running profile and the need for rapid changes of pace (Krustrup et al., 2002; Reilly & Gregson, 2006). ARs require greater emphasis on lateral accelerations, short sprints, change-of-direction drills and

neuromuscular control to tolerate frequent braking and re-acceleration along the touchline (Gomes et al., 2024; Krustrup et al., 2002). Both roles still need a solid aerobic base to sustain overall match demands, but the relative emphasis and periodisation of training should diverge according to the distribution of speeds and actions identified in the present results.

The speed-zone distributions (Figure 2) further reinforce this interpretation. As referees progress to higher competitive categories, a larger proportion of their distance is expected to shift into higher-speed zones and more frequent high-intensity bouts (Birk Preissler et al., 2023; Martinho et al., 2023). Consequently, tracking the percentage of distance covered at high-intensity and sprint speeds may provide a simple, actionable indicator for evaluating readiness for promotion or exposure to more demanding competitions. Routine reporting of these metrics over time can assist referee coaches in individualising training plans, managing return-to-play after injury and aligning match assignments with current physical capacity.

Integrated load management and practical utility

The strong positive correlations observed between high-intensity external load variables (sprint distance, accelerations and decelerations) and RPE support an integrated view of load management that combines external and internal indicators. Greater physical output was consistently associated with increased perceived exertion, underscoring the interconnected nature of mechanical work and psychophysiological stress in this cohort (Castillo-Rodríguez et al., 2023). This relationship is particularly relevant in a non-professional context, where limited time for structured training and recovery may heighten vulnerability to cumulative fatigue (Gomes et al., 2024).

Understanding this interplay offers practical benefits for regional football associations. By systematically monitoring

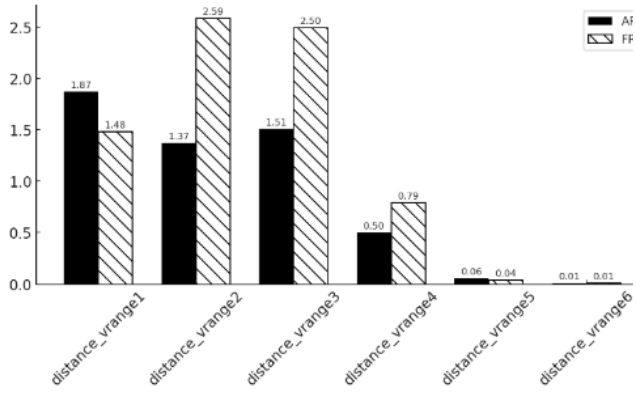


Figure 2. Comparison of distance (km) in different velocity ranges by Referee Role: Walking 1 km·h^{-1}, Jogging 4 km·h^{-1}, Low 7 km·h^{-1}, Medium 14 km·h^{-1}, High 21 km·h^{-1}, Sprint 24 km·h^{-1}.

key external metrics together with RPE and, where available, heart rate, associations can better anticipate periods of elevated fatigue, adjust training loads and plan rest or lighter appointments for heavily loaded referees (Cummins et al., 2013; Zhang et al., 2025). Over time, such practices may help reduce fatigue-related errors, mitigate injury risk and support a healthier, more sustainable progression for referees across competitive categories (Castillo-Rodríguez et al., 2023; Zhou et al., 2025).

LIMITATIONS AND FUTURE RESEARCH

This study, while offering novel insights into Portuguese regional refereeing, has inherent limitations. The relatively small sample size (8 referees and 7 assistant referees) from a single Football Association restricts statistical power and the generalizability of these findings to the broader Portuguese or international referee population. Furthermore, while the 12–14-week data collection period is substantial, it may not fully capture seasonal variations or long-term adaptations in referee performance. The unique challenges faced by non-professional referees, including limited time for structured training and recovery, require careful contextualization when comparing them with elite professional referees, whose operational and support environments differ substantially (Castillo-Rodríguez et al., 2022; Gomes et al., 2024). This study did not explicitly detail environmental conditions such as temperature, humidity, or pitch condition, which significantly influence both external and internal load, representing a further constraint on results interpretation.

Future research must build upon longitudinal studies that are essential to investigate the long-term physical development and performance trajectories of referees across AFA categories, linking specific training interventions to performance improvements and injury reduction over multiple competitive seasons. This approach nurtures continuous inquiry and enhanced training methodologies. Intervention trials, which involve designing and implementing tailored training programs for FRs and ARs based on identified demands, would rigorously evaluate their impact on match performance, physiological responses, and injury incidence. This shifts the focus from descriptive analysis to prescriptive, evidence-based interventions.

Further analysis could explore how varying match tactical approaches by teams (e.g., high press versus low block) influence referee movement patterns and physiological loads, potentially integrating tactical analysis software with GPS data. This would add a critical layer of tactical context to physical demands. Investigating advanced physiological recovery markers (e.g.,

heart rate variability, biochemical markers) in AFA referees would deepen the understanding of fatigue accumulation and recovery efficacy, particularly during congested fixture periods. This addresses the potential decoupling between perceived exertion and heart rate, providing objective insights into the psychophysiological stress experienced. Finally, studies correlating physical and mental fatigue with objective measures of referee decision-making accuracy and consistency would further elucidate the critical link between physical capacity and cognitive performance, an area often overlooked in amateur sports science. These proposed directions address the identified limitations and advance the understanding of referee performance, contributing to the continuous pursuit of optimised referee performance within the AFA and beyond.

CONCLUSION

This study shows that regional Portuguese football referees are exposed to substantial but role-specific external and internal match demands. FRs covered more total and relative distance and accumulated more running at medium velocities, whereas ARs reached higher maximal speeds, performed more high-speed efforts and decelerations, and reported higher perceived exertion. The strong associations between high-intensity external load indicators and RPE highlight the importance of monitoring explosive, intermittent actions when managing referee workload. Together, these findings support the implementation of role- and category-specific conditioning, monitoring and recovery strategies in regional referee development, rather than relying on generic endurance-based training.

Practical implications

The distinct load profiles observed for FRs and ARs indicate that conditioning programmes for regional referees should be role-specific rather than uniform. FRs require sufficient aerobic capacity and repeated medium-intensity running tolerance to sustain positioning across the full pitch, whereas ARs benefit from training that emphasises short, high-speed efforts and frequent accelerations and decelerations along the touchline.

Routine monitoring of GPS-derived indicators (e.g., sprint distance, number of accelerations and decelerations, time spent in high-speed zones) combined with simple internal load measures such as post-match RPE can provide referee coaches with actionable feedback. These data can be used to individualise training loads, support return-to-play decisions after injury and identify referees whose current physical profile may not yet match the demands of higher competitive categories.

For regional associations with limited resources, implementing basic external and internal load monitoring around competitive matches may represent a pragmatic first step towards more structured referee development. Using objective high-intensity benchmarks alongside traditional qualitative assessments could help refine selection and promotion processes, reduce fatigue-related errors and contribute to better referee retention and progression over time.

ACKNOWLEDGMENTS

The authors thank the Aveiro Football Association and its Refereeing Committee for their invaluable support and permission to conduct this study. We also extend our gratitude to the referees and assistant referees who voluntarily participated, without whom this research would not have been possible. Lastly, we thank the UBIKO SPORTS enterprise for allowing us to use the software freely.

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