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Six Sessions of Sprint Interval Training Improves Running Performance in Trained Athletes

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Abstract

Koral, J, Oranchuk, DJ, Herrera, R, and Millet, GY. Six sessions of sprint interval training improves running performance in trained athletes. *J Strength Cond Res* 32(3): 617–623, 2018—Sprint interval training (SIT) is gaining popularity with endurance athletes. Various studies have shown that SIT allows for similar or greater endurance, strength, and power performance improvements than traditional endurance training but demands less time and volume. One of the main limitations in SIT research is that most studies were performed in a laboratory using expensive treadmills or ergometers. The aim of this study was to assess the performance effects of a novel short-term and highly accessible training protocol based on maximal shuttle runs in the field (SIT-F). Sixteen (12 male, 4 female) trained trail runners completed a 2-week procedure consisting of 4–7 bouts of 30 seconds at maximal intensity interspersed by 4 minutes of recovery, 3 times a week. Maximal aerobic speed (MAS), time to exhaustion at 90% of MAS before test (Tmax at 90% MAS), and 3,000-m time trial (TT3000m) were evaluated before and after training. Data were analyzed using a paired samples *t*-test, and Cohen's (d) effect sizes were calculated. Maximal aerobic speed improved by 2.3% ($p = 0.01$, $d = 0.22$), whereas peak power (PP) and mean power (MP) increased by 2.4% ($p = 0.009$, $d = 0.33$) and 2.8% ($p = 0.002$, $d = 0.41$), respectively. TT3000m was 6% shorter ($p < 0.001$, $d = 0.35$), whereas Tmax at 90% MAS was 42% longer ($p < 0.001$, $d = 0.74$). Sprint interval training in the field significantly improved the 3,000-m run, time to exhaustion, PP, and MP in trained trail runners. Sprint interval training in the field is a time-efficient and cost-free means of improving both endurance and power performance in trained athletes.

Key Words endurance, field, metabolism, repeated sprints, power, capacity

Introduction

Sprint interval training (SIT) is based on repeated short-maximal or near-maximal sprints (6,8,29,31). From a theoretical point of view, SIT performed for relatively short periods, a few weeks, to a few months, has been shown to induce enzymatic adaptations in the 3 energetic systems (31). For instance, an increase in the activity of glycolytic enzymes and increased markers of aerobic metabolism have been established after SIT training (23,29,31). These results can be explained by the significant contribution of the aerobic metabolism during SIT (5,16,18,24,30,36). Moreover, several meta-analyses have concluded that SIT significantly increases aerobic and anaerobic performance in both trained and untrained athletes (17,26,37).

From a practical standpoint, Taylor et al. (34) show that SIT can induce small to large improvements in activities where strength, power, and speed are needed, such as countermovement jumps or 10–30-m sprints. Taylor et al. (34) also highlighted that in some cases, repeated sprints are even more efficient at improving short-sprint performance than methods such as plyometric training. Recent studies have also shown promising results using repeated sprints on improving cognitive function (11), attenuating rating of perceived exertion and leg pain (2), and even assisting clinical decision making regarding return to sport after injuries (28).

Although methods using repeated sprints are valuable, the existing literature has a clear lack of studies performed in the field as most SIT research studies (3,4,7,9,12,13,15,19–21,23,24,31,33,35,38,39) have been completed in a laboratory setting. For instance, in studies that used a 2-week intervention period, the use of a Wingate protocol on a cycle ergometer was systematic (3,7,19,21,31,35,38). In addition, in the 4–10-week protocols, cycle ergometers or treadmills were

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used indifferently (4,9,12,13,15,20,23,24,33,39), which makes sense because SIT on a treadmill has recently shown similar benefits to SIT performed on cycle ergometers (39). However, cycle ergometers and treadmills can be expensive and time-consuming, especially when several subjects are training at the same time (4). Therefore, they are not practical for most practitioners. In addition, time and resources are often limited; so, protocols lasting 4–10 weeks are not always applicable.

