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AUTHOR
Glaister, Mark; Witmer, Chad; Clarke, Dustin W.; et al.

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Familiarization, Reliability, and Evaluation of a Multiple Sprint Running Test Using Self-Selected Recovery Periods

[1]MARK GLAISTER, [2]CHAD WITMER, [2]DUSTIN W. CLARKE, [2]JOHN J. GUERS, [2]JUSTIN L. HELLER, AND [2]GAVIN MOIR.

Affiliation

[1]School of Human Sciences, St Mary's University College, Strawberry Hill, Twickenham, UK; [2]School of Health Sciences & Human Performance, East Stroudsburg University, Pennsylvania, USA

Corresponding Author:

Dr M Glaister

School of Human Sciences

St Mary's University College

Waldegrave Road

Strawberry Hill

Twickenham, UK.

Phone: 0208 240 4012

Fax: 0208 240 4255

E-mail: Glaistem@smuc.ac.uk

Brief running head: Reliability of self-selected recovery

ABSTRACT

The aims of the present study were to investigate the process of self-selected recovery in a multiple sprint test with a view to using self-selected recovery time as a means of reliably quantifying an individual's ability to resist fatigue in this type of exercise. Twenty physically active exercise science students (Means ± standard deviation for age, height, body mass, body fat, and VO_{2max} of the subjects were: 21 ± 2 years, 1.79 ± 0.09 m, 83.7 ± 10.8 kg, 16.6 ± 3.9%, and 52.7± 7.2 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively) completed four trials of a 12 × 30 m multiple sprint running test under the instruction that they should allow sufficient recovery time between sprints to enable maximal sprint performance to be maintained throughout each trial. Mean recovery times across the four trials were 73.9 ± 24.7 s, 82.3 ± 23.8 s, 77.6 ± 19.1 s, and 77.5 ± 13.9 s respectively; with variability across the first three trials considered evidence of learning effects. Test-retest reliability across trials 3-4 revealed a good level of reliability as evidenced by a coefficient of variation of 11.1% (95% likely range: 8.0 to 18.1%) and an intraclass correlation coefficient of 0.76 (95% likely range: 0.40 to 0.91). Despite no change in sprint performance throughout the trials, RPE increased progressively and significantly ($p < 0.001$) from a value of 10 ± 2 after sprint 3 to 14 ± 2 after sprint 12. The correlation between relative VO_{2max} and mean recovery time was 0.14 (95% likely range: -0.37 to 0.58). The results of the present study show that following the completion of two familiarization trials, the ability to maintain sprinting performance in a series of repeated sprints can be self-regulated by an athlete to a high degree of accuracy without the need for external timepieces.

Key words: RSA, intermittent, perceived recovery, multiple sprint work

INTRODUCTION

Tests of multiple sprint performance are a popular means of evaluating the performance capabilities of athletes involved in field and court sports. Based on the results of several time-motion analyses, these tests have typically comprised of several ($5 \leq n \leq 20$) short (≤ 6 s) sprints interspersed with relatively short (≤ 60 s) passive recovery periods (15). The key performance determinants arising from these tests are: a) the ability to produce a high sprint speed; and b) the ability to resist fatigue and thereby maintain a high sprint speed for the duration of the test. Whilst measures of the former have been shown to have good test-retest reliability; the same is not true of the latter (6,9). In fact, of eight different approaches used to quantify fatigue in multiple sprint work, the best only gives a test-retest coefficient of variation (CV) of around 30% (11).

Since the recovery of sprint performance is an aerobic process, it follows that individuals with a high level of aerobic fitness should have an enhanced capacity to recover between sprints (7). However, whilst there is some evidence that endurance-trained athletes display less fatigue in multiple sprint tests than team-sport players (1,12) the effects of endurance training on repeated sprint ability are inconclusive (5,10). Similar contradictions exist in the results of investigations into the relationship between one of the key parameters of endurance fitness, namely maximal oxygen uptake (VO_{2max}), and fatigue during multiple sprint work (7). Since many of these discrepancies may be the result of the large variability associated with fatigue measures, an alternative and somewhat radical approach to address this problem may be to allow individuals to choose their own recovery time in a multiple sprint test, based on individual perceptions of recovery, and to use mean recovery time as an index of fatigue. In effect, it is anticipated that those individuals with the highest levels of fatigue would typically choose the longest recovery times.

