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Research article

Fast Start Strategy in High-Intensity Interval Training in Rugby Union Academy Players

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Abstract

A fast-start strategy, characterized by higher-intensity efforts during the initial work intervals, in high-intensity interval training (HIIT-FS) have been shown to optimize time spent at high oxygen uptake levels in endurance sports, but their effects in team sport athletes remain unexplored. This study aimed to compare the physiological (gas exchange, heart rate), perceptual responses (Rate of Perceived Exertion (RPE), and external load responses (Global Positioning System (GPS) derived distance) between a high-intensity interval training protocol using a fast-start strategy high-intensity interval training (HIIT-FS) and a constant-intensity high-intensity interval training (HIIT-C) protocol in academy rugby union players. Eight male rugby players (19.9 ± 2.2 years) from two professional French teams performed three sessions: (1) a 30-15 Intermittent Fitness Test (30-15 IFT) to determine velocity at intermittent fitness test (VIFT) and fitness assessment ($\dot{V}O_{2peak}$), (2) a HIIT-C session: 2 x 8 intervals of 30 s at 88% VIFT with 15 s rest between intervals and 3 minutes passive rest between sets, and (3) a HIIT-FS session: 2 x 8 intervals consisting of 4 x 30 s at 98% VIFT followed by 4 x 30 s at 78% VIFT, each separated by 15 s rest and 3 minutes rest between sets. Physiological measures included time spent at or above 90% of peak oxygen uptake ($T \geq 90\%\ \dot{V}O_{2peak}$) and peak heart rate ($T \geq 90\%\ HR_{peak}$), peak heart rate ($HR_{peak}$), mean oxygen uptake ($\dot{V}O_{2mean}$), mean percentage of peak oxygen uptake (mean $\%\dot{V}O_{2peak}$) and peak heart rate (HR_{peak}), mean minute ventilation ($\dot{V}E_{mean}$), and mean respiratory frequency (f_{Rmean}). External load variables were total distance, distance ≥ 7 km·h⁻¹, distance ≥ 16 km·h⁻¹, and mechanical work distance. Perceptual response was assessed using RPE. HIIT-FS significantly increased $T \geq 90\%\ \dot{V}O_{2peak}$ (318.8 ± 138.9 s versus 230.6 ± 115.6 s; d=0.88; $p < 0.05$) and mean % $\dot{V}O_{2peak}$ (86.1 ± 3% versus 82.1 ± 3.2%; $d = 1.54$; $p < 0.05$) compared to HIIT-C, primarily during the first four intervals of each set, where higher intensities (98% VIFT) were prescribed. No significant differences were observed in external load metrics between protocols. Regarding heart rate responses, only $T \geq 90\%\ HR_{peak}$ during intervals 1-4 of set 2 was significantly greater in the HIIT-FS protocol (129.8 ± 24.0 s vs. 109.0 ± 34.0 s; d = 0.90; $p < 0.05$). Perceptual response (RPE) was also significantly higher following HIIT-FS (9.0 ± 0.5 vs. 7.8 ± 0.7; d = 1.80; $p < 0.05$). HIIT-FS increases time spent at high $\dot{V}O_2$ levels in rugby players without increasing external load, making it a promising training strategy to improve aerobic capacity. However, due to its higher perceived exertion, HIIT-FS may be more appropriate when only a limited number of sets can be performed (e.g., two), and should be balanced with classic HIIT protocols when session volume allows more time. Future research should investigate its long-term adaptations and applicability in different team-sport populations.

Key words: HIIT, physical fitness, cardiovascular, team sport, intense exercise.

Introduction

Physical fitness is one of the major determinants of performance and success in sport (Joyner and Coyle, 2008). Aerobic capacity has been consistently identified as a critical performance indicator, particularly in endurance-based activities (Lucia et al., 2001; Haugen et al., 2022). In rugby, aerobic capacity is strongly associated with performance outcomes such as repeated high-intensity efforts and total running distance (Swaby et al., 2016; Vachon et al., 2021) which become increasingly important at higher levels of competition, especially in professional team sports (Metaxas et al., 2009). Previous studies (Smart et al., 2014; Cunningham et al., 2018) have established a relationship between endurance capacity and game-specific actions in rugby, such as ruck efficiency, tackling success, work rate, and activity rate. Rugby union is inherently intermittent, requiring repeated high-intensity efforts (e.g., accelerations, sprints, and physical collisions) interspersed with lower-intensity activities (e.g., walking and jogging) (Duthie et al., 2003; Cunniffe et al., 2009; Cahill et al., 2013; Lacome et al., 2014). These intermittent demands underscore the importance of aerobic capacity in maintaining high-intensity performance throughout a match (Yuan et al., 2024).

Aerobic capacity is known to improve an athlete's ability to perform repeated high-intensity efforts (Girard et al., 2011; Vachon et al., 2021). When aiming to improve aerobic performance, increasing maximal oxygen uptake ($\dot{V}O_{2max}$) is a primary objective. Two methods are commonly used to increase aerobic qualities: continuous exercise performed as a single bout over a long period with moderate intensity (Steele et al., 2021) and high-intensity interval training (HIIT). HIIT consists of repeated bouts of exercise at intensities between the second lactate threshold and near $\dot{V}O_{2max}$, interspersed with periods of lower-intensity recovery (Billat, 2001; Buchheit and Laursen, 2013a; Seiler, 2024), and is a time-efficient method that exposes athletes to higher training intensities, which are favorable for improving cardiorespiratory fitness (Midgley et al., 2007; Buchheit and Laursen, 2013a). Consequently, in team sports such as rugby union, HIIT is suggested as an effective training strategy, as it better replicates the sport's physiological and mechanical demands while improving aerobic capacity (Buchheit and Laursen, 2013b; Tee et al., 2016; Yuan et al., 2024).

Therefore, accumulating time spent at or above 90% of peak oxygen uptake ($T \geq 90\%\ \dot{V}O_{2peak}$) may lead to

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greater training adaptations, such as improvements in peak oxygen uptake ($\dot{V}O_{2peak}$) and repeated sprint ability while enhancing the overall efficiency of HIIT protocols, thereby supporting the use of a fast-start strategy high-intensity interval training (HIIT-FS) to optimize the training stimulus (Wenger and Bell, 1986; Thevenet et al., 2006; Midgley et al., 2007; Buchheit and Laursen, 2013a; Manuel Clemente et al., 2021; Seiler, 2024). Programming HIIT involves adjusting up to nine different parameters (Buchheit and Laursen, 2013a), including the intensity and duration of the work intervals, the intensity and duration of the rest intervals; the mode of exercise, the number of repetitions, the number of sets, and the duration and intensity of recovery periods between sets.

HIIT protocols can be modified by adjusting the intensity and/or duration parameters within the sets (e.g., fast-start strategy), to better align with specific training objectives and the nonlinear, variable demands of team sports (Wilson, 2016; Harper et al., 2019). In this context, short-interval HIIT formats are commonly used (Buchheit and Laursen, 2013b). Recent studies have found that varying the intensity parameters within a HIIT session, including the HIIT-FS with initial work intervals at higher intensities, can increase T ≥ 90% $\dot{V}O_{2peak}$ compared to other strategies (e.g., constant-intensity HIIT) in individual endurance sport such as running (De Aguiar et al., 2013), cycling (Lisbôa et al., 2015; Bossi et al., 2020; Miller, Perez and Farrell, 2023), and cross-country skiing (Rønnestad et al., 2020; 2022). However, its effects in team sports remain poorly understood, as no study to date has investigated the physiological responses to a HIIT session with varied parameters in a rugby-specific context. A faster $\dot{V}O_2$ kinetics, that is, a quicker rise in oxygen uptake, has been observed with fast-start strategies and may improve the ability to repeat high-intensity efforts in rugby, potentially increasing T ≥ 90% $\dot{V}O_{2peak}$ (Bailey et al., 2011). However, this mechanism remains unclear in team sports, particularly in rugby union.

