Artículo original

High-intensity training effects on top-level soccer referees' repeated sprint ability and cardiovascular performance

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Summary

Given that the interest for effective and sustainable training methods to develop soccer refereeing performance, the aim of this study was to analyze the effects of a10 weeks high-intensity training (HIT) program on repeated sprint ability (RSA) and aerobic capacity in top-level soccer referees. Sixteen referees were randomly allocated in a HIT program, (EG, n = 8) and a control group (CG, n = 8). All referees were eligible to officiate in the professional Spanish *La Liga* championships (first and second soccer division) or were involved in the talent identification program for promotion to professional level. The training program was carried out during the 10 weeks and referees performed the RSA test and a laboratory incremental treadmill test for maximal oxygen consumption (VO_2max) and ventilatory threshold (VT) assessment both pre and post training intervention. EG improved the RSA performance considered as sprint decrement index over 15 m (Sdec 15 m) and 30 m (Sdec 30 m), and fatigue index over 15 m (Change 15 m) and 30 m (Change 30 m) (ES = -0.52; ±0.31 CL / -0.86; ±0.49 CL; Very Likely small to Very Likely moderate effect after the 10 weeks). In addition, EG decreased the absolute oxygen consumption at ventilatory threshold (VO2VT) (ES = -0.51; ±.60 CL; Likely small). No changes were found in CG performance for in Sdec 15 m, Sdec 30 m, Change 15 m, and Change 30 m (ES = 0.06; ±0.14 CL / 0.78; 1.19CL; Unclear to Likely trivial) or in aerobic performance variables. The results of this study suggest HIT as an effective training intervention to reduce fatigue in RSA and to maintain aerobic capacity on top-level soccer referees.

Key words:
Association football. Match officials. Intermittent exercise. Oxygen uptake. Physical performance.

Efectos del entrenamiento de alta intensidad sobre la habilidad de repetir esprines y el rendimiento cardiovascular en árbitros de fútbol de alto nivel

Resumen

Considerando el interés acerca de los métodos de entrenamiento más efectivos para optimizar el rendimiento físico del árbitro de fútbol, el objetivo de este estudio fue analizar los efectos de un programa de entrenamiento de alta intensidad (HIT) de 10 semanas de duración sobre la habilidad de repetir esprines (RSA) y sobre el rendimiento cardiovascular en árbitros de fútbol de alto nivel. Dieciséis árbitros distribuidos en un grupo experimental (EG) que llevó a cabo un programa HIT (EG, n = 8) y un grupo control (CG, n = 8) participaron en este estudio. Todos los árbitros podían ser elegidos para oficiar a nivel profesional en *La Liga* (Primera o Segunda División) o pertenecían al programa de talentos de árbitros para promocionar al ámbito profesional. El programa de entrenamiento fue realizado durante 10 semanas y los árbitros fueron evaluados del rendimiento en RSA y de un test incremental de laboratorio donde se obtuvo el consumo máximo de oxígeno (VO_2max) y los umbrales ventilatorios (VT) antes y después del programa de intervención. El EG mejoró el rendimiento RSA considerado como el índice de pérdida en el esprint en 15 m (Sdec15 m) y en 30 m (Sdec 30 m), y el índice de fatiga en 15 m (Change 15 m) y en 30 m (Change 30 m) (ES = -0,52; ±0,31CL / -0,86; ±0,49 CL; Muy Probable pequeño a Muy Probable moderado). No se encontraron cambios en el rendimiento del grupo control para las variables Sdec 15 m, Sdec 30 m, Change15 m, and Change 30 m (ES = 0,06; ±0,14CL / 0,78; 1,19 CL; *Unclear to Likely* trivial) ni para el rendimiento cardiovascular tras las 10 semanas de intervención. Los resultados de este estudio sugieren el HIT como una estrategia de entrenamiento efectiva para reducir la fatiga en el RSA y para mantener un óptimo nivel aeróbico en árbitros de alto nivel.

Palabras clave:
Fútbol. Colegiados. Ejercicio intermitente. Consumo de oxígeno. Rendimiento físico.

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Introduction

Soccer refereeing was considered as an intermittent high-intensity activity with elite field referees (FRs) exercising at 85-90% of the individual maximal heart-rate (HRmax)[1] and taxing 70-80% of their maximal oxygen up-take[2]. During a competitive match elite-level soccer FRs were reported to cover 10-12 km performing approximately 40 sprints (1539 ± 115 m) at a speed above 18 km•h^{-1}[3]. Interestingly more than 70 high-intensity accelerations (> 1.5 m•s^{-2}) interspersed with less 20 s of recovery were reported in continental cup matches[4] and around the 60% of total accelerations were at high intensity (> 1.5 m•s^{-2})[5]. Considering arbitrary running speed thresholds, FRs were reported to cover almost 25% of the total match distance with short high-intensity actions[3,5]. Given the nature of the internal and external load experienced by elite level FRs during competitive matches high-intensity training (HIT) was proposed to improve aerobic fitness and their ability to perform short sprints with limited recovery time[6].