Given the relatively novel nature of the above approach, the aims of the present study were threefold: First, if individuals are able to accurately predict their own recovery time, it was important to investigate if there were any learning effects associated with the process. Secondly, it was important to establish how reliable self-selected recovery is once any of the aforementioned learning effects have been reconciled, particularly if this approach is to be used as a routine means of evaluating repeated sprint ability. Thirdly, if the duration of self-selected recovery was indeed related to an individual's level of aerobic fitness, it was important to evaluate the magnitude of that relationship.

METHODS

Experimental Approach to the Problem

To provide sufficient data for familiarization and reliability analysis, all subjects completed four trials of the multiple sprint test, which consisted of 12 x 30 m straight-line sprints on an indoor synthetic running surface. Following completion of the multiple sprint trials, subjects completed a graded exercise test on a motorised treadmill (Q-Stress TM55: Quinton Inc., Bothell, WA, USA) to evaluate the relationship between self-selected recovery time and VO_{2max}. All trials were completed at approximately the same time of day with seven days between trials 1 and 2 (to allow recovery from any initial post-exercise muscle soreness) and a minimum of 48 hours between the remaining trials. Subjects were instructed to avoid food and drink in the hour before testing and to avoid strenuous exercise and caffeine consumption 24 hours before each trial. Heart rate and ratings of perceived exertion (RPE) were recorded through each multiple sprint trial to provide an indication of physiological and psychological strain, respectively.

Subjects

20 male Exercise Science students volunteered for the study, which was approved by St Mary's University College Ethics Committee and the Institutional Review Board (for the use of Human Subjects) of East Stroudsburg University. Prior to testing, subjects received written and verbal instructions regarding the nature of the investigation and completed a training history questionnaire, which indicated that all had been actively involved in sport for approximately 14 years and that most (n = 16) regularly participated in some form of multiple sprint sport. Mean times spent training and competing each week were reported as 8.9 ± 4.1 hours and 8.0 ± 4.9 hours, respectively. Prior to commencement, all subjects completed a health-screening questionnaire and provided written informed consent. Means ± standard deviation (SD) for age, height, body mass, body fat (4), and VO_{2max} of the subjects were: 21 ± 2 years, 1.79 ± 0.09 m, 83.7 ± 10.8 kg, 16.6 ± 3.9%, and 52.7 ± 7.2 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively.

Procedures

Prior to each multiple sprint test, subjects performed a standardized warm-up (approximately five-minutes) comprising 400 m of jogging (self-selected pace), a series of sprint drills (3 x 10 m each of high-knees, heel-flicks, and walking lunges), and three practice sprints. Following the warm-up, subjects were given five minutes to stretch and prepare themselves for the multiple sprint test. Each sprint was initiated from a line 30 cm behind the start line (to prevent false triggering of the first timing gate) and all sprint and recovery times were recorded electronically via twin-beam photocells (Swift Performance Equipment, Lismore, Australia) placed at each end of the 30 m runway. This equipment has been shown to have very good test-retest reliability (CV = 1.51%; ICC = 0.91) (9). Alternate sprints were performed in the opposite direction to enable subjects to maximize the passive recovery time between sprints. Prior to the start of each trial, subjects were instructed to perform each sprint with maximal effort and to allow sufficient recovery time between sprints to enable performance to be maintained such that Sprint 12 was as fast as Sprint 1. All timepieces were removed from the testing environment so that subjects had no external reference of recovery time. Heart rate was monitored throughout each trial (Polar Accurex Plus: Polar Electro Oy, Kempele, Finland), with RPE recorded after every three sprints using a 15-point scale (2). Fatigue during each trial was calculated from 30 m sprint times using the percentage decrement calculation (6):

Percentage decrement calculation

Fatigue = (100 x (total sprint time ÷ ideal sprint time)) – 100

Where:

Total sprint time = sum of sprint times from all sprints.

Ideal time = number of sprints × fastest sprint time.

