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Influence of recovery duration during 6-s sprint interval exercise on time spent at high rates of oxygen uptake

Qingde Shi [a,*], Tomas K. Tong [b], Shengyan Sun [c,d], Zhaowei Kong [c], Chan Kit Chan [a], Wei Liu [e], Jinlei Nie [a]

[a] School of Physical Education and Sports, Macao Polytechnic Institute, Macao, China
[b] Dr. Stephen Hui Research Centre for Physical Recreation and Wellness, Department of Physical Education, Hong Kong Baptist University, Hong Kong, China
[c] Faculty of Education, University of Macau, Macao, China
[d] Institute of Physical Education, Huzhou University, Huzhou, Zhejiang, China
[e] Department of Cardiology, Beijing Hospital of the Ministry of Health, Beijing, China

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ABSTRACT

This study examined whether time spent at high rates of oxygen consumption (VO_2) during 6-s sprint interval exercises (SIE) is a function of recovery interval duration. In a randomised crossover study, thirteen male endurance runners performed 40 × 6-s all-out sprints interspersed with 15-s, 30-s and 60-s passive recovery intervals (SIE_{15}, SIE_{30}, and SIE_{60} trials respectively), and a work duration-matched Wingate-SIE (8 × 30-s all-out sprints with 4-min passive recovery, SIE_{Win} trial). The accumulated exercise time at ≥ 80%, 85%, 90%, 95% and 100% of VO_{2max}, and maximum heart rate (HR_{max}) in the four trials were compared. During the 6-s SIEs, accumulated time spent at all selected high rates of VO_{2max} increased as recovery time decreased, whilst the SIE work rate decreased ($p < .05$). In SIE_{Win}, although the exercise lasted longer, the time spent at ≥90% VO_{2max} (74 ± 16 s) was significant less than that in SIE_{15} (368 ± 63 s, $p < .05$), yet comparable to that in SIE_{30} (118 ± 30 s, $p > .05$), and longer than that in SIE_{60} (20 ± 14 s, $p < .05$). The differences between the four trials in accumulated time at high percentages of HR_{max} were similar to those for VO_2, although the temporal characteristics of the increases in HR and VO_2 during the SIEs were different. In conclusion, the duration of the recovery interval in 6-s SIE protocols appears to be a crucial parameter when sprint interval training is prescribed to enhance aerobic capacity. Further, the SIE_{15} protocol may represent a potential alternative to 30-s SIE_{Win} in the development of time-efficient aerobic training intervention.

1. Introduction

High-intensity interval training appears to be more effective than continuous training in raising athletes' maximum oxygen uptake (VO_{2max}) to the trainable limit, as it allows athletes to tolerate metabolic loading at or close to maximum for a prolonged period of time.[1] Moreover, brief interval training regimes consisting of sprint interval exercises (SIE) are often adopted by athletes to enhance their endurance performance, and by recreationally active persons to improve cardiometabolic health including aerobic fitness, because of its time efficient.[2] A typical SIE protocol consisting of repeating four 30-s Wingate sprints interspersed with 4- or 4.5-min recovery intervals has been shown to tax the cardiorespiratory functional capacity of active individuals at above 80% during each interval.[3] It has been reported that Wingate-based sprint interval training elicits aerobic adaptations comparable to those resulting from continuous endurance training of moderate intensity, with training duration ≥ 30 min.[4]

Notwithstanding, a rather time-efficient interval training programme, in comparison to the Wingate regime, consisting of a further brief SIE protocol (10 x 6-s cycle sprint against 7.5% body mass with 60-s passive recovery) have been shown to improve the aerobic capacity and endurance performance markedly in tri-athletes.[5] Moreover, when the exercise time and work-rest ratio of the Wingate-based and 6-s sprint interval training regimes were matched, the two training regimes produced similar improvements

* Corresponding author. School of Physical Education and Sports, Macao Polytechnic Institute, Rua de Luis Gonzaga Gomes, Macao, China.
E-mail address: qdshi@ipm.edu.mo (Q. Shi).

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in self-paced 10-km time trial performance in active individuals.[6] However, whether the 6-s cycle SIE could be a potential alternative to the Wingate protocol in the development of time-efficient aerobic training intervention has not be investigated. It has been shown that in high-intensity interval training the load and duration of the work intervals determine the time spent at high percentages of VO_{2max}, a parameter which is crucial to eliciting aerobic adaptations to the training.[7,8] Although researchers continue to address the methodological variables of interval training that can affect the duration and degree of cardiovascular and metabolic stress that individuals can tolerate in a single session, it is not clear whether the time spent at high rates of VO_2 ($\geq$90% VO_{2max}) during a 6-s SIE protocol is a function of recovery duration *per se*. A recent study[9] reported that total exercise time above 80–95% VO_{2max} was comparable regardless of whether 2- or 4-min recovery intervals were used during an aerobic interval exercise (4 x 4-min runs at 90% of maximal aerobic velocity). However, such findings may not have implications for 6-s SIE protocols where the recovery interval is $\leq$ 60 s, as the haemodynamic and metabolic challenges, and the dominant sources of energy during the exercise, are apparently different from those in aerobic interval exercise.