Therefore, the aim of the current study was to test the effects of a novel, short-term SIT method performed in the field (SIT-F), which requires only cones and a chronometer, on performance in trained athletes. The tested hypothesis was that 6 sessions of SIT-F spread over only 2 weeks, with 2 days of recovery between sessions, would significantly improve short-term running performance as measured using a 3,000-m time trial (TT3000m) and time to exhaustion at 90% of maximum aerobic speed (MAS).

Methods

Experimental Approach to the Problem

The experimental protocol, adapted from Burgomaster et al. (7), included a familiarization procedure, a pretest, 2 weeks of SIT, and a posttest. Pre-intervention to post-intervention changes in MAS, TT300m and Tmax at 90% MAS were compared.

Subjects

Sixteen (12 male, 4 female) healthy individuals volunteered to take part in the experiment. Mean (±*SD*) age, height, and body mass were 21.1 ± 3.6 years (18–28 years), 175 ± 7.4 cm, 62.1 ± 9.2 kg, respectively, for men, and 22.8 ± 3.0 years (19–27 years), 167.2 ± 6.8 cm, 56.8 ± 8.3 kg, respectively, for women. All subjects were trained trail runners who performed regular moderate-intensity exercise 3–5 times per week for a total weekly distance of at least 50 km for at least 3 years (estimated $\dot{V}O_2max$ at PRE was 61.5 ± 2.8 $ml \cdot kg^{-1} \cdot min^{-1}$ for men and 47.9 ± 3.2 $ml \cdot kg^{-1} \cdot min^{-1}$ for women). Intense intermittent training was not permitted during the 3 months preceding this intervention. The Universities Ethics Board and Human Research Ethics Committee (Catholic University of Valencia) approved the study, and after a routine medical screening, the subjects were informed of the procedures to be used as well as the associated risks and benefits of the intervention. An institutionally approved written consent form was provided and signed by all participants before any training or testing. Because no subjects were younger than 18 years, parental or guardian consent was not collected.

Procedures

The experimental protocol, adapted from Burgomaster et al. (7), included a familiarization procedure, a pretest, 2 weeks of SIT, and a posttest. All familiarization, testing, and training sessions were conducted in the afternoon (3–5 PM) to avoid performance fluctuations because of circadian rhythms. Participants were encouraged to drink water before, during, and after each testing and training session.

Familiarization Procedures. Before taking part in any experimental trial (baseline measurements), all subjects performed familiarization trials to become oriented with all testing procedures. The familiarization also consisted of 4 maximal bouts of 30-second shuttle runs with 4 minutes of recovery between bouts to be familiar with the training method.

Pretesting and Posttesting. Baseline measurements for all subjects consisted of a MAS test, a time to exhaustion at 90% of MAS, and finally a 3000-m time trial. Each baseline test was conducted on a separate day with 48 hours of rest between tests. An experienced strength and conditioning coach provided the participants with strong verbal encouragement and supervised each test session.

Maximal Aerobic Speed Test. A continuous running, multistage field test, known as the "University of Montreal Track Test" (22) was used. This protocol was run on a 400-m flat running track, with markers located every 50 m along the track. According to Leger and Boucher (22), no warm-up was performed before the test. The speed of the initial stage was set at 8 $km \cdot h^{-1}$ and increased by 1 $km \cdot h^{-1}$ every 2 minutes. The speed changes were indicated by audio cues from a prerecorded audio file. The test ceased when the subject fell 5-m short of the designated marker or when the subject reached volitional failure. The validity and reliability of this test are well established (22). $\dot{V}O_2max$ was estimated using the following equation (22): $\dot{V}O_2max = 14.49 + 2.143 \times v + 0.0324 \times v^2$, where v is the velocity sustained during the last 30 seconds.

Time to Exhaustion at 90% of Maximal Aerobic Speed (Tmax at 90% PRE–Maximal Aerobic Speed). Subjects were supervised and instructed to run at 90% of MAS as long as possible on a 400-m flat running track in a local stadium. Cones were placed every 50 m, and a prerecorded audio track was played to give the subjects feedback on their pace.

