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The influence of age and refereeing experience on the official matches' physical and physiological responses of football referees

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Abstract: This study analyzed the influence of age, refereeing experience, and experience at the current competitive level on amateur football referees' physical and physiological responses. Twenty-three referees (age: 25.65 ± 3.30 years) from the División de Honor de Vizcaya (Spain) participated. Physical responses (e.g., distance, power, speed, cadence, ground contact time, stiffness) were measured using a Stryd Power Meter, while physiological responses (e.g., heart rate, training impulse) were monitored via Polar Team 2. A split-group analytical design using independent-samples test was used to examine differences between groups, as well as correlation analyses to explore associations between experience-related variables and match responses. Referees were grouped by age (< 26 vs. > 26 years), refereeing experience (< 9 vs. > 9 years), and experience in the current category (< 3 vs. > 3 years). Older referees showed lower vertical oscillation ($p < 0.05$, $d = -1.12$ to -1.85) and longer ground contact time ($p < 0.05$, $d = 1.18$). More experienced referees covered less distance and had lower power and speed ($p < 0.05$, $d = -1.04$ to -1.93). Referees with greater experience at the current competition level registered higher peak power and speed ($p < 0.05$, $d = 0.91$ to 1.13). In conclusion, greater refereeing experience and familiarity with the competition level help referees optimize their physical performance, allowing them to execute high-intensity efforts during key match moments.

Keywords: field referees; external load; internal load; competition level; category; soccer referees.

1. Introduction

Refereeing is an intermittent activity that primarily requires the involvement of the aerobic system (oxidative phosphorylation), although it is interspersed with periods of high intensity that require the

anaerobic system (PCr and anaerobic glycolysis) (Stølen et al., 2005). Specifically, amateur referees cover around 10 to 11 km per match, of which almost 3 km are covered at high intensity (over $13 \text{ km}\cdot\text{h}^{-1}$), and approximately 800 m are covered at high speed (over $18 \text{ km}\cdot\text{h}^{-1}$) (Castillo et al., 2018).



Refereeing is a highly demanding psychophysiological activity characterized by a high physiological load, with referees maintaining a mean heart rate (HR_{mean}) above 85% of their peak heart rate (HR_{peak}), spending over 24 minutes above 90% of their maximum heart rate (HR_{max}), and reporting high ratings of perceived exertion (RPE), particularly muscular exertion (RPE_{mus}), with values ranging between 6.2 and 7.2 (Castagna et al., 2007; Ozaeta Beaskoetxea et al., 2018).

As previously mentioned, objective variables such as distance and heart rate have been extensively analyzed using GPS devices and heart rate monitors. However, few studies have explored the potential of Stryd in refereeing. Stryd, a foot-mounted power meter, provides key metrics such as power output, vertical oscillation, cadence, ground contact time, and leg stiffness (Dearing & Paton, 2023; Van Rassel et al., 2023). Studies on football referees using Stryd have reported an average power output of 120 W during matches (Ozaeta et al., 2021), offering a novel perspective on workload distribution. Unlike GPS, which primarily measures external load through distance parameters, Stryd captures biomechanical variables, providing deeper insights into referees' physical responses during matches (Ozaeta et al., 2021). Integrating Stryd into referee performance assessment could enhance monitoring strategies and optimize training programs.

Referees' match physical and physiological responses may vary depending on the context (Ozaeta, Yanci, et al., 2022) or the characteristics of the referees, such as age or experience refereeing (Muñoz-Arjona et al., 2021; Weston et al., 2010). Altogether,

these previous studies have shown that more experienced referees register higher physiological responses during matches than their younger counterparts (Muñoz-Arjona et al., 2021). Notably, more experienced referees spent more time above 95% of their HR_{peak} (Muñoz-Arjona et al., 2021). Paradoxically, despite these higher physiological responses, older referees tend to show lower physical responses regarding total distance covered, high-intensity running, and performed sprints (Weston et al., 2010). It would be interesting to understand the demands that referees are exposed to, considering not only their age but also their experience refereeing and their experience refereeing at the current level, as these differences found in the literature could be attributable to better energy management and more efficient decision-making based on accumulated experience over the years (Weston et al., 2010).