Despite the interest of HIT on FRs fitness development, only few training studies addressing this interesting issue are available in the international literature[7,8]. Furthermore, they were performed with uncontrolled research design and with variable training protocols performed at exercise intensity in the range of 85-95% of FRs HRmax. However, the provided results were encouraging showing positive effect on intermittent high-intensity aerobic performance (i.e., Yo-Yo Intermittent Recovery Test level 1) and match high-intensity, suggesting the interest of high-intensity interval running in soccer refereeing[2] in order to allow players enhancing better repeated sprint ability (RSA) and aerobic performances.

Although soccer refereeing implies the necessity to perform high-intensity and short actions and a greater cardiovascular capacity to be better positioned throughout the match-play[1,5], unfortunately the mentioned studies did not report the effect of HIT on the RSA considered as relevant physiological ability in FRs and in aerobic fitness key variables[9]. Furthermore, the reported HIT interventions did not consider a control group[7,8]. With the aim to enforce the rule of the game and regulate players' behavior the FRs must keep up with the game whatever the tempo is[7,8]. Match experience and appropriate physical fitness are prerequisite for refereeing at elite level in soccer[7,8]. Given that the interest for effective and sustainable training methods to develop soccer refereeing performance relevant variables are warranted. This with the aim to prepare FRs to cope with game physical demands to attain optimal positioning when making key decisions[1].

Therefore, the aim of this study was to examine the effects of a short-term high-intensity training program (i.e. 10 weeks, HIT) on aerobic-fitness and RSA in top-level soccer FRs. As work hypothesis was assumed the effectiveness of HIT in enhancing either RSA and aerobic-fitness variables of top-level FRs.

Material and method

Participants

Eighteen Spanish soccer referees (age: 28.8 ± 5.1 years; height: 179 ± 7 cm; body mass: 73.2 ± 6.6 kg; body mass index (BMI): 22.82 ± 1.38 kg•m^{-2}) volunteered to participate in this study. All referees were eligible to officiate in the professional Spanish *La Liga* championships (first and second soccer division) or were involved in the talent identification program for promotion to professional level. During the 10 weeks training program two referees abandoned the study due to they were involved in international tournaments and, consequently, they did not carry out this training protocol and/or the second testing session. Participants were randomly allocated in either the training experimental group (EG, n = 8, age: 28.8± 5.3 years; height: 176 ± 7 cm; body mass: 68.9 ± 4.9 kg; BMI: 22.12 ± 1.23 kg•m^{-2}) or control group (CG, n = 8, age: 28.9± 5.2 years; height: 182 ± 5 cm; body mass: 77.6 ± 5.0 kg; BMI: 23.52 ± 1.22 kg•m^{-2}). Each referee had at least 10 years of refereeing experience, trained 3 to 4 times a week and officiated 3 to 4 matches each month during the competitive season. During the study course, all referees were instructed to maintain their usual diet and water intake. Participants were informed of the procedures, methods, benefits, and possible risks involved in the study before giving their written consent. All the FRs were familiar with the procedures considered in this study as they were part of their follow-up measures. The study was conducted according to the Declaration of Helsinki (2013) protocol and was fully approved by the University Ethics Committee (CEISH/261/2014), before the commencement of the assessments and met the ethical standards in Sport and Exercise Science Research[10].

Procedures

This study was carried out during the last 10 weeks of the 2016-2017 (April to June) competitive season. The assessments were carried out pre and post training intervention (T1 and T2, respectively) under similar conditions (temperature: 20-22 ºC; relative humidity: 65-75%; barometric pressure: 720-725 mmHg) and at the same time of the day (09:00-15:00). All testing procedures were preceded by 48 h during which FRs refrained from physical exercise and consumed a diet consisting in 55% carbohydrate, 25% fat, and 20% protein derived calories. Prior to testing participants performed a general standardized warm-up based on continuous running (3 min), 6 min of progressive-speed sprints preceding 2 min of static stretching. The testing procedures order consisted in the RSA test followed by a laboratory incremental treadmill test for maximal oxygen consumption (VO_{2max}) and ventilatory threshold (VT) assessment. According to Weston *et al.*[11] the RSA test consisted in 6 x 30 m sprint with 25 s recovery that was a modified version of the FIFA fitness test at the time of the study used for selecting international level FRs. For consistency the RSA test was performed on an indoor artificial pitch in all the testing occasions. The FRs aerobic-fitness was assessed considering VO_{2max} and VT as they were reported to be associated with physical match-performance in elite-level soccer referees[12]. After T1 the EG was submitted to a 10 weeks HIT protocol performed each Tuesday and Thursday (~60 min each session). The CG during the study period performed on the same occasion unstructured training consisting on endurance training (i.e., extensive running). Training and match internal training load (i.e. TL) were assessed in either group using the differentiated session rate of perceived exertion method (dRPE-based TL)[13] across the study duration.

