Recovery time variation during sprint interval training impacts amateur soccer players adaptations – a pilot study

AUTHORS: Gürkan Diker[1], Abdulkerim Darendeli[1], Karim Chamari[2,3], Alexandre Dellal[4], Sürhat Müniroğlu[5], Sadi Ön[6], Hüseyin Özkamçı[7]

[1] Department of Physical Education Teaching, Faculty of Sports Sciences, Sivas Cumhuriyet University, Sivas, Turkey
[2] Aspetar, Orthopaedic and Sports Medicine Hospital, FIFA Medical Centre of Excellence, Doha, Qatar
[3] ISSEP Ksar-Said, La Manouba University, Tunisia
[4] FIFA Medical Excellence Centre, Santy Orthopedicae Clinical, Sport Science and Research Department, Lyon, France
[5] Department of Coaching Education, Faculty of Sports Sciences, Ankara University, Ankara, Turkey
[6] Department of Coaching Education, Collage of Physical Education and Sports, Ahi Evran University, Kırşehir, Turkey
[7] Department of Coaching Education, Faculty of Sports Sciences, Dokuz Eylül University, İzmir, Turkey

Corresponding author:
Gürkan Diker
Department of Physical Education Teaching, Faculty of Sports Sciences, Sivas Cumhuriyet University, Sivas, Turkey
Tel: +90 505 340 35 26
E-mail: gdiker@cumhuriyet.edu.tr

ORCID:
Gürkan Diker
0000-0003-0407-8238

Abdulkerim Darendeli
0000-0002-4581-5567

Karim Chamari
0000-0001-9178-7678

Alexandre Dellal
0000-0002-1831-7626

Sürhat Müniroğlu
0000-0003-1250-5420

Sadi Ön
0000-0002-8047-9861

Hüseyin Özkamçı
0000-0003-3372-2299

ABSTRACT: The objective of the present study was to investigate the selected performance adaptations of amateur soccer players to 2 different running-based sprint interval training (SIT) protocols with different recovery intervals and work-rest ratios (1:5 & 1:1). Twenty-three subjects (age 21.4 ± 1.1 years; height 175.4 ± 4.7 cm; body mass 69 ± 6.4 kg) participated in the study. Before the 6-weeks training period, participants completed 3-weeks of low-intensity training preparation. Subsequently, the pre-tests (anthropometric measurements, repeated sprint test [12×20-m with 30-s recovery intervals], Yo-Yo$_{IRT1}$ & Yo-Yo$_{IRT2}$ and treadmill VO$_{2max}$ test) were conducted. Thereafter, participants were randomly divided into 3 sub-groups (1 – SIT with 150 s recovery intervals [SIT150, n = 8]; 2 – SIT with 30 s recovery intervals [SIT30, n = 7]; and 3 – control group [CG, n = 8]). SIT150 and SIT30 training groups completed sprint interval training (2-days/week; 30-s all-out running, 6–10 repetition with 150 s recovery intervals for SIT150 and 30 s for SIT30 groups, respectively), a soccer match (1-day) and routine soccer training (3-days) per week. The CG attended only routine training sessions and the soccer-match (4-days). The study experiments and the trainings were conducted during off-season. Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$, and VO$_{2max}$ were significantly improved both in SIT30 and SIT150 ($p < 0.05$) groups. Yo-Yo$_{IRT1}$ and VO$_{2max}$ were also significantly improved in CG ($p < 0.05$). Both the SIT150 and SIT30 training were shown to improve Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and VO$_{2max}$ performance compared to the control group, nevertheless, SIT150 was more efficient in improving the Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ than SIT30. The authors of this study suggest using SIT150 to induce more effective performance outputs in amateur soccer players.

INTRODUCTION

It is known that short-lasting maximal and near-maximal efforts with varying recovery intervals represent essential characteristics of the physical activity within soccer games [1, 2]. Soccer players perform between 10496 m (central defender) and 11779 m (axial mid-fielder) including 193.6 m – 278.2 m runs > 24.1 km·h^{-1} [3]. 243–364 changes of directions $< 90°$ and 1000–1400 actions including 220 at high intensity (HI) [4]. Consequently, it is imperative to have sufficient physical capacity for soccer players to be able to cope with fatigue through the intense periods of the game where the anaerobic mechanisms prevail, especially very high intensity (VHI) activities [5, 6, 7, 8]. The need to produce HI and VHI activities all across soccer game encourages coaches and sports

scientists to utilize different training methods based on HI efforts. To increase the capacity of the players to produce repeated HI and VHI activities, short-lasting high-intensity exercises such as sprint interval training (SIT) can be used in training.

SIT generally utilize three to seven 10–30 s all-out sprint bouts with various recovery periods in between [9, 10, 11]. Soccer players spend more time in HI exercise domain during SIT [9]. which is one of the most effective means to improve running performance. However, its effectiveness depends on recovery, positional roles and individual differences among soccer players. Lloyd Jones et al., [12] compared two SIT protocols with matched work-rest ratio and total sprint duration (the first group: 6 s all-out effort, 20 reps with

48 s rest; and the second group: 30 s all-out effort, 4 reps with 4 min rest; for two weeks) and investigated their adaptations on VO$_{2max}$ performance. Authors reported that both 6 and 30 s all-out SIT training elicited similar changes in performance. Another study, comparing two 10 s (with 2 and 4 recovery intervals min) and a 30 s SIT exercises, showed that all three of the SIT protocols increased oxidative and anaerobic performance [13].