Following the multiple sprint test, subjects completed the graded exercise test, which commenced with a five minute warm-up at 8 km·h^{-1} on a 1% gradient. After a further five minute rest period the test began, again on a 1% gradient and at a speed estimated to achieve exhaustion in 8 to 15 minutes. Every minute during the test the treadmill gradient was increased by 1% until subjects reached volitional exhaustion. During the tests respiratory gases were analysed breath-by-breath using an online gas analyser (TrueOne 2400: Parvomedics, Sandy, UT, USA), which was calibrated before every test in accordance with the manufacturer's instructions. VO_{2max} was determined as the highest 30 s average VO_2 observed during the test provided that at least two of the following criteria had been met:

- A plateau in VO_2; as determined by an increase of less than 2 ml·kg^{-1}·min^{-1} over the previous stage
- A RER ≥ 1.15
- A heart rate within 10 b·min^{-1} of age predicted maximum
- A RPE ≥ 19

Statistical Analyses

All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS for Windows, SPSS Inc., Chicago, IL, USA). Measures of centrality and spread are presented as means ± SD. The process of familiarization was examined in three ways: First, since recovery time was only relevant if subjects were able to maintain sprint performance, the ability of subjects to achieve this goal was quantified by the attainment of two criteria:

1. The absence of an obvious pattern of fatigue.
2. A within-trial CV ≤ 2.02% (the upper confidence limit of the CV of fastest sprint time in this type of exercise [9]).

In effect, if subjects were not able to achieve the above criteria in the early trials, this was considered evidence of learning effects.

Secondly, learning effects were evaluated from between-trial differences in mean recovery time assessed via a one-way analysis of variance (ANOVA). Thirdly, learning effects were evaluated by examining changes in the reliability of mean recovery time between consecutive pairs of trials using a two-way ANOVA as described by Schabort *et al.* (14), with mean recovery time as the dependent variable in each model, subject number included as a random effect, and trial number as a fixed effect.

After determining the number of trials required to limit the effects of familiarization and after eliminating those subjects who had failed to maintain sprinting performance on every trial, reliability was evaluated across the remaining trials, again using a two-way ANOVA, with measures of reliability determined as CV and intraclass correlation coefficients (ICC). 95% confidence limits for CV and ICC were calculated using chi square and McGraw and Wong (13) estimates, respectively.

The pattern of the recovery times and the RPE responses was investigated by performing a one-way repeated measures ANOVA on Trial 4, with a Pearson correlation used to investigate the relationship between VO_{2max} and mean recovery time. Correlation coefficients were interpreted in accordance with the following scale of magnitudes as devised by Cohen (3): $r < 0.1$ is trivial; $0.1 \leq r < 0.3$ is small; $0.3 \leq r < 0.5$ is moderate; $r \geq 0.5$ is large. Significant main effects for all ANOVA were followed up using Bonferonni adjustments. α was set at 5% for all analyses.

RESULTS

Familiarization

The number of subjects failing to meet the absence of fatigue criteria during trials 1 – 4 were 9, 10, 5, and 3, respectively. However, despite the trend for an increase in mean self-selected recovery time between trials 1 and 2 and a subsequent decrease between trials 2 and 3 (Table 1), the difference in mean recovery time between trials was not statistically significant ($F_{(2.07,39.35)} = 2.101$; $p = 0.134$). Nevertheless, between-trial test-retest reliability revealed better reliability between trials 2 – 3 and 3 – 4, than between trials 1 – 2 (Table 2). To err on the side of caution, familiarization effects were considered evident across the first two trials and therefore reliability of mean recovery time was evaluated across trials 3 – 4 after excluding those subjects (*n* = 5) who had failed to meet the required inclusion criteria in trial 3.

Table 1. Mean sprint times, recovery times, and fatigue data for 12 × 30 m sprints repeated at self-selected recovery periods (*n* = 20).

	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**
Sprint time (s)	4.47 ± 0.27	4.47 ± 0.24	4.44 ± 0.20	4.41 ± 0.20
Recovery time (s)	73.85 ± 24.65	82.28 ± 23.82	77.62 ± 19.14	77.53 ± 13.90
Fatigue (%)	3.3 ± 1.6	2.9 ± 1.1	2.2 ± 1.0	2.0 ± 0.6

Reliability

Test-retest reliability of mean recovery time across trials 3 – 4 (*n* = 15) revealed a good level of reliability as evidenced by a CV of 11.1% (95% likely range: 8.0 to 18.1%) and an ICC of 0.76 (95% likely range: 0.40 to 0.91).