Based on the aforementioned literature, this study had two main objectives: (1) To compare the differences in physical responses, physiological responses, and perceived exertion among amateur referees based on their age, refereeing experience, and experience at their current competitive level; and (2) To analyze the influence of amateur referees' age, refereeing experience, and experience at their current competitive level on their physical responses, physiological responses, and perceived exertion.

For the first objective, we hypothesize that there may be significant differences in physical responses, physiological responses, and perceived exertion among amateur referees based on their age, refereeing experience, and experience at their current competitive level. Specifically, older referees

might exhibit lower physical and physiological responses, possibly due to a better understanding of the match and improved positioning on the field.

For the second objective, we hypothesize that age, refereeing experience, and experience at the current competitive level may significantly influence physical responses, physiological responses, and perceived exertion, potentially reducing these responses. This effect could be explained by accumulated refereeing experience, which may enhance their ability to interpret the match more effectively and optimize their movements on the field.

2. Materials and Methods

Subjects - Twenty-three male amateur soccer referees (age: 25.65 ± 3.30 years; height: 173.4 ± 3.8 cm; body mass: 64.86 ± 5.82 kg; body mass index, BMI: 21.56 ± 1.67 kg·m⁻²) who officiated matches in *División de Honor (Bizkaia)*, participated in the present study. The statistical power analysis was performed using the G*Power software (Universität Kiel, Kiel, Germany). With a sample size of $N = 23$ and a significance level of $\alpha = 0.05$, the study achieved a statistical power ($1 - \beta$) of 0.75 to detect a correlation or standardized difference of 0.50. All participants trained at least two times a week and officiated matches at this competitive level at least twice a month. Referees had at least 3 years of refereeing experience. Participants were informed of the procedures, methods, benefits, and possible risks involved in the study before providing written informed consent. This investigation was conducted in accordance with the Declaration of Helsinki and was approved by

the Ethics Committee of The University of the Basque Country (Code: M10/2018/289).

Design - This study employed a descriptive, cross-sectional design to compare and examine the associations between age, years of experience refereeing, and experience in the Division de Honor category, with match physical and physiological responses, was carried out. To make the comparison between groups, the referees were divided into two groups by the median for each of the independent variables of the present study (age, experience as a referee, and experience refereeing in the current category), a previously applied approach in football when dealing with continuous variables (Rampinini et al., 2007). For age comparisons, referees were divided into two groups: under 26 years (AgeU26, $n = 12$; 22.44 ± 1.51 years) and over 26 years (AgeA26, $n = 11$; 28.18 ± 2.40 years). For EXPREF, groups were under 9 years (ExprefU9, $n = 12$; 23.70 ± 2.45 years) and over 9 years (ExprefA9, $n = 11$; 27.90 ± 3.00 years). For EXPCAT, groups were under 3 years (ExpcatU3, $n = 14$; 25.44 ± 2.36 years) and over 3 years (ExpcatA3, $n = 9$; 25.79 ± 4.56 years). Before the start of the match, referees performed a 10-minute warm-up consisting of running, stretching, short sprints, and progressive sprints.

Measures - Match physical responses: Referees' physical responses were monitored using a Stryd Power Meter (Stryd, Inc., Boulder, Colorado, USA), which was placed over the right soccer boot with a plastic clip regardless of their lower limb dominance (Navalta et al., 2019). The Stryd Power Meter has previously been utilized to measure physical responses in soccer referees (Ozaeta

et al., 2021). Offline data collection was activated in accordance with the manufacturer's recommendations. Stryd records total match data for the following variables: [total distance covered (TD), mean power (PWRm), peak power (PWRp), mean speed (SPDm), peak speed (SPDp), mean cadence (CADm), peak cadence (CADp), mean vertical oscillation (VOSCm), peak vertical oscillation (VOSCp), mean GCT (GCTm), peak GCT (GCTp), mean stiffness (STIFFm) and peak stiffness (STIFFp)].

