ORIGINAL ARTICLE

Shorter sprints, greater gains? Effects of sprint duration on soccer physical performance

Enrico Perri . *Department of Biomedical Sciences for Health. University of Milan. Milan, Italy.*
David Bishop. *Institute for Health and Sport. Victoria University. Melbourne, Australia.*
Carlo Simonelli. *Department of Biotechnology and Life Sciences. University of Insubria. Varese, Italy.*
Athos Trecroci. *Department of Biomedical Sciences for Health. University of Milan. Milan, Italy.*
Francesco Zanasi. *Department of Biomedical Sciences for Health. University of Milan. Milan, Italy.*
Marco Savino. *Department of Human Sciences, Philosophy and Education. University of Salerno. Italy.*
Giampietro Alberti. *Department of Biomedical Sciences for Health. University of Milan. Milan, Italy.*
Marcello Fedon Iaia. *Department of Biomedical Sciences for Health. University of Milan. Milan, Italy.*

ABSTRACT

Purpose: To examine the effect of sprint bout duration during speed-endurance training on soccer-specific performance. Methods: Sixteen male soccer players (18.0 ± 0.8 y; 179.9 ± 4.8 cm; 71.4 ± 6.6 kg) completed two training protocols for 4 weeks, twice weekly: 10-s sprints (SEP10; n = 8) or 20-s sprints (SEP20; n = 8). SEP10 involved 8–12 × 10-s all-out runs with 60-s rest; SEP20 involved 4–6 × 20-s all-out runs with 120-s rest. Before and after training, players performed 20- and 200-m sprints, a repeated-sprint ability (RSA) test, and the Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2). Sprint time, blood lactate, and GPS data were collected during training sessions. Results: RSA total time decreased by 1.1% (SEP20) and 1.5% (SEP10; $p < .05$). Yo-Yo IR2 performance improved by 10% (SEP20) and 16% (SEP10; $p < .05$). Shorter sprint duration (10 vs. 20 s) elicited higher power output and lower blood lactate. Conclusion: Both 10- and 20-s sprint-based training improved high-intensity performance and RSA in soccer players, with 10-s sprints inducing more favourable physiological responses.

Keywords: Performance analysis, Speed-endurance training, Sprint duration, Soccer performance, Repeat sprint ability (RSA), Yo-Yo intermittent recovery test.

Cite this article as:
Perri, E., Bishop, D., Simonelli, C., Trecroci, A., Zanasi, F., Savino, M., Alberti, G., & Iaia, M. F. (2026). Shorter sprints, greater gains? Effects of sprint duration on soccer physical performance. *Journal of Human Sport and Exercise, 21*(2), 503-515. https://doi.org/10.55860/ryayq643

Corresponding author. *Department of Biomedical Sciences for Health. Università degli Studi di Milano. Milano, Italy.*
E-mail: enrico.perri@unimi.it
Submitted for publication September 30, 2025.
Accepted for publication November 04, 2026.
Published February 21, 2026.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/ryayq643

INTRODUCTION

In elite soccer, the increasing number of matches limits the time available for physical conditioning during the competitive season. Training is often prioritized toward recovery and technical–tactical preparation rather than physical development (Anderson et al., 2016; Malone et al., 2015; Martín-García et al., 2018; Simonelli et al., 2025; Trecroci et al., 2019). Under these constraints, selecting the most effective training stimuli is crucial to maximize physiological adaptations and performance outcomes.

Speed-endurance training using repeated sprints (5–30 s) has emerged as a time-efficient strategy to enhance supramaximal performance (Bangsbo et al., 2009; Gibala et al., 2006; Iaia & Bangsbo, 2010; Iaia et al., 2009), repeated-sprint ability (RSA) (Iaia et al., 2015; Mohr & Krustrup, 2016), and high-intensity intermittent exercise in well-trained athletes (Iaia et al., 2008), even with reduced overall training volume (Bangsbo et al., 2009; Gunnarsson et al., 2012; Iaia & Bangsbo, 2010; Iaia et al., 2009). However, the wide range of possible training variables (e.g., intensity, recovery, exercise type, and work-to-rest ratio) can elicit distinct physiological responses. For example, speed-endurance production (SEP) training, characterized by ~20-s all-out sprints with long recoveries, has been shown to improve RSA and intermittent high-intensity performance (Castagna et al., 2017; Iaia et al., 2015; Mohr & Krustrup, 2016). Moreover, the efficacy of this training modality is possibly ascribed to the maintenance of high mechanical power (Iaia et al., 2015), and adaptations in glycolytic (MacDougall et al., 1998) and oxidative enzymes activity (Burgomaster et al., 2006; Burgomaster et al., 2005; Granata et al., 2017) as well as in pH regulation (Iaia et al., 2008) and ion transport (Bangsbo et al., 2009; Iaia et al., 2008).

While there is consensus that longer recovery intervals enhance soccer-related performance (Castagna et al., 2017; Iaia et al., 2015; Mohr & Krustrup, 2016), the effect of sprint duration remains less clear. Evidence indicates that both short (≤10 s) (Iaia et al., 2017) and longer (≥20 s) (Iaia et al., 2015) sprint bouts can improve performance, albeit through different metabolic pathways (Buchheit & Laursen, 2013a). Longer sprints increase anaerobic energy production and cardiopulmonary responses (Fiorenza et al., 2019), whereas shorter sprints elicit higher power output, reduced lactate accumulation, and less peripheral fatigue, potentially allowing faster recovery (Buchheit & Laursen, 2013a). Furthermore, short sprints have been associated with greater improvements in sprint times over 20–40 m (Iaia et al., 2017; Iaia et al., 2015; Mohr et al., 2007a).

Despite these observations, direct comparisons between short and long sprint durations in soccer players are lacking. Most studies have focused on aerobic outcomes (e.g., $\dot{V}O_{2max}$, endurance performance), with inconsistent results. Some report superior adaptations with longer sprints, while others show that reducing sprint duration to 10–20 s yields comparable improvements in both aerobic and anaerobic markers (Gillen et al., 2016; Gillen et al., 2014; Hazell et al., 2010; McKie et al., 2018; Nalcakan et al., 2018; Yamagishi & Babraj, 2017; Zelt et al., 2014).

