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Scheduling Sprint Interval Training at a Constant Rather Than Variable Time of Day Does Not Influence the Gains in Endurance Performance

Original Research

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Abstract

Introduction: The benefits of consistently exercising at the same time of day are currently unknown. The endurance benefits (10km cycle time-trial) of sprint interval training (SIT) were compared when SIT (six sessions of 4-to-7 x 30-second sprints) was completed at a constant or variable time of day.

Methods: Twenty-six adults were assigned to a training schedule: Constant- training and pre/post (Post1) time-trials occurred at a fixed time of day; Variable- training never occurred within 6-hours of the time of day of the previous session; post-SIT time-trials (Post1) for the Variable group were completed at the same time of day as pre-SIT time-trials. A second post-SIT time-trial (Post2) occurred ≥6-hours earlier/later than the time of day of (Post1).

Results: The coefficient of variation of oral temperature, measured prior to each SIT session, was greater (P=0.02) in the Variable compared with the Constant group. SIT improved time-trial performance (P<0.001) at Post2; the magnitude of improvement was not different between schedules (Constant: Pre 1158±164, Post1 1144±165, & Post2 1124±146 s *vs.* Variable: Pre 1216±136, Post1 1189±130, & Post2 1165±121 seconds (mean±SD); group-x-training P=0.646).

Conclusions: Consistently training at the same time of day does not appear to be a critical consideration when scheduling regular exercise.

Key Words: circadian, time-trial, zeitgeber

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Introduction

Exercise chronophysiology is a relatively new field of research that explores interactions between exercise timing and adaptation, and the potential role of exercise as a zeitgeber[1,2]. It has been suggested that some of the health and athletic performance benefits of regularly scheduled exercise may be mediated, in part, by entrainment of molecular clock genes and/or establishment of habitual healthy behaviors[3]. Reciprocally, the time of day and circadian phase during which exercise is performed may be an important physiological determinant of health and athletic adaptations[4-6], although not all studies support this notion[7,8]. In light of the many demands competing for attention in today's modern lifestyle, scheduling healthy behaviors, such as daily exercise, at or around the same time of day can be difficult. Further, it is not clear if scheduling daily exercise at or around the same time of day is critical to deriving the benefits of exercise. Accordingly, the purpose of this study was to compare the endurance benefits of short-term sprint interval training (SIT) when SIT was completed at a constant or variable time of day. Our rationale for the choice of short-term SIT as our training intervention was based on multiple studies that have demonstrated appreciable endurance benefits after only two weeks or less[9-15]. Based on the potential for regularly scheduled exercise to evoke clock gene entrainment, we hypothesized that exercise scheduled at a constant time of day would elicit the greatest improvements in endurance performance.

An additional exploratory aim pertained to timing of the assessment of endurance performance. When designing experiments, to decrease trial-to-trial variability, many investigators schedule post-intervention exercise testing (such as assessment of maximal oxygen uptake (VO_{2max}), time-trials, time-to-exhaustion, etc.,) at, or around, the same time of day as pre-intervention exercise testing. Additionally, with view to sport and competition, it has been previously demonstrated that cycling performance in an early morning, laboratory-based cycle time-trial was improved by morning exercise the day before, but not by exercise the afternoon before[4]. Further, some athletes perform best when their habitual training time is the same as their competition time[6]. Thus, the second and exploratory aim of the current investigation was to compare the improvements in endurance performance when assessed at the same time of day as pre-training *vs.* six or more hours earlier/later. We hypothesized that the largest magnitude of improvement in endurance performance would be evident when the post-training assessment was conducted at the same time of day as training and pre-training assessment.

Methods

Participants

Healthy, recreationally active men and women, aged 18-50 years, were invited to participate. Exclusion criteria included employment that required shift work, and contra-indications to exercise as reported via a medical history questionnaire and/or identified during a graded exercise test incorporating 12-lead electrocardiogram assessment and indirect calorimetry (Parvo Medics, Sandy, Utah, USA). All study procedures were approved by the local Institutional Review Board; all participants provided written informed consent prior to study initiation.

Protocol

Participants completed six sessions of cycle ergometer SIT over a period of two weeks. Prior to and following SIT, endurance performance was assessed using a laboratory-based cycle ergometer time-trial, and body composition was determined using dual energy x-ray absorptiometry (Hologic, Discovery W, QDR Series, Bedford, Massachusetts, USA). Participants were randomly assigned to one of two training conditions: (1) Constant, in which all training occurred at a fixed time of day that was not necessarily the same time for each participant; or, (2) Variable, in which all training was scheduled such that each session never occurred within 6-hours of the time of day of the previous session. All participants completed two post-SIT time trials: Post1 was completed the day after the final SIT session, at the same time of day as pre-SIT time trial. Post2 was completed at a time of day a minimum of 6-hours earlier/later than the time of day of the first post-SIT time trial and was usually completed two days after Post1.

