International Journal of Sport Studies for Health

Journal Homepage

Effects of Different Rest-Time Models on Neuromuscular and Performance Outcomes during Short High-Intensity Interval Training in Male Soccer Players

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A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Abedinpour, R. & Nobari, H. (2026). Effects of Different Rest-Time Models on Neuromuscular and Performance Outcomes during Short High-Intensity Interval Training in Male Soccer Players. *International Journal of Sport Studies for Health, 9*(4), 1-11.
http://dx.doi.org/10.61838/kman.intjssh.5891

A B S T R A C T

Objective: Short-interval high-intensity interval training (HIIT) is widely used in soccer conditioning, yet it remains unclear whether distributing recovery periods differently within a session influences neuromuscular and performance adaptations. This study compared ascending, descending, and constant rest-time models during short-interval HIIT in semi-professional male soccer players.

Methods: Twenty-four players were stratified by playing position and randomly allocated to ascending-rest (A-HIIT), descending-rest (D-HIIT), or constant-rest (C-HIIT) groups (n = 8 each). Participants completed eight preseason HIIT sessions, performed twice weekly. Each session comprised two sets of seven 30-s shuttle-running bouts prescribed relative to individual 30–15 Intermittent Fitness Test velocity. Recovery duration increased progressively in A-HIIT, decreased progressively in D-HIIT, and remained constant in C-HIIT, while total work and recovery time were matched across protocols. Countermovement jump (CMJ), 30-m sprint, 5-0-5 change-of-direction (COD), and Wingate peak power were assessed before and after training. Within-group changes were analysed using Wilcoxon signed-rank tests and between-group differences in change scores using Kruskal–Wallis tests, with Holm correction for multiple comparisons.

Results: All participants completed the intervention, although valid observations varied by outcome because of incomplete or unusable post-intervention data. Before correction, nominally significant within-group changes were observed for CMJ height, sprint time, right- and left-leg COD times, and Wingate peak power (unadjusted p = 0.012–0.046). These changes reflected an improvement only in CMJ height in D-HIIT; the significant sprint, COD, and Wingate changes represented performance decrements. However, none remained statistically

Article history:
Received 02 August 2026
Revised 18 August 2026
Accepted 22 August 2026
Initial Publication 26 August 2026
Final Publication 01 October 2026

significant after Holm correction (adjusted p = 0.180–0.460). No significant between-group differences were found for any outcome (p = 0.191–0.914).
Conclusion: Ascending, descending, and constant recovery distributions produced limited and broadly comparable neuromuscular and performance responses, with no evidence that any protocol was superior. Given the small sample, short intervention, and absence of a non-HIIT control group, these findings should be interpreted as preliminary and hypothesis-generating.
Keywords: *HIIT; Rest Interval Manipulation; Soccer Performance; Neuromuscular Adaptation; Change of Direction Ability; Sprint Performance; Countermovement Jump*

1. Introduction

Soccer is a high-demand intermittent sport that requires frequent sprints, rapid accelerations, explosive neuromuscular actions (e.g., jumps), and repeated changes of direction. These actions cumulatively place significant physical stress on the lower limbs (1, 2). In the context of a soccer match, it is estimated that each player covers an average distance of approximately 1,990 ± 386 metres of high-metabolic-power running, defined as running at a rate of over 25 W·kg^{-1}, which is equivalent to approximately 18.6% of the total distance. In addition, it is estimated that each player completes approximately 140–180 brief 'power events', defined as 5-second bursts separated by 24–31 seconds of recovery. This highlights the sport's significant physiological and neuromuscular demands (3). Therefore, players must undergo appropriate physical preparation to meet match demands, improve performance, and reduce injury risk (4). Consequently, it is imperative that soccer players adopt training methods that enhance both endurance and neuromuscular performance to ensure optimal results.

High-intensity interval training (HIIT) consists of short periods of high-intensity exercise interspersed with recovery periods. According to Buchheit and Laursen, they identified five main HIIT formats: long-interval HIIT, short-interval HIIT, repeated-sprint training, sprint interval training, and game-based HIIT (5) . Short-interval HIIT is a form of exercise involving periods of less than 60 seconds of work, followed by a period of rest, which are repeated at regular intervals. Short-interval HIIT is commonly used during pre-season and in-season periods in soccer, particularly for individual top-up conditioning and rehabilitation contexts (5-8). It is a malleable training modality that allows coaches to address three primary physiological responses that soccer players require concurrently: (1) aerobic metabolic, (2) anaerobic metabolism, (3) neuromuscular qualities.