Match physiological responses: Referees' HR was monitored during matches with a Polar Team 2 device (Polar Team System™, Kempele, Finland) at 1s intervals previously used in soccer referees (Castillo et al., 2018; Ozaeta et al., 2021). The HRmean and HRpeak were considered for this study and training impulse (TRIMP) was also calculated. According to the study by Edwards (Edwards, 1993), intensity was represented by the time spent in 5 arbitrary HR zones (Zone 1, 50-60% of their HRp; Zone 2, 60-70% of their HRp; Zone 3, 70-80% of their HRp; Zone 4, 80-90% of their HRp; and Zone 5, 90-100% of their HRp) multiplied by the number of each zone (1, 2, 3, 4, and 5). The sum of values obtained for each zone represented TRIMP, measured by arbitrary units (AU) (Castagna et al., 2017; Castillo et al., 2018).

Differentiated perceived exertion (dRPE): To quantify soccer referees' differentiated perceived exertion, the dRPE scale was employed (Castillo et al., 2017; Ozaeta Beaskoetxea et al., 2018). At the end of the match, each referee was presented with the RPE scale ranging from 0-10 (Foster et al., 2001), distinguishing between the perceived respiratory exertion (RPEres) and perceived

muscular exertion (RPEmus) previously used in football referees (Castillo et al., 2017; Ozaeta Beaskoetxea et al., 2018).

Statistical analysis - Data are presented as mean $\pm$ standard deviation (SD). Maximum, minimum, and median values were calculated for AGE, EXPREF, and EXPCAT to assess distribution and variability. Normality and homoscedasticity were tested using the Shapiro-Wilk and Levene tests. Parametric tests were applied when assumptions were met; otherwise, non-parametric equivalents were used. Between-group comparisons, based on median-split analysis of AGE, EXPREF, and EXPCAT, were performed using Student's t-test or Mann-Whitney U test. Effect sizes were calculated using Cohen's *d* (Cohen, 1988) for parametric data (large > 0.8 , moderate 0.5–0.8, small 0.2–0.5, trivial < 0.2) and rank biserial correlation (r_b) for non-parametric data (large > 0.5 , moderate 0.3–0.49, small 0.1–0.29, trivial < 0.1) (López Martín & Ardura Martínez, 2023). Associations between match responses and independent variables were assessed using Pearson's *r* for parametric and Spearman's rho for non-parametric data. Correlation strength was interpreted as trivial (< 0.1), low (0.1–0.3), moderate (0.3–0.5), high (0.5–0.7), very high (0.7–0.9), and almost perfect (> 0.9) (Hopkins et al., 2009). To control for multiple comparisons, significance in correlation analyses was adjusted using the Bonferroni correction. Statistical analyses were conducted using JASP software (version 0.13, Amsterdam, Netherlands), with significance set at $p < 0.05$.

3. Results

The 23 participants in the study had an average age of 25.65 ± 3.3 years (median: 26

years; minimum: 20 years; maximum: 33 years). The mean EXPREF was 9.87 ± 2.42 years (median: 9 years; minimum: 5 years; maximum: 13 years), and the average EXPCAT was 3.49 ± 1.37 years (median: 3 years; minimum: 1 year; maximum: 6 years). The match physical and physiological responses registered by the referees during official matches are shown in Table 1.