Thomassen et al. [14] compared two groups of SIT. They reported that group-1 (6–8 reps of 20-s all-out running, with 120-s of passive recovery in-between) and group-2 (same efforts, with 40-s of passive recovery intervals) training improved Yo-Yo$_{IRT2}$ (intermittent recovery test) performance by 10% and 4% respectively. Similar studies also support that high-intensity interval training enhances aerobic and anaerobic performances [15, 16, 17, 18]. Considering various training options, this topic needs further investigations. Indeed, the changes in duration, intensity, number of sets and recovery intervals of training provide different metabolic, cardiovascular and neuromuscular improvements [16, 17, 18, 19]. Furthermore, there is a lack of information about how amateur soccer players adapt to widely used SIT protocols with different work-rest ratio. Therefore, the aim of the present study was to investigate the selected performance adaptations of amateur soccer players to 2 different running-based SIT protocols with different recovery intervals and work-rest ratios (1:5 & 1:1). We hypothesized that SIT150 protocol would improve Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and VO$_{2max}$ relatively better compared to SIT30.

MATERIALS AND METHODS

Subjects

A total sample size of 21 was required to detect an effect size of 0.4 with α = 0.05 and 80% power. Initially, twenty-four male soccer players competing in an amateur soccer team with at least 5-year active soccer exercise background volunteered in this study. The participants were randomly subdivided into 3 sub-groups (1 – SIT150: n = 8, 30-s all-out running, 6–10 repetition with 150 s recovery intervals; 2 – SIT30: n = 7, 30-s all-out running, 6–10 repetition with 30 s recovery intervals; and 3 – CG: n = 8, control group). During the training 1 participant (from SIT30 group) was injured and consequently excluded from the study, leaving a total of 23 participants (SIT150: mean ± SD; age 21.1 ± 1.3 years, height 176.6 ± 4.7 cm, body mass 71 ± 5.9 kg; SIT30: age 21.4 ± 1.1 years, height 177 ± 5.4 cm, body mass 69.4 ± 7.3 kg; CG: age 21.4 ± 1.1 years, height 173 ± 3.5 cm, body mass 66.7 ± 6) (Table 1.). This study was approved by the Ankara University Faculty of Medicine Ethics Committee (ID: 01-13-17) before the data collection process and was conducted in accordance with the standards of ethics. Prior to signing informed consent form, all subjects were informed about the aim, methodology, possible risks, and benefits of the investigation.

Experimental Approach

Pre- and post-training tests including anthropometric evaluations, treadmill VO$_{2max}$ test, Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and repeated sprint ability (RSA) tests were performed to examine the performance adaptations
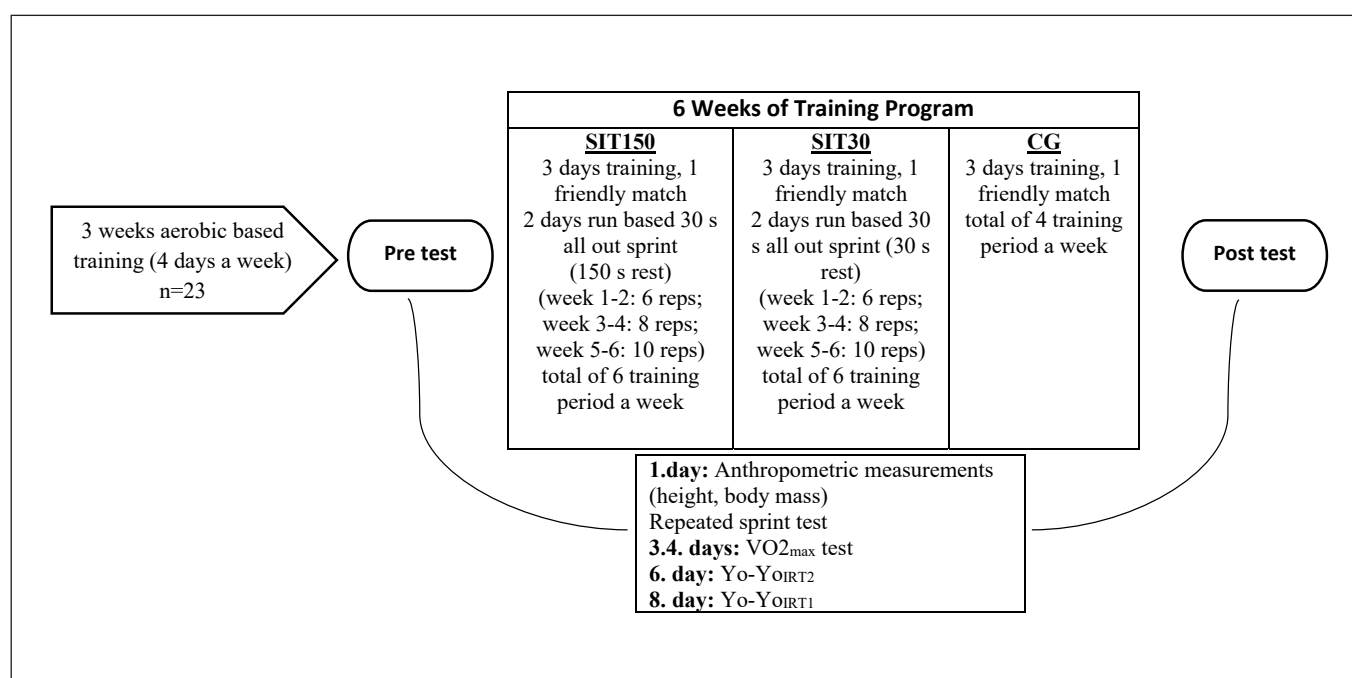

FIG. 1. Depiction of the study design.

induced by 2 different speed endurance training (Figure 1). Pre-training tests took place 3 weeks after the end of the amateur league finale (pre-season, from April to June 2017). The study orientation, training and testing sessions spanned 12 weeks. During the first 3 weeks (4 days a week), low-intensity exercises were completed for orientation. Before and after the 6 weeks of speed interval training, pre- and post-training tests were performed (in a total of 3 weeks). Temperature, humidity and the altitude of the testing and the training environment were ~18–21℃, % 45–60 and 1285 m respectively.