High exercise intensity, defined as activities requiring >90% of the velocity of VO2max (vVO2max) or the maximal velocity for sprinting and agility, necessitates substantial neuromuscular engagemen (9). It is a commonly accepted principle that shorter intervals generally demand a higher level of work intensity. High-intensity running efforts impose substantial neuromuscular demands, with previous evidence showing increased hamstring muscle activity as running speed increases (10). In short-interval HIIT, several programming variables can be manipulated to target specific adaptations, and rest duration is considered a key factor influencing the overall training stimulus (11, 12). However, the manipulation of rest intervals has received comparatively less attention from researchers.

Many studies have focused on the work: rest ratio, or the effect of the duration of rest on performance. For instance, in a repeated-sprint exercise, reducing the time between each sprint has been shown to impair sprint performance (i.e., repeated-sprint ability) without significantly exacerbating neuromuscular fatigue (e.g. maximum voluntary contraction, voluntary activation) when compared with longer recovery times (13). Furthermore, the 1:4 rest schedule (30 seconds of work followed by 120 seconds of rest) has been shown to be effective in enhancing both VO_2max and Wingate power, with an increase greater than 1:2 or 1:8 (14). Most previous research in this field has focused on constant rest intervals between sets. However, studies on variable rest-interval sequences (ascending or descending), in which rest duration changes across sets, are limited, despite many coaches applying such strategies during HIIT.

Considering that in football matches and training, rest durations are often random and variable, and players encounter different recovery periods, this study aims to investigate whether variable rest-time models (ascending or descending) compared to a constant rest model can produce more ecologically valid improvements in long-term neuromuscular performance and physical capacities in male soccer players. Therefore, we hypothesized that applying ascending or descending rest-time models with controlled variations between sets will enhance long-term performance outcomes more effectively than a constant rest model, as these models better simulate the random and fluctuating recovery patterns observed in real football.

2. Methods and Materials

2.1 Study design

This study was a parallel-group randomized controlled trial with three intervention groups differing in rest-interval distribution during short-interval HIIT: ascending (A-HIIT), descending (D-HIIT), and constant (C-HIIT). Because playing position in soccer is associated with different physical demands, participants were first stratified by position (goalkeeper, centre-back, full-back, midfielder, wing-forward, and centre-forward). Within each positional stratum, players were then randomly allocated to one of the three intervention groups. The final allocation resulted in an identical positional distribution across groups: each group included one goalkeeper, one centre-back, one full-back, three midfielders, one wing-forward, and one centre-forward. This procedure was used to minimise the potential influence of position-specific physical demands on the comparison between the A-HIIT, D-HIIT, and C-HIIT groups. Within each positional stratum, players were randomly assigned to one of the three HIIT conditions using a computer-generated randomization sequence created in IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). The randomization sequence was generated after baseline testing, and allocation was implemented after baseline measurements were completed. Players were informed of their group assignment only after completion of the randomization process. Because of the practical nature of the training intervention, players and coaches could not be blinded to group allocation. The distribution of playing positions was balanced across groups through the stratified randomization procedure. This stratified randomization procedure was used to balance position-specific workload demands across groups and to strengthen the validity of between-group comparisons (15, 16).

2.2 Participants

Twenty-four semi-professional male soccer players from one men's team were recruited during the club's pre-season. The study was coordinated with the club's coaching staff and technical team prior to implementation. All participants were informed about the study procedures, potential risks, and benefits, and provided written informed consent before participation. Inclusion criteria were: (i) at least three years of organized football experience, (ii) participating in at least three training sessions per week, (iii) no musculoskeletal injury in the previous three months, and (iv) medical clearance to perform high-intensity exercise

2.3 Intervention

Throughout the pre-season, participants completed eight brief HIIT sessions, performed twice weekly with a minimum of 48 h between sessions and scheduled at a consistent time of day (±1 h). The HIIT sessions were integrated into the team's normal pre-season micro-cycle, which typically included two HIIT sessions, tactical training, and recovery sessions. No additional neuromuscular, strength, or plyometric training was introduced to isolate the effect of rest-time manipulation. Each HIIT session followed the same structure: a standardized warm-up, two sets of 7 repetitions of 30 s running efforts, and a brief small-sided game (SSG) block between sets as active recovery (Figure 1).

