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Research article

Effects of Two In-Season Short High-Intensity Interval Training Formats on Aerobic and Neuromuscular Performance in Young Soccer Players

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Abstract
Supplementary high-intensity interval training (HIIT) programs, focusing on different aspects of fitness, are commonly used in soccer practice. This study examined the impact of two different HIIT formats applied during the competitive season on aerobic and neuromuscular performance. Twenty-six young players from two youth amateur soccer teams (aged 18.1 ± 0.7 and 18.7 ± 1.1 years) participated. In a randomized design, Team A served as an experimental group, performing either a 10s/10s linear running HIIT or a 15s/15s HIIT with changes of direction, both at 100% of maximum aerobic speed, twice per week for six weeks. In that period, team B acted as a control group, maintaining their usual training soccer regimen. Following two weeks of lower volume and frequency training, team B added the two HIIT formats in their training for six weeks, while team A acted as control. Before and after each 6-weeks period, aerobic fitness and neuromuscular performance was evaluated by the countermovement jump (CMJ). The 3-way ANOVA showed that both HIIT formats significantly enhanced Yo-Yo Intermittent Recovery Test Level 1 (Yo-YO IR1) performance compared to the respective control periods. However, the main finding was that the 10s/10s compared with the 15s/15s HIIT format induced 45 - 50% greater improvements in Yo-YO IR1 (total distance: 18.5 ± 11.7% vs. 9.0 ± 8.5%, V́O2max: 5.6 ± 3.2% vs. 3.0 ± 2.7%, and vV́O_2max: (3.3 ± 1.9% vs. 1.8 ± 1.7%, all p = 0.39, d = 0.85). Countermovement jump performance remained unchanged across both groups (p > 0.68). During HIIT rating of perceived exertion was higher in the 15s/15s vs. the 10s/10s format (6.4 ± 0.5 vs. 4.7 ± 1.2 a.u., p < 0.001). These findings suggest that while both HIIT formats effectively enhance aerobic performance during the season, the 10s/10s format offers superior benefits with less perceived exertion, while the 15s/15s format induces higher internal load.

Key words: Countermovement jump, perceived exertion, supplementary training.

Introduction

During the competitive period in football, strength and conditioning coaches aim to maintain high fitness levels (aerobic-anaerobic capacity, strength and sprint ability), so that players can maintain high levels of physical performance during matches (Dupont et al., 2004; Mohr and Krustrup, 2014). However, training load during in-season microcycles is adjusted to maintain the players' readiness to perform on the weekly games, without overload (Castillo et al., 2021; Oliveira et al., 2019; Scott et al., 2014). In several cases, differences in playing time and physical demands faced by starters versus non-starters can present challenges in ensuring optimal fitness and recovery, necessitating an individualized approach to supplementary training to meet the specific needs of each group (Milheiro et al., 2024). Physical fitness training during the weekly microcycle may contain both running drills (e.g. high intensity interval training-HIIT) and a variety of small-, medium- and large-sided games (Owen et al., 2011; Rosenblat et al., 2020). The use of different HIIT formats to improve aerobic and anaerobic fitness in football has been demonstrated in several previous studies as a time-efficient method of improving endurance, leaving more time for training sport-specific skills (Engel et al., 2018; Hostrup and Bangsbo, 2023; Thomakos et al., 2024). HIIT using longer or shorter bouts of repeated exercise, ranging from 10 s to 4 min, is considered an appropriate mode of exercise during pre-season to improve aerobic and anaerobic capacities (Faude et al., 2013; Callahan et al., 2021; Thomakos et al., 2023; Hostrup and Bangsbo, 2023) as well as to enhance game performance, such as distance covered at high speed, number of sprints and ball involvements (Chmura et al., 2022; Helgerud et al., 2001). Previous studies have shown that the ability to perform repeated high intensity exercise is related to aerobic and anaerobic fitness and influences match results and the team's overall performance expressed either as running performance on the field or as a positive match result (Dupont et al., 2004; Clemente et al., 2021; Thomakos et al., 2024).

Along with aerobic-anaerobic fitness development, lower limb muscle power should also be improved, especially in young football players (Asín-Izquierdo et al., 2024; Gee et al., 2021; McQuilliam et al., 2023). This is because lower limb muscle power is important for acceleration, deceleration and change of direction, as well as for sprinting and jumping during the game (Gee et al., 2021; Stern et al., 2020). Also, lower limb power is important for injury prevention by reducing injury risk, while young soccer players are highly trainable in terms of strength and power (Darragi et al., 2024; Vasileiou et al., 2024). The countermovement jump (CMJ) is commonly used by strength and conditioning coaches and researchers to assess lower-limb power, since it is valid and reliable (Petrigna et al., 2019). Due to the ease of application, CMJ is also used for assessing the level of fatigue after a game (Rowell et al., 2017), or after a period of high training load (Thomakos et al., 2023). An important question concerning non-specific power training of the lower limbs is whether countermovement jump (CMJ) performance can improve during

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HIIT sessions that include changes of direction. It has been shown that HIIT improves aerobic fitness via an increase in $\dot{V}O_2max$ through central and peripheral mechanisms, as well as the anaerobic capacity and leg power, depending on the protocol used (Kilpatrick et al., 2014). The latter is particularly relevant because HIIT including changes of direction demands the ability to generate high eccentric and concentric force and power output, especially at high approach speeds (Dos'Santos et al., 2018).

The duration of the work bout and recovery interval is important regarding the physiological and metabolic responses to HIIT (Rosenblat et al., 2020; Bogdanis et al., 2022). Usually, short bouts (lasting between 5 and 15s) with intensities ranging from 100 to 120% of the running speed corresponding to maximum oxygen uptake (v$\dot{V}$O2max) are employed during in-season (Buchheit and Laursen, 2013; Dellal et al., 2015; Faude et al., 2013). This type of HIIT is usually performed once per week to maintain (Dupont et al., 2004) or even enhance (Thomakos et al., 2024) aerobic and anaerobic fitness, due to its effectiveness and its time-efficient nature (5 - 12 min per session), which results in significant adaptations without causing excessive fatigue (Dellal et al, 2012; Dupont et al., 2004; Clemente et al., 2021). However, the need to develop physical fitness in young athletes (i.e., academy players) is higher compared to senior players, and thus the application of HIIT protocols of different structure at a higher frequency within the week in an ecologically valid setting (i.e. during a team's normal training schedule) warrants further investigation. Taking the above into consideration, the present study aims to compare two different HIIT formats (i.e., 10s/10s linear and 15s/15s with a change of direction) performed twice per week by two groups of players, with the same duration and relative intensity during the in-season. The main outcome of the study was Yo-yo IR1 test and CMJ performance, while rating of perceived exertion (RPE) was also obtained to assess internal load during these two HIIT formats. It was hypothesized that the two HIIT formats would present a similar aerobic stimulus, while the 15/15 s training format with changes of direction would result in greater improvements in CMJ, but would induce higher RPE, due to the longer bout duration and the changes of direction involved (Bogdanis et al., 2022; Fessi et al.2018; Dellal et al. 2010).