Training Protocols
In addition to their routine training (on Monday, Wednesday, Friday) participants from the SIT150 and SIT30 training groups performed running-based 30 s all-out sprints under supervision 2 times per week (on Tuesday and Thursday) (week 1–2: 6 reps; week 3–4: 8 reps; week 5–6: 10 reps). All participants also played a 90-min soccer match among themselves (on Saturday). Before every test and training session, a standard warm-up (5-min jogging, 3-min dynamic stretching [20] and 7-min specific drills) was instructed and supervised by the coach. The recovery intervals between the two bouts for SIT150 and SIT30 training groups were 150 and 30 s respectively. The CG attended solely routine soccer training sessions and 90-min soccer matches. Routine soccer training consisted of low to moderate intensity running based drills with and without a ball (on Monday), small sided games (3×3, 4×4, 5×5, 7×7) (on Wednesday), short-distance (5–10 m) maximal sprint, reaction and acceleration training (on Friday).

Yo-Yo$_{IRT1}$ and Yo-Yo$_{IRT2}$
All subjects were instructed to run between cones placed 20-m apart accordingly with the pre-recorded sound signal and the speed was increased as Bangsbo et al. [21] and Krustrup et al. (2006) stated. After every 40-m run, subjects had 10-s rest in 5-m-long area. The tests were completed when the subject missed two consecutive cones [22]. Although they have the same test settings, the initial running speeds for Yo-Yo$_{IRT1}$ and Yo-Yo$_{IRT2}$ were 10 and 13 $km \cdot h^{-1}$ respectively.

Graded Treadmill Test
The subjects were instructed to complete a continuous incremental run on treadmill to determine their VO$_{2max}$. The initial speed of the test was 9 $km \cdot h^{-1}$ and was increased 1 $km \cdot h^{-1}$ every minute until reaching the final speed the treadmill allows (16 $km \cdot h^{-1}$). After that, the treadmill grade was increased by 1% every minute until volitional exhaustion. The protocols where treadmill grade was increased by 1% has been shown to provide a valid VO$_{2max}$ measurement [23, 24]. Throughout the tests, expired gas was recorded using Masterscreen metabolic cart (Viasys Healthcare, Jaeger, Würzburg, Germany). The gas analyzers were calibrated as instructed by the manufacturer, with a certified gas mixture of known concentrations. It was considered VO$_{2max}$ if at least two of the following criteria met:

the presence of VO$_2$ plateau, a respiratory exchange ratio greater than 1.1, and a peak heart rate (HR) greater than 90% of age-predicted maximum (220-age) [25].

Repeated Sprint Test
Subjects completed twelve 20-m sprints with a 30-s recovery in-between on a grass field [26]. Newtest (Powertimer 300-series, Finland) telemetric system was used and photocells were placed at 0- and 20-m. Following each sprint, the subjects walked back to the starting line. After the test, the best sprint time (RST$_{best}$), total sprint time (RST$_{total}$; total sprinting time of 12 attempts) and percentage decrement of repeated sprinting times (RST$_{dec}$) were calculated as Glaister et al. [27] suggested.

$$Percentage\ of\ performance\ decrement$$
$$= (\frac{s1 + s2 + \ldots + sn}{BST \times n} - 1) \times 100$$

where RST$_{best}$ was the best sprint time; s was a given sprint performance (in second), n was the number of the final sprint (in this case 12).

Statistical Analysis
The study results and descriptive data were reported as mean ± SD. Normality of data was analyzed using Shapiro-Wilk test. Two-way repeated measures ANOVA was used with one within factor (time: pre vs. post) and one between factor (group: SIT150 vs. SIT30 vs. CG). The partial eta squared value (η_p^2) was calculated to indicate effect sizes, which can be interpreted as a proportion of variance. Comparing pre- and post-training test results, Paired samples t test (if data was normally distributed) and Wilcoxon test (if data was not normally distributed) were used. Cohen's d effect sizes were also calculated and the outputs were described as follows: < 0.20 (trivial), 0.20–0.59 (small), 0.6–1.19 (moderate), 1.2–1.99 (large); ≥ 2.0 (very large) [30]. Intraclass correlation coefficient (ICC) with 2-way random model [28] was used to test the consistency of pre & post measurements [29]. Based on 95% confidence interval of the ICC estimate, the values were classified as follows: < 0.5 (poor), 0.5–0.75 (moderate), 0.75–0.9 (good), > 0.90 (excellent). The significance level was set at 0.05 for all tests.

TABLE 1. Subject characteristics.