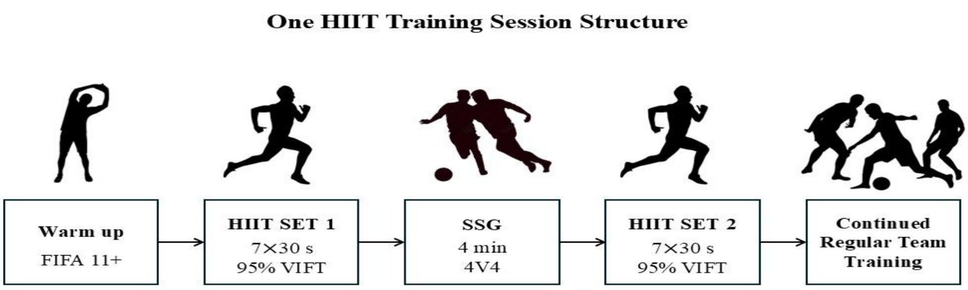

Figure 1. HIIT training session structure

Note. The figure illustrates the structure of one HIIT training session. Each session began with a FIFA 11+ warm-up, followed by two HIIT sets consisting of 7 × 30-s shuttle-running bouts at 95% VIFT. A 4-min 4v4 small-sided game was performed between the two HIIT sets before players continued with regular team training. VIFT = final velocity reached during the 30–15 Intermittent Fitness Test.

Running intensity was individualized using velocity from the 30–15 Intermittent Fitness Test (VIFT). Changes of direction (COD) were incorporated into the running bouts because of their known influence on neuromuscular responses. The only experimental factor manipulated was the distribution of rest intervals between bouts (Figure 2).

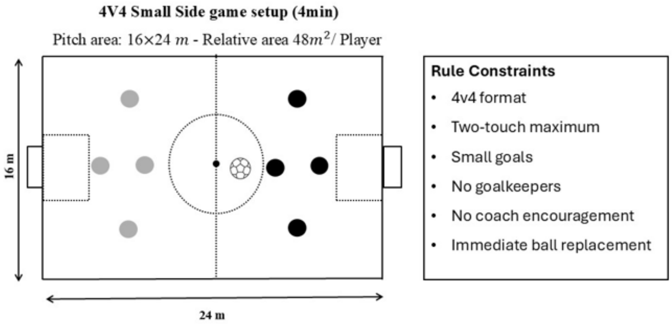

Figure 2. HIIT shuttle-running protocol and rest-time patterns

Note. The HIIT plan was developed in accordance with the methodology outlined by Buchheit & Laursen [5]. HIIT bouts were performed for 30 s at 95% VIFT with 180° changes of direction. Running distance was individualized for each player based on VIFT. Rest duration varied by group: ascending, 15–90 s; descending, 90–15 s; constant, 52.5 s. Total passive rest time was 315 s per set.

In A-HIIT, recovery increased across the session (15, 30, 45, 60, 75, and 90 s); in D-HIIT, recovery decreased in the reverse order (90, 75, 60, 45, 30, and 15 s); and in C-HIIT, recovery remained constant at 52.5 s, with total rest time matched across groups (Figure 2). Attendance records and adverse events were monitored throughout the intervention. During the inter-set period, SSG was prescribed, monitored, and standardized according to the approach of Rampinini et al (17) (Figure 3). Specifically, the SSG was performed in a 4v4 format on a 16 × 24 m pitch, with no coach encouragement, no goalkeepers, small goals, a two-touch limit, and immediate ball replacement when the ball went out of play. Post-intervention testing was performed 48 hours after the final HIIT session, at approximately the same time of day as baseline testing.

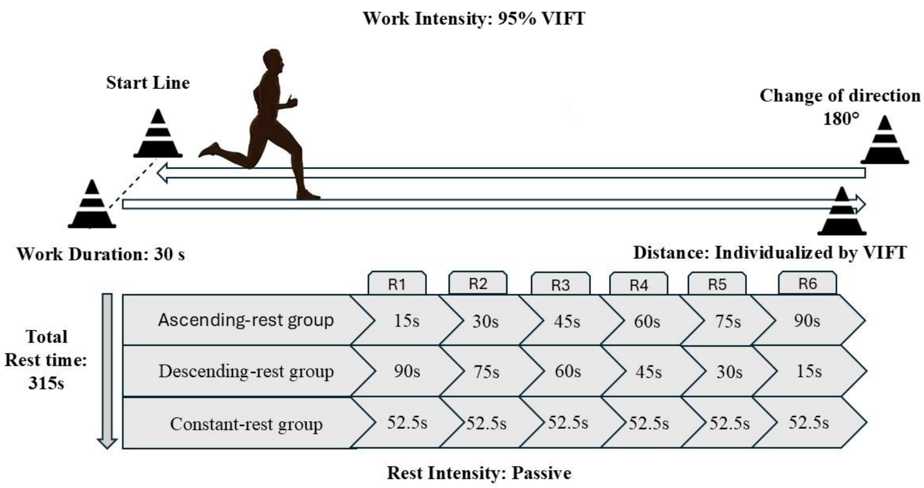

Figure 3. 4v4 small-sided game setup

Note. The figure illustrates the 4-min 4v4 small-sided game used as between-set recovery. The pitch measured 16 × 24 m, corresponding to 48 m² per player. All task rules and pitch constraints were planned based on the small-sided game methodology described by Rampinini et al (17).