Three Thousand–Meter Time Trial (TT3000m). The subjects ran 3,000 m as quickly as possible on a 400-m flat running track. Participants completed a 15-minute warm-up including light muscular contractions and 5 minutes of light aerobic exercise followed by 4 sets of 20-m progressive runs. Participants were supervised and encouraged to run maximally at their own pace. The validity and reliability of this kind of time trial test have been established by Denham et al. (13) with an intraclass correlation coefficient = 0.99 and a 3.4% coefficient of variation.

Training Period. The SIT-F training period commenced 2 days after the pretesting procedure. The SIT-F training consisted of a standardized program performed 3 times a week over 2 weeks. The SIT volume increased from 4 to 7 bouts over the first 5 sessions and was reduced to 4 bouts in the last session (total of 6 sessions) Each training session consisted of repeated 30 seconds of "all-out" efforts using a shuttle run protocol interspersed by a period of 4 minutes of rest (Table 1). Subjects received strong verbal

TABLE 1. Description of the 2-week sprint interval training program.

Week	Session number	Training load sprints	Training sprint time (min)	Total session time (min)
1	1	4	2	14
	2	5	2.5	18.5
	3	6	3	23
2	4	6	3	23
	5	7	3.5	27.5
	6	4	2	14
	Total	32	16	110

encouragement to continue running maximally without pacing throughout the 30-second bouts. Before each training session, participants completed a standardized warm-up consisting of light muscular contractions and 5 minutes of light aerobic exercise followed by 6 sets of 20-m progressive runs from 50 to 80% of the effort.

Sprint Interval Training in the Field. On a flat running track, each lane was materialized by placing cones 5 m from each other for a total of 30 m (Figure 1). Several subjects can be evaluated simultaneously, which allows for an efficient use of the time of both the coaches and athletes. The instructions were to travel the greatest distance possible in 30 seconds, making trips of 5, 10, 15 m, etc. During the 4-minute recovery period, the athletes walked back to the start line where they waited for the following repetitions.

Three variables were obtained for each session:

- Peak power (PP) output: longest total distance covered in a 30-second period.
- Mean power (MP) output: total distance of the session divided by the number of repetitions (n). For example, during a session consisting of 4 sets, MP = (PP1 + PP2 + PP3 + PP4)/4.
- Fatigue index (FI): difference between the longest and the shortest distance traveled during each session; FI = (shortest distance/longest distance) × 100.

All participants were instructed not to deviate from their current dietary habits or hydration patterns throughout the duration of the study. They were not allowed to have any kind of physical activity during the experiment.

Statistical Analyses

The data were analyzed using the 2016 SPSS version 24 (IBM Corporation, Armonk, NY, USA) statistical analysis software. Normality and equality of variance were verified using the Shapiro-Wilk's test and Levene's test, respectively. The data were analyzed with paired-samples *t*-tests with significance level set at $p \leq 0.05$ with 95% confidence intervals (CIs). All data are presented as mean ± *SD*. Cohen's effect sizes (*d*) were calculated to measure the magnitude of practical effect, with the following criteria used: 0.1 as trivial, 0.2 as small, 0.5 as medium, and 0.8 as large (8).

RESULTS

Pretesting and Posttesting

Changes in MAS, Tmax at 90% MAS, and TT3000m are presented in Figure 2.

Maximal aerobic speed displayed a significant increase of 0.41 $km \cdot h^{-1}$ ($p = 0.01$, 95% CI [0.11–0.70]). This 2.8% improvement represented a small effect size ($d = 0.22$). Similarly, Tmax at 90% MAS displayed a significant increase of 158.9 seconds ($p = 0.001$, 95% CI [77.9–239.9]). This 42% improvement represented a large effect size ($d = 0.74$). There was also a statistically significant decrease in TT3000m of 50.4 seconds ($p < 0.001$, 95% CI [31.9–68.8]). This 5.7% improvement represented a small-to-medium effect size ($d = 0.35$).

