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Four weeks of sprint interval training improves 5 km run performance

Short title: SIT improves 5 km run performance

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ABSTRACT

Sprint interval training (SIT) rapidly improves cardio-respiratory fitness but demands less training time and volume than traditional endurance training. While the health and fitness benefits caused by SIT have received considerable research focus, the effect of short-term SIT on 5 km run performance is unknown. Thirty healthy untrained participants (aged 18–25 years) were allocated to a control (n = 10) or a SIT (n = 20) group. SIT involved three to eight sprints at maximal intensity, three times a week for four weeks. Sprints were progressed to eight by the 12th session. All participants completed a 5 km time-trial on a public running track and an incremental treadmill test in an exercise physiology laboratory to determine 5 km run performance and maximum oxygen uptake, respectively, before and after the four week intervention. Relative to the controls, sprint interval trained participants improved 5 km run performance by 4.5% ($p < 0.001$) and this was accompanied by improvements in absolute and relative maximum oxygen uptake (4.9%, $p = 0.04$ and 4.5%, $p = 0.045$, respectively). Therefore, Short-term SIT significantly improves 5 km run performance in untrained young men. We believe SIT is a time-efficient means of improving cardio-respiratory fitness and 5 km endurance performance.

KEYWORDS: Time-trial, training load, SIT, VO_{2max}

INTRODUCTION

Endurance run performance is important for individuals of average cardio-respiratory fitness who aspire to improve their fitness and performance quickly and efficiently. Moreover, considering the importance of cardio-respiratory fitness and endurance performance in ball sports such as soccer, Australian Rules Football and cricket (5, 15, 18) there is immense coaching emphasis on reducing training load to minimise injury risk, but maximise training time to focus on other skills important to the sport. SIT is an alternative mode of training to traditional constant-rate training as SIT improves cardio-respiratory fitness to a similar degree as constant-rate training but requires 90% less weekly energy expenditure and 66% less total training time (7).

Typically SIT consists of short, maximal efforts of 15–30 s, repeated several times interspersed with 3–5 mins of recovery. Indeed, SIT may be more effective at improving endurance performance than both continuous running and other high-intensity interval training (HIT) programmes. For example, 20 individuals who completed seven to twelve efforts of 30 s sprints thrice weekly for six weeks, improved 3 km run performance greater than individuals who completed constant rate running or four to six four minute efforts at 3 km average running velocity, over six weeks (4). Others have, however, demonstrated recreationally active participants similarly improve 2 km run performance after either six weeks of SIT (4.6%) or constant rate running (5.9%) (13). Therefore, SIT seems to enhance run performance over 2-3 km after six weeks of training, but whether these endurance benefits improve run performance in untrained participants in shorter time-frames and over distances exceeding 3 km (a distance requiring greater reliance on aerobic metabolism) is unknown. Furthermore, the lack of inclusion of experimental controls in previous studies (4, 6, 13) obfuscates the genuine impact of SIT on endurance run performance.

Therefore, the purpose of our study was to determine whether a novel and relatively short-term (four week), thrice weekly SIT programme improves cardio-respiratory fitness and 5 km run performance. To that end, we assessed 5 km run performance and $\dot{V}O_{2max}$ before and after either a novel four week SIT (four to eight 30-s maximal sprints, thrice weekly) programme for cases (n = 20), or no training for controls (n = 10). We hypothesised that relative to the controls, the sprint-interval trained individuals would significantly improve 5 km run performance and $\dot{V}O_{2max}$.

METHODS

Experimental approach to the problem

This study is a controlled trial, where healthy participants performed either four weeks of SIT or no training, to evaluate the effect of SIT on 5 km run performance and $\dot{V}O_{2max}$. $\dot{V}O_{2max}$ was measured during a maximal treadmill test conducted in the university exercise physiology laboratory and the 5 km time-trial was assessed at a public running track. These tests were performed on separate days within one week of commencing the initial SIT session and within one week after the final SIT session.