2.1 Outcome measures

2.1.1 Anthropometrics

Body mass was measured using a SECA 703 digital scale with an accuracy of ±0.1 kg. Measurements were taken with players standing barefoot on the scale while wearing only underwear, and body mass was recorded in kilograms. Standing height was measured using a SECA 217 portable stadiometer with an accuracy of ±0.1 cm. Players stood barefoot in an upright position with their feet together and their body properly aligned. The headpiece was then lowered to the highest point of the head, and height was recorded in centimetres. Body mass and standing height were measured using calibrated equipment according to standardized anthropometric procedures (18).

2.1.2 Countermovement Jump (CMJ)

Each player completed three maximal countermovement jumps (CMJs) with hands on hips, with a 180-second rest period between each attempt. The most effective jump was retained. Jumps were filmed from the side (at approximately 3–4 m, with the camera positioned at hip height) using an iPhone 13 and were recorded at 120 frames per second (19). Subsequent analysis was conducted in Kinovea (v0.9.5). The take-off and landing processes were meticulously analysed frame by frame, and the jump height was calculated from flight time in accordance with the approach delineated by (20) formula below. Intraclass correlation coefficient (ICC) = 0.96 (95% CI: 0.92–0.98).

$$h = t^2 \times 1.22625$$

Linear sprint (30 m) and 5-0-5 change-of-direction (COD)

The timing of sprint and COD events was obtained through video-based analysis. All trials were recorded with an iPhone 13 Pro (Apple Inc., USA) positioned approximately 10 m from the testing lane, perpendicular to the start and finish lines, and mounted on a tripod at approximately 1.0–1.2 m height. The videos were analysed frame by frame using Kinovea software, which allowed more accurate determination of start and finish times than handheld timing (21). For both sprint and COD timing, the start time was defined as the frame in which the player's trunk crossed the start line, and the finish time was defined as the frame in which the player's trunk crossed the finish line. The video assessor was blinded to group allocation during sprint and COD analysis. All videos were analysed frame by frame by the same assessor using Kinovea software. The 30-metre sprint was completed with three trials commencing from the standing start position, followed by a minimum of five minutes of recovery time for the participant. The fastest times achieved over the initial 30 metres were then analysed for the purposes of this study. Before testing, all players completed a standardised warm-up that included light jogging and dynamic movements to prepare for the sprint test. After the warm-up, players waited near the testing area until called by the instructor. Each player then moved to the starting position and began the test after receiving the instructor's instructions. After the 30-m sprint test, players stayed in the testing area and were given enough time to recover before the 5-0-5 change-of-direction test. When called by the instructor, each player moved to the starting position and completed the test according to the instructions. The 5-0-5 COD test included a 10-m entry sprint, a 180° turn at the 5-m line, and a return sprint. Players completed two trials on each leg, preferred and non-preferred, with a 3-minute rest period between trials. The fastest time for each side was used for analysis. ICC = 0.94 for 30-m sprint and ICC = 0.89 for 5-0-5 COD.

2.1.3 Wingate 30-s test (lower limb)

The participants completed a standardised warm-up, followed by one 30-second all-out bout on a Monark Ergometric 834E cycle ergometer (Monark Exercise AB, Sweden). The braking resistance was individualized and set at 7.5% of each participant's body mass, corresponding to 0.075 $kg \cdot kg^{-1}$ body mass. Peak power was defined as the highest 5-s power output recorded during the Wingate test, calculated from the applied load, the number of pedal revolutions, and the ergometer-specific conversion factor. ICC = 0.93 for peak power.

2.1.4 30-15 Intermittent Fitness Test (30-15 IFT)

The 30-15 IFT was performed according to the standard protocol (22). The test was conducted on the same pitch, and the final velocity achieved (VIFT, $km \cdot h^{-1}$) was recorded and used to individualize HIIT intensity (22). During this test, players completed repeated 30-second shuttle runs over 40 m, with 15 seconds of recovery between runs. The starting speed was 8 $km \cdot h^{-1}$ and increased by 0.5 $km \cdot h^{-1}$ at each stage. The test finished when a player reached exhaustion or could no longer maintain the required pace. The final speed completed was recorded as VIFT.ICC = 0.97 (95% CI: 0.94–0.99).

2.2 Ethical considerations

This study was approved by the Bioethics and Biosafety Committee of the University of Extremadura, Badajoz, Spain (approval number: 180/2024; approval date: 21 November 2024). All procedures were conducted in accordance with the Declaration of Helsinki. Before participation, all players were informed about the study aims, procedures, potential risks, and benefits, and written informed consent was obtained. The study protocol was approved by the ethics committee before data collection; however, the study was not prospectively registered in a public trial registry.