	SIT150	S30	CG
Age (years)	21.1 ± 1.3	21.2 ± 0.9	22.1 ± 1.2
Height (cm)	176.6 ± 4.7	177.0 ± 5.4	173.0 ± 3.5
Body Mass (kg)	71.0 ± 5.9	69.4 ± 7.3	66.7 ± 6.1

RESULTS

Inter- and intra- group performances are shown in Table 2 for RSA (RST$_{best}$, RST$_{total}$ and RST$_{dec}$), Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and VO$_{2max}$.

The two-way repeated measures ANOVA results revealed that there was a significant main effect of time (pre- post) for Yo-Yo$_{IRT1}$ (p = 0.001, η_p^2 = 0.88), Yo-Yo$_{IRT2}$ (p = 0.01, η_p^2 = 0.70) and VO$_{2max}$ (p = 0.001, η_p^2 = 0.84); and no significant main effect of time or group (S150, SIT30, CG) for RST$_{best}$, RST$_{total}$ and RST$_{dec}$ (p > 0.05). There was no time*group interaction effect for any variable (Figure 2).

Intra-group comparisons indicated significant differences. A significant performance decrement in RST$_{best}$ (3.5%, p = 0.029, Cohen's d = 0.17) and RST$_{total}$ (2.5%, p = 0.038, Cohen's d = 0.74) was present in the SIT30 training group, whereas no significant difference in RST$_{dec}$ was found (p > 0.05). In the SIT150 training group, RST$_{best}$ did not significantly change (p > 0.05), similarly, no statistically significant change was present in RST$_{total}$ (0.5%) and RST$_{dec}$ (13.9%), nonetheless, there were relative improvements. Although there was no significant difference in RST$_{best}$, RST$_{total}$ and RST$_{dec}$, performance improvement in CG was seen in RST$_{dec}$ (24.3%, p > 0.05).

A greater improvement was seen in Yo-Yo$_{IRT1}$ performance in SIT150 group (43%, p = 0.001, Cohen's d = 1.48) compared to SIT30 (23%, p = 0.002, Cohen's d = 0.76) and CG (20%, p = 0.013, Cohen's d = 0.57).

There was a significant improvement in Yo-Yo$_{IRT2}$ performance in SIT30 (26.2%, p = 0.018, Cohen's d = 1.28) and even a greater improvement in SIT150 (32.8%, p = 0.008, Cohen's d = 1.25) training group.

VO$_{2max}$ (ml·kg^{-1}·min^{-1}) significantly changed in all groups (SIT150 [18%, p = 0.010, Cohen's d = 1.56], SIT30 [19.1%, p = 0.001, Cohen's d = 1.97], and CG [13.4%, p = 0.002, Cohen's d = 0.75]).

ICC for pre- and post- tests was as follows: SIT30 VO$_{2max}$ (.802, p = 0.035), Yo-Yo$_{IRT1}$ (.958, p = 0.001), Yo-Yo$_{IRT2}$ (.890, p = 0.008), RST$_{best}$ (.857, p = 0.016), RST$_{total}$ (.890, p = 0.008), and RST$_{dec}$ (.403, p = 0.273); SIT150 VO$_{2max}$ (.334, p = 0.303), Yo-Yo$_{IRT1}$
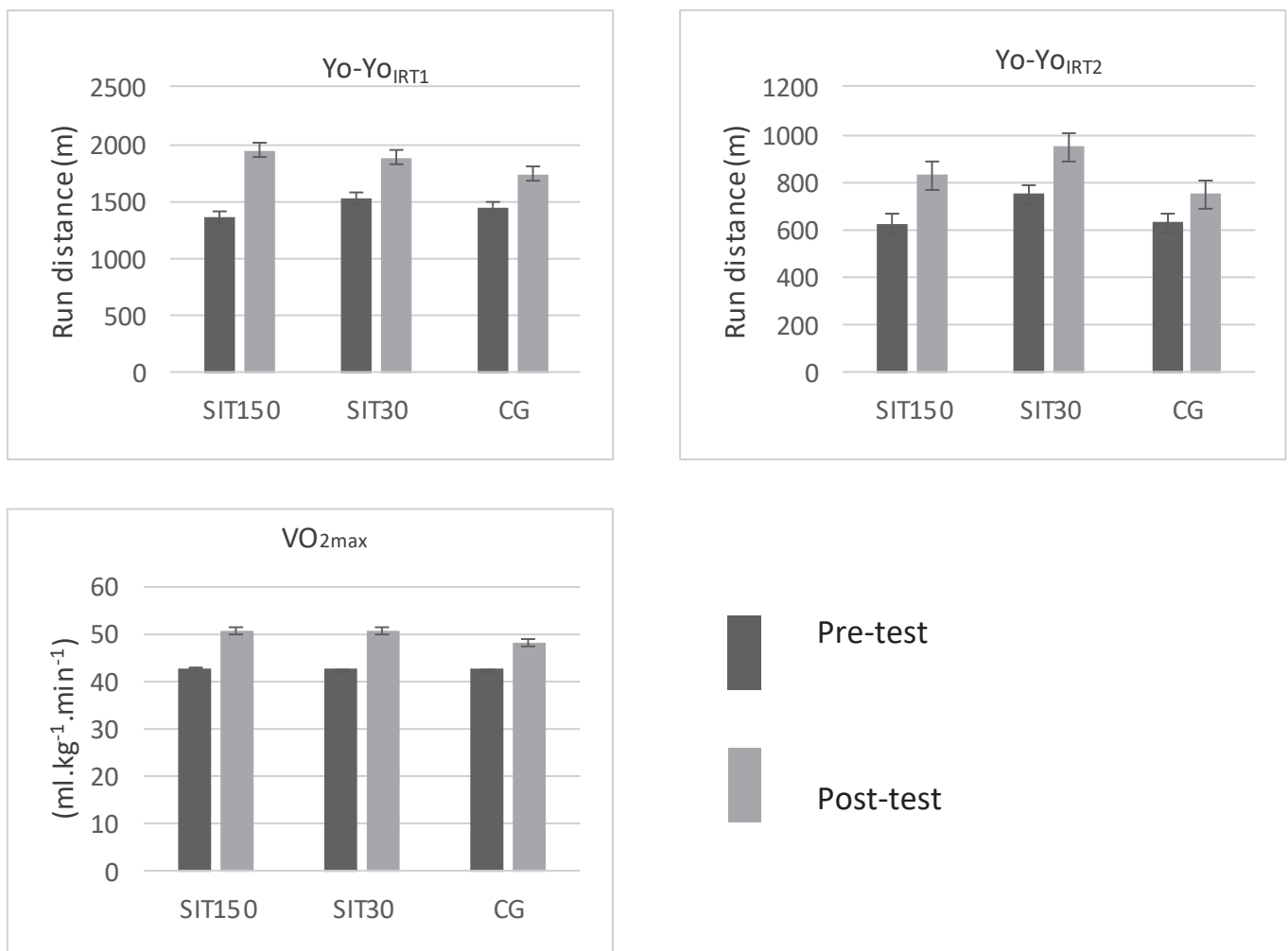