Subjects

Thirty, apparently healthy young men (18–25 years) were recruited for this study. Participants were initially screened to ensure they were not currently engaging in any structured high-intensity aerobic exercise training. All participants had not completed any structured aerobic exercise training in the past year. Twenty participants were allocated to the SIT (cases) group and 10 participants were allocated to the control group.

Participants gave written informed consent and this study was approved by the University's Human Research Ethics Committee.

Procedures

Participant $\dot{V}O_{2max}$ was assessed during a maximal treadmill test, by pulmonary analysis conducted in an exercise physiology laboratory at the university. Before the $\dot{V}O_{2max}$ test participants were fitted with a two-way breathing valve (Hans Rudolph) and expired air was collected into an online metabolic system (Moxus) for gas (O_2 and CO_2) analysis. The metabolic system was calibrated before each test using ambient air and gas of known composition. Participants were given a standardised 3-min warm-up at 10 $km \cdot h^{-1}$. The $\dot{V}O_{2max}$ test commenced at 10 $km \cdot h^{-1}$, and treadmill speed was progressively increased by 1 $km \cdot h^{-1}$ every second minute until volitional exhaustion. $\dot{V}O_{2max}$ was determined as the highest O_2 value averaged over 60-s. All laboratory testing was performed preprandially at the same time of day (8–10 AM). Participants were encouraged to hydrate the night before and morning of testing. Within a week of the $\dot{V}O_{2max}$ assessment each participant completed a supervised 5 km run time-trial on a flat running track in a local park. Participants were familiar with 5 km circuit and were advised to hydrate before running. All testing was conducted in the afternoon (4–6 PM). Briefly, participants completed a short 10-min warm-up including some light aerobic exercise and dynamic stretches. Participants were supervised and instructed to run maximally at their own pace.

Cases completed a standardised SIT programme performed three times a week over four weeks (total of 12 sessions). The sprint duration and recovery period was controlled at 30-s and 4-mins (passive), respectively. Participants were requested to run maximally without pacing for each 30-s sprint. All training was conducted on the University's sports oval and an Accredited Exercise Physiologist (with Exercise and Sport Science Australia) provided participants with verbal encouragement, and supervised each training session. The SIT volume increased from four to eight sprints over the four week intervention (Table 1). Before each training session, participants completed a standardised warm-up entailing a 5-min aerobic warm-up, dynamic stretches and some short (20 m) runs at approximately 70, 80, 90 and 100% effort.

<<Table 1 about here>>

All participants were instructed not to deviate from their current physical activity, exercise (if any) and dietary habits during the four week intervention period.

Statistical analyses

All statistical analyses were performed using IBM SPSS Statistics for Windows (Version 20, IBM Corp, Armonk, NY). Data were tested for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests, and non-parametric data was log-transformed before further analysis. Paired samples *t*-tests were used to examine fitness and performance changes after SIT, relative to the control group. To ascertain the test-retest reliability of VO_{2max} and 5 km time-trial performance, the intraclass correlation coefficient (2, k), coefficient of variation (log-transformed), standard error of measurement, and systematic bias (determined by paired samples *t*-test) were calculated. Significance was set at $p < 0.05$.

RESULTS

Test-retest reliability data is outlined in Table 2. The 5 km time-trial test had excellent reliability with an intraclass correlation coefficient of 0.99 and a 3.4% coefficient of variation.

<<Table 2 about here>>

Figure 1 outlines the fitness and performance changes after four weeks of SIT. Relative to the control group who showed a marginal increase in 5 km time-trial performance (mean ± SD: 1478 ± 350 to 1447 ± 347, -2%, $p = 0.20$, Table 2 and Figure 1), cases had a significant improvement in 5 km time-trial performance by an average of 65 s (mean ± SD: 1464 ± 298 to 1368 ± 270, -4.4%, $p < 0.001$) following four weeks of SIT (Figure 1). While absolute and relative $\dot{V}O_{2max}$ increased after SIT in cases (mean ± SD: 3.8 ± 0.6 to 4.0 ± 0.6, 4.9%, $p = 0.04$ and 49.6 ± 4.6 to 51.4 ± 3.8, 4.5%, $p = 0.045$, respectively), absolute and relative $\dot{V}O_{2max}$ were unchanged in controls (mean ± SD: 3.7 ± 0.6 to 3.7 ± 0.6, 0.6%, $p = 0.73$ and 49.6 ± 6.7 to 49.3 ± 6.7 -0.6%, $p = 0.72$, respectively, Table 2 and Figure 1).