2.3 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 29.0 (IBM Corporation, Armonk, NY, USA). Data are presented as mean ± standard deviation (SD). The distribution of data was assessed using the Shapiro–Wilk test. Due to the small sample size and non-normal distribution of several variables, non-parametric statistical tests were employed. Within-session reliability for all performance tests (except the 30-15 IFT) was assessed using the intraclass correlation coefficient (ICC). For the 30-15 IFT, test-retest reliability was used. According to (23), ICC values greater than 0.70 were considered suitable for this study. Within-group changes (pre- vs. post-intervention) were analysed using the Wilcoxon signed-rank test. Between-group differences in change scores (Δ = post – pre) were examined using the Kruskal–Wallis test, followed by Mann–Whitney U post-hoc tests when significant. Statistical significance was set at $p \leq 0.05$. Holm correction was applied to the 15 within-group Wilcoxon tests to account for multiple comparisons. Unadjusted p-values are presented descriptively, and findings that did not remain statistically significant after Holm correction were interpreted as exploratory. Effect sizes were calculated and interpreted as small (r = 0.10), medium (r = 0.30), and large (r = 0.50) for non-parametric tests. The valid sample size was balanced across groups for each outcome analysis. Effect sizes were calculated according to the number of players included in each test. No a priori sample-size calculation was performed because the study was carried out with players from a single team during the pre-season period.

3. Results

Baseline participant characteristics are presented in Table 1. Baseline demographic and anthropometric variables (age, height, body mass) were normally distributed according to the Shapiro–Wilk test and were therefore compared between groups using one-way ANOVA. Overall, the intervention resulted in small and variable changes in neuromuscular and performance outcomes across the three groups. Although some unadjusted significant within-group changes were observed in CMJ, 5-0-5 COD , and Wingate peak power, between-group comparisons did not reveal significant differences in the magnitude of change. Sprint performance showed only minor numerical variations from pre- to post-intervention. After Holm correction for multiple comparisons, none of the within-group changes remained statistically significant; therefore, the unadjusted within-group p-values are presented descriptively. All 24 participants completed the intervention. However, valid data differed across outcomes because of incomplete or unusable observations. Valid data were available for 8 players per group for CMJ, 7 players per group for 30-m sprint, 7 players per group for right- and left-leg 5-0-5 COD, and 6 players per group for Wingate peak power. Therefore, outcome analyses were performed using the available valid cases for each test.

Table 1. Demographic and anthropometric characteristics of the study groups

Variable	A-HIIT (n = 8)	D-HIIT (n = 8)	C-HIIT (n = 8)	*P* -Value
Age (years)	24.7 ± 5.31	22.7 ± 5.60	23.0 ± 4.60	0.41
Height (cm)	175.8 ± 6.51	175.2 ± 5.09	178.2 ± 5.04	0.57
Body mass (kg)	75.80 ± 6.50	74.36 ± 6.31	71.40 ± 4.97	0.39

Note. Data are expressed as mean ± standard deviation. A-HIIT = ascending rest-time group; D-HIIT = descending rest-time group; C-HIIT = constant rest-time group. Baseline between-group comparisons were performed using one-way ANOVA. No significant differences were observed among groups for age, height, or body mass.

3.1 Countermovement jump

The CMJ height results are presented in Table 2, and the individual responses are illustrated in Figure 4. For CMJ height, the Wilcoxon signed-rank test showed no unadjusted within-group change in the A-HIIT group (Z = -1.122, p = 0.262, r = 0.40) or the C-HIIT group (Z = -1.524, p = 0.128, r = 0.54). In contrast, the D-HIIT group showed an unadjusted within-group improvement in CMJ height, with a large effect size (Z = -2.524, p = 0.012, r = 0.89; Holm-adjusted p = 0.180). Mean CMJ height increased from 30.81 ± 4.80 cm to 32.67 ± 3.77 cm in A-HIIT, from 33.27 ± 6.98 cm to 35.89 ± 6.09 cm in D-HIIT, and from 30.24 ± 6.23 cm to 31.00 ± 7.88 cm in C-HIIT. However, the Kruskal–Wallis test showed no significant between-group difference in CMJ change scores, H (2) = 2.002, *p* = 0.368, ε² = 0.00.