FIG. 2. Baseline and post training Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and VO$_{2max}$ performance level of SIT150, SIT30 and CG.

TABLE 2. Pre- and post-training performance, percentage change and effect size for the sub-groups

	SIT150 n = 8				SIT30 n = 7				CG n = 8			
	Pre	Post	d	%Ch	Pre	Post	d	%Ch	Pre	Post	d	%Ch
RST_{best} (s)	2.8 ± 0.1	2.8 ± 0.1	0	0	2.8 ± 0.1	2.9 ± 0.8*	0.17 trivial	↑3.5	2.9 ± 0.1	2.9 ± 0.1	0	0
RST_{total} (s)	35.8 ± 7.1	35.6 ± 11.9	0.02 trivial	↓0.5	35.5 ± 1.7	36.4 ± 1.1*	0.74 moderate	↑2.5	36.6 ± 1.6	36.4 ± 1.8	0.11 trivial	↓0.5
RST_{dec} (s)	4.3 ± 2.2	3.7 ± 1.9	0.29 small	↓13.9	3.6 ± 2.4	3.7 ± 1.2*	0.05 trivial	↑3.7	5.1 ± 2.3	4.1 ± 2.2	0.44 small	↓24.3
$Yo-Yo_{IRT1}$ (m)	1360 ± 389.5	1945 ± 397*	1.48 large	↑43	1531 ± 411	1885 ± 512*	0.76 moderate	↑23.1	1445 ± 493	1735 ± 524*	0.57 small	↑20
$Yo-Yo_{IRT2}$ (m)	625 ± 135.1	830 ± 187.3*	1.25 large	↑32.8	751 ± 165	948 ± 141*	1.28 large	↑26.2	630 ± 262	750 ± 247	0.47 Small	↑19
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	42.7 ± 5.3	50.4 ± 4.5*	1.56 large	↑18	42.4 ± 3.4	50.5 ± 4.7*	1.97 large	↑19.1	42.4 ± 8.3	48.1 ± 6.8*	0.75 moderate	↑13.4

Data presented as mean ± SD. RST_{best}: best sprint time; RST_{total}: total sprint time; RST_{dec}: the percentage of performance decrement; $Yo-Yo_{IRT1}$: Intermittent Recovery Test level 1; $Yo-Yo_{IRT2}$: Intermittent Recovery Test level 2; VO_{2max}: maximal oxygen uptake; (d): Cohen's d effect size; %Ch: percentage change. * Significant difference between pre- and post-training

(.822, p = 0.018), $Yo-Yo_{IRT2}$ (.696, p = 0.070), RST_{best} (.0, p = 0.926), RST_{total} (.0, p = 0.648), and RST_{dec} (.131, p = 0.429); CG VO_{2max} (.948, p = 0.001), $Yo-Yo_{IRT1}$ (.936, p = 0.001), $Yo-Yo_{IRT2}$ (.522, p = 0.176), RST_{best} (.941, p = 0.001), RST_{total} (.796, p = 0.026), and RST_{dec} (.736, p = 0.05) (Table 3).

DISCUSSION

In this study, the performance adaptations of soccer players to 2 variations of 6 weeks running-based SIT protocols with different recovery intervals were investigated. The main findings of the study indicated that both SIT150 and SIT30 training methods improve $Yo-Yo_{IRT1}$, $Yo-Yo_{IRT2}$ and VO_{2max} performance. However, SIT150 training appeared to ensure greater performance improvements.

TABLE 3. Pre and post test conditions Intraclass Correlation Coefficients for VO_{2max}, $Yo-Yo_{IRT1}$, $Yo-Yo_{IRT2}$, RST_{best}, RST_{total}, and RST_{dec}.