Repeated Sprint Ability (RSA)

The RSA test consisted in 6 maximum sprints of 30 m with 25 s of active recovery between them. The sprint time was measured using three photoelectric cells (Microgate™ Polifemo Radio Light, Bolzano, Italy) set at 0,15 and 30 m. As indicators of RSA performance the sum of sprint times (i.e., total time, TT) to cover the 6 x 15-m (TT15m) and 6 x 30-m (TT30m) were considered[14]. Sprint performance decrement was considered according to Spencer *et al.*[15] as percentage of ideal time (i.e., best sprint performance) and TT ratio for the 6 x 15-m and 6 x 30-m condition (i.e., Sdec15m and Sdec30m, respectively) and as change in first and last sprint performance (over 15 and 30-m) using the following equation[14]: Change=((RSA last-RSA first)/(RSA first))×100. The validity and reliability of RSA test was reported in football referees[16].

Aerobic test

Aerobic fitness was assessed using a progressive incremental protocol to exhaustion on a monitorised treadmill (ERGelek™ EG2, Vitoria, Spain) according to the procedures used by Casajus *et al.*[17] in elite level FRs. Attainment of VO_{2max} was considered when at least two of the following criteria were satisfied: (a) plateau in VO_2 despite an increase in exercise intensity; (b) HR greater than 90% of the age-predicted maximal value (220-age); (c) a respiratory exchange ratio (RER) greater than 1.15[17]. The exercise HR was recorded every 1 s using short-term telemetry (Polar™ Electro Oy, Kempele, Finland) with peak treadmill test values considered as HRmax. Collected data were downloaded in a computer and processed using the Polar Precision 2.0 software (Polar™, Kempele, Finland). Gas exchange measurements were performed using breath-by-breath technology during the test and for 3 min after exercise exhaustion (Medisoft™ Ergocard, Medisoft Group, Sorinnes, Belgium). The FRs aerobic-fitness variables (i.e., velocity, HR, $VO_{2absolute}$, $VO_{2relative}$) and RPE[18] was assessed considering at VT and at exhaustion.

Differentiated Ratings of Perceived Exertion (dRPE)

Either the EG and CG were supervised by an accredited fitness trainer during all the training period and regularly officiated in championship matches. During the intervention period the CG had freedom in their physical training. The TL was assessed using the 0-10 point scale according to the procedures suggested by Foster *et al.*[19] with RPE recalled by each referee 10 min after the end of each training session and match. With the aim to obtain more detailed information regarding the nature of effort perception a differential approach was considered in this study according to Castillo *et al.*[1]. Indeed during each occasion (i.e., training session or match) the FRs had to provide differentiated RPE (dRPE) for respiratory (RPE_{res}) and leg muscle (RPE_{mus}) exertion perception[20]. In accordance to Foster *et al.*[19] to estimate the RPE-derived TL, the RPE_{res} and RPE_{mus} values were multiplied by the total duration of the training or match (min). Referees were fully familiarized with the 0-10 point scale before the data collection since measurements were part of the used strategies to assess TL during the precedent competitive seasons.

Periodization of training

The post-match training day (MD+1) consisted in a recovery low-intensity session. Similarly the pre-competition day (MD-1) consisted in a low-volume training session. The EG performed each Tuesday (i.e., 48 h post-match) of the 10 weeks intervention HIT training (HIT-1) (Table 1). During each Thursday (HIT-2) of the first 5 weeks of HIT the EG performed according to Weston *et al.*[8] two series, interspersed by 5 min active recovery, of what follows:

- 30 s at 90% HR_{max} followed by 30 s of active recovery
- 60 s at 90% HR_{max} followed by 60 s of active recovery
- 90 s at 90% HR_{max} followed by 90 s of active recovery
- 120 s at 90% HR_{max} followed by 120 s of active recovery

Table 1. Results in pretest (T1) and posttest (T2) in the repeated sprint ability (RSA) test in the experimental (EG) and the control group (GC).