Table 2. Pre- and post-intervention changes in neuromuscular performance and anaerobic power across HIIT groups

Variable	Group	Pre (Mean ± SD)	Post (Mean ± SD)	Within-group p	Between-group p
CMJ height (cm)	A-HIIT	30.81 ± 4.80	32.67 ± 3.77	0.262	0.368
	D-HIIT	33.26 ± 6.98	35.88 ± 6.09	0.012	
	C-HIIT	30.24 ± 6.23	31.00 ± 7.88	0.128	
30-m sprint (s)	A-HIIT	4.977 ± 0.286	5.110 ± 0.296	0.028	0.191
	D-HIIT	4.981 ± 0.150	5.041± 0.196	0.149	
	C-HIIT	5.011 ± 0.177	5.050 ± 0.203	0.237	
5-0-5 COD right leg (ms)	A-HIIT	2429.14 ± 79.29	2533.14 ± 89.04	0.028	0.914
	D-HIIT	2360.14 ± 112.89	2444.71 ± 143.04	0.091	
	C-HIIT	2390.57 ± 121.08	2484.14 ± 135.06	0.173	
5-0-5 COD left leg (ms)	A-HIIT	2463.14 ± 131.45	2520.86 ± 67.87	0.176	0.795
	D-HIIT	2414.57 ± 118.00	2488.57 ± 147.89	0.028	
	C-HIIT	2394.00 ± 100.34	2497.71 ± 23.55	0.046	
Wingate peak power (W)	A-HIIT	895.1 ± 81.8	877.0 ± 148.93	0.893	0.542
	D-HIIT	961.81 ± 93.06	988.87± 113.716	0.753	
	C-HIIT	893.80 ± 69.70	876.56 ± 75.43	0.039	

Note. Values are mean ± SD. The Wilcoxon signed-rank test was used to test within-group differences, and the Kruskal–Wallis test was used to test between-group differences. Within-group p-values are unadjusted. Holm correction was applied to the 15 within-group Wilcoxon tests; after correction, none of the within-group changes remained statistically significant. For sprint and COD outcomes, lower values indicate better performance; therefore, increases represent performance decrements. Valid sample sizes were n = 8 per group for CMJ, n = 7 per group for 30-m sprint, n = 7 per group for right- and left-leg 5-0-5 COD, and n = 6 per group for Wingate peak power.

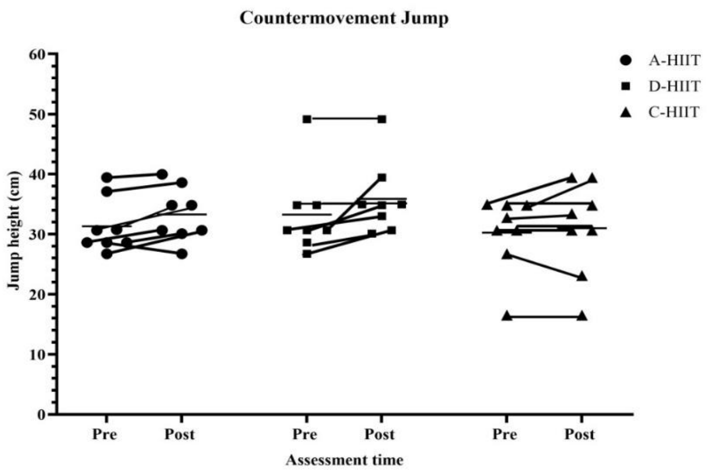

Figure 4. Individual changes in countermovement jump height before and after the intervention.

Note. Each symbol represents one participant, with lines connecting pre- and post-test values. Horizontal bars indicate group mean values.

3.2 Linear sprint (30 m)

The 30-m sprint results are presented in Table 2. The Wilcoxon signed-rank test showed an unadjusted within-group increase in 30-m sprint time in the A-HIIT group, with a large effect size (Z = -2.197, p = 0.028, r = 0.83; Holm-adjusted p = 0.392), indicating reduced performance. No unadjusted within-group changes were observed in the D-HIIT group (Z = -1.442, p = 0.149, r = 0.55) or the C-HIIT group (Z = -1.183, p = 0.237, r = 0.45). Sprint time increased from 4.977 ± 0.286 s to 5.110 ± 0.296 s in A-HIIT, from 4.981 ± 0.150 s to 5.041 ± 0.196 s in D-HIIT, and from 5.011 ± 0.177 s to 5.050 ± 0.203 s in C-HIIT. Since a higher sprint time indicates slower performance, the change in A-HIIT reflects a decline rather than an improvement. Although sprint time increased numerically in all groups, the Kruskal–Wallis test showed no significant between-group difference in sprint change scores, H(2) = 3.312, p = 0.191, ε^2 = 0.07.