	SIT30		SIT150		CG	
	ICC	p	ICC	p	ICC	p
VO_{2max}	.802	.035	.334	.303	.948	.001
$Yo-Yo_{IRT1}$	.958	.001	.822	.018	.936	.001
$Yo-Yo_{IRT2}$	.890	.008	.696	.070	.522	.176
RST_{best}	.857	.016	.0	.926	.941	.001
RST_{total}	.890	.008	.0	.648	.796	.026
RST_{dec}	.403	.273	.131	.429	.736	.05

The structure of $Yo-Yo_{IRT1}$ is known to fit the soccer game profile [31]. Previous research showed that HI training enhances $Yo-Yo_{IRT1}$ performance [14, 32, 33, 34]. Nyberg et al., [32] investigated the effects of 9 weeks HIIT interval training (30 m all-out runs, 8–10 reps with 10 s rest in between; 3 sets with 3 minutes recovery intervals) in 13 semi-professional male soccer players during league season and reported that after the training period $Yo-Yo_{IRT1}$ performance was improved by 11.6%. Hill-Hass et al. [33]. showed that 7 weeks of speed endurance training enhanced $Yo-Yo_{IRT1}$ performance by 22.1% whereas Thomassen et al. [14] reported a 6.1% improvement in $Yo-Yo_{IRT1}$ performance after 4 weeks of training (10–12 reps. × 30-s all-out running, 3 days a week). Our results were similar to the findings of previous investigations ($Yo-Yo_{IRT1}$ improved by 43% in SIT150 and 23% in SIT30). The SIT30 training has shorter recovery intervals compared to the SIT150 training method, causing the SIT30 method to rely more on the anaerobic pathways for exercise metabolism. As supported by the previous research and the findings of this study, SIT150 training may be considered as a convenient method to enhance oxidative systems during a soccer match. High intensity interval training (HIIT) with relatively longer recovery bouts seemed to stimulate intra-muscle adaptations and produce a better quality training period compared to same training with shorter recovery intervals. Consequently, this method can be used in soccer players to enhance their capacity to perform high-intensity exercises.

In a study conducted by Mohr & Krustrup [15] on 18 sub-elite soccer players, 4 weeks of HIIT induced improvements in $Yo-Yo_{IRT2}$ performance of training group-1 (W:R; 1:1) (26%), and even greater improvements training group-2 (W:R; 1:5) (50%). Authors also

emphasized that having longer recovery periods after a high-intensity exercise, SIT150 training may have improved the fatigue resistance by stimulating a wide range of muscular system adaptations. In a similar study by Iaia et al. [35] 13 soccer players were trained for 3 weeks with 3 sessions per week. The observed performance improvements of Yo-Yo$_{IRT2}$ were greater in group-1 (6–8 reps × 20 s with 120 s recovery intervals) (10%, p < 0.001) compared to group-2 (6–8 reps × 20 s with 40 s recovery intervals) (4%, p < 0.049). Also, it was highlighted that Yo-Yo$_{IRT2}$ performance improvements were more likely to associate with the ability of the muscle to produce forceful bouts rather than enhancing exercise tolerance [36]. While, no studies were investigating the effects of HI training at short and long recovery intervals that were utilized in this study (*i.e.* 150-s & 30), our results were in line with the observations reported in the literature. Moreover, the present study showed that the SIT150 improved the capacity to perform high-intensity exercises (improvements in Yo-Yo$_{IRT2}$ performance by 32%). It should be noted that considering the Yo-Yo$_{IRT2}$ and soccer have a similar nature (*i.e.* HI running bouts, change of direction & intermittent nature), SIT150 training may provide great performance gains in soccer.

Both the total distance covered and the distance covered at HI runs are particularly important in soccer. It was shown that Yo-Yo$_{IRT1}$ results correlated with the total distance covered in a soccer match [36] whereas Yo-Yo$_{IRT2}$ performance correlated with distance covered at HI [37]. Consequently, both these tests reflect various aspects of fitness level [38].

SIT protocols with different recovery periods elicited similar increase in VO$_{2max}$ [11, 13]. Olek et al. [11] reported similar VO$_{2max}$ improvements after 2 weeks SIT period (3 sessions a week, 6 sessions in total) in two different SIT training groups (W:R; 10:60 s; 10:240 s). Similarly, Hazel et al. [13] showed that 2-weeks SIT protocols with different recovery intervals (10 s all-out run with either 120 s or 240 s rest) induced similar increase in VO$_{2max}$. The results of the present study showed similar VO$_{2max}$ improvements both in SIT150 and SIT30 training groups. As a result, to enhance VO$_{2max}$ in amateur soccer players, either one of these methods may be utilized. Common finding of these studies indicate that the change in the duration of the recovery period may not be the key variable to get better VO$_{2max}$ gains after VHI training sessions.

Mohr & Krustrup [15] reported that 4 weeks of HIIT improved the RST$_{best}$ (1.7%), RST$_{dec}$ (4.4%) and RST$_{total}$ (2.1%) in SIT group (30 s all-out running, 8–10 repetitions with a passive rest period of 150 s in between). Iaia et al. [35], investigating the effects of HIIT on RSA, reported that group-1 (20 s all-out running with a rest period of 120 s; 6–8 repetitions) had improvements (%2.5), while there were no changes in group-1 (20 s all-out running with a rest period of 40 s; 6–8 repetitions). Furthermore, Ingebrigtsen et al. [39] showed that RSA was not improved significantly after 6 weeks of HIIT in young elite soccer players. In our study, the RST$_{dec}$ (13.9%) and RST$_{total}$ (0.5%) were improved in SIT150 and were impaired in SIT30 training group.