	EG (n = 8)				CG (n = 8)				Paralell Groups
	T1	T2	ES (mean; ±90%CL)	Δ% (% mean ± SD); MBI; Rating	T1	T2	ES (mean; ±90%CL)	Δ% (% mean ± SD); MBI; Rating	ES (mean; ± CL); MBI; Rating
TT15m (s)	15.25 ± 0.68	15.36 ± 0.52	0.15; ±0.56	0.7 ± 2.7; Unclear; 43/44/14	15.27 ± 0.40	15.21 ± 0.37	-0.13; ±0.29	-0.4 ± 0.9; Possibly Trivial; 3/64/33	0.26; ±0.92; Unclear; 57/32/11
TT30m (s)	26.42 ± 1.06	26.74 ± 1.15	0.24; ±0.28	1.2 ± 1.4; Possibly small; 61/38/1	26.77 ± 0.53	26.86 ± 0.51	0.14; ±0.57	0.3 ± 1.3; Unclear; 42/44/14	0.24; ±0.48; Unclear; 56/38/6
Sdec15m (%)	2.79 ± 1.10	2.52 ± 0.96	-0.21; ±0.91	-8.3 ± 49.7; Unclear; 20/29/51	1.72 ± 0.73	2.48 ± 0.90	0.78; ±1.19	44.2 ± 97.5; Unclear; 81/11/8	-0.82; ±1.18; Unclear; 7/11/82
Sdec30m (%)	3.59 ± 1.13	2.83 ± 0.87	-0.63; ±0.67	-21.0 ± 24.2; Likely Moderate; 3/10/87	3.07 ± 2.03	3.84 ± 2.21	0.31; ±0.47	35.5 ± 53.8; Possibly Small; 67/29/4	-0.81; ±0.70; Likely Moderate; 1/6/93
Change15m (%)	4.87 ± 2.68	2.30 ± 2.65	-0.86; ±0.49	-62.6 ± 72.5; Very Likely Moderate; 0/2/98	2.57 ± 1.93	2.78 ± 2.39	0.08; ±0.81	2.8 ± 160.4; Unclear; 39/35/26	-1.07; ±0.82; Very Likely Moderate; 1/3/96
Change30m (%)	6.80 ± 4.12	4.37 ± 3.74	-0.52; ±0.31	-42.7 ± 47.7; Very Likely Small; 0/4/96	5.90 ± 5.34	6.21 ± 5.92	0.05; ±0.14	0.6 ± 19.3; Likely Trivial; 4/95/1	-0.51; ±0.29; Very Likely Small; 0/4/96

Δ%: percentage of change between T2 and T1; ES: effect size; TT15m: total time over 15 m; TT30m: total time over 30 m; Sdec15m: sprint decrement index over 15 m; Sdec30m: sprint decrement index over 30 m; Change15m: change in the fatigue index over 15 m; Change30m: change in the fatigue index over 30 m.; ES: effect size; SD: standard deviation; CL: confidence limits; MBI: magnitude based inferences.

- 90 s at 90% HR_{max} followed by 90 s of active recovery
- 60 s at 90% HR_{max} followed by 60 s of active recovery
- 30 s at 90% HR_{max} followed by 30 s of active recovery

During the remaining 5 weeks Thursdays the EG performed twice during each training session the following interval training protocol[8]:

- 30 s at 90% HR_{max} followed by 30 s of active recovery
- 45 s at 90% HR_{max} followed by 45 s of active recovery
- 60 s at 90% HR_{max} followed by 60 s of active recovery
- 75 s at 90% HR_{max} followed by 75 s of active recovery

Repeated twice, followed by 5 min active recovery before set 2:

- 75 s at 90% HR_{max} followed by 75 s of active recovery
- 60 s at 90% HR_{max} followed by 60 s of active recovery
- 45 s at 90% HR_{max} followed by 45 s of active recovery
- 30 s at 90% HR_{max} followed by 30 s of active recovery

Statistical analysis

Results are presented as means ± standard deviations (SD). We opted to use effect sizes (ES), with the uncertainty of the estimates shown as 90% confidence intervals (CI), to quantify the magnitude of the difference between T1 and T2 performance measures in both EG and CG separately[22]. We used the parallel groups controlled trial with adjustment for a predictor to analyze T1-T2 performance differences between EG and CG. ESs were classified as trivial (<0.2), small (0.2 to 0.6), moderate (0.6 to 1.2), large (1.2 to 2.0), very large (2.0 to 4.0) and extremely large (>4.0)[22]. These changes were then qualified via probabilistic terms and assigned using the following scale: 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; >99.5%, most likely[22]. Inference was classified as unclear if the 90% confidence limits (CLs) overlapped the thresholds for the smallest worthwhile positive and negative effects[22]. Mean differences, confidence intervals, effect sizes and magnitude-based inferences (MBI) were calculated using a custom-made spreadsheet[23].