The purpose of this study was to compare the physiological, perceptual, and external load responses of a HIIT session using a HIIT-FS strategy to a constant-intensity HIIT protocol (HIIT-C) in professional rugby union players. The primary aim was to evaluate differences in T ≥ 90% $\dot{V}O_{2peak}$ between protocols. The secondary aim was exploratory: to compare external load variables (e.g., total distance, distance ≥ 7 km·h^{-1}, distance ≥ 16 km·h^{-1}, mechanical work distance), heart rate responses, and rating of perceived exertion (RPE) between the two conditions.
We hypothesized that (i) HIIT-FS would result in a longer T ≥ 90% $\dot{V}O_{2peak}$ compared to HIIT-C, and (ii) no significant differences would be observed in perceptual responses or external load due to the matched average intensities. These hypotheses were tested at the whole-session level, with additional sub-analyses performed across fragmented time segments within the protocol.

Methods

Participants

Fifteen healthy, male academy rugby players (Table 1) volunteered to participate in this study (19.4 ± 1.7 years old; 184.6 ± 7.8 cm; 88.5 ± 12.7 kg). Sample size was estimated based on the primary outcome, T ≥ 90% $\dot{V}O_{2peak}$, using prior work comparing Constant-Intensity High-Intensity Interval Training (HIIT-C) and HIIT-FS in running (De Aguiar et al., 2013). With α = 0.05 and β = 0.2, the required sample size was calculated as 7 (G*Power 3.1.9.6, Universität Kiel, Germany) All players were recruited from two clubs competing in the first and second divisions of French professional rugby union during the 2023/24 season. All procedures were in accordance with the Declaration of Helsinki and participants signed informed consent forms. The inclusion criteria were: athletes aged over 18 years, and athletes who had been part of an academy program for more than one year. Exclusion criteria were: (1) pre-study -participation in other sports or injury in the previous two weeks; and (2) mid-study dropout - inability to complete the three sessions due to illness, injury, or breathing discomfort while wearing the gas analysis (required for valid gas analysis) due to breathing difficulties. Due to illness (n = 2), injury (n = 4) and incapacity to sustain the sessions (n = 1), eight participants completed all sessions (19.9 ± 2.2 years old; 184.1 ± 8.8 cm; 89.4 ± 15.7 kg).

Table 1. Characteristics of the rugby players.

Age (years)	19.4 ± 1.7
Height (m)	1.84 ± 0.8
Weight (kg)	88.5 ± 12.7
BMI (kg.m^{-2})	26.1 ± 2.8
30-15 IFT	
$\dot{V}O_{2peak}$ (ml.min^{-1}.kg^{-1})	54 ± 5.1
HR_{peak} (bpm)	196 ± 5.8
$\dot{V}E_{peak}$ (l.min^{-1})	179 ± 19.2
f_{Rpeak} (cycles·min^{-1})	66.8 ± 8
VIFT (km/h)	19 ± 0.9

30 - 15 IFT: 30 - 15 intermittent fitness test, BMI: body mass index, $\dot{V}O_{2peak}$: peak oxygen uptake, HR_{peak}: peak heart rate, $\dot{V}E_{peak}$: peak minute ventilation, f_{Rpeak}: peak respiratory frequency, VIFT: maximal running velocity.

Study design

Participants completed three sessions (Figure 1) over a ten-day period, with at least one rest day between each. All sessions were scheduled during a three-week in-season window without championship matches. Conditioning sessions replaced regular rugby-specific fitness training to maintain overall training load, while lower-body resistance training was removed during the study period. Participants were instructed to arrive 90 minutes before the sessions, in a rested state and fully hydrated with water provided on arrival. The first session involved the 30 - 15 Intermittent Fitness Test (30 - 15 IFT) to assess aerobic fitness and determine the velocity at intermittent fitness test (VIFT) and $\dot{V}O_{2peak}$ (Buchheit, 2008). This test consisted of 30-second 40-m shuttle runs, interspersed by 15 seconds of passive recovery. Velocity began at 8 km.h^{-1} and increased by 0.5 km.h^{-1} per stage, with pacing guided by auditory signals every 20 m. The test ended when a participant failed to reach the 3-meter marker three times in one stage. The final completed stage was used to determine VIFT. All tests were supervised by experienced strength and conditioning coaches, with verbal encouragement provided throughout.

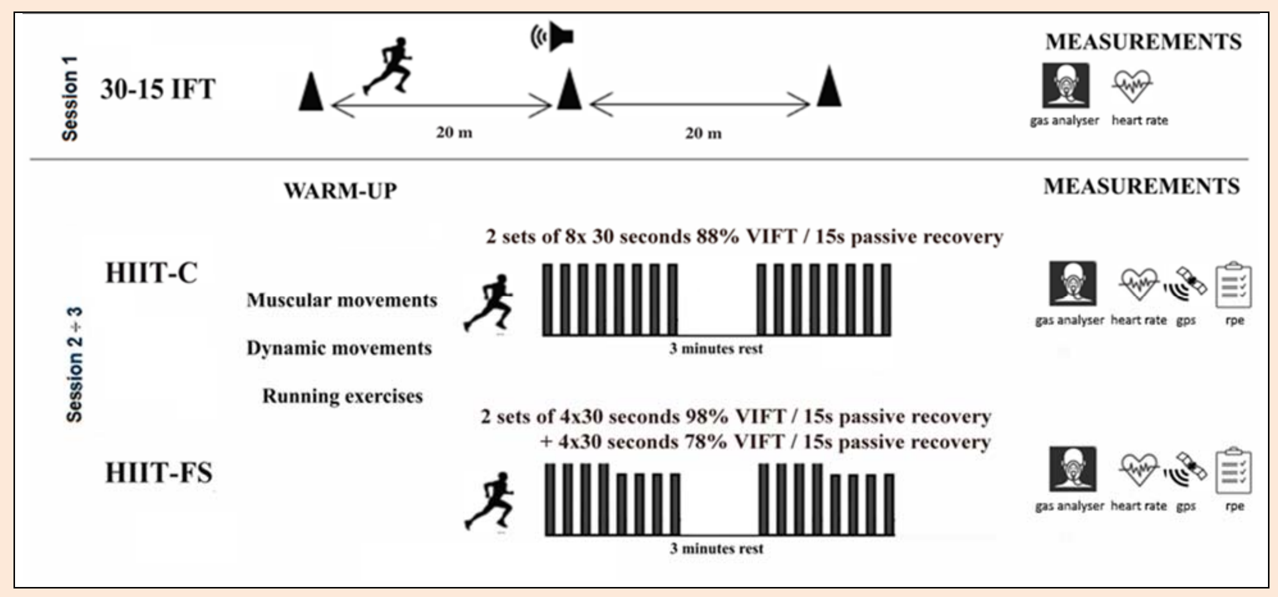

Figure 1. Study design. Session 1) 30-15 intermittent fitness test (30-15 IFT). Gas exchanges and heart rate recorded. Session 2 and 3) A standardized warm-up based on movements and running. High-intensity interval training with constant intensity interval (HIIT-C) and high-intensity interval training with fast start strategy (HIIT-FS). Intensity was prescribed as a percentage of the individual's speed of 30-15 intermittent fitness test (VIFT). Gas exchanges, heart rate and external load were recorded. Rate of perceived exertion was recorded after the HIIT sessions.