The purpose of this study was to compare the time spent at high rates of VO_2 ($\geq$80% VO_{2max}) under three SIE protocols in which the load and duration of the work interval were identical (40 × 6 s all-out sprints) but the duration of the recovery interval duration varied (15-s, 30-s or 60-s passive recovery). The temporal characteristics of the increase in VO_2 elicited by the three 6-s SIE protocols were also compared with those for a Wingate-based SIE protocol (8 × 30-s all-out sprints with 4-min passive recovery) in which the total work interval duration was matched to that of the four SIE protocols. It was hypothesised that time spent at high rates of VO_2 during a single bout of 6-s SIE would be a function of recovery interval duration, and that the time efficiency of the 6-s SIE protocol for inducing strenuous aerobic demand was higher than that of the work duration-matched Wingate-based SIE protocol.

2. Method

2.1. Research design

In this study, participants performed four single SIE sessions on a Wingate testing cycle ergometer (Monark 894 E, Stockholm, Sweden) on separate days. In three of the SIEs, participants performed 40 x 6-s all-out sprints interspersed with 15-s (SIE_{15}), 30-s (SIE_{30}) or 60-s (SIE_{60}) of passive recovery. The remaining session was a Wingate-based SIE consisting of 8 × 30-s all-out sprints with 4-min passive recovery intervals (SIE_{Win}), performed on the same ergometer. In all SIEs, the ergometer resistance was set at 7.5% of the participant's body mass. The order in which the four SIE trials were performed was counterbalanced and the assignment of participants to orders was random. The accumulated time spent at $\geq$ 80%, 85%, 90%, 95% and 100% of VO_{2max} and HR_{max} were compared across the four trials.

2.2. Participants

Thirteen male athletes [age: 26.2 ± 6.2 yrs, height: 172.8 ± 7.3 cm, weight: 60.8 ± 3.8 kg, VO_{2max}: 61.3 ± 9.1 ml min^{-1}·kg^{-1}, maximum heart rate (HR_{max}): 164.9 ± 8.1 beat·min^{-1}] who had been engaged in long-distance running for over five years participated voluntarily. The sample size was computed based on the formula $n = \sigma^2 (-z_0+z_1)^2/(\mu_0-\mu_1)$[2,10] where the mean differences (μ_0-μ_1) and standard deviation (σ) were estimated from pilot testing results. Alpha and power level were set at 0.05 and 0.9, respectively. z_0 is the critical value for effect size under the null distribution and z_1 is the critical value associated with the alternative distribution.

The participants had no familial history of cardiovascular disease and were not taking any cardiovascular medication. Moreover, none had prior experience of nutritional or ergogenic supplements. Following an explanation of the purpose and requirements of the study, participants gave written informed consent. Study approval was obtained from the Research Ethics Board, University of Macau.

2.3. Preliminary and familiarization trials

First, the participants' physical characteristics were measured. Body mass was measured using a bioelectrical impedance analyser (InBody 720, Biospace, Tokyo, Japan) and used to determine the resistance used in subsequent SIE tests. Next, participants were familiarised with the all-out SIE protocols over two days.

During the experimental period, all participants were asked to maintain their daily activity as well as their training load and volume, and avoid altering their eating habits. Participants were asked to refrain from eating and participation in strenuous physical activity for, respectively, at least 2 h and one day before trials. All experimental trials were performed under identical, controlled laboratory conditions (temp: 22 °C, RH: 75%). All trials were scheduled to occur at the same time of day and were separated by at least five days.

2.4. Graded exercise test

The test was carried out on an electronically braked cycle ergometer (Monark 839E, Stockholm, Sweden). Following a 3-min warm-up at 25 W, the test started with an initial work rate of 50 W. Participants were asked to maintain a pedalling cadence of 60 rpm, and the power was increased by 25 W every minute, until volitional exhaustion. Metabolic data were recorded during the test using the Metamax 3B gas analysis system (Cortex, Leipzig, Germany) and HR was monitored using a Polar HR sensor (H3, Finland). Ten-s means were calculated and the highest values were the maximal. Participants were assumed to have achieved their VO_{2max} when they met any three of the following criteria: 1) apparent exhaustion; 2) plateau in VO_2, ΔVO_2<2.1 ml kg^{-1}·min^{-1} regardless of increase in workload; 3) HR_{max} >90% of the predicted maximum (220 - age); 4) respiratory exchange ratio $\geq$1.15.

2.5. Sprint interval exercise test

All SIE trials consisted of a standardised warm-up exercise consisting of 5-min cycling exercise at 60 W, five 6-s cycle sprints at progressively increasing speed and 5-min of stretching. During the SIE recovery intervals, participants remained seated but stationary on the cycle ergometer. During the last 5 s of each recovery interval participants were given a 5-s countdown and in the last 2 s they were instructed to accelerate from a stationary start with minimum friction applied to the flywheel. At the start of the work interval, the preset load was applied instantaneously with an electromagnetic device. Participants remained seated whilst cycling and their feet were secured to the pedals using toe clips. Verbal encouragement was given throughout each sprint to ensure all-out effort. Power output in each sprint was recorded using Monark Anaerobic Test Software (3.0, Stockholm, Sweden) with a preset sampling rate of 50 Hz. VO_2 and HR were recorded throughout the exercise using the Metamax 3B system and Polar HR sensor, respectively. Immediately after exercise, participants used the Borg scale (6–20) to provide ratings of perceived exertion (RPE). Five-s VO_2 means were plotted against exercise time. Horizontal lines at 80%, 85%, 90%, 95%, and 100% of VO_{2max} were drawn on the graph. The total time spent at