Differences in physical and physiological responses between groups of AGE, EXPREF and EXPCAT are shown in Table 2. AgeA26 registered lower VOSCm, VOSCp, and HRmean than the AgeU26

group ($p < 0.05$, $d = -1.12$ to -1.85 ; almost perfect). Moreover, AgeA26 referees registered higher values of GCTm ($p < 0.05$, $d = 1.18$; almost perfect) than the referees of AgeU26. Referees of the group ExprefA9 covered less TD and registered lower PWRm and SPDm than ExprefU9 referees ($p < 0.05$, $d = -1.04$ to -1.93 ; almost perfect). In addition, they also registered higher values of GCTm ($p < 0.05$, $d = 1.61$; almost perfect). Finally, ExpcatA3 referees registered higher PWRp, SPDp, STIFFm, and HRmean ($p < 0.05$, $d = 0.91$ to 1.13 ; almost perfect) than the referees of ExpcatU3 group.

Table 1. Physical and physiological demands of soccer referees during official matches.

	Mean	SD	Min	Max
<i>Physical responses</i>				
TD (km)	8.65	0.83	6.58	10.20
PWRm (W)	120.72	11.53	101.72	146.12
PWRp (W)	425.50	67.24	328.50	595.50
SPDm ($\text{km}\cdot\text{h}^{-1}$)	7.11	0.64	6.13	8.13
SPDp ($\text{km}\cdot\text{h}^{-1}$)	24.13	1.83	21.35	27.79
CADm ($\text{steps}\cdot\text{min}^{-1}$)	62.83	1.75	60.06	65.79
CADp ($\text{steps}\cdot\text{min}^{-1}$)	129.76	18.31	109.50	165.50
VOSCm (cm)	7.99	0.52	7.44	9.27
VOSCp (cm)	42.38	9.64	26.09	68.13
GCTm ($\text{m}\cdot\text{s}^{-1}$)	541.21	59.02	446.13	644.61
GCTp ($\text{m}\cdot\text{s}^{-1}$)	2036.61	204.73	1794.00	2642.00
STIFFm ($\text{KN}\cdot\text{m}^{-1}$)	9.28	0.56	8.37	10.59
STIFFp ($\text{KN}\cdot\text{m}^{-1}$)	35.92	8.03	20.85	49.90
<i>Physiological responses</i>				
HRmean (bpm)	158.67	11.99	136.46	183.7
HRpeak (bpm)	189.83	13.40	170.00	222.00
Zone 1 (min)	1.36	3.27	0.00	12.53
Zone 2 (min)	4.51	9.99	0.00	48.63
Zone 3 (min)	21.73	15.89	2.38	68.53
Zone 4 (min)	41.69	11.78	5.27	59.18
Zone 5 (min)	24.36	13.83	0.22	51.43
TRIMP (AU)	364.11	44.66	236.92	425.67
RPEres	3.91	1.59	1.00	7.00
RPEmus	5.20	1.88	2.00	8.00

Note. EXPCAT: experience in the current competitive level; TD: total distance; PWRm: mean power; PWRp: peak power; SPDm: mean speed; SPDp: peak speed; CADm: mean cadence; CADp: peak cadence; VOSCm: mean vertical oscillation; VOSCp: peak vertical oscillation; GCTm: mean ground contact time; GCTp: peak ground contact time; STIFFm: mean stiffness; STIFFp: peak stiffness; HRm: mean heart rate; HRp: peak heart rate; TRIMP: training impulse; RPEres: perceived respiratory exertion; RPEmus: perceived muscular exertion.

Table 2. Differences in physical and physiological responses between groups (age, referee experience and experience in the current competition level)