A limitation of this study is the control group which did not match with the total volume of the training groups. Most studies did not use a control group making it difficult to understand the amplitude of the change induced by speed endurance training. Given that these investigations tested the effects of additional training combined with routine training, it was not clear what caused the changes in performance. Another limitation of the present study was that the graded treadmill test protocol was not used in the literature. The maximum speed that the treadmill could reach was 16 km·h^{-1}. To raise the intensity of the test we increased the treadmill grade by 1% every minute. Additionally, in this study design we did not control the workload, since the players were not used to any workload monitoring system; however, we have tried our best to ensure that both training interventions resulted in a consistent amount of sprints performed by the players of both groups. We are aware that the difference in recovery time in-between sprints would potentially result in a difference in overall sessions' training load, making this a weakness of the present study. Therefore, further studies with similar protocols should consider monitoring training load. Lastly, the population of the present study was limited to only 23 amateur soccer players.

CONCLUSIONS

This study was the first to investigate two SIT protocols with different work-rest ratios (1:5 & 1:1) in amateur soccer players. Both SIT protocols were effective in improving Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and VO$_{2max}$ performance. However, SIT150 training (30 s all-out sprints with 150 s recovery intervals; 6 to 10 reps; for 6 weeks) induced greater improvements likely due to having longer recovery intervals between repetitions, and can be used as a training method to improve Yo-Yo$_{IRT1}$, Yo-Yo$_{IRT2}$ and VO$_{2max}$ performance of amateur soccer players. Such a method may be particularly useful for amateur soccer players to improve a range of performance characteristics.

REFERENCES

1. Vitale JA, Povìa V, Vitale ND, et al. The effect of two different speed endurance training protocols on a multiple shuttle run performance in young elite male soccer players. Res Sports Med. 2018;26(4):436-449. doi: 10.1080/15438627.2018.1492402.

2. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. Sports Med. 2005;35(6):501-36. doi: 10.2165/00007256-200535060-00004.

3. Dellal A, Chamari K, Wong DP, Ahmaidi S, Keller D, Barros R, Bisciotti GN, Carling C. Comparison of physical and technical performance in European soccer match-play: FA Premier League and La Liga. Eur J Sport Sci. 2011;11(1):51-59. doi: 10.1080/17461391.2010.481334.

4. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different playing

positions in FA Premier League soccer. J Sports Sci Med. 2007;6(1):63- 70.

5. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci. 2003;21(7):519-528. doi: 10.1080/0264041031000071182.

6. Wisloff U, Helgerud J, Hoff J. Strength and endurance of elite soccer players. Med Sci Sports Exerc. 1998;30:462–7. doi: 10.1097/00005768-199803000-00019.

7. Chamari K, Padulo J. ‚Aerobic' and ‚Anaerobic' terms used in exercise physiology: a critical terminology reflection. Sports Med Open. 2015;1(1):9. doi: 10.1186/s40798-015-0012-1.

8. Darendeli A. Vitiello D. Billat V. Diker G. Cuğ M. Comparison of different exercise testing modalities to determine maximal aerobic speed in amateur soccer players. Sci Sports. 2021;36(2):105-111. doi: 10.1016/j.scispo.2020.09.006.

9. Sloth M, Sloth D, Overgaard K, & Dalgas U. Effects of sprint interval training on VO2max and aerobic exercise performance: A systematic review and meta-analysis. Scand J Med Sci Sports. 2013;23:e341–e352. doi: 10.1111/sms.12092.

10. Vollaard NBJ, Metcalfe RS, & Williams S. Effect of number of sprints in an SIT session on change in VO2max: a meta-analysis. Med Sci Sports Exerc. 2017;49:1147–1156. doi: 10.1249/MSS.0000000000001204.

11. Olek RA, Kujach S, Ziemann E, Ziolkowski W, Waz P and Laskowski R. Adaptive Changes After 2 Weeks of 10-s Sprint Interval Training With Various Recovery Times. Front Physiol. 2018;9:392. doi: 10.3389/fphys.2018.00392.

12. Lloyd Jones MC, Morris MG, Jakeman JR. Impact of time and work:rest ratio matched sprint interval training programmes on performance: a randomised controlled trial. J Sci Med Sport. 2017;20(11):1034-1038. doi: 10.1016/j.jsams.2017.03.020.

13. Hazell TJ, Macpherson RE, Gravelle BM, & Lemon PW. 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. Eur J Appl Physiol. 2010;110: 153–160. doi: 10.1007/s00421-010-1474-y.

14. Thomassen M, Christensen PM, Gunnarsson TP, Nybo L, Bangsbo J. Effect of 2-wk intensified training and inactivity on muscle Na+-K+ pump expression, phospholemman (FXYD1) phosphorylation, and performance in soccer players. J Appl Physiol. 2010;108(4):898-905. doi:10.1152/japplphysiol.01015.2009.

15. Mohr M, Krustrup P. Comparison between two types of anaerobic speed endurance training in competitive soccer players. J Hum Kinet. 2016;51:183-192. doi: 10.1515/hukin-2015-0181.

16. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. Sports Med. 2013;43(5):313-338. doi: 10.1007/s40279-013-0029-x.

17. Greig MP, McNaughton LR, Lovell RJ. Physiological and mechanical response to soccer-specific intermittent activity and steady-state activity. Res Sports Med. 2006;14(1):29-52. doi: 10.1080/15438620500528257.