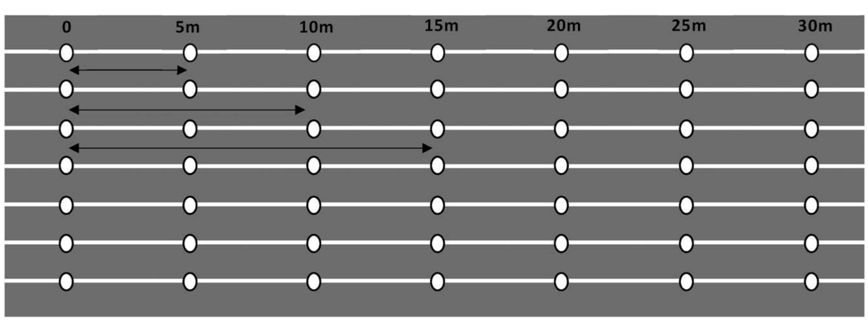

Figure 1. Representation of the sprint interval training in the field situation.

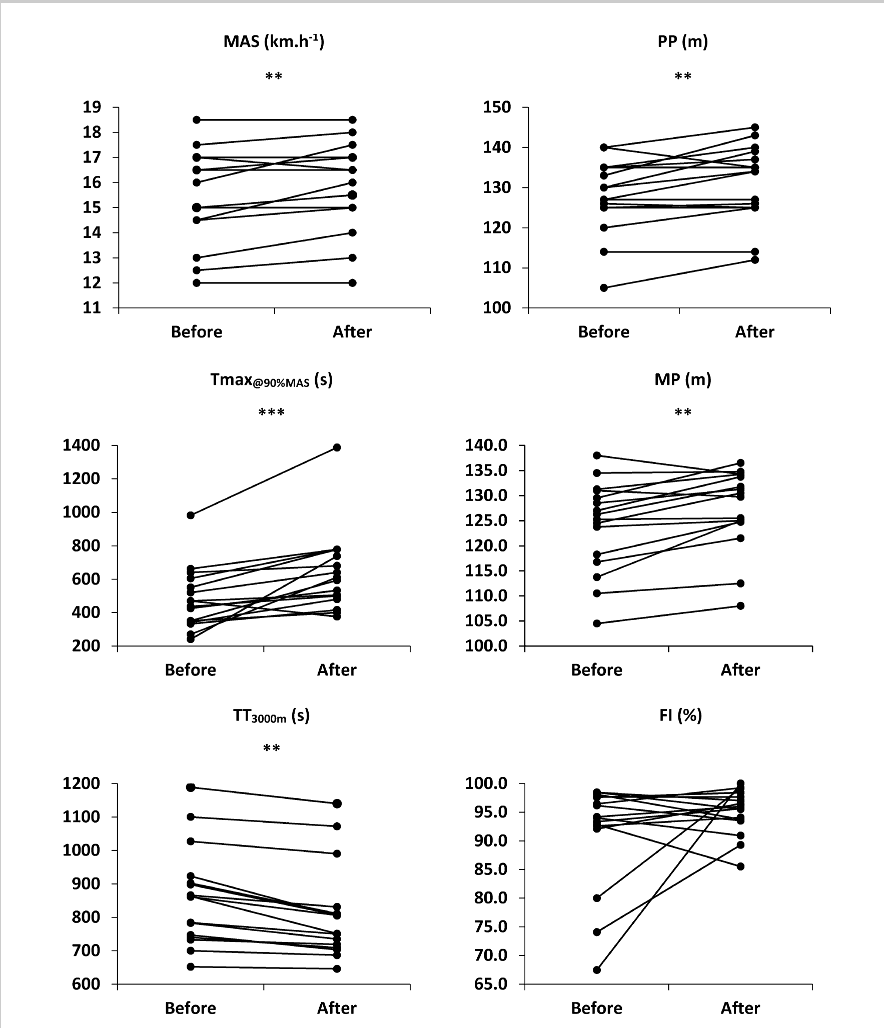

Figure 2. Maximal aerobic speed (MAS), time to exhaustion at 90% of PRE-MAS (Tmax at 90% MAS), 3-km time-trial performance (TT3000m), peak power (PP) output, mean power (MP) output, and fatigue index (FI) before and after sprint interval training on the field. $^{**}p \le 0.01$; $^{***}p \le 0.001$.