3.3 5-0-5 change-of-direction (COD)

The 5-0-5 COD test results are presented in Table 2. For right-leg performance, the Wilcoxon signed-rank test showed an unadjusted within-group increase in 5-0-5 COD time in the A-HIIT group, with a large effect size (Z = -2.201, p = 0.028, r = 0.83; Holm-adjusted p = 0.392), indicating reduced performance. No unadjusted within-group changes were observed in the D-HIIT group (Z = -1.690, p = 0.091, r = 0.64) or the C-HIIT group (Z = -1.363, p = 0.173, r = 0.52). Right-leg 5-0-5 time increased from 2429.14 ± 79.29 ms to 2533.14 ± 89.04 ms in A-HIIT, from 2360.14 ± 112.89 ms to 2444.71 ± 143.04 ms in D-HIIT, and from 2390.57 ± 121.08 ms to 2484.14 ± 135.06 ms in C-HIIT. However, the Kruskal–Wallis test showed no significant between-group difference in right-leg COD change scores, H(2) = 0.180, p = 0.914, ε^2 = 0.00.

For left-leg performance, the Wilcoxon signed-rank test showed no unadjusted within-group change in the A-HIIT group (Z = -1.352, p = 0.176, r = 0.51). However, unadjusted within-group increases in 5-0-5 COD time were observed in the D-HIIT group (Z = -2.197, p = 0.028, r = 0.83; Holm-adjusted p = 0.392) and the C-HIIT group (Z = -1.992, p = 0.046, r = 0.75; Holm-adjusted p = 0.460), indicating reduced performance before correction for multiple comparisons. Left-leg 5-0-5 time increased from 2463.14 ± 131.45 ms to 2520.86 ± 67.87 ms in A-HIIT, from 2414.57 ± 118.00 ms to 2488.57 ± 147.89 ms in D-HIIT, and from 2394.00 ± 100.34 ms to 2497.71 ± 23.55 ms in C-HIIT. However, the Kruskal–Wallis test showed no significant between-group difference in left-leg COD change scores, H(2) = 0.459, p = 0.795, ε^2 = 0.00.

3.4 Wingate Test

The Wilcoxon signed-rank test showed no unadjusted within-group change in peak power in the A-HIIT group (Z = -0.135, p = 0.893, r = 0.06) or the D-HIIT group (Z = -0.314, p = 0.753, r = 0.13). However, the C-HIIT group showed an unadjusted within-group decrease in peak power, with a large effect size (Z = -2.060, p = 0.039, r = 0.84; Holm-adjusted p = 0.429). Peak power changed from 895.1 ± 81.8 W to 877.0 ± 148.9 W in A-HIIT, from 961.81 ± 93.06 W to 988.87 ± 113.72 W in D-HIIT, and from 893.80 ± 69.70 W to 876.56 ± 75.43 W in C-HIIT. Despite this unadjusted within-group decrease in C-HIIT, the Kruskal–Wallis test showed no significant between-group difference in peak power change scores, H(2) = 1.226, p = 0.542, ε^2= 0.00.

4. Discussion

This study aimed to determine whether ascending, descending, and constant rest-time models during short-interval HIIT would produce different neuromuscular and performance responses. We hypothesized that ascending or descending rest-time models could be more effective than a constant rest-time model, as these approaches are commonly used to provide varied conditioning stimuli in football. However, the main finding was that manipulating rest intervals produced no significant differences between groups for any neuromuscular or performance outcome. Several unadjusted within-group changes were observed, including CMJ height in the D-HIIT group, 5-0-5 performance in specific limbs, and a decline in Wingate peak power in the C-HIIT group. However, after Holm correction for the 15 within-group Wilcoxon tests, none of these within-group changes remained statistically significant. Because the primary between-group comparisons were also non-significant throughout, these within-group findings should be interpreted as exploratory and hypothesis-generating rather than as evidence that any one rest-time model was more effective than the others. Therefore, rather than identifying a superior rest-time model, the present findings suggest that ascending, descending, and constant rest-time structures produced broadly similar neuromuscular and performance responses within the conditions of this study.

No between-group differences were found for CMJ height, although the D-HIIT group showed an unadjusted within-group improvement before Holm correction. One speculative explanation is that longer early-session recovery periods may have supported phosphocreatine resynthesis during initial repetitions, potentially aiding explosive output before recovery periods shortened later in the session (8, 24). However, this remains an unconfirmed, exploratory interpretation, since the absence of a between-group effect means we cannot attribute this change specifically to the descending-rest structure. A more parsimonious explanation is that the three protocols, matched for total work, total recovery time, and overall training stimulus, produced broadly similar training loads, and the isolated D-HIIT result reflects limited statistical power and sample size rather than a true protocol-specific effect (25, 26).