Methods

Study design

A counterbalanced cross-over study design was implemented. The experimental period lasted fourteen weeks and was conducted during the competitive period (Figure 1). Two teams took part in the study and one team performed the supplementary HIIT program in the first six weeks, while the other team performed it in the last six weeks. Both the order of supplementary HIIT program application (at a team level) and the allocation of the players to the training protocol were randomized using simple randomization (drawing lots). We did not apply a stratified randomization by player's position, but the final allocation of players was balanced in the two HIIT format groups (3 vs 4 full-backs, 2 vs. 3 central defenders, 5 vs. 4 midfielders and 3 vs. 2 attackers in 10s/10s and 15s15.s groups, respectively). Two weeks separated the two 6-weeks periods. These two weeks included Christmas holidays and consisted of 7 days of complete rest and 7 days of very low volume, intensity training with the ball. CMJ and Yo-Yo intermittent recovery (IR) 1 were carried out before and after each 6-weeks period (Figure 1). Testing was performed four days after the last match to avoid residual fatigue. All participants were familiar with the tests used (CMJ and Yo-yo IR1) as they routinely performed them in previous years. When a team followed the supplementary training program, half of the players were randomly allocated to perform the 10s/10s protocol, and the other half performed the 15s/15s protocol with changes of direction. Supplementary training program frequency was 2 times per week, on the first and third day of the training week. The control trained only with the ball, and training included passing games, small- medium- and large-sided games and tactical drills. The match participation time was recorded for all players in all matches.

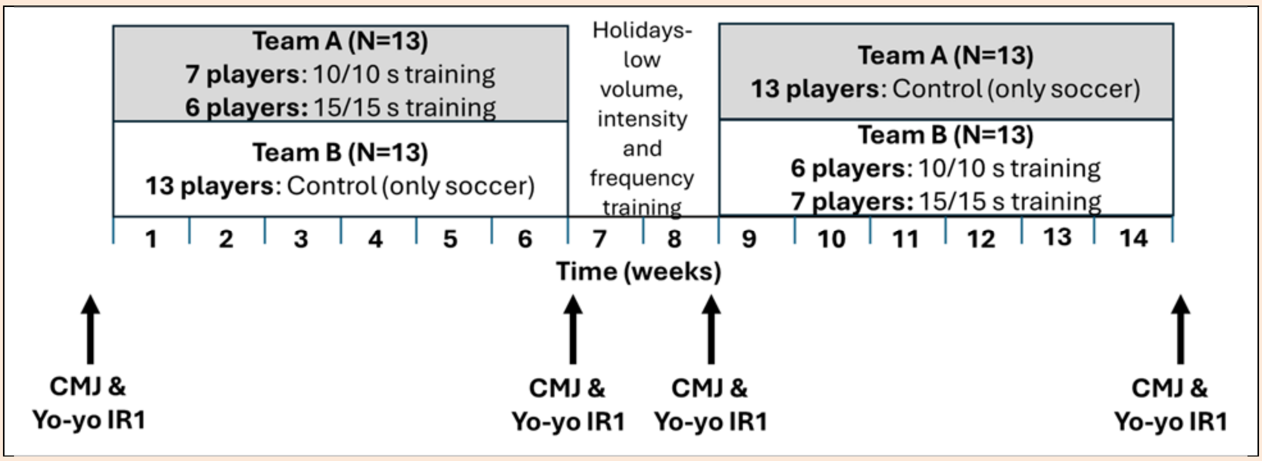

Figure 1. Study design. The number of players who completed the study from Team A and Team B is presented here. CMJ: countermovement jump test; Yo-yo IR1: Yo-yo intermittent recovery 1 test 10s/10s training: 2 sets x 6 min of linear running for 10 seconds with 10 seconds passive recovery totaling 18 repetitions per set; 15s/15s training: 2 sets x 6 min of shuttle-running (back and forth) for 15 seconds, with 15 seconds passive recovery totaling 12 repetitions per set.

Participants

Players from two different teams participated in the present study. We selected these teams because we had access to the teams, and coaches agreed to implement the intervention program and to test the players during the season. The first team (Team A) competed in Superleague U19 (1st Division of the Greek league) and included 22 youth players, while the second team (Team B) competed in the (4th Division of Greece - 1st Regional Division of Athens) and included 18 young players (excluding goalkeepers). The players who abstained from more than three training sessions for any reason (>25% of total) were excluded from the study. Also, the participants with match playing time of <270 min in the six matches (<45 min average) were excluded. Nine players from team A were not included in the final measurements due to minor musculoskeletal injuries during the games (3 players) or sickness (3 players) or with less than 270 min of match play (2 players) or absence from training for other reasons (1 player). Five players from team B were not included in the final measurements due to minor musculoskeletal injuries during the games (2 players) or with less than 270 min of match play (2 players) or sickness (1 player). The Consort flow diagram is presented in Figure 2. Finally, 26 players completed the present study (Team A: N = 13, age: 18.1 ± 0.7 years, height: 176.4 ± 2.8 cm, body mass: 72.0 ± 5.0 kg, body fat: 8.0 ± 3.0 % and Team B: N = 13, age: 18.7 ± 1.1 years, body mass: 72.2 ± 7.1 kg, body height: 180.8 ± 6.6 cm, body fat: 8.0 ± 3.6 %). A priori power analysis for model ANOVA interaction (group x time) was conducted to determine the minimum sample size required based on a power of 0.80, alpha of 0.05, and correlation coefficient of 0.6 between repeated measures (G-Power software, v. 3.1.9.2, Universität Kiel, Kiel, Germany). In a recent systematic review, the effect size regarding improvements in aerobic fitness was assessed by the Yo-yo test after 4 - 8 weeks of HIIT with similar protocols (Thomakos et al., 2023; Wong et al., 2010). We therefore opted to use an effect size within this range (η^2 = 0.1) in the a priori power analysis, which yielded 9 participants per group as a minimum requirement. None of the players received any medication or illegal nutritional supplements, and they signed a written informed consent before entering the research procedure. All procedures were in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece (Ref. number: 1495/2023).