Therefore, the present study aimed to (i) compare the physiological and mechanical responses to sprint training with different bout durations (10 vs. 20 s), and (ii) examine the subsequent effects on soccer-specific performance. Based on previous evidence (Iaia et al., 2017; Iaia et al., 2015; Mohr et al., 2007b), we hypothesized that shorter bouts (10 s) would improve repeated-sprint performance, whereas longer bouts (20 s) would provide a stronger stimulus for exhaustive high-intensity performance.

METHODS

Participants

Sixteen young male soccer players from the same amateur team (age: 18.0 ± 0.8 y; height: 179.9 ± 4.8 cm; body mass: 71.4 ± 6.6 kg) were recruited. All participants had a minimum of 7 years of soccer training experience. Participants and their parents provided written informed consent after being fully briefed on potential risks and discomfort associated with the experimental procedures. The study was approved by the Ethical Committee of the University of Milan and conducted in accordance with the Declaration of Helsinki.

Experimental approach

A parallel, pre-to-post, two-group, work-matched longitudinal design was employed to examine the effects of two speed-endurance training protocols. Participants were matched based on baseline physical performance and randomly assigned to either the 20-s sprint protocol (SEP20; n = 8) or the 10-s sprint protocol (SEP10; n = 8). Randomization was based on performance scores derived from all baseline tests, with each participant assigned a score from 1 (lowest) to 16 (highest) for each test; the sum determined group allocation.

Data collection occurred during the final phase of the competitive season (April–May) and included a familiarization period, 1 week of baseline testing (Pre), a 4-week training intervention, and 1 week of post-testing (Post). Performance tests included: (i) aerobic fitness (Mognoni test), (ii) 20-m sprint, (iii) repeated-sprint ability (RSA) test, (iv) 200-m sprint, and (v) Yo-Yo Intermittent Recovery Test Level 2 (Yo-Yo IR2). During the 2nd and 8th training sessions, internal load was monitored via heart rate (HR), blood lactate ([La⁻]), and session rating of perceived exertion (sRPE), while external load was tracked using GPS technology.

Training protocols

SEP10 consisted of 6–12 repetitions of 10-s all-out bouts (2 × 30-m shuttle runs) interspersed with 60-s of passive recovery. SEP20 comprised 3–6 repetitions of 20-s all-out bouts (3 × 40-m shuttle runs) with 120-s of passive recovery. Both protocols were matched for total work and performed twice weekly over 4 weeks (Figure 1).

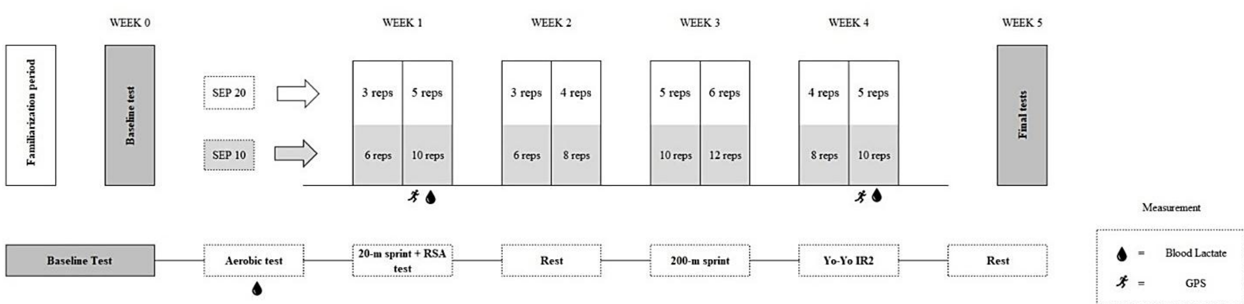


Figure 1. Overview of experimental days and training. Speed endurance production training 20 s of sprint (SEP 20), Speed endurance production training 10 s of sprint (SEP 10), Repeated sprint ability test (RSA), Yo-Yo intermittent recovery Test level 2 (Yo-Yo IR2), Repetitions (Reps).

Training monitoring

During the 2nd and final training sessions, blood samples were collected from the earlobe at specified points: before the 5th and after the 1st, 2nd, 3rd, and 5th bout in SEP20, and before the 10th and after the 1st, 4th, 6th, and 10th bout in SEP10. Lactate concentration ([La⁻]) was analysed using a portable lactate analyser (Lactate Plus, Nova Biomedical, Waltham, MA, USA). Sprint times were recorded via photoelectric cells (Witty, Microgate, Bolzano, Italy).

GPS collection and analysis

External load was tracked using GPS units (10 Hz, 400 Hz tri-axial accelerometer; Playertek, Dundalk, Ireland) positioned between the shoulder blades and activated 15 min before training. Players wore the same unit throughout the study to minimize inter-device error. Parameters analysed included high-intensity distance (>19.8 $km \cdot h^{-1}$), sprint distance (>25.1 $km \cdot h^{-1}$), top speed, and number of accelerations/decelerations >3 $m \cdot s^{-2}$. Energy cost (EC, $J \cdot kg^{-1} \cdot m^{-1}$) and average metabolic power (P Met aver $W \cdot kg^{-1}$) were calculated, with average Pmet and distance above 20 $W \cdot kg^{-1}$ also reported.

Performance assessment

Testing was conducted on four separate days both pre- and post-intervention: Monday (MD-6), Mognoni aerobic fitness test; Tuesday (MD-5), 20-m sprint and RSA test; Thursday (MD-3), 200-m sprint; Friday (MD-2), Yo-Yo IR2. A rest day was provided on Wednesday (MD-4) and Saturday (MD-1). Participants were familiarized with all procedures before testing and refrained from strenuous exercise, alcohol, and caffeine for 24 h prior. Nutritional intake (~60% carbohydrate) was recorded and replicated during all test days.

Aerobic fitness test (Mognoni)

Submaximal run at 13.5 $km \cdot h^{-1}$ for 6 min on natural turf. [La⁻] measured from earlobe immediately post-test (Sirtori, 1993).