30-m sprint performance showed no improvement in any group, with times increasing slightly from pre- to post-test across all conditions. Although only the A-HIIT group showed an unadjusted within-group decline before Holm correction, no significant between-group difference was observed, indicating that this decline cannot be attributed specifically to one rest-time model. Possible contributors include the accumulation of pre-season fatigue reducing neuromuscular freshness at post-test, the absence of dedicated sprint training, and a possible interference effect between aerobic conditioning and sprint-specific adaptations. This is consistent with prior work suggesting HIIT alone is often insufficient to drive sprint performance gains (27).

5-0-5 change-of-direction performance followed the same overall pattern: unadjusted within-group changes occurred depending on turning leg, but with no between-group differences, and where significant, these changes represented a deterioration rather than an improvement. As with CMJ and Wingate, these limb-specific effects should not be read as evidence that any rest-time sequence benefited COD performance. Given that faster COD performance has been linked more directly to braking and propulsive mechanics, targeted neuromuscular and technical training may be more relevant to COD enhancement than adjustments to HIIT recovery structure (28).

Similarly, in the Wingate test, only the C-HIIT group showed an unadjusted within-group decrease before Holm correction, with no significant change in A-HIIT or D-HIIT and no significant between-group difference. This isolated decline should not be interpreted as the constant-rest model being inferior; more plausible explanations include pre-season fatigue, individual variability in response, and the short duration of the intervention, particularly given that total work and recovery time were matched across all three protocols.

An important issue in interpreting the present findings is the lack of significant between- group differences despite several unadjusted within-group changes. It should be noted that no strength or power interventions or resistance training were considered during this period to observe the effects of different rest times in HIIT. One possible explanation is that soccer performance depends not only on metabolic conditioning, but also on sprint-specific mechanical and neuromuscular qualities such as horizontal force production, rate of force development, and rapid recruitment of high-threshold motor units. The improvement of these qualities is generally more effective through dedicated sprint training, resisted sprinting, or strength-power interventions than through short-interval HIIT alone (27, 29, 30).

5. Limitation

The sample was small, with only eight players in each group, and no a priori sample-size calculation was conducted. This may have reduced statistical power, limited the generalisability of the findings, and made it harder to detect clear differences between groups. For this reason, the results, especially the isolated within-group changes, should be interpreted as exploratory. Although video-based analysis was used for sprint, CMJ and COD timing, the relatively low frame rate may have reduced temporal precision compared with electronic timing gates or higher-frame-rate video systems. The intervention was also short, consisting of only eight HIIT sessions, so the time available for clear adaptation was limited. Another limitation is the absence of a non-HIIT control group, which makes causal interpretation more difficult. Since all players came from the same team, the influence of team-specific training routines cannot be ruled out. Accumulated pre-season fatigue may also have affected post-test performance. Training load, recovery status, sleep, and session-RPE were monitored as part of a separate pre-season dataset and were not included in the present analysis. Because all groups followed the same team programme and the HIIT protocols were matched for total work and total recovery time, major between-group differences in accumulated fatigue are unlikely; however, a general pre-season fatigue effect cannot be excluded. Finally, the study did not include detailed biomechanical analysis, such as force–velocity profiling, which limited the ability to explain the mechanisms behind the observed changes.

6. Conclusion

Eight sessions of short-interval HIIT using ascending, descending, or constant rest-time configurations produced broadly comparable neuromuscular and performance responses in semi-professional soccer players. Although some within-group changes were observed before correction for multiple comparisons, these findings did not remain statistically significant after Holm correction and should be interpreted as exploratory. Therefore, no rest-time model demonstrated superiority under the conditions of this study.

Authors' Contributions

R.A. contributed to study design, data collection, data analysis, interpretation of results, and manuscript preparation. H.N. contributed to study supervision, study design, interpretation of results, and manuscript revision. Both authors reviewed and approved the final manuscript.

Declaration

Artificial intelligence tools were used only for language editing and manuscript formatting support. The authors take full responsibility for the accuracy, originality, and scientific content of the manuscript.

Transparency Statement

All data analyzed in this systematic review were extracted from previously published studies and are summarized within this article. No new datasets were generated during the review. Additional extraction details are available from the corresponding author upon reasonable request.

Acknowledgments

The authors thank the players, coaching staff, and club personnel for their cooperation during data collection.

Declaration of Interest

The authors report no conflict of interest.

Funding

Funding for this work was provided through a postgraduate scholarship awarded by the Mexican Secretariat of Science, Humanities, Technology, and Innovation.

Ethical Considerations

This study was approved by the Bioethics and Biosafety Committee of the University of Extremadura, Badajoz, Spain (approval number: 180/2024; approval date: 21 November 2024). All participants provided written informed consent. The study was not prospectively registered in a public trial registry.

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