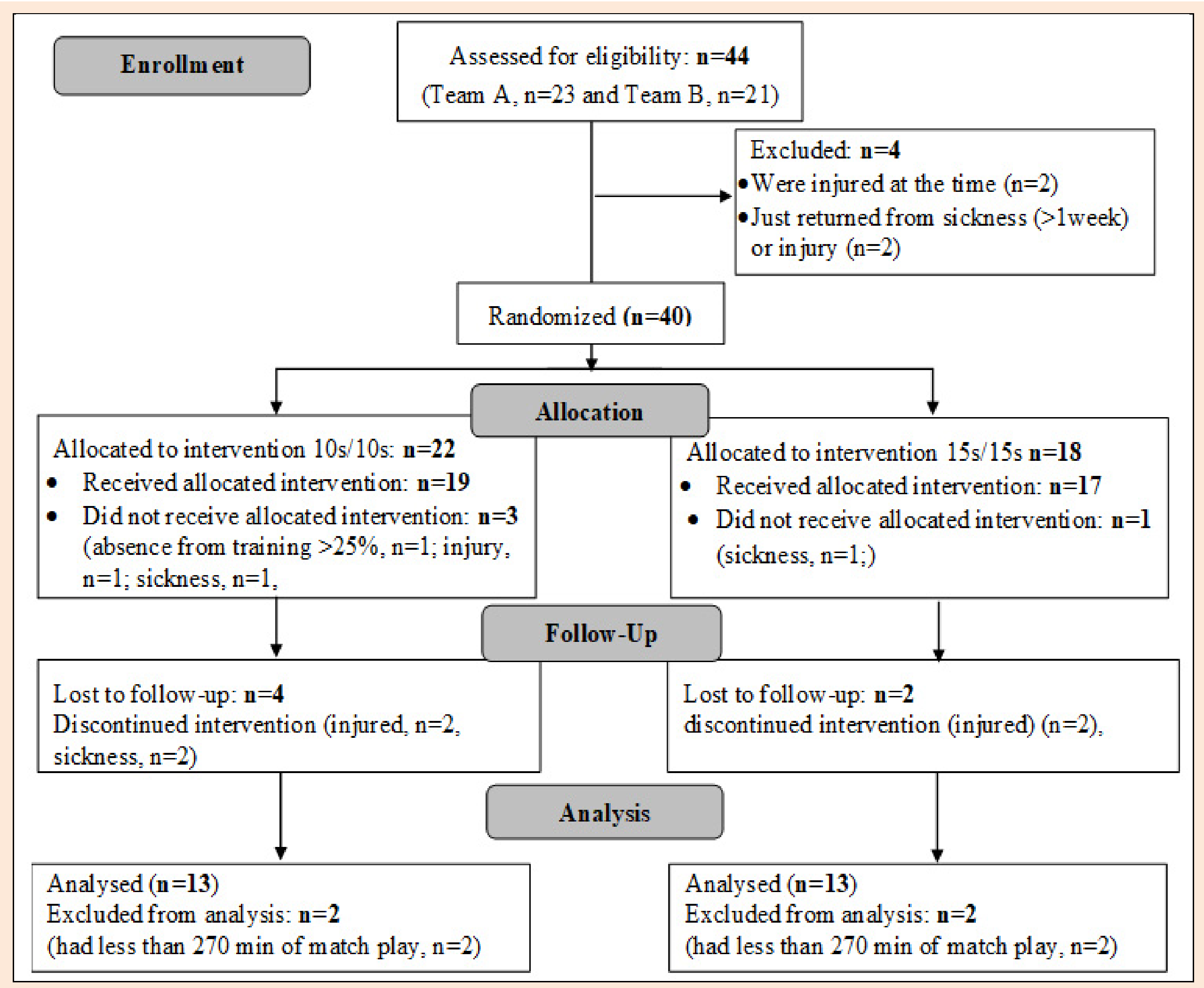

Figure 2. Study flowchart.

Procedures

Training programs

During the intervention period, both teams underwent a standardized microcycle plan, with one match per week (Saturday or Sunday depending on the games calendar), and five training sessions per week (i.e., one training session per day in the afternoon) and one day off (the day after the match day). The contents and duration of training were similar in the two teams and included passing games, small- and medium-sided games and tactical drills. In the Control period, players followed a standardized weekly training routine. No specific strength training was conducted, apart from injury prevention exercises with body weight. A typical weekly training schedule during the intervention and the control periods is presented in Table 1.

Each training session lasted 50-90 minutes. Supplementary training was performed twice per week two and four days after the match (MD+2 and MD+4). The supplementary HIIT included 2 sets of 6 minutes each at 100% $v\dot{V}O_2max$ with 3 minutes of recovery between sets. One group performed linear running from the center line of field to approximately the goal line (distance 44 – 48 m depending on the player's $v\dot{V}O_2max$) for 10 seconds with 10 seconds passive recovery (10s/10s), totaling 18 repetitions per set and the other group performed shuttle-running (back and forth) starting from the center line of the field to markers placed 33 - 37 m away (depending on the player's $v\dot{V}O2max$) and returning to the same line in 15 seconds, with 15 seconds passive recovery (15s/15s), totaling 12 repetitions per set.

Aerobic fitness test

Aerobic fitness was evaluated by the Yo-yo intermittent recovery test level 1. The test consisted of repeated 2 x 20 m runs back and forth, with progressively increasing speed controlled by audio beeps from a CD on a computer with speakers (Bangsbosport.com). Between each running bout, the participants had a 10 s active rest period, consisting of 2 x 5 m of jogging. When the participants failed twice to reach the finishing lines, the distance covered was recorded and kept as the test result. $\dot{V}O_2max$ was calculated from the following equation: y = 0.0084 x + 36.4, where x is distance covered in the test and y is $\dot{V}O_2max$ in ml/kg/min (Bangsbo et al., 2008). The speed corresponding to $\dot{V}O_2max$ ($v\dot{V}O_2max$) was estimated from the equation $\dot{V}O_2$ (ml/kg/min) = 2.209 + 3.163 x speed (km/h) (Léger and Mercier 1984). Heart rate was recorded every 5 seconds using a wireless heart rate monitor worn around the chest (Suunto Team POD, Dual Comfort Belt, Finland).

Table 1. Typical weekly training schedule during the intervention (upper part) and the control periods (lower part).

Day 1 (90 min)	Day 2 (90 min)	Day 3 (90 min)	Day 4 (90 min)	Day 5 (50 min)	Match day	Day off
Typical training schedule during the intervention period						
HIIT/ BallTrain	**$Ball_{Train}$**	**HIIT/ BallTrain**	**$Ball_{Train}$**	**$Ball_{Train}$**		
Warm-up routine -HIIT (10s/10s or 15s/15s), 2 x 6 min/3 min rest. -Small sided games, 2 x 6 min/3 min rest. -Tactical games, 3 x 8 min/3 min rest. Cool-down routine	-Passing games, 2 x 8 min/3 min rest. -Small-sided games, 4 x 4 min/3 min rest. -Tactical games, 2 x 8 min/3 min rest. Cool-down routine	-HIIT (10s/10s or 15s/15s), 2 x 6 min/3 min rest. -Small sided games, 2 x 6 min/3 min rest. -Tactical games, 3 x 8 min/3 min rest. Cool-down routine	-Agility 8 min/3 min rest. -Middle-sided games, 2 x 6 min/3 min rest. -Tactical games 3 x 8 min/3 min rest. Cool-down routine	-Agility 8 min/3 min rest. -Passing games, 2 x 6 min/3 min rest. -Tactical games, 2 x 6 min/3 min rest. Cool-down routine		Rest
Typical training schedule during the control period						
Day 1 (90 min)	**Day 2 (90 min)**	**Day 3 (90 min)**	**Day 4 (90 min)**	**Day 5 (50 min)**	**Match day**	**Day off**
$Ball_{Train}$	**$Ball_{Train}$**	**$Ball_{Train}$**	**$Ball_{Train}$**	**$Ball_{Train}$**		
-Passing games, 2 x 6 min/3 min rest. -Small-sided games, 2 x 6 min/3 min rest. -Tactical games, 3 x 8 min/3 min rest. Cool-down routine	-Passing games, 2 x 8 min/3 min rest. -Small-sided games, 4 x 4 min/3 min rest. -Tactical games, 2 x 8 min/3 min rest. Cool-down routine	-Passing games, 2 x 6 min/3 min rest. -Small-sided games, 2 x 6 min/3 min rest. -Tactical games, 3 x 8 min/3 min rest. Cool-down routine	-Agility 8 min/3 min rest. -Middle-sided games, 2 x 6 min/3 min rest. -Tactical games 3 x 8 min/3 min rest. Cool-down routine	-Agility 8 min/3 min rest. -Passing games, 2 x 6 min/3 min rest. -Tactical games, 2 x 6 min/3 min rest. Cool-down routine		Rest

Agility: ladder drills, hurdles, bosu and ball; $Ball_{Train}$: training with ball; HIIT: high intensity interval training; Sessions: Day of week (duration of session).