<<Figure 1 about here>>

DISCUSSION

The purpose of our study was to determine whether a novel and short-term (four week), thrice weekly SIT programme improves cardio-respiratory fitness and 5 km run performance in untrained males. To our knowledge, we are the first to demonstrate that 5 km run performance is significantly improved following short-term (four weeks), low-volume SIT. Considering the marginal but not statistically significant improvement in the controls (31 s, 2%), the marked (96 s, 6.5%) improvement after four weeks of SIT translated to a mean 65 s

(4.4%) faster 5 km run performance in cases. Notably, 5 km run performance was improved in conjunction with increased $\dot{V}O_{2max}$ (4.5%).

Our data showing SIT enhances 5 km run performance corroborates others' showing SIT enhances 2 km (13) and 3 km (4, 6) run performance in recreationally trained individuals. We are the first to demonstrate four weeks of three times per week SIT, in the form of running, significantly improves 5 km run performance – a prestigious and Olympic running distance. Interestingly, the impact of SIT on 5 km endurance performance is established in other exercise modalities. A short-term (two-week) cycle SIT intervention improved 5 km cycle performance to a similar magnitude to our protocol (5.2%) (10). Whether SIT improves run performance over longer distances warrants attention. Additionally, whether SIT benefits already well-trained runners is yet to be fully understood, as data has, to date, been equivocal (1, 11). Nevertheless, we verify SIT as an effective means of improving running endurance performance in untrained young men.

The increased 5 km run performance in our study is similar to previously observed improvements after traditional constant-rate endurance training. It was reported, an intervention of three running sessions per week at 75% of $\dot{V}O_{2max}$ for six weeks improved 5 km run time by approximately 80 s (~5%) in 39 untrained individuals (20). Additionally, others have shown 5 km time-trial improved by 78 s (5%) in a group that ran for 20 mins three times per week for six weeks, initially starting at 0.8 $km \cdot hr^{-1}$ below their individual lactate threshold speed with progression to 0.8 $km \cdot hr^{-1}$ above their individual pre-training lactate threshold speed (14). Importantly, a control group was not included in these studies to establish the error of the 5 km time-trial test, which we established was 31 s. Collectively, it appears SIT improves 5 km run performance to a similar extent as constant-rate training, but in a quicker time frame (four vs. six weeks) and a smaller training duration (249 mins vs. 360 mins) (14).

The improvement in run performance was accompanied by a corresponding improvement in $\dot{V}O_{2max}$. Although previous constant-rate training studies have demonstrated participants increased their $\dot{V}O_{2max}$ to a similar magnitude observed in the our study (3.8–7.7%), they also showed marked improvements in their participants lactate threshold, which could have contributed to the improvements in run performance (14, 20), particularly because not all cases had improvements to $\dot{V}O_{2max}$. Alternatively, an improvement in cardiac output may have facilitated the improvement in 5 km run speed, as opposed to improvements in muscle oxidative capability, based on the concepts $\dot{V}O_{2max}$ is chiefly governed by the maximal cardiac output and the lactate threshold by muscle oxidative capability (12). Other mechanisms by which SIT may enhance 5 km run performance include improved run economy, running mechanics and potassium regulation. It was previously reported that moderately-trained runners' run economy was improved by 7% after four weeks of SIT, but these subject did not improve their 10 km time-trial performance (11). Moreover, increases in knee flexor endurance, coupled with decreases in knee flexion torque and knee flexion/extension ratios are also adaptations associated with sprint training that could have contributed to the improvement in 5 km run performance observed in our study (19). Others have shown in well-trained runners, SIT enhanced key components of the Na^+/K^+ pump that would aid to minimise disturbances in nerve membrane potential and maintain sprint performance, and this was associated with an approximate 3% improvement in 3 km and 10km run performance (1). The increase in muscle oxidative and anaerobic enzyme activity are adaptations gained from SIT and is another possible mechanism for the facilitated endurance performance observed in participants from our study (2, 3, 8, 16).