In-Session Changes

Changes from first to sixth session in PP output, MP output, and FI are presented in Figure 2.

Peak power improved significantly by 3.06 m ($p = 0.009$, 95% CI [0.88–5.24]). This 2.4% improvement represented a small-to-medium effect size ($d = 0.33$). There was also a significant improvement in MP of 13.9 m ($p = 0.002$, 95% CI [5.99–21.9]). This 2.9% improvement represented a medium effect size ($d = 0.41$). Positive trends in FI did not reach statistical significance ($p = 0.17$), despite a medium effect size ($d = 0.51$).

Discussion

This study demonstrated that 2 weeks of SIT-F improved high-intensity endurance performance in trained trail runners. This is noteworthy because most of the existing literature has focused on untrained or recreationally trained subjects (2,4,7–9,12,13,19,23–25,29,31,35,38,39). Furthermore, to our knowledge, this is the first study of its kind to be completed in 2 weeks by running outside a laboratory setting.

Time to exhaustion at 90% of MAS was significantly ($p = 0.001$) improved from pretest to posttest (42%) after the 2-week intervention. This increase is lower than the 100 and 48.2% improvements found by Burgomaster et al. (7) and Bayati et al. (4), respectively. This may primarily be explained by the difference in initial training status of the participants because the $\dot{V}O_2max$ of the participants of the current study was ~55 vs. ~45 $ml \cdot kg^{-1} \cdot min^{-1}$ for Burgomaster et al. (7) and Bayati et al. (4), respectively. Therefore, it is likely that the potential for improvement was lower in our population. However, the athletes in the current study were still able to obtain statistically and practically significant ($p = 0.001$, $d = 0.74$) improvements in only 2 weeks. These findings reinforce that the SIT-F protocol in the current study is very effective for improving performance in trained athletes in a short period.

In that context, an improvement greater than 40% in 2 weeks is quite remarkable. This is reinforced by the results found by Farzad et al. (15) and Esfarjani and Laursen (14) who used running protocols on a laboratory treadmill. They measured improvements of ~32% in trained subjects with $\dot{V}O_2max$ values of ~50 $ml \cdot kg^{-1} \cdot min^{-1}$. It may be objected that they used a time to exhaustion at 100% MAS, whereas the current study used time to exhaustion at 90% of MAS. It is crucial to notice that these studies varied in length from 4 to 10 weeks, compared with the 2-week intervention period of the current study.

After only 2 weeks of SIT-F, the subjects of this study completed the TT3000m 5.7% faster than pretesting. This improvement in the TT3000m was statistically significant ($p < 0.001$); however, the practical effect was found to be small to medium ($d = 0.35$). Compared with our results in time to exhaustion, the improvement is much lower; however, the results are similar to Amann et al. (1) who found that the difference in time to exhaustion was much greater than the difference in time-trial performance when comparing normoxia and hypoxia. More specifically, very few SIT studies have examined 3,000-m time trials and were lasting from 6 (Ciciony-Kolsky et al. (12); untrained) to 10 weeks (Esfarjani and Laursen (14); trained). Nonetheless, the improvements seen in the current study are comparable or greater.

If we consider that time trials completed at 2,000 and 5,000 m are also relevant to the current study, we once again obtained similar or greater performance increases than studies with untrained subjects cycling or running on treadmills, and lasting 2 (Hazell et al. (19); −5.2% on TT5000m), 4 (Willoughby et al. (39); −5.9% on TT2000m/Denham et al. (13); −4.5% on TT5000m), or 6 weeks (Macpherson et al. (25); −4.6% on TT2000m).

In 10-km time trials, Iaia et al. (20) saw no improvement. Burgomaster et al. (8) and Jakeman et al. (21) showed that performance was improved by ~10% in 2 weeks. The difference with the current study can be explained by the fact that their subjects were untrained (8) and the training and testing protocols were different compared with ours (21).

Maximal aerobic speed improved significantly ($p = 0.01$) by 2.8% in following the 2-week intervention. With the exception of Burgomaster et al. (7) who did not see an effect on $\dot{V}O_2max$, all literature that used a 2-week intervention period (2,8,19,31,35,38) exhibit a range of improvements from 5.5 to 13%, which is higher than this study. The differences in study design can at least partially explain the different percentages of improvement seen in $\dot{V}O_2max$ because they all used a cycle ergometer as their training and testing apparatus and were conducted in untrained subjects.