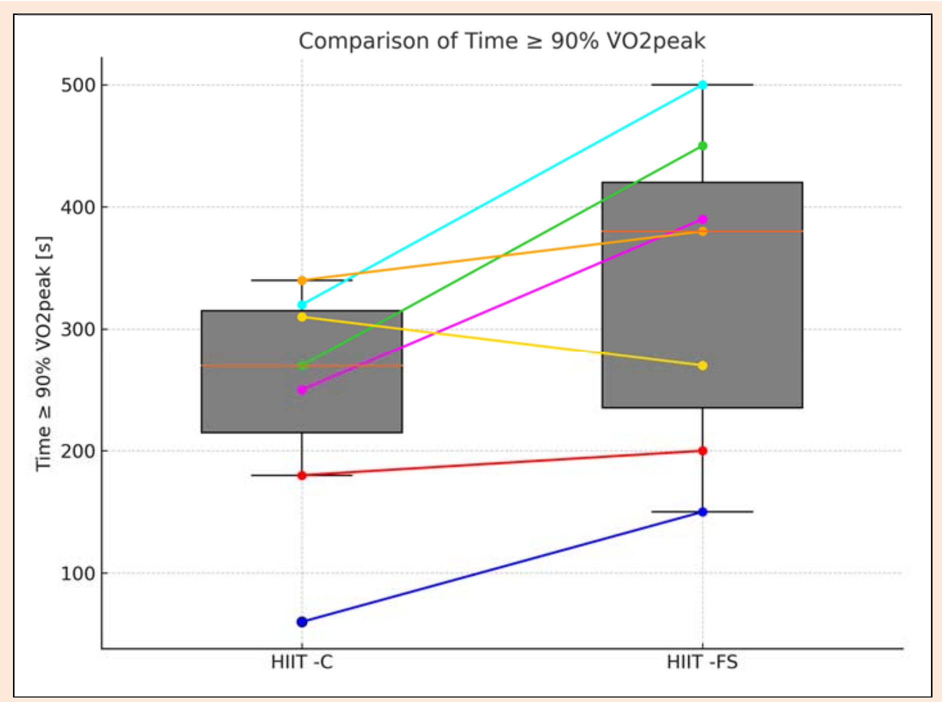

Figure 2. Time spent ≥ 90% of peak oxygen uptake ($\dot{V}O_{2peak}$) for HIIT-C and HIIT-FS during the total session. Individual trends and boxplots with median, interquartile range, individual, minimum and maximum values.

In the second and third sessions, participants completed the HIIT-C and HIIT-FS protocols in randomized order. Both protocols were matched for work-to-rest ratio and average intensity to compare physiological responses (e.g., T ≥ 90% $\dot{V}O_{2peak}$) with HIIT-FS. The HIIT-C protocol (Figure 1) consisted of 2 sets of 8 repetitions of 30 s intervals at 88% VIFT (Buchheit, 2008), with 15 s of passive recovery between intervals and 3 minutes of passive recovery between sets. The HIIT-FS protocol (Figure 2) matched the average intensity of HIIT-C (88% VIFT) but was structured with varied intensity: intervals 1 - 4 at 98% VIFT and intervals 5 - 8 at 78% VIFT, resulting in a weighted mean of 88% VIFT per set. This weighted mean was based on average running velocity, not total distance or energy expenditure.

All sessions took place on the same outdoor synthetic turf with an average temperature of 24.1 ± 3.2 ºC, with a relative humidity of 70.2 ± 3.4% between 4:00pm to 6:30pm. Interval pacing was guided by audio signals, and cones were individually spaced according to each athlete's target velocity.

A standardized three-phase warm-up preceded both HIIT sessions. Phase 1 included general movements (10 squats, 10 lunges, 10 hip thrusts). Phase 2 involved two sets of two squat jumps and two countermovement jumps. Phase 3 consisted of 10 × 20-m running drills, 5 × 50-m accelerations, and one 30-second run at 90% of VIFT.

Outcomes measures

30-15 IFT measurements

The peak heart rate (HR_{peak}), the peak oxygen uptake ($\dot{V}O_{2peak}$) and VIFT were determined by the 30-15 intermittent fitness test (30-15 IFT) (Buchheit, 2008). HR was recorded continuously using a Polar H10 heart rate monitor (Polar Electro Oy, Kempele, Finland) with a sampling frequency of 1 Hz. HR_{peak} was defined as the highest 1-second HR value recorded during the test. Gas exchanges were measured continuously at 15-second intervals throughout the test using a Metamax 3B-R2 (Cortex Biophysics, Leipzig, Germany) previously validated by Macfarlane and Wong (Macfarlane and Wong, 2012). Participants wore the unit secured with a vest positioned on the thorax, with the system carefully aligned over the clavicle to allow full arm mobility during running. An oronasal face mask (7450 series V2, HansRudolph, Shawnee, KS, United States) was fitted to enable gas flow through a bi-directional digital turbine. Prior to each test, the flow sensor was calibrated with a 3 L syringe, and gas analyzers were calibrated with ambient air and reference gas (15% O_2, 5% CO_2), following the manufacturer's recommendations. HR_{peak} and $\dot{V}O_{2peak}$ were defined as the highest HR and oxygen uptake measured during a 30-second period prior to the subject's voluntary exhaustion during the test.

HIIT sessions measurements

Heart Rate was continuously monitored using a Polar H10 heart rate monitor with a sampling frequency of 1 Hz. The time spent at or above 90% of peak heart rate ($T \geq 90\%HR_{peak}$) was defined as the cumulative duration during which heart rate values equalled or exceeded 90% of HR_{peak}, as established during the 30-15 IFT. Mean HR (HR_{mean}) was defined as the average HR values across all work intervals during the HIIT session. The percentage of HR_{peak} ($\%HR_{peak}$) was calculated using the following equation $\%HR_{peak} = (HR_{mean}/HR_{peak}) \times 100$.

Gas exchanges were recorded continuously at 5-second intervals using the same metabolic card and calibration procedures as during the 30-15 IFT (Cortex Metamax 3B-R2, Cortex Biophysik GmbH, Leipzig, Germany). $T \geq 90\% \dot{V}O_{2peak}$ was defined as the cumulative time during which $\dot{V}O_2$ was equal to or greater than 90% of $\dot{V}O_{2peak}$. Mean oxygen uptake ($\dot{V}O_{2mean}$) was defined as the average $\dot{V}O_2$ across all work intervals during the HIIT sessions. The percentage of $\dot{V}O_{2peak}$ ($\% \dot{V}O_{2peak}$) was calculated using the equation $\% \dot{V}O_{2peak} = (\dot{V}O_{2mean}/ \dot{V}O_{2peak}) \times 100$. Mean ventilation ($\dot{V}E_{mean}$) and mean breathing frequency (f_{Rmean}) were also determined as the average values across all work intervals during the HIIT session.

External loads of each HIIT session were measured using GPS devices sampled at 10Hz (GPS, Vector S7, Catapult Innovations, Melbourne, Australia). Each device was positioned between the scapulae in a sport vest and was turned on 15 min prior to data collection in accordance with the manufacturer's guidelines to guarantee signal quality. Signal quality was verified by an average horizontal dilution of precision (HDOP) of 0.75 ± 0.07 and an average of 15.2 ± 0.5 connected satellites. To minimize inter-unit variability, the same device was used by each participant across sessions. Total distance was defined as the sum of meters covered during the session, while running distance referred to the distance covered at speeds greater than 7 $km.h^{-1}$, a threshold recognized as the transition from walking to running (Varley et al., 2017). High-speed running distance was calculated as the total distance covered at speeds above 16 $km.h^{-1}$ (Varley et al., 2017). Mechanical work distance was defined as the total distance covered in meters greater than 2$m.s^{-1}$ during both acceleration and deceleration phases (Buchheit et al., 2014).