	Age			EXPREF			EXPCAT		
	AgeU26	AgeA26	d/r _b	ExprefU9	ExprefA9	d/r _b	ExpcatU3	ExpcatA3	d/r _b
<i>Physical responses</i>									
TD (km)	8.54±1.00	8.68±0.76	0.155 (-1.04; 0.73)	9.13±0.69	8.43±0.64	-1.044* (-1.97; -0.09)	8.77±0.76	8.47±0.95	-0.357
PWRm (W)	122.84±11.30	117.42±11.92	-0.466 (-1.35; 0.43)	128.05±11.63	114.62±9.04	-1.290** (-2.25; -0.30)	119.18±12.05	123.11±10.92	0.338
PWRp (W)	420.28±61.49	429.14±80.68	0.122 (-0.76; 1.02)	428.90±54.59	427.70±83.07	-0.017 (-0.89; 0.86)	400.36±39.29	464.61±84.25	1.062*
SPDm (km·h ⁻¹)	7.22±0.61	6.88±0.63	-0.547 (-1.44; 0.36)	7.60±0.50	6.69±0.44	-1.927** (-2.99; -0.83)	7.08±0.69	7.16±0.58	0.118
SPDp (km·h ⁻¹)	24.31±2.35	24.00±1.60	-0.155 (-1.04; 0.73)	24.85±1.77	24.02±1.73	-0.473 (-1.36; 0.42)	23.41±1.02	25.25±2.28	1.133*
CADm (steps·min ⁻¹)	62.08±0.98	62.80±1.92	0.451 (-0.45; 1.34)	63.43±1.70	62.26±1.72	-0.685 (-1.58; 0.23)	62.73±2.04	62.98±1.28	0.139
CADp (steps·min ⁻¹)	126.28±14.89	136.86±20.25	0.586 (-0.32; 1.48)	127.30±19.13	128.90±17.10	0.088 (-0.79; 0.96)	128.29±18.82	132.06±18.33	0.202
VOScm (cm)	8.46±0.54	7.73±0.22	-1.852** (-2.90; 0.77)	8.23±0.70	7.80±0.22	-0.827 (-1.73; 0.10)	7.91±0.43	8.13±0.65	0.429
VOScp (cm)	48.25±9.60	38.42±6.72	-1.209* (-2.16; 0.23)	42.24±10.64	40.45±5.58	-0.211 (-1.09; 0.67)	42.31±12.01	42.48±4.63	0.017
GCTm (m·s ⁻¹)	518.05±39.78	577.21±57.41	1.175* (0.20; 2.12)	512.25±34.62	584.97±53.74	1.609* (0.57; 2.61)	557.73±63.72	515.51±41.96	-0.748
GCTp (m·s ⁻¹)	2137.11±151.03	1952.55±238.54	-0.903 (-1.82; 0.04)	2115.20±132.62	1975.60±264.68	-0.667 (-1.56; 0.25)	2006.86±228.04	2082.89±163.72	0.369
STIFFm (KN·m ⁻¹)	9.46±0.75	9.17±0.38	-0.507 (-1.40; 0.40)	9.28±0.66	9.25±0.42	-0.056 (-0.93; 0.82)	9.09±0.41	9.58±0.65	0.942*
STIFFp (KN·m ⁻¹)	33.09±8.19	39.36±7.83	0.785 (-0.14; 1.69)	33.90±8.84	39.31±6.86	0.684 (-0.23; 1.58)	37.69±7.73	33.17±8.15	0.572
<i>Physiological responses</i>									
HRmean (bpm)	165.71±11.35	153.24±11.06	-1.115* (-2.05; -0.15)	161.94±10.07	153.01±11.69	-0.810 (-1.72; 0.12)	154.71±11.87	164.84±9.83	0.910*
HRpeak (bpm)	193.56±11.00	187.55±16.61	-0.417 (-1.30; 0.48)	190.90±9.60	188.30±17.32	-0.186 (-1.06; 0.70)	188.29±15.08	192.22±10.67	0.290
Zone 1 (min)	0.05±0.08	2.65±4.47	0.780 (0.15; 1.69)	0.23±0.33	2.91±4.62	0.820 (-0.11; 1.73)	2.23±4.01	0.01±0.03	-0.703
Zone 2 (min)	1.60±2.19	7.42±14.04	0.550 (-0.36; 1.44)	2.18±2.16	8.13±14.58	0.571 (-0.33; 1.46)	6.59±12.41	1.26±2.23	-0.541
Zone 3 (min)	19.48±20.08	23.15±13.78	0.218 (-0.67; 1.10)	23.13±18.63	23.88±14.38	0.045 (-0.83; 0.92)	23.52±13.48	18.94±19.62	-0.285
Zone 4 (min)	44.34±11.78	39.74±13.51	-0.360 (-1.24; 0.53)	40.26±8.25	38.68±13.57	-0.141 (-1.02; 0.74)	39.95±12.30	44.39±11.05	0.375