Sprint Interval Training

SIT consisted of six sessions of 4-to-7 x 30-second sprints on a stationary, electromagnetically braked, computer-controlled cycle ergometer (Dynafit Velotron; Racermate Inc., Seattle, Washington, USA) completed over two weeks, as per previous studies[9,12]. Flywheel resistance was equivalent to 7.5% body mass. Each sprint was separated by 4-minutes of low-intensity active recovery (e.g. loadless cycling and/or brief walking within lab).

Core Temperature Fluctuation

Core temperature influences anaerobic power output and reflects circadian rhythm[16]. To document lower circadian variation in the Constant *vs.* Variable group, prior to each SIT session, resting core temperature was estimated using an electronic oral thermometer (SureTemp Plus 690; Welch Allyn, Milwaukee, Wisconsin, USA) and the coefficients of variation in SIT session-to-session body temperature, ((standard deviation/mean) x 100%), were compared.

Endurance Performance

Participants completed stationary cycle ergometer exercise, equivalent to 10-km, as quickly as possible. During the time-trials, feedback pertaining to distance cycled was provided but all time cues were hidden. Heart rate and ratings of perceived exertion were determined after cycling 2, 4, 6, 8 and 10 km. Prior to the pre-SIT time trial, participants completed two practice time-trials for the purpose of protocol habituation (H1 and H2).

Statistical Analysis

Statistical analysis was completed using commercially available software (SigmaStat 3.0, Systat Software Inc., San Jose, CA, USA). Two-way analysis of variance (training condition x Pre/Post1/Post2 SIT) with repeated measures (Pre/Post1/Post2 SIT) was used to investigate changes in endurance performance and body composition. The data pertaining to the coefficients of variation of body temperature were not normally distributed, thus between group differences were explored using the non-parametric Kruskal-Wallis one-way analysis of variance on ranks. All data are presented as mean and standard deviation, unless otherwise stated. The level of statistical significance was set at $P<0.05$.

Results

Baseline physiological characteristics, together with pre/post SIT body composition data are presented in Table 1. Following SIT, there were no changes in body composition (all main effects of SIT: $P>0.20$; all group x SIT interactions $P>0.30$) with the exception of an increase in leg lean mass (main effect of SIT $P=0.02$; group x SIT interaction $P=0.94$).

Table 1. Baseline physiological characteristics, and body composition determined pre/post sprint interval training (SIT).

	CONSTANT PRE-SIT	CONSTANT POST-SIT	VARIABLE PRE-SIT	VARIABLE POST-SIT
SEX (MALE/FEMALE**)**	8/4	-	8/6	-
AGE (YEARS)	25 ± 9	-	21 ± 2	-
HEIGHT (M)	1.72 ± 0.13	-	1.71 ± 0.07	-
BODY MASS (KG)	73.6 ± 11.8	73.6 ± 11.8	71.3±11.2	71.5±11.2
BMI (KG/M²)	24.7±2.1	24.7±2.1	24.5±3.4	24.5±3.4
VO_{2PEAK} (ML/KG/MIN)	49.0±9.4	-	41.9±7.1	-
FAT MASS (KG)	18.0±3.5	17.6±3.3	18.6±5.6	18.4±5.2
%BODY FAT	24.9±5.7	24.3±5.3	25.6±5.9	25.6±5.4
LEAN MASS (KG)	53.1±11.1	53.5±11.0	50.5±8.2	50.7±8.4
LEG LEAN MASS (KG)*	18.3±3.9	18.7±4.0	17.0±2.7	17.4±2.7

Data are Means ± SD

BMI: Body Mass Index. VO_{2peak}: Peak oxygen uptake.

* Denotes main effect of SIT ($P=0.02$)

Sprint Interval Training

The timing of all activities, including SIT sessions are presented in Figure 1. All SIT sessions were scheduled to begin between 06:00 and 22:00. By design, timing of the start of each session was irregular in the Variable compared with the Constant group. Consistent with this design, the coefficient of variation of oral temperature was greater (P=0.02) in the Variable (mean: 0.97%; median: 0.80%; inter-quartile range: 0.49%) compared with the Constant group (mean: 0.56%; median: 0.52%; inter-quartile range: 0.37%).

Endurance Performance

Individual time-trial performance data are presented in Figure 2. SIT improved time trial performance (main effect $P<0.001$) but only when the time trial did not occur at the same time of day as training (i.e. only at Post2); the magnitude of improvement was not influenced by whether the training was completed at a constant or variable time of day (Constant: Pre 1158 ± 164, Post1 1144 ± 165, & Post2 1124 ± 146 s vs. Variable: Pre 1216 ± 136, Post1 1189 ± 130, & Post2 1165 ± 121 seconds; group x training interaction $P=0.646$). Time trial performance at Post1 was not different from Pre (mean difference: 21.3 s; $P=0.11$) or Post2 (mean difference: 22.1 s; $P=0.09$). Time trial performance at Post2 was faster than Pre (mean difference: 43.5 s; $P<0.001$). Heart rates and ratings of perceived exertion were similar across all time trials (data not shown; $P>0.10$).