Thirty minutes after each HIIT session, participants rated their perceived exertion using the Borg CR10 scale (Foster et al., 2001).

Statistical analysis

The statistical analysis was structured in two main phases, the first consisting of a global comparison between the two experimental protocols, in which mean values calculated over the entire duration of each protocol were evaluated to provide an overall assessment. The second phase involved a more detailed, time-specific comparison, where the protocols were analysed at distinct time points, both at the level of the complete sets and at the level of half-sets segments.

For the time-specific analysis, comparisons were conducted between equivalent sets of the two protocols (i.e., Set 1 of HIIT-C vs. Set 1 of HIIT-FS; Set 2 of HIIT-C vs. Set 2 of HIIT-FS). Each set was further subdivided into two 3-minute halves (intervals 1 - 4 and intervals 5 - 8), enabling a segment-by-segment comparison of protocol effects.

Statistics are presented as means ± standard deviation (SD), along with 95% confidence intervals (CI). Data normality was assessed using the Shapiro–Wilk test. Depending on the distribution and variance, either a paired t-test or a Wilcoxon signed-rank test was used to evaluate differences between protocols.

Analyses were conducted across physiological variables ($T \geq 90\% \dot{V}O_{2peak}$, $\dot{V}O_{2mean}$, mean $\%\dot{V}O_{2peak}$, HR_{mean}, mean $\%HR_{peak}$, $\dot{V}E_{mean}$, and f_{Rmean}), external load variables (total distance, distance ≥ 7 km·h⁻¹, distance ≥ 16 km·h⁻¹, and mechanical work distance), and the perceptual variable rating of perceived exertion (RPE).

The effect size was calculated using Cohen's effect sizes (*d*), with interpretations categorized as trivial (< 0.2), small (≥ 0.2), moderate (≥ 0.5), or large (≥ 0.8). Statistical significance was set at $p < 0.05$. All calculations were performed using JASP software (version 0.19.3; JASP Team, Amsterd am, Netherlands) and Microsoft Excel (Redmond, USA).

Result

Physiological responses

Physiological responses are summarized in Table 2 and illustrated in Figure 2 and Figure 3. During the set 1, (Table 2) HIIT-FS protocol elicited significantly greater $\dot{V}O_{2mean}$ (47.1 ± 3.8 $ml \cdot kg^{-1} \cdot min^{-1}$ vs 44.5 ± 4.0; +2.6%; $p < 0.05$;

d = 1, large), mean %$\dot{V}O_{2peak}$ (87.2 ± 2.8 % vs 82.5 ± 3.8 %; +4.7 percentage points; d = 1, large), and T ≥ 90% $\dot{V}O_{2peak}$ (179.4 ± 60.3 s vs 128.1 ± 66.8 s; CI 95% = 128.9 - 229.9 vs 72.3 - 184; +40%; $p < 0.05$; d = 2.07, large; CI 95% = 0.82 - 4.26) (figure 3) compared to HIIT-C. In set 2, (Table 2) although the HIIT-FS protocol still resulted in significantly higher $\dot{V}O_{2mean}$ (45.8 ± 3.6 vs. 44.1 ± 4.3 mL·kg^{-1}·min^{-1}; +1.6%; p < 0.05; d = 0.8, large) and mean %$\dot{V}O_{2peak}$ (84.8 ± 3.4% vs. 81.8 ± 3.0%; +3.0 percentage points; p = 0.05; d = 0.8, large), the difference in T ≥ 90% $\dot{V}O_{2peak}$ was not statistically significant (139.4 ± 82.9 s vs. 102.5 ± 59.6 s; p = 0.28) (Figure 3). Over the total session (Table 2), HIIT-FS protocol resulted in significantly higher $\dot{V}O_{2mean}$ (46.5 ± 3.7 mL·kg^{-1}·min^{-1} vs 44.3 ± 4.1; +2.2%; d = 1.6, large), mean %$\dot{V}O_{2peak}$ (86.1 ± 3.0 % vs 82.1 ± 3.2 %; +4 percentage points; d = 1.5, large), and T ≥ 90% $\dot{V}O_{2peak}$ (318.8 ± 138.9 s vs 230.6 ± 115.6 s; CI 95% = 202.6 - 434.9 vs 134 - 327.2; +38.2%; d = 0.88, large; CI 95% = 0.03 - 1.70) (Figure 2), compared to the HIIT-C protocol ($p \le 0.05$).

Table 2. Comparison of physiological parameters between HIIT-C and HIIT-FS protocols.