Zone 5 (min)	28.90±15.18	20.78±12.25	-0.596 (-1.49; 0.31)	27.40±16.04	20.16±12.77	-0.499 (-1.38; 0.40)	20.96±14.19	29.65±12.13	0.646
TRIMP (AU)	383.55±39.95	349.77±48.58	-0.752 (-1.66; 0.17)	371.98±38.24	346.31±50.01	-0.577 (-1.47; 0.33)	350.58±45.26	385.16±36.56	0.820
RPE _{res}	4.33±1.79	3.46±1.29	-0.574 (-1.47; 0.33)	4.20±1.86	3.60±1.27	-0.377 (-1.26; 0.51)	3.57±1.44	4.44±1.74	0.559
RPE _{mus}	4.94±1.85	5.18±1.99	0.123 (-0.76; 1.00)	5.45±1.71	5.30±2.06	-0.079 (-0.96; 0.80)	5.46±1.69	4.78±2.17	-0.364

Note. In italics: non-parametric variables; *d/r*: Cohen's *d* / rank biserial correlation EXPREF: experience refereeing; EXPCAT: experience in the current competitive level; U26: under 26 years; A26: above 26 years; U9: under 9 years; A9: above 9 years; U3: under 3 years; A3: above 3 years; TD: total distance; PWR_m: mean power; PWR_p: peak power; SPD_m: mean speed; SPD_p: peak speed; CAD_m: mean cadence; CAD_p: peak cadence; VOSC_m: mean vertical oscillation; VOSC_p: peak vertical oscillation; GCT_m: mean ground contact time; GCT_p: peak ground contact time; STIFF_m: mean stiffness; STIFF_p: peak stiffness; * $p < 0.05$; ** $p < 0.01$.

Table 3. Correlation (r or Rho) between official match responses and age, referee experience and experience in the current competition level in amateur football referees.

	Age	EXPREF	EXPCAT
<i>Physical responses</i>			
TD (km)	0.016	-0.237	-0.273
PWR _m (W)	-0.174	-0.511*	-0.089
PWR _p (W)	0.402	-0.075	0.479*
SPD _m (km·h ⁻¹)	-0.198	-0.677**	-0.154
SPD _p (km·h ⁻¹)	0.169	-0.121	0.417*
CAD _m (steps·min ⁻¹)	0.297	-0.259	0.198
CAD _p (steps·min ⁻¹)	0.185	0.087	0.128
VOSC _m (cm)	-0.671**	-0.397	-0.228
VOSC _p (cm)	-0.281	-0.205	-0.065
GCT _m (m·s ⁻¹)	0.318	0.725**	-0.117
GCT _p (m·s ⁻¹)	-0.355	-0.279	-0.062
STIFF _m (KN·m ⁻¹)	-0.098	-0.050	0.254
STIFF _p (KN·m ⁻¹)	0.205	0.223	-0.257
<i>Physiological responses</i>			
HR _{mean} (bpm)	-0.203	-0.486*	0.122
HR _{peak} (bpm)	-0.081	-0.112	0.024
Zone 1 (min)	0.211	0.271	-0.128
Zone 2 (min)	0.206	0.308	-0.117
Zone 3 (min)	0.230	0.217	-0.063
Zone 4 (min)	-0.085	-0.244	0.146
Zone 5 (min)	-0.105	-0.348	0.066
TRIMP (AU)	-0.156	-0.431*	0.127
RPE _{res}	-0.097	-0.068	0.142
RPE _{mus}	0.012	0.191	0.331