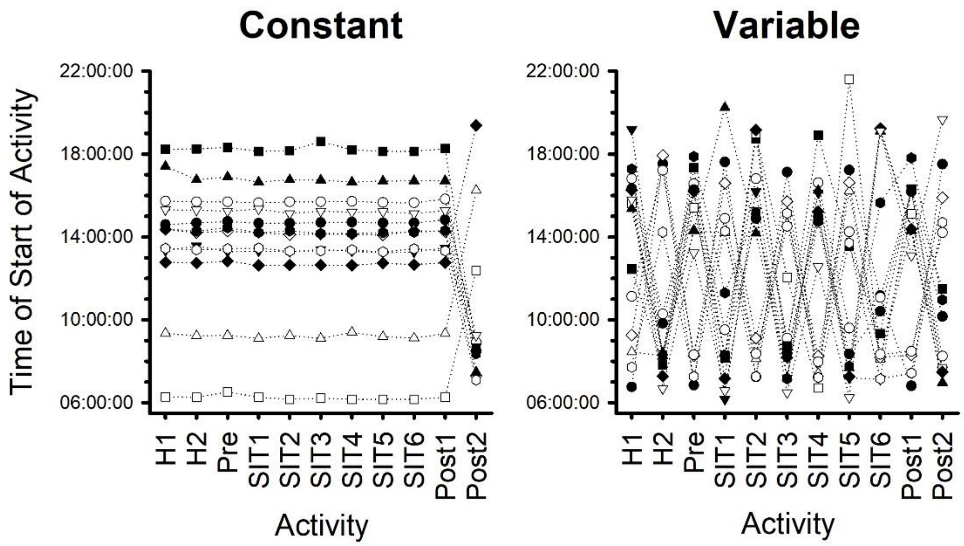

Figure 1. The time of day at which each activity began for each research participant. H1 and H2 refer to habituation (familiarization) time-trials. Pre refers to the time-trial completed prior to sprint interval training. Post1 refers to the time-trial completed the day following the final session of sprint interval training and at the same time of day as Pre. Post 2 refers to the time trial completed after sprint interval training at a time six hours earlier/later than Pre. SIT refers to the individual sessions of sprint interval training.

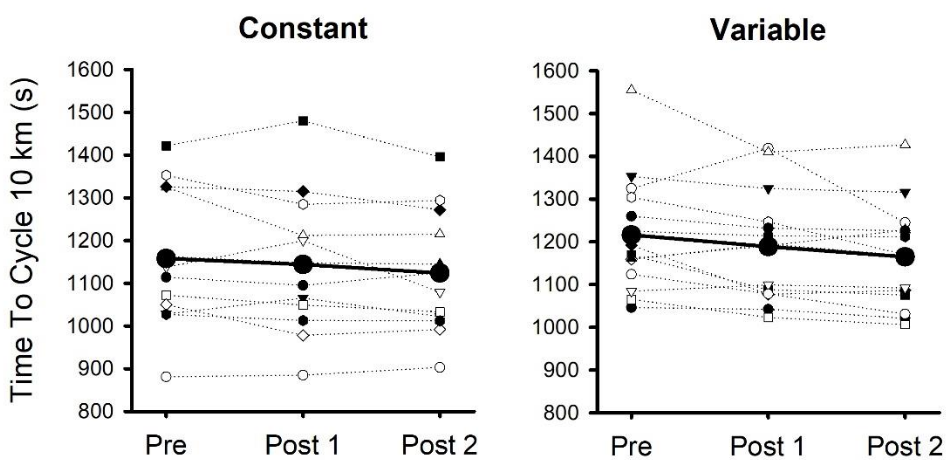

Figure 2. The time taken to complete stationary cycle ergometer exercise equivalent to 10-km. Post1 was completed the day after the final SIT session, at the same time of day as pre-SIT time trial. Post2 was completed at a time of day a minimum of 6-hours earlier/later than the time of day of the first post-SIT time trial. SIT improved time trial performance (main effect $P<0.001$) but only when the time trial did not occur at the same time of day as training (i.e. Post2); the magnitude of improvement was not influenced by whether the training was completed at a constant or variable time of day (group x training interaction $P=0.646$). Time trial performance at Post1 was not different from Pre ($P=0.11$) or Post2 ($P=0.09$). Time trial performance at Post2 was faster than Pre ($P<0.001$).