20-m sprint test

Three maximal sprints with 150 s passive recovery between trials; best time used for analysis. Start from standing, 0.3 m before first gate (Iaia et al., 2015). Time was recorded using photoelectric cells (Witty, Microgate, Bolzano, Italy).

Repeated Sprint Ability (RSA) test

Following the 20-m sprint test (after 10 min of recovery) participants performed an RSA test consisting of 5 repetitions of 30-m all-out sprints interspersed by 25 s of passive recovery. Best sprint time (RSA_{best}) and total sprint time (RSA_t) for the five sprints (S_1, S_2, S_3, …) were determined. Also, to quantify fatigue during the RSA test, the percentage decrement score (RSA_{dec}) was calculated as follows (Girard et al., 2011):

$$RSAdec = \left[\frac{S_1 + S_2 + S_3 \cdots + S_{final}}{S_{best} \times number\ of\ sprints} - 1\right] \times 100 \quad (1)$$

200 m sprint test

An all-out run was performed over 200 m. Time recordings were obtained using photoelectric cells.

Yo-Yo IR2 test

The Yo-Yo Intermittent Recovery Test level-2 was performed. The test consists of 2 x 20-m shuttle runs at increasing speeds, interspersed with 10 s of active recovery, controlled by audio signals. The distance achieved was recorded when the participants were no longer able to maintain the required speed (Bangsbo et al., 2008).

Statistical analyses

The normal distribution of each variable was examined by the Shapiro-Wilk's test. An unpaired t-test was used to assess between-group differences in the Pre-test measurements. Data were analysed using a two-factor repeated-measure ANOVA with one between factor (group: SEP 20 vs. SEP 10) and one within factor (time: Pre-vs Post). In case of significant interaction, a Bonferroni post-hoc test was employed to evaluate each comparison. The level of statistical significance was set for all analyses at $p < .05$. Moreover, Pre-post effect size was measured as suggested by Hedge (Wasserman, 1988). In addition to null-hypothesis testing, a statistical approach based on the magnitudes of change was also utilized (Hopkins et al., 2009). The corresponding quantitative chances of beneficial, unclear of harmful changes were evaluated as follows: < 25% *trivial*, 25-75%, *possibly*; 75-95%, *likely*; 95-99%, *very likely*; and > 99%, *almost certainly*. If the chance of obtaining greater and poorer differences was both >5%, the true difference was assessed as *unclear*. To perform each calculation and interpretation related to the magnitude-based inference approach, customized spreadsheets, available at https://www.sportsci.org/index.html, were utilized. Data are presented as means ± SD, whereas relative changes are presented as means ±90% confidence intervals.

RESULTS

Performance

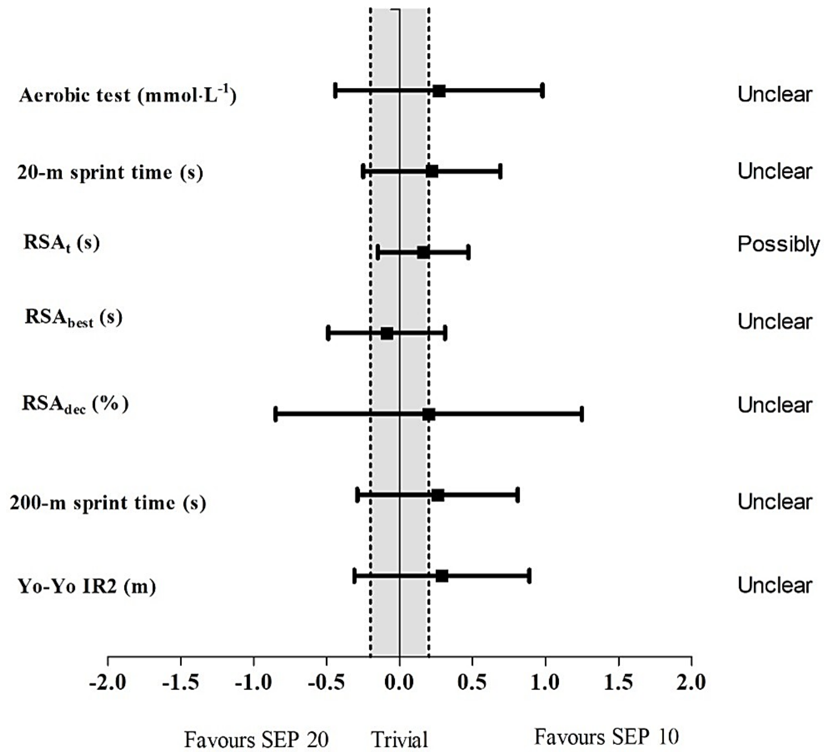
All performance measures showed no significant differences between groups at the pre-intervention stage ($p > .05$). Post-intervention, there were no significant changes in RSA_{dec}, 200-m sprint time, or blood lactate concentration at the end of the aerobic fitness test for either group ($p > .05$). The 20-m sprint time decreased by 0.8% and 1.8% following the training intervention, in SEP 20 and SEP 10, respectively (F = 6,00; $p < .05$). The RSA_t decreased by 1.1% and 1.5% following the training intervention, in SEP 20 and SEP 10, respectively (F = 18,37; $p < .05$). The RSA_{best} decrease by 1.2% and 1.5% following the training intervention, in SEP 10 and SEP 20, respectively ($p < .05$). The Yo-Yo IR2 performance improved by 10% and 16% in SEP 20 and SEP 10, respectively (F = 12.92; $p < .05$). No significant interaction was found after the intervention for all performance tests (Table 1).

Table 1. Changes in performance following speed endurance training consisting of different sprint durations.