The PP (2.4%, $p = 0.009$) and MP (2.9%, $p = 0.002$) improved significantly but with only small-to-medium ($d = 0.33$) and medium ($d = 0.41$) practical effects. Significant p values, at least in part, are likely due to nearly the entire cohort (14/16 athletes) experiencing maintained or improved performance. Comparatively, obtaining large practical improvements in merely 2 weeks can be substantially more difficult (10). Nonetheless, improvements seen were lower than the bulk of the literature, which experienced 3–17% improvements in PP and MP outputs (4,7,8,15,19,21,23,24,29,31,38). Besides the previously discussed differences in subject training experience, the current study used a series of field tests, which do not allow for the same level of accuracy as a cycle ergometer or direct physiological measures. This limitation may also explain why FI did not reach statistical significance ($p = 0.17$), despite showing a potentially meaningful effect ($d = 0.51$).

Although muscle biopsies could not be obtained, it is speculated that the rapid improvement seen was largely due to an increase in the enzymatic activity of the aerobic system as demonstrated in several studies (5,23,24,30,31,36). Furthermore, FI and anaerobic capacity also improved in our study, although the improvements in FI did not reach statistical significance ($p = 0.17$, $d = 0.51$). Sprint interval training performed for relatively short periods, from weeks to a few months, have been shown to result in important changes at the musculoskeletal level causing enzymatic adaptations in the energetic systems (32). Likewise, an increase in the activity of glycolytic enzymes (hexokinase and phosphofructokinase) and increased markers of aerobic metabolism (citrate synthase, 3-hydroxyacyl-CoA dehydrogenase, and malate dehydrogenase) have also been established (23,31). In addition, Parra et al. (29) found significant improvements in the activity of creatine kinase, pyruvate kinase, and lactate dehydrogenase. Furthermore, the type of training performed in this study could have potentially improved neuromuscular capacity in elite endurance runners. These adaptations may result in improved running economy and, therefore, performance (27). Further studies using biopsies, electromyography, and direct $\dot{V}O_2$ measurements should be implemented in the future to confirm these speculations.

Shuttle runs were selected over straight-line sprints in this study for a variety of reasons. First, the physiological tests used in the current study were completed on a 400-m running track and required none of the change of direction skills needed to perform shuttle runs. This difference was designed to avoid an increase in results that were simply due to skill acquisition and to isolate the physiological adaptations. Second, shuttle runs allow for higher levels of interaction and "competition" between multiple athletes (Figure 1), which may lead to greater motivation. Finally, shuttle runs have a practical advantage over sprinting on a track because running for 30 seconds requires a relatively large area, whereas shuttle runs can be performed in much smaller spaces.

Although the use of a control group is generally valuable, 100% of SIT studies that have included 1 saw no statistical changes, regardless of the population (2,4,8–10,12,14,15,20,25,33). Furthermore, finding trained athletes is difficult; therefore, we decided not to reduce the number of subjects in the intervention group by delegating several to a group that would likely show no significant changes. A direct measure of $\dot{V}O_2max$ was not performed in this study. This potential limitation may be an area to examine with future research on SIT in the field.

Practical Applications

Modern coaches often deal with an increasingly large number of competitions during the competitive season, which subsequently reduces the preparation time available. The results of the current study demonstrate that a very short-term low-volume SIT on a track or field is an effective means of improving both endurance and anaerobic performance. Moreover, there are other benefits of integrating the novel SIT-F method from this study. First, it is nearly costless because no special equipment is needed. Second, this method can be used nearly anywhere because only 30 m of continuous space is required. This can be especially valuable if and when suboptimal weather conditions force practitioners to move indoors. Third, several athletes can be run through the training protocol at once, which help to ensure high levels of motivation and effective use of time. Finally, in individual sports, SIT can also be used as a tapering method by subsequently allowing for high intensities and low volume levels.

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