		HIIT-C	HIIT-FS	Δ	Cohen's d (95% CI)
SET 1	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	44.5 ± 4.0 (41.1–47.8)	47.1 ± 3.8* (43.9–50.3)	+ 2.6	2.65 (0.87-4.42)
	Mean % $\dot{V}O_{2peak}$	82.5 ± 3.8 (79.3–85.6)	87.2 ± 2.8* (84.9–89.5)	+ 4.7	2.54 (0.82-4.26)
	HR_{mean} (bpm)	177 ± 7 (171–183)	178 ± 6 (173–183)	+ 1	/
	Mean %HR_{peak}	90.7 ± 3.9 (87.5–94.0)	91.1 ± 3.0 (88.6–93.6)	+ 0.4	/
	T ≥ 90%HR_{peak} (s)	256 ± 58 (207–304)	280 ± 30 (255–306)	+ 24	/
	$\dot{V}E_{mean}$ (l.min^{-1})	131.4 ± 13.4 (119.2–141.6)	138.6 ± 12.5 (128.1–149)	+ 7.2	/
	f_{Rmean} (cycles·min^{-1})	52.9 ± 6.9 (47.1–58.6)	54.9 ± 7.5* (48.6–61.2)	+ 2	0.9 (0.06 to 1.2)
SET 1 (1-4)	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	40.8 ± 3.9 (37.6–44.1)	45.3 ± 4.0† (41.9–48.6)	+ 4.5	3.0 (1.3 to 4.7)
	Mean % $\dot{V}O_{2peak}$	75.8 ± 4.4 (72.1–79.5)	83.8 ± 2.0† (82.1–85.4)	+ 8	3.0 (1.3 to 4.7)
	HR_{mean} (bpm)	169 ± 9 (162–176)	172 ± 6 (167–177)	+ 3	/
	Mean %HR_{peak}	86.3 ± 5.0 (82.2–90.5)	88.0 ± 3.3 (85.2–90.8)	+ 1.7	/
	T ≥ 90%HR_{peak} (s)	78 ± 50 (38–121)	106 ± 28 (83–129)	+ 28	/
	$\dot{V}E_{mean}$ (l.min^{-1})	114.2 ± 11.3 (104.8–123.6)	129.2 ± 11.5† (119.6–138.8) 53.3	+ 15	1.2 (0.3 to 2.2)
	f_{Rmean} (cycles·min^{-1})	48.9 ± 6.6 (43.3–54.4)	± 8* (46.6–59.9)	+ 4.9	0.9 (0.6 to 1.0)
SET 1 (5-8)	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	48.1 ± 4.5 (44.4–51.8)	48.9 ± 3.7 (45.8–52.0)	+ 0.8	/
	Mean % $\dot{V}O_{2peak}$	89.2 ± 3.9 (85.9–92.4)	90.7 ± 4.0 (87.3–94)	+1.5	/
	HR_{mean} (bpm)	186 ± 7 (180–192)	184 ± 5 (180–189)	- 2	/
	Mean %HR_{peak}	95.1 ± 3.0 (92.7–97.6)	94.2 ± 3 (92.0–96.3)	- 0.9	/
	T ≥ 90%HR_{peak} (s)	176 ± 12 (166–186)	175 ± 6 (170–180)	- 1	/
	$\dot{V}E_{mean}$ (l.min^{-1})	146.6 ± 16.4 (132.9–160.3)	147.9 ± 14.8 (135.6–160.3)	+ 1.3	/
	f_{Rmean} (cycles·min^{-1})	56.9 ± 7.4 (50.7–63.1)	56.5 ± 7.4 (50.3–62.7)	- 0.4	/
SET 2	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	44.2 ± 4.3 (40.5–47.8)	45.8 ± 3.6* (42.8–48.8)	+ 1.6	0.8 (0.001 to 1.6)
	Mean % $\dot{V}O_{2peak}$	81.8 ± 3.0 (79.3–84.3)	84.9 ± 3.5* (82.0–87.8)	+ 3.1	0.8 (-0.01 to 1.6)
	HR_{mean} (bpm)	181 ± 5 (177–186)	183 ± 5 (178–187)	+ 2	/
	Mean %HR_{peak}	92.7 ± 2.7 (90.5–95)	93.4 ± 3.0 (91.0–96.0)	+ 0.7	/
	T ≥ 90%HR_{peak} (s)	289 ± 34 (261–317)	306 ± 39 (282–331)	+ 17	/
	$\dot{V}E_{mean}$ (l.min^{-1})	139.6 ± 14.6 (127.4–151.8)	147.8 ± 16.4 (134.1–161.4)	+ 8.2	/
	f_{Rmean} (cycles·min^{-1})	57.9 ± 6.5 (52.5–63.3)	61.7 ± 6.2† (56.6–67.0)	+ 3.8	2.0 (0.7 to 3.2)
SET 2 (1-4)	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	40.9 ± 4.3 (37.3–44.5)	44.0 ± 3.4* (41.2–46.7)	+ 3.1	1.6 (0.5 to 2.7)
	Mean % $\dot{V}O_{2peak}$	75.7 ± 3.8 (72.5–79.0)	81.6 ± 3.3* (78.8–84.3)	+ 5.9	1.6 (0.5 to 2.6)
	HR_{mean} (bpm)	174 ± 6.5 (168–179)	177 ± 5.2 (173–182)	+ 3	/
	Mean %HR_{peak}	88.9 ± 3.9 (85.6–92.2)	90.7 ± 3.3 (88–93.5)	+ 1.8	/
	T ≥ 90%HR_{peak} (s)	109 ± 34 (81–137)	129.8 ± 24* (110–150)	+20	0.9 (0.02 to 1.6)
	$\dot{V}E_{mean}$ (l.min^{-1})	125.2 ± 14.4 (113.2–137.2)	139.3 ± 15.2* (126.6–152)	+14	1.2 (0.2 to 2.1)
	f_{Rmean} (cycles·min^{-1})	53.9 ± 6.3 (48.6–59.2)	60.0 ± 6.2† (54.8–65.1)	+ 6.1	2.6 (1.1 to 4.2)
SET 2 (5-8)	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	47.4 ± 4.5 (43.6–51.2)	47.6 ± 3.9 (44.3–51)	+ 0.2	/
	Mean % $\dot{V}O_{2peak}$	87.9 ± 3.0 (85.4–90.3)	88.2 ± 4.0 (84.9–91.6)	+ 0.3	/
	HR_{mean} (bpm)	189 ± 5.3 (184–193)	188 ± 6 (183–193)	-1	/
	Mean %HR_{peak}	96.6 ± 1.6 (95.3–98.0)	96.2 ± 2.7 (94.0–98.4)	-0.4	/
	T ≥ 90%HR_{peak} (s)	180 ± 0 (180–180)	177 ± 7 (170–183)	-3	/
	$\dot{V}E_{mean}$ (l.min^{-1})	154.1 ± 16.1 (140.6–167.5)	156.3 ± 17.9 (141.3–171.2)	+ 2.2	/
	f_{Rmean} (cycles·min^{-1})	61.9 ± 6.8 (56.3–67.6)	63.5 ± 6.7 (57.9–69.1)	+1.6	/
Total session	**$\dot{V}O_{2mean}$ (ml.min^{-1}.kg^{-1})**	44.3 ± 4.1 (56.3–67.6)	46.5 ± 3.7* (57.9–69.1)	+ 2.2	1.6 (0.5 to 2.6)
	Mean % $\dot{V}O_{2peak}$	82.1 ± 3.2 (79.4–84.9)	86.1 ± 3.0* (83.6–88.6)	+ 4	1.5 (0.5 to 2.6)
	HR_{mean} (bpm)	180 ± 6 (174–184)	180 ± 5 (176–185)	0	/
	Mean %HR_{peak}	91.7 ± 3.2 (89.0–94.4)	92.3 ± 2.9 (89.9–94.7)	+ 0.6	/
	T ≥ 90%HR_{peak} (s)	545 ± 91 (469–621)	587 ± 56 (540–634)	+ 42	/
	$\dot{V}E_{mean}$ (l.min^{-1})	135.0 ± 13.9 (123.4–146.6)	143.2 ± 14.2* (131.3–155.1)	+ 8.2	0.9 (0.04 to 1.7)
	f_{Rmean} (cycles·min^{-1})	55.4 ± 6.6 (49.9–60.9)	58.3 ± 6.7† (52.7–63.9)	+ 2.9	2.2 (0.8 to 3.5)

$\dot{V}O_{2mean}$: mean oxygen uptake, mean % $\dot{V}O_{2peak}$: mean percentage of peak oxygen uptake, HR_{mean}: mean heart rate, mean %HR_{peak}: mean percentage of peak heart rate. T ≥ 90%HR_{peak} (s): cumulative time during which HR were equal to or greater than 90% of HR_{peak}, f_{Rmean} (cycles·min^{-1}): mean breathing frequency, $\dot{V}E_{mean}$ (l·min^{-1}): mean minute ventilation. Values are mean ±SD (95% CI). Δ = value of HIIT-FS protocol – value of HIIT-C protocol. *: significant (p ≤ 0.05) different from HIIT-C. †: significant (p ≤ 0.01) different from HIIT-.

Result

Physiological responses

Physiological responses are summarized in Table 2 and illustrated in Figure 2 and Figure 3. During the set 1, (Table 2) HIIT-FS protocol elicited significantly greater $\dot{V}O_{2mean}$ (47.1 ± 3.8 ml·kg⁻¹·min⁻¹ vs 44.5 ± 4.0; +2.6%; $p < 0.05$; $d = 1$, large), mean %$\dot{V}O_{2peak}$ (87.2 ± 2.8 % vs 82.5 ± 3.8 %; +4.7 percentage points; $d = 1$, large), and T ≥ 90% $\dot{V}O_{2peak}$ (179.4 ± 60.3 s vs 128.1 ± 66.8 s; CI 95% = 128.9 - 229.9 vs 72.3 - 184; +40%; $p < 0.05$; $d = 2.07$, large; CI 95% = 0.82 - 4.26) (figure 3) compared to HIIT-C. In set 2, (Table 2) although the HIIT-FS protocol still resulted in significantly higher $\dot{V}O_{2mean}$ (45.8 ± 3.6 vs. 44.1 ± 4.3 mL·kg⁻¹·min⁻¹; +1.6%; p < 0.05; d = 0.8, large) and mean %$\dot{V}O_{2peak}$ (84.8 ± 3.4% vs. 81.8 ± 3.0%; +3.0 percentage points; p = 0.05; d = 0.8, large), the difference in T ≥ 90% $\dot{V}O_{2peak}$ was not statistically significant (139.4 ± 82.9 s vs. 102.5 ± 59.6 s; p = 0.28) (Figure 3). Over the total session (Table 2), HIIT-FS protocol resulted in significantly higher $\dot{V}O_{2mean}$ (46.5 ± 3.7 mL·kg⁻¹·min⁻¹ vs 44.3 ± 4.1; +2.2%; $d = 1.6$, large), mean %$\dot{V}O_{2peak}$ (86.1 ± 3.0 % vs 82.1 ± 3.2 %; +4 percentage points; $d = 1.5$, large), and T ≥ 90% $\dot{V}O_{2peak}$ (318.8 ± 138.9 s vs 230.6 ± 115.6 s; CI 95% = 202.6 - 434.9 vs 134 - 327.2; +38.2%; $d = 0.88$, large; CI 95% = 0.03 - 1.70) (Figure 2), compared to the HIIT-C protocol ($p \leq 0.05$).