Results

The session respiratory perceived exertion training load ($sRPE_{res}$ TL) and the session muscular perceived exertion training load ($sRPE_{mus}$ TL) are reported in Figures 1 and 2, respectively. No between groups significant differences (sRPEres TL: ES = -1.32 ± 1.83 / 0.26 ± 0.72, unclear; $sRPE_{mus}$ TL: ES = -1.45 ± 2.55 / 0.26 ± 0.72, unclear) were reported between EG and CG for the dRPE TL values.

Very Likely small to moderate differences between groups were detected for Sdec30m, Change15m and Change30m. The EG post-intervention performance in Sdec30m, Change15m and Change30m improved (Δ% = -21.0 ± 24.2 / -62.6 ± 72.5, ES = -0.52; ±0.31CL / -0.86; ±0.49CL; Very Likely small to Very Likely moderate). On the other side, in the CG performance no improvements were observed in Sdec15m, Sdec30m, Change15m and Change30m (Δ% = 0.6 ± 19.3 / 44.2 ± 97.5, ES = 0.06; ±0.14CL / 0.78; 1.19CL; Unclear to Likely trivial) (Table 1).

The individual Δ% (T1 to T2) after 10 weeks in Sdec30m (Figure 3A, ES = 1.32; ± 1.13CL; MBI = 95/3/2), in Change30m (Figure 3B, ES = 1.32; ± 0.76CL; MBI = 99/1/0) and in Change15m (Figure 3C, ES = 1.31; ± 0.99CL; MBI = 96/3/1) was better in EG than in CG.

Figure 1. Respiratory perceived exertion training load ($sRPE_{res}$ TL) results during each week of experimental group (EG) and control group (CG).

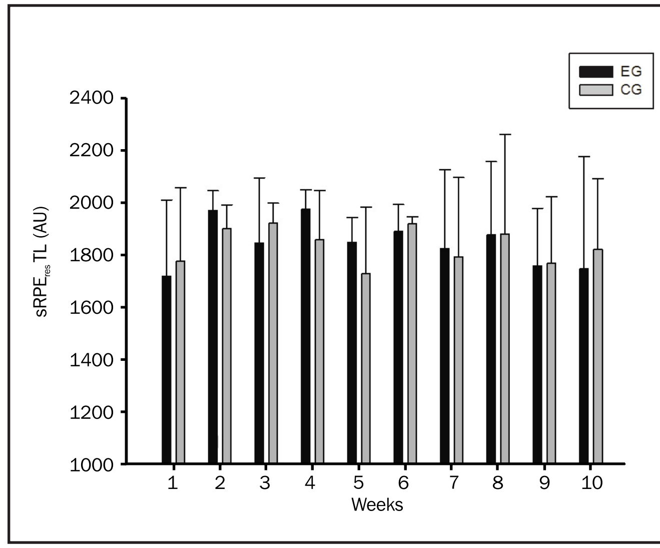
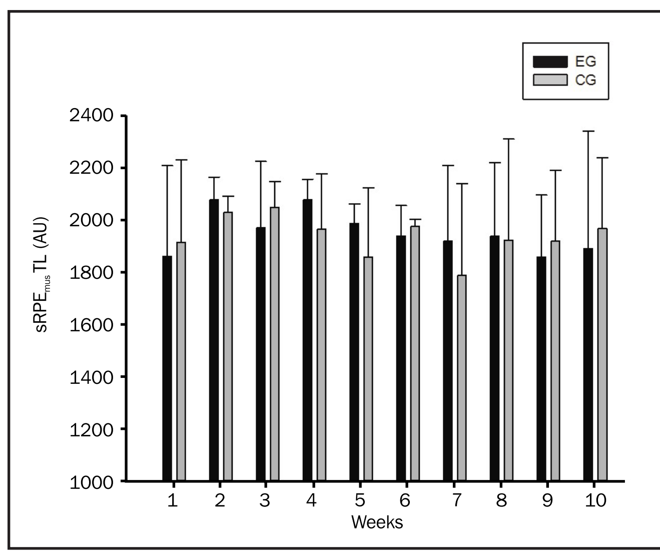


Figure 2. Leg muscle perceived exertion training load ($sRPE_{mus}$ TL) during each week of experimental group (EG) and control group (CG).