Discussion

The primary purpose of this study was to compare the endurance benefits of short-term SIT when SIT was completed at a constant or variable time of day. Our data suggest that scheduling exercise at a constant time of day may not be an important determinant of the gains in endurance performance. The second and exploratory aim was to compare the improvements in endurance performance when assessed at the same time of day as pre-training *vs.* six or more hours earlier/later. Contrary to our hypothesis, it may not be necessary to schedule post-intervention endurance performance assessments at the same time as pre-intervention assessments, although we believe this second interpretation warrants further consideration.

Our rationale for scheduling Post1 the day immediately after the final SIT session was based on a previous observation that a single bout of exercise performed at the same time as competition, the day beforehand, bestowed a time-trial performance benefit[4]. The implication being that an athletically/physiologically relevant entrainment may have been evoked after only one training session. In the current investigation, it is plausible that 24-hours may have been insufficient to recover from the considerable exertion typically associated with SIT. Indeed, in the previous study[4], the exercise completed the day before competition was moderate, comprising only of 30-minutes of stationary cycling at 60% VO_{2peak}. In contrast, in the current investigation, the exercise comprised four 30-second "all-out" sprints on a cycle ergometer with a heavily weighted flywheel. When comparing the magnitudes of improvement above baseline time-trial performance between Post1 and Post2 (21 *vs.* 43 s, respectively; main effect P=0.03), the research participants potentially benefitted from the additional day of recovery from SIT. Thus, we recommend caution when scheduling post-intervention exercise assessments and suggest it may be prudent to continue keeping the timing of assessments constant until further exploration of the issue has been completed. From the perspective of the athlete, exercising the day before at the same time of competition may provide a performance benefit[4] if the exercise is moderate.

Pertinent to our primary aim, to the best of our knowledge this is the first study to empirically demonstrate scheduling exercise training at a constant rather than a variable time of day does not appear to influence the potential gains in endurance performance and leg lean mass. It has been suggested that the benefits of exercise may, in part, be mediated by entrainment of molecular clock genes[1,17]. A variety of physiological functions, including control of body energy balance, blood glucose and blood pressure[18,19] are regulated by expression of genes that in turn may be controlled by molecular clock genes[20]. Regularly scheduled exercise is a powerful modulator of the clock genes[21,22], and in some instances has been shown to restore function in rodent models of circadian disruption[23]. Intuitively, habitual exercise at a constant time of day, within the same circadian phase, should provide a powerful entrainment stimulus to the molecular clocks. However, our data suggest that when completed in variable circadian phases, as reflected by the session-to-session variability in core temperature, SIT was able to bestow appreciable endurance benefits that did not differ in magnitude to those provided by SIT completed at a constant time of day.

One potentially important consideration, in the current study we did not take into account an overall circadian influence (i.e. exercise during the morning *vs.* the afternoon/evening), nor did we formally consider the personal preference of each of the research participants with respect to timing/scheduling of exercise. The majority of participants assigned to the Constant schedule completed their training after noon, while those assigned to the Variable schedule, by design, exercised across all times of the day. For superior athletic gains, the evidence in support of regular exercise in the morning vs. afternoon/evening is unclear as several studies have not demonstrated a superior time for the scheduling of training[8,24-29]. Nevertheless, a potential circadian influence cannot be disregarded. Intuitively, one might also assume that scheduling regular exercise at a preferred time of day, rather than just an available time of day, might promote adherence and potentially augment benefits. In the current study, compliance was equally excellent (100%) in both groups, and although not formally examined in a balanced fashion (i.e. matched distribution of participants exercising at preferred vs. non-preferred times), preference for the scheduling of exercise did not appear to influence training outcomes. We suggest that notable differences in adherence are perhaps more likely to be evident for longer-term training (i.e. months not weeks) and that scheduling preference might be something to consider in future studies.

The current study examined whether exercise scheduled at a constant vs. variable time of day would elicit the greatest improvements in endurance performance. Our observations may have several important implications for the design of exercise training/intervention studies and for public health. With the caveat that we studied the influence of a very specific type of exercise training (i.e. SIT) on a very specific outcome (i.e. time-trial performance), scheduling exercise at a constant time of day may not be an important determinant of the beneficial outcomes; exercise at any time(s) of the day should be encouraged.

Media-Friendly Summary

In light of the many demands competing for our attention in today's modern lifestyle, scheduling healthy behaviors, such as daily exercise, at or around the same time of day can be difficult. The purpose of this study was to compare the endurance benefits of short-term sprint interval training when the training was completed at a constant or variable time of day. Sprint interval training improved performance of a laboratory based 10-km time trial on an exercise bike, irrespective of whether it was completed at a constant or variable time of day. From a public health perspective, scheduling regular exercise at or around the same time of day does not appear to be important for obtaining endurance benefits.

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