Compared to HIIT-C, $\dot{V}E_{mean}$ during HIIT-FS approached statistical significance in both set 1 (138.6 ± 12.5 vs. 131.4 ± 13.4 L·min⁻¹; +5.5%; p = 0.052; d = 0.83, large) and set 2 (147.8 ± 16.4 vs. 139.6 ± 14.6 L·min⁻¹; +5.9%; p = 0.055; d = 0.81, large). Over the entire session, $\dot{V}E_{mean}$ was significantly higher for HIIT-FS compared to HIIT-C (143.2 ± 14.2 vs. 135.0 ± 13.9 L·min⁻¹; +6.0%; p = 0.041; d = 0.89, large) (Table 2). In addition, f_{Rmean} was significantly greater during HIIT-FS in set 1 (54.9 ± 7.5 vs. 52.9 ± 6.9 cycles·min⁻¹; +3.8%; p = 0.036; d = 0.92, large), in set 2 (61.7 ± 6.2 vs. 57.9 ± 6.5 cycles·min⁻¹; +6.6%; p < 0.001; d = 1.99, large), and across the total session (58.3 ± 6.7 vs. 55.4 ± 6.6 cycles·min⁻¹; +5.3%; p < 0.001; d = 2.92, large) (Table 2), when compared to HIIT-C.

However, no significant difference between the two protocols was observed for HR_{mean}, HR_{peak}, mean %HR_{peak} and T ≥ 90%HR_{peak} for set 1, set 2 and the total session (p > 0.05) (Table 2).

When the analysis was carried out by two intervals blocks (1 - 4 and 5 - 8), the HIIT-FS protocol elicited greater physiological responses in intervals 1–4. $\dot{V}O_{2mean}$ was significantly higher for HIIT-FS in both set 1 (45.3 ± 4 mL·kg⁻¹·min⁻¹ vs 40.8 ± 3.9; +4.5%; $p < 0.001$; $d = 3$, large) and set 2 (44 ± 3.4 mL·kg⁻¹·min⁻¹ vs 40.8 ± 4.3; +3.1%; p = 0.002; $d = 1.6$, large) (Table 2). Similarly, mean %$\dot{V}O_{2peak}$ was significantly higher in set 1 (83.8 ± 2% vs 75.8 ± 4.4%; +8 percentage points; $p < 0.001$; $d = 3$, large) and set 2 (81.6 ± 3.3% vs 75.8 ± 3.8%; +5.8 percentage points; $d = 1.6$, large) (Table 2). T ≥ 90% $\dot{V}O_{2peak}$ was also significantly greater for HIIT-FS in set 1 (75 ± 23.5 s vs 31.2 ± 24.2 s; CI 95% = 55.4 - 94.6 vs 11 - 51.5; +140%; $p < 0.001$; $d = 4.1$, large; CI 95% = 0.18 - 2.0), and in set 2 (60.6 ± 34.2 s vs 30 ± 18.6 s; CI 95% = 32.1 - 89.2 vs 14.5 - 45.5; +77%; p = 0.018; $d = 1.09$, large; CI 95%= 0.18 - 2) (Figure 3). $\dot{V}E_{mean}$ was significantly higher for HIIT-FS in set 1 (129.2 ± 11.5 L·min⁻¹ vs 114.2 ± 11.3; +13%; $p = 0.01$; $d = 1.2$, large) and set 2 (139.3 ± 15.2 L·min⁻¹ vs 125.2 ± 14.4; +11%, $p = 0.012$; $d = 1.2$, large) (Table 2). Finally, f_{Rmean} was significantly higher in set 1 (53.3 ± 8 cycles·min⁻¹ vs 48.9 ± 6.6; +9%; $p = 0.023$; $d = 0.89$, large), and set 2 (60 ± 6.2 cycles·min⁻¹ vs 53.9 ± 6.3; +11.3%; $p < 0.001$; $d = 2.6$, large) (Table 2) compared to HIIT-C. No significant differences were observed between HIIT-FS and HIIT-C protocols during intervals 5–8 in either set 1 or set 2 for $\dot{V}O_{2mean}$, mean %$\dot{V}O_{2peak}$, T ≥ 90% $\dot{V}O_{2peak}$, $\dot{V}E_{mean}$, or f_{Rmean} (p > 0.05) (Table 2; Figure 3). Similarly, (Table 2), for sets 1–2 across both interval blocks (1 - 4 and 5 - 8), HR_{mean}, HR_{peak}, and mean %HR_{peak} did not significantly differ between protocols (p > 0.05). However, T ≥ 90% HR_{peak} was significantly greater for the HIIT-FS protocol compared to HIIT-C (129.8 ± 24 s vs. 109 ± 34 s; +19.1%; p < 0.05; d = 0.9) (Table 2).

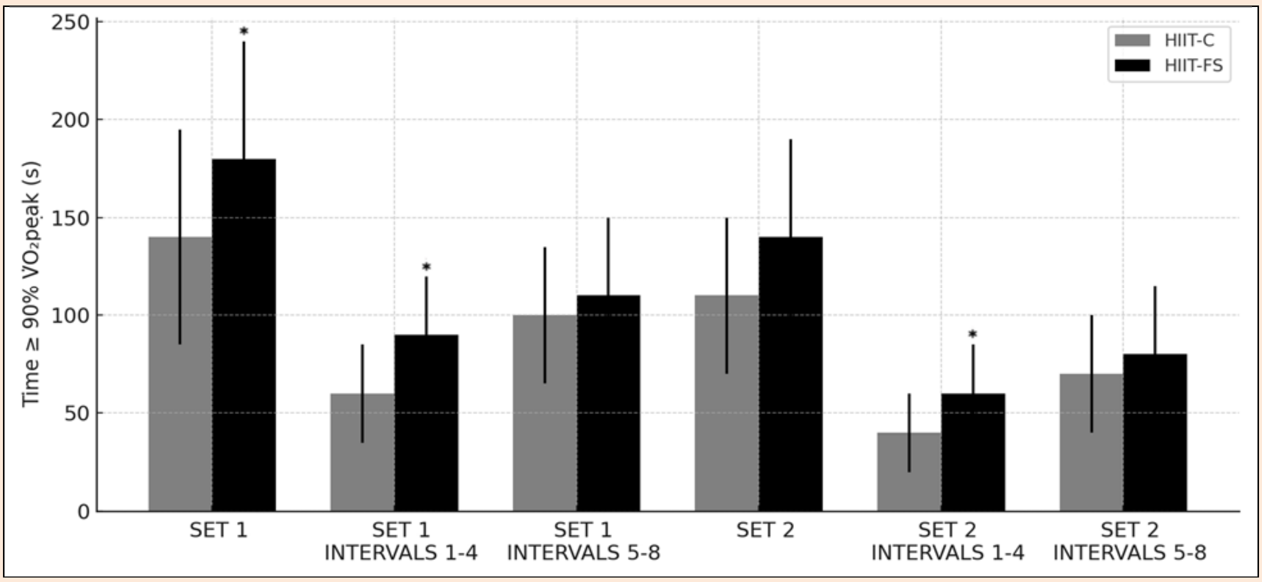

Figure 3. Time spent ≥90% of peak oxygen uptake ($\dot{V}O_{2peak}$) for HIIT-C and HIIT-FS for intervals 1-4 and intervals 5-8 for set 1 and 2, and for set 1 and 2. * Significantly from HIIT-C (p ≤ .05).