Despite in both groups cardiovascular variables at maximal intensities (i.e. Vel_{max}, HR_{max}, VO_{2max} absolute, VO_{2max} relative and RPE_{max}) have not improved in T2 in comparison to T1, at submaximal intensities (VT) CG worsened the performance in velocity at VT (Vel_{VT}) (Δ% = -0.8 ± 1.1, ES = -0.28; ±0.43CL; Possibly small). However the performance in Vel_{VT} (Δ% = -1.1 ± 4.6, ES = 0.16; ±0.55CL; Unclear) in EG did not change significantly. Besides, EG decreased the VO_{2VT} absolute (Δ% = -6.3 ± 7.9, ES = -0.51; ±0.60CL; Likely small). Unclear differences between groups were detected for the maximal values of aerobic-fitness variables considered. The individual Δ% (T1 to T2) after 10 weeks in the cardiovascular variables were unclear in all cases (ES = -0.79; ± 1.65CL / 0.34; 1.91CL) (Table 2).

Figure 3. Differences between experimental (EG) and control group (CG) in the individual percentage changes (Δ%) after 10 weeks training (pretest: T1 to posttest: T2) on Sdec30m (Figure 3A), Change30m (Figure 3B) and Change15m (Figure 3C) on the repeated sprint ability (RSA) test. ES: effect size.

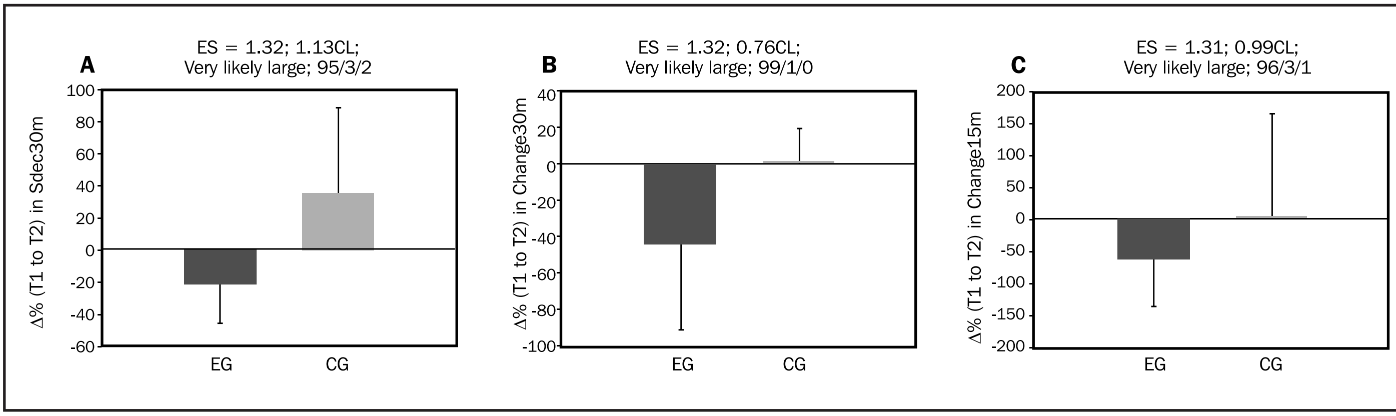


Table 2. Results in pretest (T1) and posttest (T2) in the endurance capacity in the experimental (EG) and the control group (GC).