Vertical jump test

The CMJ was used to evaluate the lower limb power. Athletes were required to perform a downward movement followed by a complete, rapid extension of the lower limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement and athletes were directed to jump as high as possible and land close to the take-off point with the same body posture as that at takeoff. They executed three maximal trials with a 1 min rest. The CMJ was performed on an electronic mat (CHRONOJUMP - Bosco system, Din-A4 297 x 210 m, Spain) with previously established validity and reliability (Pagaduan and de Blas Foix, 2012) and jump height was calculated using the following equation: $h = t_f^2 \times g \times 8^{-1}$. Where h is the height expressed in cm, t_f^2 is flight time in square exposure and g is gravity (9.81 m/sec^{-2}). The coefficient of variation of the CMJ height measurement was 2.0 ± 0.9%. The highest jump was kept for analysis.

Rating of Perceived Exertion (RPE)

Only for the HIIT intervention group, after five minutes of the finish of the intervention program a Borg scale (CR10-scale) was used to evaluate the rating of perceived exertion (RPE). The researchers called each player alone, presented a visual scale and recorded the player's response.

Match play time

Match play time was recorded for every participant throughout the duration of the study.

Statistical analysis

Data are presented as mean ± standard deviation. Statistical analysis was performed using the SPSS (Version 26, Chicago USA). A mixed-model three-way analysis of variance with repeated measures on two factors (pre vs. post the 6-weeks period and experimental vs. control period) and two groups (10/10 s and 15/15 s) was used to examine differences in Yo-yo IR1 parameters (i.e., total distance, $\dot{V}O_2max$, $v\dot{V}O_2max$), CMJ, RPE and match play time. Tukey's post-hoc test was used to explore mean differences when a main effect or interactions were found. Cohen's effect sizes (ESs) (Cohen's 1988) were computed to determine the magnitude of paired comparisons and were classified as trivial (<0.2), small (>0.2 - 0.5), moderate (>0.5 - 0.8), large (>0.8). The level of significance was set at $p < 0.05$.

Results

There was no difference in training time or match play time between the two training formats or between the experimental and control conditions (p = 0.41 to 0.94). There was no significant 3-way interaction for the Yo-Yo IR1 performance test variables ($p = 0.20$, $\eta^2 = 0.07$-medium). No-significant differences were found in the distance covered: 2154 ± 346 vs. 2246 ± 354 m; $\dot{V}O_{2max}$: 54.2 ± 2.7 vs. 55.3 ± 3.0 $ml\cdot kg^{-1}\cdot min^{-1}$; $v\dot{V}O_{2max}$: 16.6 ± 0.7 vs. 16.9 ± 0.7 $km\cdot h^{-1}$), HR and CMJ at pre-intervention periods between the two conditions. There was a 2-way interaction between pre vs. post and experimental vs. control period ($p<0.001$, $\eta^2 = 0.61$). Tukey's post-hoc tests showed an increase in Yo-Yo test performance during the intervention period, independent of group ($p<0.001$, d = 0.83), while there was no change during the control period (p = 0.201, Table 2 and Figure 3). Specifically, the percent increase in running distance was 13.8 ± 11.1%, the increase in $\dot{V}O_2max$ was 4.3 ± 3.2% and the increase in $v\dot{V}O2max$ was 2.6 ± 1.9% (all $p<0.001$, d = 0.83). There was no significant 3-way interaction for the peak heart rate ($p = 0.08$, $\eta^2 = 0.12$-medium). Peak heart rate remained unchanged (196 ± 5 vs. 196 ± 5 beats/min in the experimental condition and in the control condition; 196 ± 6 vs. 196 ± 6 beats/min). Also, there was no significant 3-way interaction for CMJ ($p = 0.98$, $\eta^2 < 0.001$). CMJ performance was similar in the two groups and remained unchanged after both the experimental and control periods ($p>0.68$, Figure 3).

Differences in the effectiveness of the two HIIT formats were examined by calculating and comparing the change in Yo-yo IR1 test performance before and after each 6-weeks period. As seen in Table 2, both training formats resulted in Yo-yo IR1 performance increases following training, while there was a non-significant decrease in performance during the control periods, where only soccer training was applied. HR and CMJ were similar at baseline between 10s/10s and 15s/15s groups and remained unchanged in all conditions. However, the change in Yo-yo test performance was 45 - 50% larger after the 10s/10s intervention compared with the 15s/15s intervention (p = 0.039, d = 0.85). RPE after training was lower after the 10s/10s compared with the 15s/15s format (4.7 ± 1.2 vs. 6.4 ± 0.5 a.u., $p<0.001$, d = 1.86) Specifically, following the 10s/10s training, distance covered improved by 18.5 ± 11.7% vs. 9.0 ± 8.5%, $\dot{V}O_2max$ improved by 5.6 ± 3.2% vs. 3.0 ± 2.7%, and $v\dot{V}O_2max$ improved by 3.3 ± 1.9% vs. 1.8 ± 1.7%, compared with the 15s/15s training format (Table 2).

The design of the present study allows a comparison of the effects of supplementary HIIT over time during in-season. Team A followed the supplementary HIIT program in the first 6 weeks, while Team B followed in weeks 8-14. By performing a 3-way ANOVA by team (and not by training format intervention), revealed a significant interaction, between team and training time ($p<0.01$).

Post-hoc tests showed that Team A, which performed the HIIT training first (both formats), improved Yo-yo IR1 test performance in the first 6 weeks but could not maintain it until the end of the 14-week period, demonstrating a progressive decrease. In contrast, team B, which performed HIIT training in weeks 8-14, improved Yo-yo IR1 test performance only after that period (Figure 4). There were no main effects or interactions ($p>0.40$) for match play time. Match play time was similar between the intervention and control periods for the 10s/10s group (420 ± 83 vs. 420 ± 83 min) and for the 15s/15s group (436 ± 56 vs. 427 ± 54 min).

Table 2. Aerobic fitness variables assessed by the Yo-yo IR1 test, peak heart rate (HR) and vertical jump (CMJ) for all groups before and after the experimental and control periods. In the control period the group name remains, but no supplementary HIIT training was performed.