Note. In italics, non-parametric variables; EXPREF: experience refereeing; EXPCAT: experience in the current competitive level; TD: total distance; PWR_m: mean power; PWR_p: peak power; SPD_m: mean speed; SPD_p: peak speed; CAD_m: mean cadence; CAD_p: peak cadence; VOSC_m: mean vertical oscillation; VOSC_p: peak vertical oscillation; GCT_m: mean ground contact time; GCT_p: peak ground contact time; STIFF_m: mean stiffness; STIFF_p: peak stiffness.

4. Discussion

This study aimed to compare and analyze the effects of age, refereeing experience, and experience at the current competitive level on amateur referees' match physical and physiological responses and differentiated perceived exertion. While prior research explored age and experience (Muñoz-Arjona et al., 2021; Weston et al., 2010), this is the first to examine the influence of current level experience. It also uniquely assessed how age and experience affect physical responses using the Stryd Power Meter. The study seeks to deepen understanding of how these factors shape referees' physical and physiological demands and perceived effort during competition.

Previous pioneering studies have employed the Stryd device with football referees, providing insights into match physical demands such as power output, vertical oscillation, GCT, and stiffness (Ozaeta, Fernández-Lasa, et al., 2022). These investigations have also highlighted how contextual factors—including field dimensions, type of turf, environmental temperature, and period of the season—can influence referees' physical performance during matches (Ozaeta, Yanci, et al., 2022). Our findings extend this body of research by showing that, in addition to these contextual variables, personal characteristics such as AGE, EXPREF, and EXPCAT also contribute to differences in referees' physical responses. This suggests that different factors interact to shape the physical demands of officiating, underscoring the multidimensional nature of refereeing.

This study showed that the referees of the AgeA26 group registered lower VOScm,

VOSCp, HRmean, and higher GCTm than the AgeU26 group. What is more, VOScm correlates with referees' age. On the other hand, no significant differences or correlations were observed between the referees' age and the reported RPE. These results stand in contrast partially to the findings of Weston et al. (2010), whose research showed that older referees register lower physical responses and higher RPE values than younger referees, but they did not find any differences in physiological responses between both groups. This discrepancy may be attributed to differences in the age ranges examined, as Weston et al. (2010) established an age range of 31 to 48 years and were professional referees, whereas, in the present study, the referees' age ranged from 20 to 33 years and were amateur referees. Therefore, despite the differences between Weston et al. (2010) study and the present study, both studies have confirmed that age influences physical responses in football referees' match responses, with older referees registering lower match responses than younger referees.

In this study, it has been observed that referees of the ExprefA9 registered lower physical and physiological responses (TD, PWRm, SPDm, GCTm) than the ExprefU9 group. Additionally, a negative correlation was found between EXPREF and PWRm, SPDm, GCTm and HRmean. These results are partially in accordance with the results of Muñoz-Arjona et al. (2021), who observed that referees with more than 10 years of refereeing experience covered more distance than referees with less than 10 years of experience. However, this comparison in total distance should be taken with caution

since in the present study, the average distance covered by the referees was 9.13 km and 8.46 km for ExprefU9 and ExprefA9 respectively, while in the Muñoz-Arjona et al. (2021) study the experienced referees covered an average of 7.77 km while the less experienced ones covered an average of 6.59 km. In this aspect, the results of the present study are more in line with the results of the study of Weston et al. (2010), where older referees registered lower TD. On the other hand, as in the present study, Muñoz-Arjona et al. (2021) found no significant differences in HRmean between more experienced and less experienced referees. When correlations are analyzed in the present study, EXPREF is negatively correlated with HRmean. However, to our knowledge, no other study has analyzed the correlation between referees' EXPREF and physical or physiological responses. In this case, correlation analysis has proven to be more sensitive to extreme cases, capturing differences in heart rate that may not be evident when referees are divided into two groups. Specifically, when the sample is divided based on the median experience level, referees with experience values close to the median may obscure potential differences between the groups.