	EG (n = 8)				CG (n = 8)				Paralell Groups ES (mean; ±CL); MBI; Rating
	T1	T2	ES (mean; ±90%CL)	Δ% (% mean ± SD); MBI; Rating	T1	T2	ES (mean; ± 90%CL)	Δ% (% mean ± SD); MBI; Rating	
Ventilatory threshold (VT)									
Vel_{VT} (Km.h^{-1})	15.80±0.93	15.99±0.11	0.16;±0.55	1.1±4.6; Unclear; 44/43/13	15.55±0.26	15.43±0.42	-0.28;±0.43	-0.8±1.1; Possibly Small; 4/32/64	0.39; ±0.89; Unclear; 66/22/12
HR_{VT} (bpm)	175.83±8.89	175.00±8.29	-0.08;±0.50	-0.5±2.9; Unclear; 16/52/33	175.17±9.43	172.00±6.69	-0.33;±0.63	-1.8±3.6; Unclear; 8/27/65	0.22; ±0.70; Unclear; 53/33/15
$VO2_{VT}$ absolute (l•min^{-1})	3.76±0.33	3.54±0.42	-0.51;±.60	-6.3±7.9; Likely Small; 3/14/83	4.33 ±0.16	4.13±0.49	-0.46;±0.82	-5.1±10.1; Unclear; 8/19/72	-0.06; ±0.89; Unclear; 30/31/39
$VO2_{VT}$ relative (ml•min^{-1}• kg^{-1})	53.00±4.15	51.67±3.72	-0.28;±0.75	-2.5±7.0; Unclear; 13/29/50	55.50±2.59	53.00±6.44	-0.43;±0.73	-5.1± 9.5; Unclear; 7/21/72	0.28; ±1.20; Unclear; 55/21/24
RPE_{VT} (AU)	7.33±0.52	6.83±1.47	-0.38;±0.87	-8.9±22.2; Unclear; 12/23/66	6.67±1.03	6.00±0.89	-0.58;±0.37	-10.0±7.2; Very Likely Small; 0/4/96	0.16; ±1.15; Unclear; 48/24/28
Maximal values (max)									
Vel_{max}	18.50±1.38	18.92±0.66	0.32;±0.59	2.4±4.2; Unclear; 66/28/7	18.47±0.73	18.37±0.50	-0.14;±0.85	-0.5±3.4; Unclear; 23/33/44	0.41; ±0.72; Unclear; 70/22/8
HR_{max}	186.33±9.27	185.50±8.71	-0.08;±0.34	-0.4±1.9; Unclear; 8/67/25	188.33±6.12	188.00±3.90	-0.05;±0.79	-0.2±2.6; Unclear; 27/36/36	-0.06; ±0.61; Unclear; 23/43/34
$VO2_{max}$ absolute (l•min^{-1})	4.02 ±0.33	4.01±0.35	-0.01;±0.48	-0.2±5.4; Unclear; 21/56/23	4.78 ±0.37	4.55±0.49	-0.44;±0.86	-5.0±10.9; Unclear; 10/20/70	0.36; ±0.75; Unclear; 65/5/10
$VO2_{max}$ relative (ml•min^{-1} •kg^{-1})	58.67±5.35	59.00±3.41	0.06;±0.45	0.8±4.2; Unclear; 28/57/15	60.33±3.93	58.50±6.83	-0.28;±0.98	-3.4±12.2; Unclear; 19/25/56	0.40; ±1.24; Unclear; 62/19/19
RPE_{max} (AU)	10.00±1.00	9.91±0.20	-0.49;±0.98	-0.9±1.7; Unclear; 11/18/71	9.50±0.45	9.50±0.55	0.00;±0.76	0.0±4.9; Unclear; 31/38/31	-0.18; ±0.98; Unclear; 24/28/48

Δ Change (%): percentage of change between T2 and T1; Vel_{VT}: velocity at ventilatory threshold; HR_{VT}: heart rate at ventilatory threshold; $VO2_{VT}$ absolute: absolute oxygen consumption; $VO2_{VT}$ relative: relative oxygen consumption; RPE_{VT}: rating of perceived exertion at ventilatory threshold; Vel_{max}: maximum velocity; HR_{max}: maximum heart rate; RPE_{max}: $VO2_{max}$ absolute: maximum absolute oxygen consumption; $VO2_{max}$ relative: maximum relative oxygen consumption; maximum rating of perceived exertion. ES: effect size; SD: standard deviation; CL: confidence limits; MBI: magnitude based inferences.

Discussion

This is the first study that examined the effect of a periodized controlled HIT training intervention on top-class FRs, on aerobic fitness and RSA variables. The main findings of this 10 weeks HIT intervention were a practical and significant improvement in RSA performance with a parallel maintenance of submaximal aerobic fitness variables (i.e., VT variables).

Top- level soccer refereeing is a physical demanding activity involving a high number of total sprints (>18 km•h^{-1}) and high-intensity accelerations (>1.5 m•s^{-2}) during match-play[3,5]. Furthermore the 37% of the distance covered by accelerations are performed by repeated accelerations sequences, defined as a minimum of three consecutive bouts (accelerations > 1.5 m•s^{-2}) during a 45 s time period. Given the logical validity of RSA, effective and sustainable training methods are of practical interest. In the present study, we have demonstrated that 10 weeks of HIT program improved RSA performance (Table 3). Indeed, FRs reported a decrement of cumulative fatigue as shown by significant changes in Sdec30m (Δ% = -21.0 ± 24.2), Change15m (Δ% = -62.6 ± 72.5) and Change30m (Δ% = -42.7 ± 47.7) values. These results come along with those obtained by Arazi *et al*.[24] who demonstrated that the HIT was effective in inducing meaningful improvements in fatigue index in female soccer players. Moreover, it has been observed that a 17-day microcycle (i.e., 13 HIT sessions) in addition to regular training significantly improved the RSA performance in elite tennis players[25]. Furthermore, 2 weeks of HIT training enhanced RSA performance variables in soccer players[26]. Given this study results, the HIT might be considered a promising way to promote large improvements in RSA variables in soccer referees.