Variable	Group	Pre	Post	*p* Pre vs. Post	*d* Pre vs. Post	*Delta change*	*Delta* Change (%)	*p* Between deltas	*d* Between deltas
Distance (m)	**10s/10s**	2083 ± 411	2434 ± 345	**<0.001**	0.92 (large)	351 ± 192	18.5 ± 11.7	**0.039**	**0.85 (large)**
	15s/15s	2225 ± 262	2418 ± 275	**0.005**	0.72 (moderate)	194 ± 175	9.0 ± 8.5		
Control period	**10s/10s**	2166 ± 418	2083 ± 349	0.587	0.22 (small)	-83 ± 281	-2.2 ± 15.2	0.973	0.01 (trivial)
	15s/15s	2317 ± 275	2231 ± 289	0.443	0.31 (small)	-86 ± 162	-3.6 ± 7.1		
$\dot{V}O_{2max}$ (ml/kg/min)	**10s/10s**	53.9 ± 3.5	56.8 ± 2.9	**<0.001**	0.92 (large)	2.9 ± 1.6	5.6 ± 3.2	**0.039**	**0.85 (large)**
	15s/15s	55.1 ± 2.2	56.7 ± 2.3	**0.005**	0.72 (moderate)	1.6 ± 1.5	3.0 ± 2.7		
Control period	**10s/10s**	54.6 ± 3.5	53.9 ± 2.9	0.587	0.22 (small)	-0.7 ± 2.4	-1.1 ± 4.4	0.973	0.35 (small)
	15s/15s	55.9 ± 2.3	55.1 ± 2.4	0.443	0.31 (small)	-0.1 ± 0.4	-1.3 ± 2.4		
$v\dot{V}O_{2max}$ (km/h)	**10s/10s**	16.6 ± 0.6	17.1 ± 0.5	**<0.001**	0.92 (large)	0.5 ± 0.3	3.3 ± 1.9	**0.039**	**0.85 (large)**
	15s/15s	16.8 ± 0.4	17.1 ± 0.4	**0.005**	0.72 (moderate)	0.3 ± 0.3	1.8 ± 1.7		
Control period	**10s/10s**	16.7 ± 0.7	16.6 ± 0.5	0.587	0.22 (small)	-0.1 ± 0.4	-0.7 ± 2.7	0.973	0.00 (trivial)
	15s/15s	16.9 ± 0.4	16.8 ± 0.5	0.443	0.31 (small)	-0.1 ± 0.3	-0.8 ± 1.5		
HR(bpm)	**10s/10s**	198 ± 5	198 ± 5	0.705	0.15 (trivial	-0.7 ± 3.3	0.4 ± 1.7	0.152	**0.58 (moderate)**
	15s/15s	194 ± 6	195 ± 5	0.683	0.16 (trivial)	0.8 ± 1.7	-0.4 ± 0.9		
Control period	**10s/10s**	197 ± 5	197 ± 7	0.820	0.09 (trivial)	0.5 ± 2.5	-.02 ± 1.3	0.416	0.33 (small)
	15s/15s	195. ± 6	195 ± 6	0.949	0.03 (trivial)	-0.2 ± 1.6	0.1 ± 0.8		
CMJ (cm)	**10s/10s**	37.8 ± 3.1	37.5 ± 3.8	0.993	0.08 (trivial)	-0.3 ± 1.9	1.0 ± 5.0	0.893	0.06 (trivial)
	15s/15s	38.1 ± 2.7	37.9 ± 2.6	0.974	0.07 (trivial)	-0.2 ± 1.4	0.6 ± 3.8		
Control period	**10s/10s**	37.9 ± 3.6	37.0 ± 3.1	0.498	0.27 (small)	-0.9 ± 1.5	2.4 ± 4.3	0.896	0.05 (trivial)
	15s/15s	38.0 ± 3.2	37.2 ± 1.9	0.449	0.30 (small)	-0.8 ± 2.6	2.1 ± 7.3		

Exp: experimental condition; Con: Control condition; Distance (m): Distance covered in the Yo-yo IR1 expressed in meters, $\dot{V}O_2$max (ml/kg/min): maximum oxygen consumption, $v\dot{V}O_2$max (km/h): running speed at $\dot{V}O_2$max, HR (bpm): Heart Rate, CMJ (cm): Counter movement jump; *d*: Effect size. Delta values were calculated from Pre-and post- training values. Data are means and standard deviations (mean±SD).

Discussion

The aim of the current study was to evaluate the effect of short-HIIT in aerobic capacity and neuromuscular performance and RPE during competitive period on soccer players. Two formats of short-HIIT 10s/10s and 15s/15s were compared in a randomized design in two youth football teams twice per week during the in-season period. The main finding of the study was that Yo-yo IR1 performance significantly improved in both HIIT groups compared with control group (by 13.8% vs. no change in the control period), with no changes in HR and CMJ. The between HIIT formats difference indicated that the improvements in distance covered, $\acute{V}O_2$max and $v\acute{V}O_2$max were almost twice as high in the 10s/10s format compared with the 15s/15s format (18.5 vs. 9.0%), despite the longer bout duration and the changes of direction performed in the later. Moreover, RPE was lower in the 10s/10s format compared to the 15s/15s format. Another important finding was revealed when Yo-yo IR1 test performance of each team was examined over time (Figure 3). This comparison revealed that supplementary HIIT training, irrespective of format, is necessary to maintain a high level of aerobic/anaerobic fitness, as assessed by the Yo-yo IR1 test (Figure 4).

The large improvements of Yo-yo IR1 test performance following the application of HIIT is an important finding of the present study. Moreover, the decline in performance when players performed football training only was evident when observing the time-course of changes in Team A in Figure 4. Notably, there was no improvement in Yo-yo IR1 performance in Team B during the initial period (weeks 1 - 6). These findings are in line with previous studies which implemented HIIT during the in-season period (Dupont et al., 2004; Mohr and Krustrup, 2014; Thomakos et al., 2024). Aerobic capacity is improved when HIIT or small-sided games are implemented. However, HIIT may provide more control over the individual intensity of training, as some players may underperform

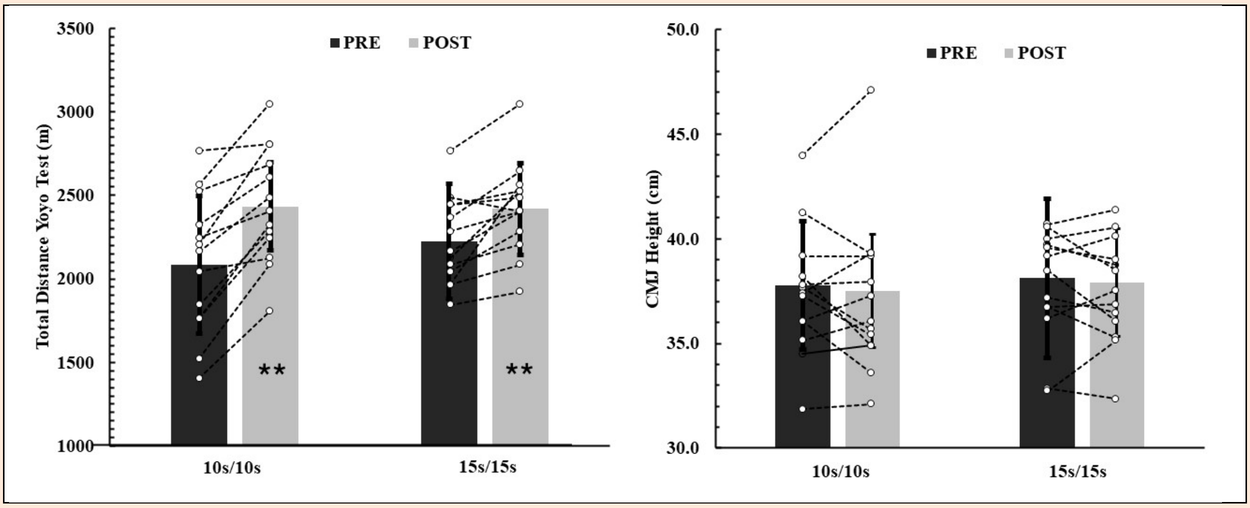

Figure 3. Distance covered during the Yo-Yo IR1 test (left panel) and countermovement jump (CMJ, right panel) before (pre) and after (post) the 10s/10s and 15s/15s supplementary high intensity interval training. ** $p \leq 0.005$ between pre and post at HIIT group.