18. Vitale JA, Povìa V, Belli E, Lombardi G, Banfi G, La Torre A. Are two different speed endurance training protocols able to affect the concentration of serum cortisol in response to a shuttle run test in soccer players?. Res Sports Med. 2020;28(2):293-301. doi: 10.1080/15438627.2019.1635131.

19. Vukadinović Jurišić M, Jakšić D, Trajković N, Rakonjac D, Peulić J, Obradović J. Effects of small-sided games and high-intensity interval training on physical performance in young female handball players. Biol Sport. 2021;38(3):359-366. doi:10.5114/biolsport.2021.100359.

20. Haddad M, Prince MS, Zarrouk N, Tabben M, Behm DG, Chamari K. Dynamic stretching alone can impair slower velocity isokinetic performance of young male handball players for at least 24 hours. PLoS One. 2019;25:14(1):e0210318. doi: 10.1371/journal.pone.0210318.

21. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. Sports Med. 2008;38(1):37-51. doi: 10.2165/00007256-200838010-00004.

22. Krustrup P, Mohr M, Nybo L, Jensen JM, Nielsen JJ, Bangsbo J. The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. Med Sci Sports Exerc. 2006;38(9):1666-1673. doi: 10.1249/01.mss.0000227538.20799.08.

23. Carter H, Jones AM, Doust JH. Effect of 6 weeks of endurance training on the lactate minimum speed. J Sports Sci. 1999;17(12):957-967.

24. Rampinini E, Sassi A, Morelli A, Mazzoni S, Fanchini M, Coutts AJ. Repeated-sprint ability in professional and amateur soccer players. Appl Physiol Nutr Metab. 2009;34(6):1048-54. doi: 10.1139/H09-111.

25. Chamari K, Moussa-Chamari I, Boussaïdi L, Hachana Y, Kaouech F, Wislöff U. Appropriate interpretation of aerobic capacity: allometric scaling in adult and young soccer players. Br J Sports Med. 2005;39(2):97-101. doi: 10.1136/bjsm.2003.010215.

26. Wadley G, Le Rossignol P. The relationship between repeated sprint ability and the aerobic and anaerobic energy systems. J Sci

Med Sport. 1998;1(2):100-110. doi: 10.1016/s1440-2440(98)80018-2.

27. Glaister M, Howatson G, Pattison JR, McInnes G. The reliability and validity of fatigue measures during multiple-sprint work: an issue revisited. J Strength Cond Res. 2008;22(5):1597-1601. doi: 10.1519/JSC.0b013e318181ab80.

28. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979;86(2):420-8. doi: 10.1037//0033-2909.86.2.420.

29. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res. 2005;19(1):231-40. doi: 10.1519/15184.1.

30. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sport Exerc. 2009;41(1):3–12. doi: 10.1249/MSS.0b013e31818cb278.

31. Ringgenberg M, Sager R, Rogan S. Endurance performance and stretch-shortening cycle in two male amateur soccer teams – a cross-sectional study. J Phys Educ Sport. 2017;17(1):194 – 197. doi:10.7752/jpes.2017.01029.

32. Nyberg M, Fiorenza M, Lund A, Christensen M, Rømer T, Piil P, Hostrup M, Christensen PM, Holbek S, Ravnholt T, Gunnarsson TP, Bangsbo J. Adaptations to Speed Endurance Training in Highly Trained Soccer Players. Med Sci Sports Exerc. 2016;48(7):1355-64. doi: 10.1249/MSS.0000000000000900.

33. Hill-Haas SV, Coutts AJ, Rowsell GJ, Dawson BT. Generic versus small-sided game training in soccer. Int J Sports Med. 2009;30(9):636-642. doi: 10.1055/s-0029-1220730.

34. Soylu Y, Arslan E, Sogut M, Kilit B, Clemente FM. Effects of self-paced high-intensity interval training and moderate intensity continuous training on the physical performance and psychophysiological responses in recreationally active young adults. Biol Sport. 2021;38(4):555-562. doi:10.5114/biolsport.2021.100359.

35. Iaia FM, Fiorenza M, Perri E, Alberti G, Millet GP, Bangsbo J. The effect of two speed endurance training regimes on performance of soccer players. PLoS One. 2015;10(9):e0138096. doi: 10.1371/journal.pone.0138096.

36. Krustrup P, Mohr M, Amstrup T, Rysgaard T, Johansen J, Steensberg A, Pedersen PK, Bangsbo J. The yo-yo intermittent recovery test: physiological response, reliability, and validity. Med Sci Sports Exerc. 2003;35(4):697-705. doi: 10.1249/01.MSS.0000058441.94520.32.

37. Bradley PS, Noakes TD. Match running performance fluctuations in elite soccer: indicative of fatigue, pacing or situational influences? J Sports Sci. 2013;31(15):1627-38. doi: 10.1080/02640414.2013.796062.

38. Rampinini E, Sassi A, Azzalin A, Castagna C, Menaspà P, Carlomagno D, Impellizzeri FM. Physiological determinants of Yo-Yo intermittent recovery tests in male soccer players. Eur J Appl Physiol. 2010;108(2):401-9. doi: 10.1007/s00421-009-1221-4.

39. Ingebrigtsen J, Bendiksen M, Randers MB, Castagna C, Krustrup P, Holtermann A. Yo-Yo IR2 testing of elite and sub-elite soccer players: performance, heart rate response and correlations to other interval tests. J Sports Sci. 2012;30(13):1337-45. doi: 10.1080/02640414.2012.711484.