Finally, the present study found no differences in football referees' reported RPEres or RPEmus based on their experience. However, Muñoz-Arjona et al. (2021) observed that more experienced referees reported higher RPE. The study of Muñoz-Arjona et al. (2021) used the 6–20 Borg scale, in contrast to the CR-10 scale employed in the present study. Additionally, the study of Muñoz-Arjona et al. (2021) did not distinguish between muscular and

respiratory RPE, whereas in the current study, RPE was differentiated into respiratory RPE (RPEres) and muscular RPE (RPEmus). Therefore, the RPE data from the present study is not comparable to those of the Muñoz-Arjona et al. (2021) study.

When EXPCAT is analyzed, referees of the ExpcatA3 registered higher PWRp, SPDp, STIFFm, and HRmean than referees of the ExpcatU3 group; moreover, PWRp correlated positively with EXPCAT. No previous studies have analyzed the influence of EXPCAT on referees' physical or physiological responses. The authors interpret these differences as suggesting that EXPCAT may be related to greater familiarity with the teams and their style of play, which could allow referees to anticipate actions more effectively and position themselves more strategically on the field, potentially reducing unnecessary movements. This might lead to more frequent short, high-intensity efforts, such as sprints and rapid changes of pace, contributing to higher PWRp and SPDp. These higher PWRp and SPDp values are consistent with the slightly greater STIFFm observed in this study, which aligns with previous findings that higher running speeds tend to be associated with increased stiffness (Liu et al., 2022; Struzik et al., 2021).

However, the limited number of between-group differences and correlations observed for AGE, EXPREF, and EXPCAT is consistent with the multidimensional nature of football and refereeing. Previous research has shown that referees' physical responses are influenced not only by individual characteristics but also by a range of contextual variables, such as team ranking (Castillo et al., 2018), match outcome (Fan et

al., 2025), and/or pitch dimensions (Ozaeta, Yanci, et al., 2022). These factors interact dynamically throughout the match and may therefore dilute or overshadow the isolated contribution of age, EXPREF or EXPCAT to referees' physical demands.

This study is not without limitations. Including a limited number of referees may restrict the generalizability of the findings to a broader population of soccer referees. Furthermore, all referees participating in this study were at the same competitive level. This homogeneity in the referee's competitive level may have introduced potential biases in the data. Future research with more diverse samples could help overcome these limitations and provide a more comprehensive understanding of the factors affecting referees in soccer matches.

5. Practical Applications.

The results of the present study highlight the greater efficiency of experienced football referees in following the play during official football matches so that physical trainers have new information to adjust the weekly training load of referees and improve recovery between matches. This highlights the need to introduce new training methods, particularly for less experienced referees, to ensure they not only maintain optimal physical condition but also reach key moments of the match with less fatigue, enabling them to perform at the highest level, as more experienced referees do. Furthermore, as evidenced by the results of the present study, a deeper understanding of the category contributes to more effective management of physical effort throughout the match. This allows referees to achieve higher performance peaks at critical

moments. Consequently, physical trainers and technical coaches should implement strategies, such as match visualization of matches of the specific category, to enhance referees' game awareness and optimize their physical effort efficiency during matches.

6. Conclusions

This study found that both overall refereeing experience and experience at the current competition level significantly affect referees' physical and physiological responses during matches. More experienced referees showed lower physical and physiological demands, suggesting greater efficiency in positioning and movement. Experience at the current level also contributed to better interpretation of play, likely due to familiarity with teams and competition dynamics. This efficiency enables experienced referees to manage effort more effectively and perform optimally during critical moments. These findings highlight that refereeing involves more than physical fitness; age, experience, and competitive level experience should be considered when planning training and recovery.

Conflicts of Interest: The authors declare no conflict of interest.

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