	Performance test	Pre	Post	Effect Size Pre-Post	Within-group comparisons: Standardized differences (Cohen's d ±90% CI)	Percent changes of worse/trivial/better performance	Qualitative inferences
SEP 10	Aerobic Test (mmol·L^{-1})	7.4 ± 1.6	6.9 ± 1.8	0.11 Small	-0.34 ± 0.60	7/27/67	Unclear
	20-m sprint time (s)	3.11 ± 0.15	3.05 ± 0.12*	0.42 Small	-0.32 ± 0.32	1/25/74	Possibly
	RSA_{best} (s)	4.45 ± 0.19	4.40 ± 0.16*	0.27 Small	-0.24 ± 0.28	1/38/61	Possibly
	RSA_t (s)	23.2 ± 0.9	22.9 ± 0.8*	0.37 Small	-0.34 ± 0.23	0/14/86	Likely
	RSA_{dec} (%)	4.1 ± 1.6	4.2 ± 1.3	0.07 Trivial	0.12 ± 0.74	43/36/22	Unclear
	200-m sprint time (s)	28.0 ± 1,3	27.5 ± 1,2	0.30 Small	-0.28 ± 0.34	2/32/66	Possibly
	Yo-Yo IR2 (m)	370 ± 126	440 ± 111*	0.74 Moderate	0.51 ± 0.38	0/8/92	Likely
SEP 20	Aerobic Test (mmol·L^{-1})	8.5 ± 2.5	8.2 ± 1.7	0.28 Small	-0.03 ± 0.42	17/59/23	Unclear
	20-m sprint time (s)	3.13 ± 0.1	3.11 ± 0.11*	0.18 Trivial	-0.24 ± 0.25	1/39/60	Possibly
	RSA_{best} (s)	4.45 ± 0.16	4.39 ± 0.18*	0.33 Small	-0.36 ± 0.27	0/15/85	Likely
	RSA_t (s)	22.9 ± 0.8	22.7 ± 0.8*	0.35 Small	-0.23 ± 0.16	0/38/62	Possibly
	RSA_{dec} (%)	2.9 ± 0.7	3.3 ± 1.6	0.56 Moderate	0.53 ± 1.04	71/17/11	Unclear
	200-m sprint time (s)	28.0 ± 1.4	27.9 ± 1.0	0.08 Trivial	-0.05 ± 0.36	11/66/23	Unclear
	Yo-Yo IR2 (m)	410 ± 88	460 ± 90*	0.53 Moderate	0.49 ± 0.36	0/8/91	Likely

*Note. Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20); confidence interval (CI); Best sprint (RSA_{best}); Total sprint time (RSA_t); Percentage decrement score (RSA_{dec}); Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2). *Significant differences pre-post (p < .05).*

Between-group changes are presented in Figure 2. Changes in RSA_t were possibly better in SEP 10 than those observed in SEP 20.



Note. Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20); Best sprint (RSAbest); Total sprint time (RSAt); Percentage decrement score (RSAdec); Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2).

Figure 2. Standardize differences between SEP 10 and SEP 20.

External training load monitoring

During the 2nd training session, significant differences were found between SEP 10 and SEP 20 for Total Number of accelerations > 3 $m{\cdot}s^{-2}$ (20 ± 1 and 15 ± 1, respectively), Total Number of decelerations < -3 $m{\cdot}s^{-2}$ (18 ± 1 and 13 ± 1, respectively), and distance > 20 $W{\cdot}kg^{-1}$ (624 ± 13 m and 587 ± 13 m) ($p < .05$). No differences between groups were observed for Total time, Sprint Decrement, High-intensity distance, Sprint distance and Top speed, and P Met aver (Table 2).

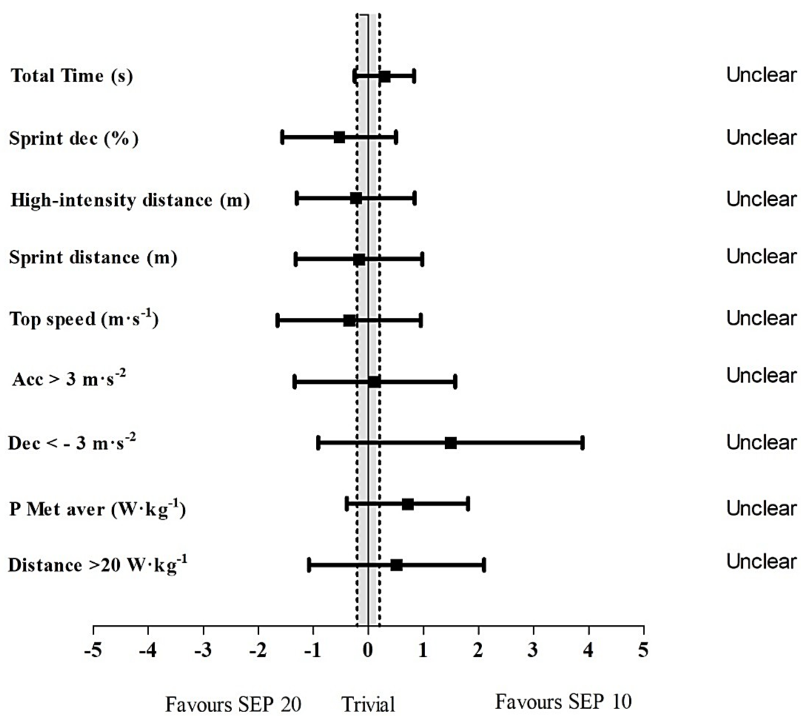
During the last training session, a time effect was detected for Total time, Number of decelerations < - 3 $m{\cdot}s^{-2}$ and Distance >20 $W{\cdot}kg^{-1}$. Total time improved by 0.9% and 1.9% in SEP 20 and SEP 10, respectively ($F = 16.01$; $p < .05$). Also, Total Number of decelerations < - 3 $m{\cdot}s^{-2}$ decreased by 7.7% in SEP 20 and by 16,6% in SEP 10 ($F = 6.53$; $p < .05$). Additionally, Distance >20 $W{\cdot}kg^{-1}$ decreased in SEP 20 by 1.5% and in SEP 10 by 2.7% ($F = 4.85$; $p < .05$).

Between-group changes are presented in Figure 3. Differences in the changes of all external load parameters were unclear.

Table 2. Training workload during the 2nd and the last training sessions for the different sprint endurance training groups.