A limitation of our study is that we did not include females. Some of the benefits gained from SIT seem to be dependent of gender. For example, males had greater muscle protein synthesis of proteins important for mitochondrial biogenesis after nine sessions of SIT compared to their female counterparts (17). Given these muscle adaptations are vital for endurance performance (2, 8, 9), whether short-term SIT improves 5 km run performance in females is left for future investigations.

Future research could focus on optimising training variables, such as the recovery time between sprints, number of sprint repetitions, time required of each sprint, number of sessions required per week and the optimal length of SIT to improve fitness and performance. In fact, the efficiency of HIT in evoking positive adaptations may even be more potent than originally envisaged. It was recently revealed one maximal 4-min effort at 90% of heart rate maximum on a cycle ergometer, performed three times a week for 10 weeks improves $\dot{V}O_{2max}$ by an average of 10% (21).

In conclusion our data reveals SIT is a highly effective strategy to improve endurance running quickly in previously untrained young men.

PRACTICAL APPLICATIONS

Physical conditioning professionals must be aware of efficient means of exercise training that augment cardio-respiratory fitness and endurance performance. The results from our study support the use of short-term, low-volume SIT as an effective means for rapidly improving cardio-respiratory fitness and endurance performance. Therefore, team sport coaches should consider incorporating short-term SIT within periodised programmes to improve athlete endurance performance quickly and also to prevent musculoskeletal overuse injuries – a risk associated with traditional forms of exercise that rely on large training volumes to improve endurance performance. What is more, SIT has an added advantage of simultaneously enhancing anaerobic qualities required in team sports. Finally, SIT should be encouraged to individuals who perceive time as an obstacle to exercising, as four weeks of thrice weekly SIT consisting of four to eight 30-s sprints (just over 4 hrs of total exercise, including rest periods) quickly enhances cardio-respiratory fitness and endurance performance.