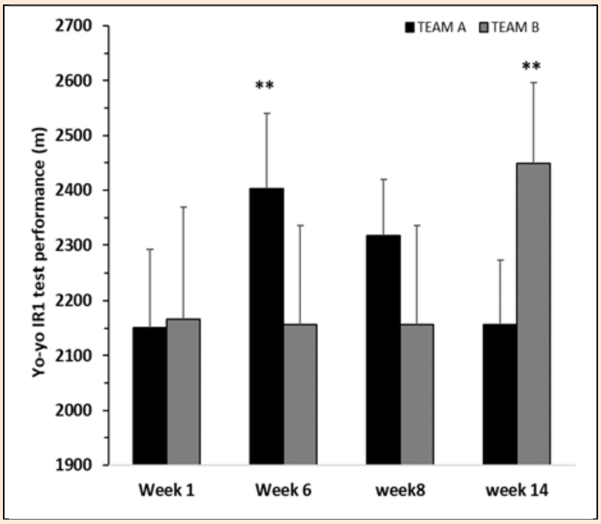

Figure 4. Yo-yo IR test performance (total distance) in Team A (which performed the HIIT protocol in the first 6 weeks) and Team B (which performed the HIIT protocol in the last 6 weeks). ** $p<0.01$ from all time points of the same team.

during small-sided games (Dellal et al., 2012; Thomakos et al., 2024). During the in-season period, coaches prefer to focus on technical and tactical drills, whereas physical qualities are maintained through games and the tactical exercises, to avoid overloading or temporary fatigue (Dupont et al., 2004). However previous studies showed that individual training intensity can be controlled better when using HIIT compared with SSG (Dellal et al., 2008; Engel et al., 2018). In fact, the HIIT has been shown to induce greater improvements in both aerobic and anaerobic capacity compared with continuous training of similar duration (Dellal et al., 2008; Engel et al., 2018). However, the counter-argument is that HIIT involving running only is much less football-specific, and several coaches prefer to perform high intensity drills with the ball instead of HIIT. Nevertheless, HIIT as a form of supplementary training, performed once per week has been shown to improve not only fitness but also match performance (i.e., match results and scoring-conceding goals) (Dupont et al., 2004; Thomakos et al., 2024).

The metabolic demands and, in turn, the adaptations to HIIT depend, among other parameters, on bout duration, with shorter bouts providing less metabolic load (i.e. lactate production) with a similar cardiorespiratory load (Bogdanis et al., 2022). HIIT has been shown to promote muscle oxidative capacity through increased mitochondrial biogenesis (Daussin et al., 2008). However, a recent study indicated that high lactate concentration may impair the process of mitochondrial biogenesis, thus reducing its effectiveness to promote aerobic adaptations (Bishop et al., 2019). Although blood lactate was not assessed in the present study, previous work clearly shows that when the same distance in HIIT is covered with a change of direction, the blood lactate responses and RPE are higher compered to linear HIIT (Dellal et al., 2010; 2012). Thus, the 15s/15s format which included back and forth running, may have a greater anaerobic component and the higher lactate and RPE may explain the lower improvement in Yo-yo IR1 test performance with the mechanism described above. In previous studies comparing HIIT formats the intensity was not the same at both modes of short-HIIT (Buchheit and Laursen, 2013; Dellal et al., 2008; 2015), while in the present study where the intensity was set to 100% of $v\acute{V}O_2max$ for both protocols. For example, Dellal et al. (2015) compared HR during a repeated sprints protocol, small-sided games and two short HIIT formats (15s/15s) performed either linearly or with 180° COD. Their findings showed that HR was higher at the 15s/15s with 180° COD protocol compared with the other exercises. In the present study the participants had higher RPE when running 15s/15s with changes of direction vs. the linear 10/10 s format. This may be because bout duration was longer and also because the 15s/15s format included a 180° change of direction (Bogdanis et al., 2022; Dellal et al., 2010).

One of the hypotheses tested in the present study was that HIIT with changes of direction could have a positive effect on CMJ performance. However, there were no changes in CMJ in all conditions, suggesting that both HIIT interventions, as well as the control periods, do not result in an increase or decrease in lower limb explosive performance. This would suggest that a specific power training program would be required to improve CMJ during the in-season period (Meylan and Malatesta, 2009; Ramírez-Campillo et al., 2014). During the in-season, training load should be adjusted accordingly so that a high level of performance is maintained during official matches. In a previous study, the authors observed that when training load was heavy, i.e. resistance training combined with HIIT in the pre-season, CMJ performance was depressed (Thomakos et al., 2023). Thus, a possible addition of resistance training in combination with HIIT performed twice per week could increase the risk of overreaching or overtraining, but this warrants further investigation.

Previous studies have shown that RPE reflects training load assessed by a combination of HR and blood lactate concentration, thus making it a fairly accurate global index of internal load during training (Foster et al., 2001; Snyder et al., 1993; Gabbett, 2016). Thus, RPE is a very useful tool to monitor and control training. In the present study, we could not obtain measurements of blood lactate after the HIIT program, as this was not practically possible because it would delay the training process. The finding that RPE was higher after the 15s/15s compared to 10s/10s format, may be explained by the higher mechanical load of the changes of direction in the later format, the acceleration and deceleration involved to perform a 180o turn, combined with the longer duration of the bout (15s vs. 10s) (Dellal et al. 2010; Dellal et al., 2012; Bogdanis et al., 2022). These would induce a higher glycolytic contribution and mechanical loading (Dellal et al., 2012), which are linked with higher RPE.

One of the interesting findings of the present study was the responsiveness of the players' organisms to HIIT, as shown in Figure 4 Specifically, Team A, which performed the HIIT training first irrespective of format, improved Yo-yo IR1 test performance in the first 6 weeks but could not maintain it until the end of the 14-week period. In contrast, team B, which performed HIIT training in weeks 8 - 14, improved Yo-yo IR1 test performance only after that period. These changes demonstrate the rapid responses of the player's to HIIT, as well as the relatively fast detraining (Mujika and Padilla, 2000). Thus, supplementary HIIT may be necessary to improve performance during in-season, while the two times per week schedule seems to be not only well tolerated, but also very effective in improving Yo-yo IR1 performance.

The current study has some limitations. We could not obtain HR or global positioning system data during training and match play, except from playing time per players. Also, blood lactate responses could not be obtained due to practical reasons in such those teams. This information would have been useful to assess training load differences between the two periods in detail. Also, it was not practically possible to perform other field or laboratory tests (e.g. sprints, change of direction tests, cardiopulmonary testing on a treadmill), because it would disrupt the in-season training program of the teams and it was not practically possible. However, the design of this study, using two teams who followed a control and an intervention period in an alternated manner, as well as the standardized training procedures followed by both teams in an equated manner, ensures that the differences in test performance observed are reliable. Also, game participation time was similar between the two periods (intervention and control), which further adds to the controlled conditions under which this intervention was performed. It is important to highlight that these results may not directly apply to women and professional soccer players. Also, the level of readiness of the players before implementing a HIIT program may interact with the magnitude of adaptations. Further studies should address these issues.

Conclusion

The present study showed that in-season supplementary short-HIIT training improves endurance performance without any change in neuromuscular performance. Both intermittent running modes (i.e., 10s/10s and 15s/15s) improved Yo-Yo IR1 test performance following the intervention program. However, the 10s/10s HIIT format induces greater improvements in performance with a lower RPE during training compared with the 15s/15s format. Young soccer players may benefit by adding a short HIIT program twice-per week during the competitive season, when the aim is to further improve aerobic fitness without compromising neuromuscular performance.