Despite many studies have shown that the HIT is an effective training strategy to enhance the aerobic capacity without affecting negatively strength, power, or sprint performance on soccer players[27–34], only a few have been focused on soccer referees[7,8]. In our study, no improvements were reported in maximal aerobic-fitness variables in the EG. Indeed, HIT resulted in a substantial maintenance of Vel_{VT}. It could be speculated that the considered HIT program, might have ameliorated the running economy of the referees at submaximal intensities promoting the reported improvements.

Krustrup *et al.*[7] using a HIT protocol similar to this study observed a 7% increase in treadmill time to exhaustion in top-level Danish FRs. However similarly to this study no significant changes in VO_{2max} were reported. These results are different from those implemented in soccer players during the in-season and the pre-season phases of the training period. Indeed, Sperlich *et al.*[30] observed an improvement of the VO_{2max} of a 7% after 5 weeks period in soccer players. Similar results (i.e., 8-9%) were reported using 8 weeks HIT training by Helgerud *et al.*[35] and Impellizzeri *et al.*[36] in junior male soccer players during the competitive-season and the pre-season, respectively. In addition, improvements of 7-21% were reported in other endurance test (i.e., Yo-Yo intermittent recovery 1, 30-15 intermittent field test) in soccer players[27,32,33]. Interestingly, Ferrari Bravo *et al.*[37] provided evidence of specific effects of HIT and sprint intermittent training (SIT) on aerobic fitness and RSA performance in male soccer players. With SIT improving either aerobic fitness and performance in addition to RSA scores compared to HIT.

In our study, despite EG did not improve the VO_{2max}, it was observed a decrement in the CG, so 10 weeks of a HIT program might help not to worsen the aerobic fitness of match officials. To our knowledge most of studies have found improvements at maximal intensities (i.e., Vel_{max}, VO_{2max}) and in intermittent endurance tests, however, in our study we demonstrated that HIT program was more effective at submaximal intensities in soccer referees. Therefore, HIT program seems to be more effective than a regular training program based on extensive running activities in order to ameliorate the running economy of the referees at submaximal intensities. This could be considered as a relevant issue as the physical performance of the elite soccer referees should be economized in order to keep up the game tempo[9]. Trainers of soccer referees should consider the inclusion of HIT sessions during the in-season period.

In our study there are some limitations which must be acknowledged. Given that this study was conducted with top-level soccer referees, it makes very difficult to have a large sample of participants. Moreover, due to the time constraint of these soccer referees, both RSA and aerobic laboratory test (pre and post occasions) were performed on the same day, but 25-30 min were taken as a rest between each other. Another limitation is the lack of objective measuring method such as global

Table 3. Periodization of the training week in experimental (EG) and control (CG) group during the intervention period.

Groups	MD+1	Tuesday	Thursday	MD-1
EG	30 min running at 65% HR_{max}.	HIT-1 4 series of 4 min performing 15 s running bouts at 120% of maximal aerobic speed (MAS) interspersed by 15 s of passive recovery (21) and 3 min of jogging at 70% of HR_{max}.	HIT-2 5 weeks: interval training protocol of Weston *et al.*[8] 5 weeks: interval training protocol of Weston *et al.*[8]	Progressive sprint-bouts (10-50 m) performed at 90% of the individual maximal
CG	30 min running at 65% HR_{max}.	Unstructured training of endurance training	Unstructured training characterized by extensive running	Progressive sprint-bouts (10-50 m) performed at 90% of the individual maximal

MD: match-day.

positioning system measurements to measure the training and match load, however, we were able to quantify using dRPE.

Conclusions

In conclusion, the present study showed that 10 weeks of HIT, performed two times per week during the in-season period, was effective to reduce the fatigue in RSA and help not to worsen the aerobic fitness and to improve the performance at submaximal intensities on soccer referees. Therefore, HIT is a promising training strategy to improve the physical conditioning of top-level soccer referees.

The main finding of this study suggests a relevant practical application for physical trainers of soccer referees, that is, to implement HIT training programs to improve the physical fitness of top-level soccer referees.

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Conflict of interest

The authors declare no conflict of interest.

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