	External training load	2nd session	Last session	Within-group comparisons: Standardized Differences (Cohen's d ±90% CI)	Percent changes of worse/trivial/better performance	Qualitative inferences
SEP 10	Total Time (s)	104.5 ± 4.0	102.6 ± 3.0*	-0.44 ± 0.23	0/4/96	Very Likely
	Sprint dec (%)	4.9 ± 3.0	4.7 ± 2.0	0.02 ± 0.72	29/39/32	Unclear
	High-intensity distance (m)	280 ± 59	284 ± 43	0.10 ± 0.81	25/33/42	Unclear
	Sprint distance (m)	212 ± 83	190 ± 65	-0.10 ± 0.81	41/34/25	Unclear
	Top speed ($m \cdot s^{-1}$)	7.8 ± 0.4	7.9 ± 0.4	0.02 ± 1.04	35/27/37	Unclear
	Acc > 3 $m \cdot s^{-2}$	20 ± 1#	20 ± 1	-0.48 ± 1.02	69/19/12	Unclear
	Dec < - 3 $m \cdot s^{-2}$	18 ± 1#	15 ± 2*	-2.08 ± 1.89	95/2/3	Likely
	P Met aver ($W \cdot kg^{-1}$)	8.1± 0.5	8.1 ± 0.5	-0.02 ± 0.87	36/32/32	Unclear
	Distance >20 $W \cdot kg^{-1}$	624 ± 13#	607 ± 16*	-1.25 ± 1.44	89/6/5	Likely
SEP 20	Total Time (s)	103.8 ± 2.2	102.9 ± 3.1*	-0.38 ± 0.68	7/24/69	Unclear
	Sprint Dec (%)	4.9± 2.0	4.0 ± 2.0	-0.66 ± 0.7	3/11/86	Likely
	High-intensity distance (m)	297 ± 40	293 ± 51	-0.12 ± 0.58	40/43/17	Unclear
	Sprint distance (m)	175 ± 58	167 ± 79	-0.39 ± 0.87	65/23/12	Unclear
	Top speed ($m \cdot s^{-1}$)	8.0 ± 0.4	7.9 ± 0.5	-0.34 ± 0.72	64/26/10	Unclear
	Acc > 3 $m \cdot s^{-2}$	15 ± 1#	15 ± 1	-0.24 ± 1.08	53/24/23	Unclear
	Dec < - 3 $m \cdot s^{-2}$	13 ± 1#	12 ± 2*	-0.91 ± 1.69	77/10/13	Unclear
	P Met aver ($W \cdot kg^{-1}$)	8.0± 0.4	8.3 ± 0.5	0.75 ± 0.54	0/4/95	Very Likely
	Distance >20 $W \cdot kg^{-1}$	587 ± 13#	578 ± 17*	-0.65 ± 0.95	80/13/7	Unclear

*Note. Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20); confidence interval (CI); Total time, percent of sprint decrement (Sprint Dec); High-intensity distance (distance between 19.8 and 25.1 $km \cdot h^{-1}$); Sprint distance (>25.1 $km \cdot h^{-1}$); Top speed ($m \cdot s^{-2}$); number of accelerations >3 $m \cdot s^{-2}$ (Acc > 3 $m \cdot s^{-2}$); number of decelerations < 3 $m \cdot s^{-2}$ (Dec. -3 $m \cdot s^{-2}$); metabolic power average (P Met aver, $W \cdot kg^{-1}$). *Significant differences pre-post ($p < .05$). # Significant differences between groups during the 2nd training session ($p < .05$).*

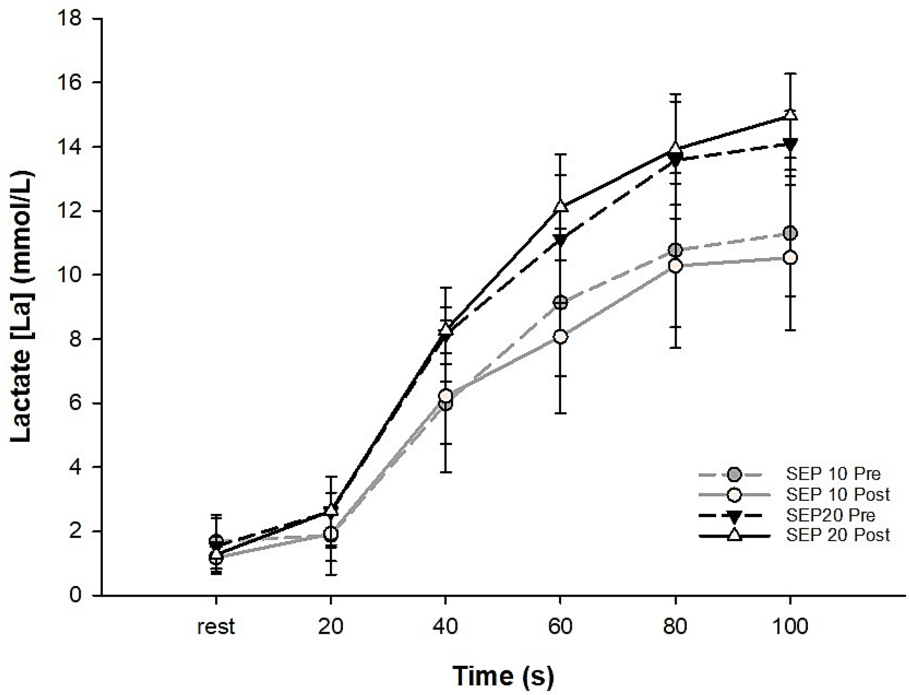


Note. Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20); Total time, percent of sprint decrement (Sprint Dec); High-intensity distance (distance between 19.8 and 25.1 $km \cdot h^{-1}$); Sprint distance (>25.1 $km \cdot h^{-1}$); Top speed ($m \cdot s^{-2}$); number of accelerations >3 $m \cdot s^{-2}$ (Acc > 3 $m \cdot s^{-2}$); number of decelerations < 3 $m \cdot s^{-2}$ (Dec . -3 $m \cdot s^{-2}$); metabolic power average (P Met aver, $W \cdot kg^{-1}$).

Figure 3. Standardize differences on external training load variables between SEP 10 and SEP 20.