Table 3. Comparison of external load and perceptual responses between HIIT-C and HIIT-FS protocols.

	HIIT-C	HIIT-FS	Δ
Total Distance (m)	2298 ± 142	2337 ± 154	38.6
Distance ≥ 7 km.h^{-1} (m)	2118 ± 140	2132 ± 145	14.3
Distance ≥ 16 km.h^{-1} (m)	1483 ± 451	1345 ± 381	137.4
MW distance (m)	148 ± 27	151 ± 24	2.8
RPE (0-10)	7.8 ± 0.7	9* ± 0.5	1.2

Values are mean ±SD. Distance ≥ 7 km.h^{-1}: distance covered at speeds greater than 7 km.h^{-1}. Distance ≥ 16 km.h^{-1}: distance covered at speeds greater than 7 km.h^{-1} MW distance: distance covered greater than 2 m.s^{-1} during both acceleration and deceleration phases. RPE: rating of perceived exertion with the Borg CR10 Scale. *: significant ($p \leq 0.05$) different from HIIT-C.

External load and perceived effort

External load as measured by GPS, revealed no significant differences between the HIIT-C and HIIT-FS groups in total distance covered (Table 3). The HIIT-C group covered 2298 ± 142.4 m and the HIIT-FS group covered 2336.5 ± 153.8 m ($p = 0.12$). Similarly, no significant difference was observed between the two HIIT protocols for distances covered above 7 km.h^{-1} and 16 km.h^{-1}, and for the MW distance. However, the HIIT-FS group reported a significantly higher RPE (Table 3) compared to the HIIT-C group with a large effect size (+15%; $p = 0.023$; $d = 1.8$, large; CI 95% = 0.6 - 2.9).

Discussion

In this study, we compared the effects of HIIT-FS and HIIT-C protocols on T ≥ 90% $\dot{V}O_{2peak}$, $\dot{V}O_{2mean}$, RPE and external load in rugby players, hypothesizing that HIIT-FS would elicit greater T ≥ 90% $\dot{V}O_{2peak}$ without differences in external load or RPE. In line with our hypothesis, HIIT-FS significantly increased T ≥ 90% $\dot{V}O_{2peak}$ with no differences in external load. However, RPE was significantly higher for HIIT-FS, contrary to our initial assumption. HIIT has been shown to improve $\dot{V}O_{2peak}$, a key determinant of aerobic fitness, and various HIIT strategies can be employed to enhance $\dot{V}O_2$ capacity (Buchheit and Laursen, 2013b). A key physiological rationale for HIIT efficacy lies in its capacity to sustain oxygen uptake near $\dot{V}O_{2max}$ for extended periods during repeated efforts, thereby maximizing cardiovascular and muscular adaptations. Specifically, time spent above 90% of $\dot{V}O_{2peak}$ has been proposed as a crucial training stimulus for improving aerobic power and endurance-related capacities (Midgley et al., 2007; Rønnestad et al., 2022). Our study highlights that the HIIT-FS method increased significantly T ≥ 90% $\dot{V}O_{2peak}$, compared to HIIT-C in total session and set 1(+38.2%; +40%, respectively; $p < 0.05$) but not in set 2 ($p > 0.05$). In addition, higher $\dot{V}O_{2mean}$ and mean %$\dot{V}O_{2peak}$ were observed in the HIIT-FS condition. This latter marker is particularly relevant, as longer durations spent at high %$\dot{V}O_{2peak}$ are associated with greater training-induced adaptations and improvements in endurance performance (Rønnestad et al., 2022; Odden et al., 2024). These differences were not observed during intervals 5 - 8 in either set, likely due to the lower prescribed intensities in the second halves of each set in the HIIT-FS protocol (78% VIFT vs. 98% VIFT in intervals 1 - 4), despite equivalent overall intensities (88% VIFT), suggesting that HIIT-FS benefits are front-loaded, optimizing early intervals. The increase in T ≥ 90% $\dot{V}O_{2peak}$ observed with HIIT-FS in this study is consistent with findings from endurance sports such as cycling (Bossi et al., 2020; Miller et al., 2023), cross-country skiing (Rønnestad et al., 2020; 2022) and running (De Aguiar et al., 2013). Two studies (Rønnestad et al., 2020; Bossi et al., 2020), demonstrated in particular that fast-start strategies resulted in longer durations ≥90% $\dot{V}O_{2peak}$ compared to constant-intensity protocols, reporting 12.0 vs 10.8 minutes and 6.8 vs 4.8 minutes, respectively. Notably, these studies also implemented HIIT-FS during interval-based efforts, though the designs varied from the present work. In contrast, one previous work (Miller et al., 2023) reported no significant difference in total T ≥ 90% $\dot{V}O_{2peak}$ between fast-start and constant intensity HIIT (25.2% vs. 26.1%). This discrepancy may stem from differences in anaerobic work capacity (W') prescriptions, which are based on the depletion of sustainable work above critical speed or power. Such an approach differs fundamentally from the VIFT-based method used in the present study, which may better reflect the intermittent demands of team sports.

Unlike prior research, which primarily focused on individual endurance athletes, the current study targeted a team-sport population, specifically rugby union players, using fast-start strategies with elevated initial intensities. By prescribing intensity based on the 30-15 Intermittent Fitness Test (IFT), this approach enhances ecological validity for team-sport applications, especially during running-based short intervals (Stanković et al., 2021). Only one study (De Aguiar et al., 2013) investigated short-interval HIIT-FS in a manner relevant to team sports. Using a protocol with 30-second running effort and 15-second rest intervals at 125 - 105% intermittent critical velocity, they observed significantly greater time ≥95% $\dot{V}O_{2peak}$ compared to standard prescriptions (286 ± 150 s vs 113 ± 40 s and 106 ± 71 s; $p < 0.05$). This approach overlaps with team-sport demands and aligns with findings from studies focused on sport-specific conditioning (Manuel Clemente et al., 2021; Kumari et al., 2023). However, it is important to note that although the work-to-rest ratio was consistent, De Aguiar et al.'s study used intensity prescriptions based on critical velocity, a method less commonly applied in team sports. In contrast, our study used the VIFT, a more sport-specific and practical tool for prescribing HIIT intensity in team settings.

In the current study, no significant differences were observed between protocols during intervals 5 - 8 ($p > 0.05$). This lack of difference reflects the reduced intensity during intervals 5 - 8 in the HIIT-FS protocol and suggests that the physiological benefits of HIIT-FS are primarily concentrated in the early phase of the session. Specifically, the elevated initial intensity (98% vs. 88% VIFT) in HIIT-

FS substantially increased cardiorespiratory demand during intervals 1 - 4, as evidenced by significantly greater $\dot{V}O_{2mean}$, mean $\%\dot{V}O_{2peak}$, and T ≥ 90% $\dot{V}O_{2peak}$ compared to HIIT-C. These findings support the notion that manipulating work-rate distribution, specifically through the HIIT-FS format within a session, can meaningfully influence $\dot{V}O_2$ demand and ventilatory load (Buchheit and Laursen, 2013a) while also replicating the specific physiological demands of rugby union activity.