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References

Asín-Izquierdo, I., Chena, M., de Dios-Álvarez, V. and Galiano, C. (2024) Relationship between relative age measured through decimal age, physical variables and anthropometry in elite youth soccer players. *The Physician and Sportsmedicine* **52(4)**, 343-348. https://doi.org/10.1080/00913847.2023.2258768

Bangsbo, J., Iaia, F.M. and Krustrup, P. (2008) The Yo-yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine* **38(1)**, 37-51. https://doi.org/10.2165/00007256-200838010-00004

Bishop, D.J., Botella, J., Genders, A.J., Lee, M.J., Saner, N.J., Kuang, J., Yan, X. and Granata, C. (2019) High-Intensity Exercise and Mitochondrial Biogenesis: Current Controversies and Future Research Directions. *Physiology (Bethesda)* **34(1)**, 56-70. https://doi.org/10.1152/physiol.00038.2018

Bogdanis, G.C., Stavrinou, P.S., Tsirigkakis, S., Mougios, V., Astorino, T.A. and Mastorakos, G. (2022) Attenuated Metabolic and Cardiorespiratory Responses to Isoenergetic High-Intensity Interval Exercise of Short Versus Long Bouts. *Medicine and Science in Sports and Exercise* **54(7)**, 1199-1209. https://doi.org/10.1249/MSS.0000000000002905

Buchheit, M. and Laursen, P.B. (2013) High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. *Sports Medicine* **43**, 927-954. https://doi.org/10.1007/s40279-013-0029-x

Callahan, M.J., Parr, E.B., Hawley, J.A. and Camera, D.M. (2021) Can high-intensity interval training promote skeletal muscle anabolism? *Sports Medicine* **51(3)**, 405-421. https://doi.org/10.1007/s40279-020-01397-3

Castillo, D., Raya-González, J., Weston, M. and Yanci, J. (2021) Distribution of External Load During Acquisition Training Sessions and Match Play of a Professional Soccer Team. *Journal of*

Strength and Conditioning Research **35(12)**, 3453-3458. https://doi.org/10.1519/JSC.0000000000003363

Chmura, P., Oliva-Lozano, J. M., Muyor, J. M., Andrzejewski, M., Chmura, J., Czarniecki, S., Kowalczuk, E., Rokita, A. and Konefał, M. (2022) Physical Performance Indicators and Team Success in the German Soccer League. *Journal of Human Kinetics* **8(83)**, 257-265. https://doi.org/doi: 10.2478/hukin-2022-0099

Clemente, F.M., Ramirez-Campillo, R., Afonso, J. and Sarmento, H. (2021). Effects of Small-Sided Games vs. Running-Based High-Intensity Interval Training on Physical Performance in Soccer Players: A Meta-Analytical Comparison. *Fronters in Physiology* **12**, 642703. https://doi.org/10.3389/fphys.2021.642703

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers

Daussin, F.N., Zoll, J., Ponsot, E., Dufour, S.P., Doutreleau, S., Lonsdorfer, E., Ventura-Clapier, R., Mettauer, B., Piquard, F., Geny, B. and Richard, R. (2008) Training at high exercise intensity promotes qualitative adaptations of mitochondrial function in human skeletal muscle. *Journal of Applied Physiology* **104(5)**, 1436-1441. https://doi.org/10.1152/japplphysiol.01135.2007

Darragi, M., Zouhal, H., Bousselmi, M., Karamti, H.M., Clark, C.C.T., Laher, I., Hackney, A.C., Granacher, U. and Zouita, A.B.M. (2024). Effects of In-Season Strength Training on Physical Fitness and Injury Prevention in North African Elite Young Female Soccer Players. *Sports Medicine Open* **10(1)**, 94. https://doi.org/10.1186/s40798-024-00762-0

Dellal, A., Casamichana, D., Castellano, J., Haddad, M., Moalla, W. and Chamari, K. (2015) Cardiac Parasympathetic Reactivation in Elite Soccer Players During Different Types of Traditional High-Intensity Training Exercise Modes and Specific Tests: Interests and Limits. *Asian Journal of Sports Medicine* **6(4)**, e25723. https://doi.org/10.5812/asjsm.25723

Dellal, A., Varliette, C., Owen, A., Chirico, E.N. and Pialoux, V. (2012) Small-sided games versus interval training in amateur soccer players: Effects on the aerobic capacity and the ability to perform intermittent exercises with changes of direction. *Journal of Strength and Conditioning Research* **26(10)**, 2712-2720. https://doi.org/10.1519/JSC.0b013e31824294c4

Dellal, A., Keller D., Carling C., Chaouachi A., Wong del P. and Chamari, K. (2010) Physiologic effects of directional changes in intermittent exercise in soccer players *Journal of Strength and Conditioning Research* **24(12)**, 3219-3226. https://doi.org/10.1519/JSC.0b013e3181b94a63

Dellal, A., Chamari, K., Pintus, A., Girard, O., Cotte, T. and Keller, D. (2008) Heart rate responses during small-sided games and short intermittent running training in elite soccer players: a comparative study *Journal of Strength and Conditioning Research* **22(5)**, 1449-1457. https://doi.org/10.1519/JSC.0b013e31817398c6

Dos'Santos, T., Thomas, C., Comfort, P. and Jones, P.A. (2018) The Effect of Angle and Velocity on Change of Direction Biomechanics: An Angle-Velocity Trade-Off. *Sports Medicine* **48**, 2235-2253. https://doi.org/10.1007/s40279-018-0968-3

Dupont, G., Akakpo, K. and Berthoin, S. (2004) The effect of in-season, high-intensity interval training in soccer players. *Journal of Strength and Conditioning Research* **18 (3)**, 584-589. https://doi.org/10.1519/00124278-200408000-00034

Engel, F.A., Ackermann, A., Chtourou, H. and Sperlich, B. (2018) High-Intensity Interval Training Performed by Young Athletes: A Systematic Review and Meta-Analysis. *Frontiers in Physiology* **9**. https://doi.org/10.3389/fphys.2018.01012.

Faude, O., Schnittker, R., Schulte-Zurhausen, R., Müller, F. and Meyer, T. (2013) High intensity interval training vs. high-volume running training during pre-season conditioning in high-level youth football: A cross-over trial. *Journal of Sports Sciences* **31(13)**, 1441-1450. https://doi.org/10.1080/02640414.2013.792953

Fessi, M.S., Farhat, F., Dellal, A., Malone, J.J. and Moalla, W. (2018) Straight-Line and Change-of-Direction Intermittent Running in Professional Soccer Players. *International Journal of Sports Physiology and Performance* **13(5)**, 562-567. https://doi.org/10.1123/ijspp.2016-0318

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P. and Dodge C. (2001) A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research* **15(1)**, 109-115. https://doi.org/10.1519/00124278-200102000-00019

Gee, T.I., Harsley, P. and Bishop, D.C. (2021) Effect of 10 Weeks of Complex Training on Speed and Power in Academy Soccer Players. *International Journal of Sports Physiology and Performance***16(8)**, 1134-1139. https://doi.org/10.1123/ijspp.2020-0139

Hostrup, M. and Bangsbo, J. (2023) Performance Adaptations to Intensified Training in Top-Level Football. *Sports Medcine* **53(3)**, 577-594. https://doi.org/10.1007/s40279-022-01791-z

Gabbett, T.J. (2016) The training-injury prevention paradox: Should athletes be training smarter and harder? *British Journal of Sports Medicine* **50(5)**, 273-280. https://doi.org/10.1136/bjsports-2015-095788