Physiological responses

The assessment of blood lactate concentrations showed significant differences between-group ($p < .01$) (Figure 4). There were no time effects for changes in blood lactate concentration for either group from 2nd to last training. The blood lactate concentration increased during exercise in both groups: Rest<20-s<40-s<60-s<80-s = 100-s ($p < .05$).



Note. Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20).

Figure 4. The assessment of blood lactate concentrations during the 2nd and the last training sessions for the different sprint endurance training groups.

Heart rate

Heart rate measurements at the 2nd and last training session are shown in Table 3. Significant between-group differences were observed for $\%HR_{mean}$ and time spent over 85% of HR_{max} ($p < .05$) but not for $\%HR_{peak}$. There were also no pre-to-post differences the in any of the HR parameters ($\%HR_{mean}$, time spent over 85% of HR_{max}, and $\%HR_{peak}$).

Table 3. Heart rate parameters during the 2nd and the last training sessions for the different sprint endurance training groups.

Heart rate parameters	SEP 10		SEP 20		Interaction
	2nd session	Last session	2nd session	Last session	
%HRmean	87 ± 2#	86 ± 5	82 ± 4#	82 ± 5	*p* = .12
%HRpeak	96 ± 2	96 ± 3	96 ± 3	95 ± 3	*p* = .66
Time > 85% HRmax (s)	492 ± 94#	422 ± 188	276 ± 111#	293 ± 119	*p* = .06

Note. Speed endurance production for 10 s (SEP 10); Speed endurance production for 20 s (SEP 20); the percentage of heart rate means ($\%HR_{mean}$); the percentage of heart rate peak ($\%HR_{peak}$); time spent above 85% of heart rate max (Time > 85% HR_{max}).
 # Significant differences between groups in the 2-session measurements($p < .05$).

DISCUSSION AND CONCLUSIONS

The main findings of the present study indicate that both speed-endurance production (SEP) training regimes significantly improved 20-m sprint, RSA_t, RSA_{best}, and Yo-Yo IR2 performance. To our knowledge, this is among the first studies to report improvements in sprint performance following SEP training. Previous studies typically reported significant speed gains only for sprint bouts shorter than 6 s. For instance, Iaia et al. (2017) observed improved sprint performance after 4 weeks of repeated short sprints (6 × 5 s, 30-s recovery), while Mohr et al. (2007) found improvements after 6 × 6-s sprints with 54-s passive recovery, but no changes after 6 × 30-s sprints (Iaia et al., 2015; Mohr et al., 2007b). Interestingly, similar enhancements in sprint performance were observed in both SEP10 and SEP20 despite differences in physiological responses, including heart rate, blood lactate concentration, and acceleration/deceleration profiles. These effects may be attributable to the all-out nature of the protocols and the recruitment of young amateur players, who may be less accustomed to maximal sprint efforts. The high neuromuscular demands of the protocols (Fiorenza et al., 2019) likely contributed to the observed improvements, highlighting their practical relevance for young players, especially considering the association between high-intensity phases and key moments of a match (Faude et al., 2012).

Another important finding was the significant increase in RSA_t in both groups (1.5% in SEP 10 and 1.1% in SEP 20, $p < .05$). The *possibly* greater effect of SEP 10 on RSA_t suggests that improvements in repeated sprint performance may be primarily related to the muscle's capacity to sustain forceful bouts. This aligns with previous evidence indicating that elevated power output and maintenance of high speed throughout repeated sprints are critical for enhancing repeated-sprint ability (Bishop et al., 2004; Iaia et al., 2017; Iaia et al., 2015). Both interventions also improved Yo-Yo IR2 performance, suggesting that the specific characteristics of each protocol (i.e. high-speed development and fatigue resistance) contribute positively to high-intensity intermittent exercise capacity.

Aerobic capacity, assessed via the Mognoni test, remained unchanged throughout the training period. It has been suggested that inducing maximal cardiovascular and peripheral aerobic adaptations requires >10–15 min per session above 85% Hr_{max} (Buchheit & Laursen, 2013b). In our study, participants spent less than 8 min above this threshold, indicating that repeated all-out efforts with long recoveries (work-to-rest ratio 1:6) are insufficient to further enhance aerobic fitness in already trained individuals. This observation is consistent with prior studies, which reported that SEP training primarily induces peripheral adaptations (e.g., muscle architectural remodelling (Gunnarsson et al., 2012; Iaia et al., 2009), changes in membrane transport proteins regulating pH(Gunnarsson et al., 2012; Iaia et al., 2008), and preservation of excitability (Bangsbo et al., 2009; Gunnarsson et al., 2012; Iaia et al., 2008)) rather than improvements in $\dot{V}O_{2max}$ (Bangsbo et al., 2009; Gunnarsson et al., 2012; Iaia et al., 2009; Iaia et al., 2008).

Despite no change in aerobic fitness, high-intensity intermittent capacity, as measured by Yo-Yo IR2 distance, increased by 10% and 16% in SEP 20 and SEP 10, respectively. These improvements are consistent with studies demonstrating enhanced fatigue resistance following SEP training (Iaia et al., 2015), although the magnitude is smaller than reported in recreational players (Mohr & Krustrup, 2016), reinforcing SEP as an effective strategy for enhancing high-intensity intermittent performance in soccer players. The similar Yo-Yo IR2 improvements between groups suggest that maintaining high mechanical output throughout repeated sprints is a key factor for enhancing high-intensity intermittent performance.

Lower end-exercise blood lactate concentration in SEP 10 compared with SEP 20 indicates that longer repeated all-out efforts are strongly associated with glycolytic anaerobic energy production, consistent with previous research (Bogdanis et al., 1998; Mohr et al., 2007b). Surprisingly, there were no significant differences between groups for 200-m performance, although the differences observed in blood lactate concentration would suggest a different amount of anaerobic contribution between groups.

Some limitations of the present study should be acknowledged, including the short training duration (4 weeks), moderate sample size, participants' competitive level, and absence of a control group. Future studies should address these limitations, potentially incorporating longer interventions in elite youth players to corroborate these findings.