Fast-start strategies have been associated with accelerated $\dot{V}O_2$ responses and improved $\dot{V}O_2$ kinetics due to their influence on pacing during high-intensity efforts (Bailey et al., 2011). In our study, higher $\dot{V}O_2$ demands in HIIT-FS intervals 1 - 4 (98% VIFT) likely reflect priming effects on $\dot{V}O_2$ (Goulding et al., 2023) as demonstrated by significant increases in $\dot{V}O_2$mean (+4.5% for set 1; +3.1% for set 2; $p < 0.05$). Higher exercise intensities appear to enhance the homogeneity of quadriceps femoris muscle recruitment and motor unit activation patterns (Hodson-Tole and Wakeling, 2009; Heinonen et al., 2012). This may involve greater type II fiber recruitment, which, due to its lower mechanical efficiency and higher O_2 demands, contributes to elevated $\dot{V}O_2$ (Vanhatalo et al., 2011). The resultant physiological stress likely includes phosphocreatine depletion (Gaitanos et al., 1993) and metabolite accumulation (e.g., hydrogen ions) (Girard et al., 2011), which may ultimately support improvements in repeat high-intensity effort capacity, an essential quality in rugby. The higher running speeds in the HIIT-FS protocol likely imposed altered running kinematics, as increased speed in HIIT has been associated with greater biomechanical stress (García-Pinillos et al., 2019).

Breathing frequency is a sensitive and immediate marker of internal load, and a key feature that differentiates f_{Rmean} from other variables is its very fast response at the onset (e.g., first 30 s of intervals) of exercise (Nicolò et al., 2017). In this study, as shown in Table 2, HIIT-FS increased f_{Rmean} significantly (+3.8% for set 1; +6.6% for set 2, $p < 0.05$), especially in intervals 1 - 4 (+9% for set 1;+11.3% for set 2, $p < 0.05$), reflecting higher starting intensities (98% vs. 88% VIFT) encountered in the HIIT-FS protocol. Similar ventilatory responses have been observed during high-intensity efforts with varying intensity (Nicolò et al., 2017). These findings highlight the elevated ventilatory demand triggered by the initial bouts of HIIT-FS, underscoring the distinct physiological loading profile of this format. In line with this, $\dot{V}E_{mean}$ was also significantly higher in HIIT-FS across the full session (+9%; $p < 0.05$), indicating greater metabolic and ventilatory stress.

Importantly, despite these physiological differences, HR measurements (HR_{mean}, HR_{peak}, mean $\%HR_{peak}$, T ≥ 90% HR_{peak}) only showed a significant difference for T ≥ 90% HR_{peak} during set 2, intervals 1 - 4. This aligns with known physiological dynamics, as HR typically lags behind $\dot{V}O_2$ in its response to exercise onset (Buchheit and Laursen, 2013a), and may not accurately reflect short-term fluctuations in effort. Similar patterns have been reported in previous fast-start HIIT studies, where HR responses showed no significant differences between protocols (Rønnestad et al., 2022). It can be suggested that a more accumulated fatigue during the second set in HIIT-FS protocol may have contributed to the reduced physiological responses observed, particularly during intervals 1 - 4. From an external load perspective, GPS data (Table 3) revealed no significant differences between protocols for total distance (2297.9 ± 142.4 m vs. 2336.5 ± 153.8 m, $p = 0.12$), running distance ≥ 7 $km \cdot h^{-1}$ (2117.5 ± 140.2 m vs. 2131.8 ± 145.1 m, $p = 0.47$), and high-speed running distance ≥ 16 $km \cdot h^{-1}$ (1482.7 ± 451.3 m vs. 1345.4 ± 380.9 m, $p = 0.2$). This is likely attributable to the matched average intensities between the two protocols and the limitations of GPS technology in detecting rapid velocity changes during short intervals (Torres-Ronda et al., 2022). However, subjective effort, as measured by RPE, was significantly higher in the HIIT-FS condition ($p < 0.05$). This contrasts with earlier findings reporting either lower RPE or no difference between interval protocols (Rønnestad et al., 2020; 2022; Bossi et al., 2020).This discrepancy may be explained by the higher starting intensities in our HIIT-FS protocol (98% vs. 88% VIFT), which aligns with previous observations (Bok et al., 2023) regarding the perceived exertion associated with higher intensities. Notably, our study is the first to specifically address a team sport context, employing running-based intensity prescription via the 30 - 15 IFT and incorporating a short-interval training protocol.

Practical implications

From a practical standpoint, the HIIT-FS strategy appears to be an effective method for increasing both the absolute time and relative percentage spent at ≥ 90% $\dot{V}O_{2peak}$ in young elite male rugby players, compared to traditional HIIT. By front-loading the effort (e.g., 30-second initial intervals at 98% VIFT) within a 30 - 15-second interval format, rugby strength coaches can better exploit early interval phases to stimulate greater aerobic stress (e.g., T ≥ 90% $\dot{V}O_{2peak}$), especially useful when working within the tight time constraints typical of rugby training schedules.

However, due to the higher perceived exertion and potentially greater mechanical load associated with HIIT-FS, careful consideration is required before implementing it. When only a small number of sets can be completed (e.g., 2 sets), HIIT-FS may be the more efficient option, as it induces greater $\dot{V}O_2$ demands early in the session. Conversely, if the session allows for higher volumes (e.g., 4 - 5 sets), the HIIT-C format may be more effective in accumulating overall T ≥ 90% $\dot{V}O_{2peak}$ across the entire session.

Because HIIT-FS elicits high running speeds and accelerations, it is especially well suited for intermittent team sports like rugby, where repeated high-intensity efforts closely reflect match demands. This format may be particularly useful during the pre-season (to build an aerobic base), late tapering (to maintain aerobic fitness with reduced volume), and even in-season congested schedules or rehabilitation phases, where minimizing total load while preserving intensity is important. Importantly, the frequency and placement of HIIT-FS sessions should be tailored to individual tolerance, fatigue status, and injury risk.

While the findings offer valuable insights, their applicability to other populations (e.g., female athletes, amateur athletes, sedentary individuals) should be interpreted with caution due to differences in subject characteristics.

Conclusion

In young elite male rugby players, the HIIT-FS protocol resulted in a longer time spent ≥ 90% $\dot{V}O_{2peak}$ and higher % $\dot{V}O_{2peak}$ compared to the HIIT-C protocol, despite having a similar exercise duration. These findings highlight the potential of the fast-start strategy to enhance the intensity and physiological impact of interval training without increasing external load or session time. While the HIIT-FS protocol was associated with a higher perceived effort (RPE), no significant differences were observed in HR responses or external workload as measured by GPS.

This study provides novel insight into the acute physiological responses to fast-start interval training in a team-sport context, using a running-based prescription aligned with the demands of rugby. However, given the short-term nature of this investigation, further research is warranted to assess the chronic adaptations to fast-start HIIT protocols over longer training periods. Future studies should also consider their application across different team sports, training phases, and athlete populations, particularly within the constraints of time-limited, high-performance environments.

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Key points

- The HIIT-FS protocol significantly increased time spent at or above 90% of $\dot{V}O_2$peak compared to the constant-intensity (HIIT-C) protocol, especially during the first intervals of each set.
- Despite similar GPS-measured external loads (e.g., total distance, high-speed distance), HIIT-FS resulted in higher physiological stress ($\dot{V}O_2$mean, %$\dot{V}O_2$peak, respiratory frequency) and significantly greater perceived exertion (RPE).
- The findings support HIIT-FS as a time-efficient strategy to maximize training adaptations, though its higher perceived intensity may not suit all training contexts.

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