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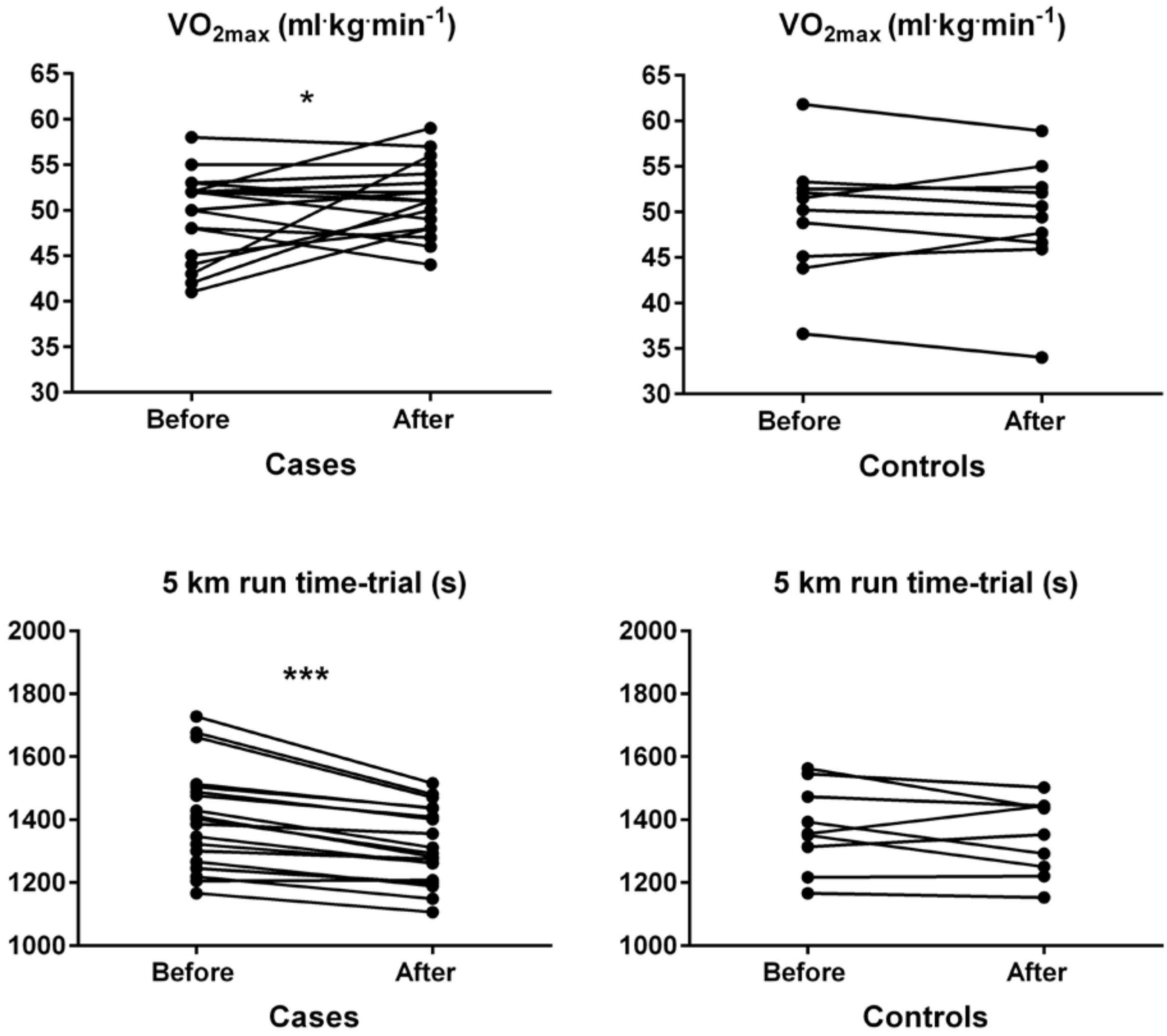

FIGURE LEGENDS

Figure 1. 5 km time-trial performance and relative $\dot{V}O_{2max}$ before and after SIT.

Relative to the controls (-2.1, $p = 0.20$), the cases had a significant improvement to 5 km run performance (-4.4%, $p < 0.001$) and relative $\dot{V}O_{2max}$ (4.5%, $p < 0.05$) after SIT. Data are expressed as mean values before and after either four weeks of SIT (cases) or no exercise training (controls).

Legend: * $p < 0.05$; *** $p < 0.001$.

TABLES

Table 1. Description of the four-week SIT programme.

Week	Session #	Training load (sprints)	Training sprint time (min)	Total session time (min)
1	1	3	1.5	9.5
	2	4	2	14
	3	5	2.5	18.5
2	4	4	2	14
	5	5	2.5	18.5
	6	6	3	23
3	7	5	2.5	18.5
	8	6	3	23
	9	7	3.5	27.5
4	10	6	3	23
	11	7	3.5	27.5
	12	8	4	32
	Total time	66	33	249

Legend: # number.

Table 2. Test-retest reliability data for the 5 km time-trial test.

Variable	**Mean trial 1**	**Mean trial 2**	**Mean difference**	***p*-value**	**SEM**	**ICC**	**CV (%)**
VO_{2max} (ml·kg·min^{-1})	49.57 ± 6.71	49.29 ± 6.67	-0.28	0.72	1.69	0.967 (0.867–0.992)	3.6 (2.5–6.7)
5 km time-trial (s)	1478.10 ± 349.95	1447.50 ± 347.24	-30.6	0.18	47.07	0.991 (0.963–0.998)	3.4 (2.4–6.4)

Results of the 5 km time-trial test in the control group (n = 10), reliability as measured by mean difference of two trials, intraclass correlation (ICC), *p*-value (two-tailed paired *t*-test), standard error of measurement (SEM) and typical error as a coefficient of variation (CV) percentage (%). Upper and lower confidence intervals are expressed in parentheses; confidence intervals are set at 95%. SDs are represented after the mean of trials 1 and 2.