In conclusion, short-term SEP training improves aspects of high-intensity performance and repeated-sprint ability in soccer players. The high metabolic power and number of accelerations (>3 $m \cdot s^{-2}$), despite lower lactate accumulation, suggest that SEP 10 is particularly effective for enhancing soccer-related physical performance. The greater number of high-intensity accelerations and decelerations in SEP 10 compared with SEP 20 indicates potential benefits for improving change-of-direction ability, though this requires further investigation.

Practical applications

Understanding the characteristics of a training stimulus and its effects on performance enables coaches to optimize training delivery. Manipulating sprint duration can alter mechanical and physiological outputs, allowing for individualized training prescriptions based on player role and characteristics. The increased neuromuscular stimulus observed with SEP 10 indicates that short sprint bouts may induce positive adaptations in soccer-specific performance with lower neuromuscular strain at the end of exercise, making this approach particularly useful in short-term training periods (Fiorenza et al., 2019).

AUTHOR CONTRIBUTIONS

EP, DB and MA have given substantial contributions to the conception or the design of the manuscript. EP, AT, FZ and MS to acquisition, analysis and interpretation of the data. All authors have participated to drafting the manuscript, GA and DB revised it critically. All authors read and approved the final version of the manuscript.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Anderson, L., Orme, P., Di Michele, R., Close, G. L., Morgans, R., Drust, B., & Morton, J. P. (2016). Quantification of training load during one-, two- and three-game week schedules in professional soccer players from the English Premier League: implications for carbohydrate periodisation. J Sports Sci, 34(13), 1250-1259. https://doi.org/10.1080/02640414.2015.1106574

Bangsbo, J., Gunnarsson, T. P., Wendell, J., Nybo, L., & Thomassen, M. (2009). Reduced volume and increased training intensity elevate muscle Na+-K+ pump alpha2-subunit expression as well as short-and long-term work capacity in humans. J Appl Physiol (1985), 107(6), 1771-1780. https://doi.org/10.1152/japplphysiol.00358.2009

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

Bishop, D., Edge, J., & Goodman, C. (2004). Muscle buffer capacity and aerobic fitness are associated with repeated-sprint ability in women. European Journal of Applied Physiology, 92(4-5), 540-547. https://doi.org/10.1007/s00421-004-1150-1

Bogdanis, G. C., Nevill, M. E., Lakomy, H. K., & Boobis, L. H. (1998). Power output and muscle metabolism during and following recovery from 10 and 20 s of maximal sprint exercise in humans. Acta Physiol Scand, 163(3), 261-272. https://doi.org/10.1046/j.1365-201x.1998.00378.x

Buchheit, M., & Laursen, P. B. (2013a). High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. Sports Med, 43(10), 927-954. https://doi.org/10.1007/s40279-013-0066-5

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

Burgomaster, K. A., Heigenhauser, G. J., & Gibala, M. J. (2006). Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. J Appl Physiol (1985), 100(6), 2041-2047. https://doi.org/10.1152/japplphysiol.01220.2005

Burgomaster, K. A., Hughes, S. C., Heigenhauser, G. J., Bradwell, S. N., & Gibala, M. J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. J Appl Physiol (1985), 98(6), 1985-1990. https://doi.org/10.1152/japplphysiol.01095.2004

Castagna, C., Francini, L., Povoas, S. C. A., & D'Ottavio, S. (2017). Long-Sprint Abilities in Soccer: Ball Versus Running Drills. Int J Sports Physiol Perform, 12(9), 1256-1263. https://doi.org/10.1123/ijspp.2016-0565

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. J Sports Sci, 30(7), 625-631. https://doi.org/10.1080/02640414.2012.665940

Fiorenza, M., Hostrup, M., Gunnarsson, T. P., Shirai, Y., Schena, F., Iaia, F. M., & Bangsbo, J. (2019). Neuromuscular Fatigue and Metabolism during High-Intensity Intermittent Exercise. Med Sci Sports Exerc, 51(8), 1642-1652. https://doi.org/10.1249/MSS.0000000000001959

Gibala, M. J., Little, J. P., van Essen, M., Wilkin, G. P., Burgomaster, K. A., Safdar, A., Raha, S., & Tarnopolsky, M. A. (2006). Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. J Physiol, 575(Pt 3), 901-911. https://doi.org/10.1113/jphysiol.2006.112094

Gillen, J. B., Martin, B. J., MacInnis, M. J., Skelly, L. E., Tarnopolsky, M. A., & Gibala, M. J. (2016). Twelve Weeks of Sprint Interval Training Improves Indices of Cardiometabolic Health Similar to Traditional Endurance Training despite a Five-Fold Lower Exercise Volume and Time Commitment. Plos One, 11(4), e0154075. https://doi.org/10.1371/journal.pone.0154075

Gillen, J. B., Percival, M. E., Skelly, L. E., Martin, B. J., Tan, R. B., Tarnopolsky, M. A., & Gibala, M. J. (2014). Three Minutes of All-Out Intermittent Exercise per Week Increases Skeletal Muscle Oxidative Capacity and Improves Cardiometabolic Health. Plos One, 9(11), e111489. https://doi.org/10.1371/journal.pone.0111489

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-Sprint Ability - Part I Factors Contributing to Fatigue. Sports Medicine, 41(8), 673-694. https://doi.org/10.2165/11590550-000000000-00000

Granata, C., Oliveira, R. S., Little, J. P., Renner, K., & Bishop, D. J. (2017). Sprint-interval but not continuous exercise increases PGC-1alpha protein content and p53 phosphorylation in nuclear fractions of human skeletal muscle. Sci Rep, 7, 44227. https://doi.org/10.1038/srep44227

Gunnarsson, T. P., Christensen, P. M., Holse, K., Christiansen, D., & Bangsbo, J. (2012). Effect of additional speed endurance training on performance and muscle adaptations. Med Sci Sports Exerc, 44(10), 1942-1948. https://doi.org/10.1249/MSS.0b013e31825ca446

Hazell, T. J., Macpherson, R. E., Gravelle, B. M., & Lemon, P. W. (2010). 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. European Journal of Applied Physiology, 110(1), 153-160. https://doi.org/10.1007/s00421-010-1474-y