Helgerud, J., Engen, L.C., Wisloff, U. and Hoff, J. (2001) Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise* **33(11)**, 1925-1931. https://doi.org/10.1097/00005768-200111000-00019

Kilpatrick, M.W., Jung, M.E. and Little, J.P. (2014) High Intensity Training: A Review of Physiological and Psychological Responses. *ACSM's Health & Fitness Journal* **18(5)**, 11-16. https://doi.org/10.1249/FIT.0000000000000067

Léger, L. and Mercier, D. (1984) Gross energy cost of horizontal treadmill and track running. *Sports Medicine* **1(4)**, 270-277. https://doi.org/10.2165/00007256-198401040-00003

McQuilliam, S.J., Clark, D.R., Erskine, R.M. and Brownlee, T.E. (2023) Effect of High-Intensity vs. Moderate-Intensity Resistance Training on Strength, Power, and Muscle Soreness in Male Academy Soccer Players. *Journal of Strength and Conditioning Research* **37(6)**, 1250-1258. https://doi.org/10.1519/JSC.0000000000004387

Meylan, C. and Malatesta, D. (2009) Effects of in-season plyometric training within soccer practice on explosive actions of young players. *Journal of Strength and Conditioning Research* **23(9)**, 2605-2613. https://doi.org/10.1519/JSC.0b013e3181b1f330

Milheiro, A., Baptista, I., Nakamura, F., Sarmento, H., Clemente, F., Silva, J. and Afonso, J. (2024) The influence of competition time in soccer players performance factors: A scoping review with evidence-gap map. Short title: Performance factors in soccer. *SportRxiv* published ahead of Print. https://doi.org/10.54499/UIDB/05913/2020

Mohr, M., and Krustrup, P. (2014) Yo-Yo intermittent recovery test performances within an entire football league during a full season. *Journal of Sports Sciences* **32(4)**, 315-327. https://doi.org/10.1080/02640414.2013.824598

Mujika, I. and Padilla, S. (2000) Detraining: loss of training-induced physiological and performance adaptations. Part I: short term insufficient training stimulus. *Sports Medicine* **30(2)**, 79-87. https://doi.org/10.2165/00007256-200030020-00002

Oliveira, R., Brito, J.P., Martins, A., Mendes, B., Marinho, D.A., Ferraz, R. and Marques, M.C. (2019) In-season internal and external training load quantification of an elite European soccer team. *Plos One* **14(4)**, e0209393. https://doi.org/10.1371/journal.pone.0303763

Owen, A.L., Wong, D.P., Mckenna, M. and Dellal, A. (2011) Heart rate responses and comparison between small-vs. large-sided games in elite professional soccer. *Journal of Strength and Conditioning Research* **25**, 2104-2110. https://doi.org/10.1519/JSC.0b013e3181f0a8a3

Pagaduan, J. C. and de Blas Foix X. (2012) reliability of a loaded countermovement jump performance using the Chronojump-Bosco-system. *Kinesiologia Slovenica* **18(2)**, 45.

Petrigna, L., Karsten, B., Marcolin, G., Paoli, A., D'Antona, G., Palma, A. and Bianco, A. (2019) A Review of Countermovement and Squat Jump Testing Methods in the Context of Public Health Examination in Adolescence: Reliability and Feasibility of Current Testing Procedures. *Frontiers in Physiology* **10**, 1-19. https://doi.org/10.3389/fphys.2019.01384

Ramírez-Campillo, R., Meylan, C., Alvarez, C., Henríquez-Olguín, C., Martínez, C., Cañas-Jamett, R., Andrade, D.C. and Izquierdo, M. (2014) Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. *Journal of Strength and Conditioning Research* **28(5)**, 1335-1342. https://doi.org/10.1519/JSC.0000000000000284

Rosenblat, M.A., Perrotta, A.S. and Thomas S.G. (2020) Effect of High-Intensity Interval Training Versus Sprint Interval Training on Time-Trial Performance: A Systematic Review and Meta-analysis. *Sports Medicine* **50(6)**, 1145-1161. Available from: https://doi.org/10.1007/s40279-020-01264-1

Rowell, A.E., Aughey, R.J., Hopkins, W.G., Stewart, A.M. and Cormack, S.J. (2017) Identification of Sensitive Measures of Recovery After External Load From Football Match Play. *International Journal of Sports Physiology and Performance* **12(7)**, 969-976. https://doi.org/10.1123/ijspp.2016-0522.

Scott, B.R., Lockie, R.G., Davies, S.J.G., Clark, A.C., Lynch, D.M. and Janse de Jonge, X.A.K. (2014) The physical demands of professional soccer players during in-season field-based training and match-play. *Journal of Australian Strength and Conditioning* **22(4)**, 48-52.

Snyder, A.C., Jeukendrup, A.E., Hesselink, M.K.C., Kuipers, H. and Foster, C. (1993) A physiological/psychological indicator of over-reaching during intensive training. *International Journal of Sports Medicine* **14(1)**, 29-32. https://doi.org/10.1055/s-2007-1021141

Stern, D., Gonzalo-Skok, O., Loturco, I., Turner, A. and Bishop, C. (2020). A Comparison of Bilateral vs. Unilateral-Biased Strength and Power Training Interventions on Measures of Physical Performance in Elite Youth Soccer Players. *Journal of Strength and Conditioning Research* **34(8)**, 2105-2111. https://doi.org/10.1519/JSC.0000000000003659

Thomakos, P., Spyrou, K., Tsoukos, A., Katsikas, C. and Bogdanis, G.C. (2024) High-Intensity Interval Training Combined with High-Load Strength Training Improves Aerobic Fitness, Match Goals and Match Result during the In-Season Period in Under-19 Soccer Players. *Sports (Basel)* **12(1)**, 2. https://doi.org/10.3390/sports12010002

Thomakos, P., Spyrou, K., Katsikas, C., Geladas, N.D. and Bogdanis, G.C. (2023) Effects of Concurrent High-Intensity and Strength Training on Muscle Power and Aerobic Performance in Young Soccer Players during the Pre-Season. *Sports (Base)* **11(3)**, 59. https://doi.org/10.3390/sports11030059

Vasileiou, S.S., Asimakidis, N.D., Dalamitros, A.A. and Manou, V. (2024) Effects of an 8-Week In-Season Explosive Power Training Program on Neuromuscular Performance and Lower-Limb Asymmetries in Young Male Soccer Players. *Journal of Strength and Conditioning Research* **14**. https://doi.org/10.1519/JSC.0000000000004917

Wong, P.L., Chaouachi, A., Chamari, K., Dellal, A. and Wisloff, U. (2010) Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players *Journal of Strength and Conditioning Research* **24(3)**, 653-660. https://doi.org/10.1519/JSC.0b013e3181aa36a2

Key points

- Both supplementary HIIT programs improved Yo-Yo IR1 performance in young soccer players
- However, training with the 10s/10s format resulted in 45-50% greater improvement in Yo-Yo IR1 performance, while rating of perceived exertion during training was lower than the 15s/15s format.
- CMJ performance remains unaffected by supplementary HIIT performed twice weekly during the in-season in young soccer players.

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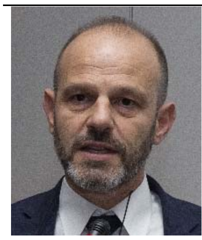

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