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc, 41(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Iaia, F. M., & Bangsbo, J. (2010). Speed endurance training is a powerful stimulus for physiological adaptations and performance improvements of athletes. Scand J Med Sci Sports, 20 Suppl 2, 11-23. https://doi.org/10.1111/j.1600-0838.2010.01193.x

Iaia, F. M., Fiorenza, M., Larghi, L., Alberti, G., Millet, G. P., & Girard, O. (2017). Short- or long-rest intervals during repeated-sprint training in soccer? Plos One, 12(2), e0171462. https://doi.org/10.1371/journal.pone.0171462

Iaia, F. M., Fiorenza, M., Perri, E., Alberti, G., Millet, G. P., & Bangsbo, J. (2015). The Effect of Two Speed Endurance Training Regimes on Performance of Soccer Players. Plos One, 10(9), e0138096. https://doi.org/10.1371/journal.pone.0138096

Iaia, F. M., Hellsten, Y., Nielsen, J. J., Fernstrom, M., Sahlin, K., & Bangsbo, J. (2009). Four weeks of speed endurance training reduces energy expenditure during exercise and maintains muscle oxidative capacity despite a reduction in training volume. J Appl Physiol (1985), 106(1), 73-80. https://doi.org/10.1152/japplphysiol.90676.2008

Iaia, F. M., Thomassen, M., Kolding, H., Gunnarsson, T., Wendell, J., Rostgaard, T., Nordsborg, N., Krustrup, P., Nybo, L., Hellsten, Y., & Bangsbo, J. (2008). Reduced volume but increased training intensity elevates muscle Na+-K+ pump alpha1-subunit and NHE1 expression as well as short-term work capacity in humans. Am J Physiol Regul Integr Comp Physiol, 294(3), R966-974. https://doi.org/10.1152/ajpregu.00666.2007

MacDougall, J. D., Hicks, A. L., MacDonald, J. R., McKelvie, R. S., Green, H. J., & Smith, K. M. (1998). Muscle performance and enzymatic adaptations to sprint interval training. J Appl Physiol (1985), 84(6), 2138-2142. https://doi.org/10.1152/jappl.1998.84.6.2138

Malone, J. J., Di Michele, R., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in elite English premier league soccer players. Int J Sports Physiol Perform, 10(4), 489-497. https://doi.org/10.1123/ijspp.2014-0352

Martín-García, A., Diaz, A., Bradley, P., Morera, F., & Casamichana, D. (2018). Quantification of a Professional Football Team's External Load Using a Microcycle Structure. https://doi.org/10.1519/JSC.0000000000002816

McKie, G. L., Islam, H., Townsend, L. K., Robertson-Wilson, J., Eys, M., & Hazell, T. J. (2018). Modified sprint interval training protocols: physiological and psychological responses to 4 weeks of training. Appl Physiol Nutr Metab, 43(6), 595-601. https://doi.org/10.1139/apnm-2017-0595

Mohr, M., & Krustrup, P. (2016). Comparison between two types of anaerobic speed endurance training in competitive soccer players. Journal of Human Kinetics, 51, 183-192. https://doi.org/10.1515/hukin-2015-0181

Mohr, M., Krustrup, P., Nielsen, J. J., Nybo, L., Rasmussen, M. K., Juel, C., & Bangsbo, J. (2007a). Different interpretation of the effect of two different intense training regimens on repeated sprint ability - Reply.

American Journal of Physiology-Regulatory Integrative and Comparative Physiology, 293(3), R1460-R1460. https://doi.org/10.1152/ajpregu.00452.2007

Mohr, M., Krustrup, P., Nielsen, J. J., Nybo, L., Rasmussen, M. K., Juel, C., & Bangsbo, J. (2007b). Effect of two different intense training regimens on skeletal muscle ion transport proteins and fatigue development. Am J Physiol Regul Integr Comp Physiol, 292(4), R1594-1602. https://doi.org/10.1152/ajpregu.00251.2006

Nalcakan, G. R., Songsorn, P., Fitzpatrick, B. L., Yuzbasioglu, Y., Brick, N. E., Metcalfe, R. S., & Vollaard, N. B. J. (2018). Decreasing sprint duration from 20 to 10 s during reduced-exertion high-intensity interval training (REHIT) attenuates the increase in maximal aerobic capacity but has no effect on affective and perceptual responses. Appl Physiol Nutr Metab, 43(4), 338-344. https://doi.org/10.1139/apnm-2017-0597

Simonelli, C., Formenti, D., & Rossi, A. (2025). Subjective recovery in professional soccer players: A machine learning and mediation approach. J Sports Sci, 43(5), 448-455. https://doi.org/10.1080/02640414.2025.2461932

Sirtori, M. D., Lorenzelli, F., Peroni-Ranchet, F., Colombini, A., & Mognoni, P. (1993). A single blood lactate measure of OBLA running velocity in soccer players. Medicina dello Sport, 43, 281-286.

Trecroci, A., Porcelli, S., Perri, E., Pedrali, M., Rasica, L., Alberti, G., Longo, S., & Iaia, F. M. (2019). Effects of Different Training Interventions on the Recovery of Physical and Neuromuscular Performance After a Soccer Match. J Strength Cond Res. https://doi.org/10.1519/JSC.0000000000003269

Wasserman, S. (1988). [Statistical Methods for Meta-Analysis, Larry V. Hedges, Ingram Olkin]. Journal of Educational Statistics, 13(1), 75-78. https://doi.org/10.2307/1164953

Yamagishi, T., & Babraj, J. (2017). Effects of reduced-volume of sprint interval training and the time course of physiological and performance adaptations. Scandinavian Journal of Medicine & Science in Sports, 27(12), 1662-1672. https://doi.org/10.1111/sms.12831

Zelt, J. G., Hankinson, P. B., Foster, W. S., Williams, C. B., Reynolds, J., Garneys, E., Tschakovsky, M. E., & Gurd, B. J. (2014). Reducing the volume of sprint interval training does not diminish maximal and submaximal performance gains in healthy men. European Journal of Applied Physiology, 114(11), 2427-2436. https://doi.org/10.1007/s00421-014-2960-4