Table 2. Reliability of mean recovery time for 12 × 30 m sprints repeated at self-selected recovery periods (n = 20). Values in parentheses are 95% confidence limits.

	Trials 1-2	**Trials 2-3**	**Trials 3-4**
CV (%)	12.3 (9.3 to 18.5)	9.9 (7.5 to 14.8)	9.9 (7.5 to 14.9)
ICC	0.87 (0.69 to 0.95)	0.88 (0.71 to 0.95)	0.83 (0.61 to 0.93)

Note: CV = coefficient of variation; ICC = intraclass correlation coefficient

Pattern of Recovery

The pattern of the self-selected recovery times is presented in Figure 1. Analysis of the recovery data revealed a significant effect of time ($F_{(4.13,66.12)}$ = 8.405; p < 0.001), with *post hoc* comparisons revealing significant differences only in those contrasts involving recovery times from the first two sprints. Analysis of within-subject recovery time revealed a mean CV of 17.0 ± 6.1% when considering recovery data from all 12 sprints, which reduced to 14.1 ± 6.0% when the first two recovery times were excluded from the analysis. The correlation between relative VO_{2max} and mean recovery time was 0.14 (95% likely range: -0.37 to 0.58).

RPE Responses

The pattern of perceived exertion throughout the multiple sprint protocol is presented in Figure 2. Despite no decline in multiple sprint performance across the trial, analysis of the RPE data revealed a significant effect of time ($F_{(1.26,20.19)}$ = 65.646; p < 0.001), with *post hoc* tests revealing significant (p < 0.001) differences between all contrasts.

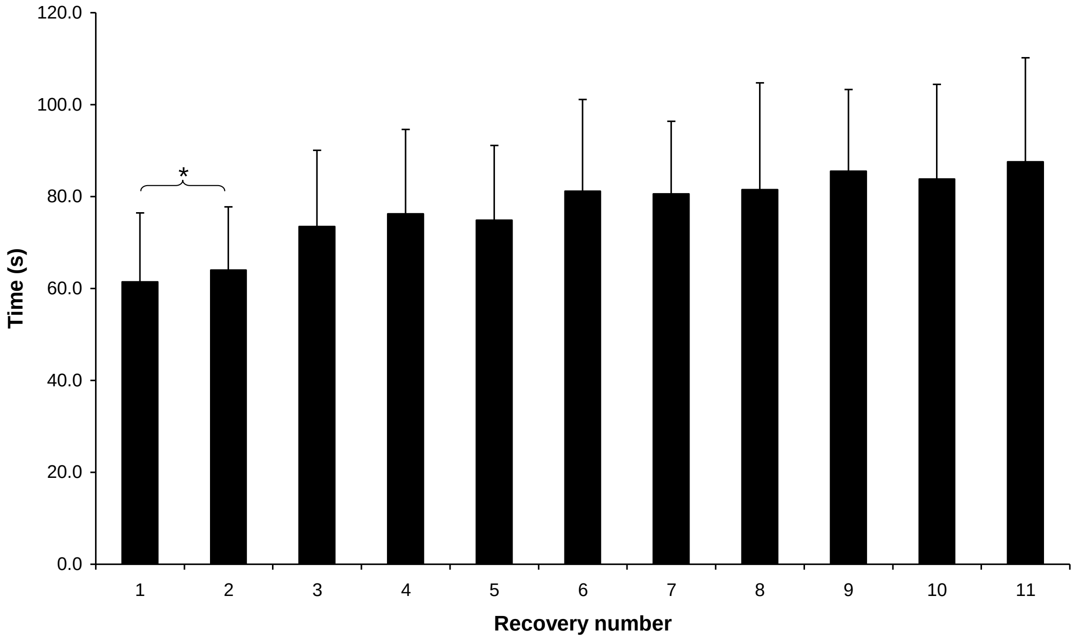

Figure 1. Self-selected recovery times from trial 4 of a 12 × 30 m multiple sprint running protocol (*n* = 17). Values are means; bars are standard deviations. *significantly different from remaining data.

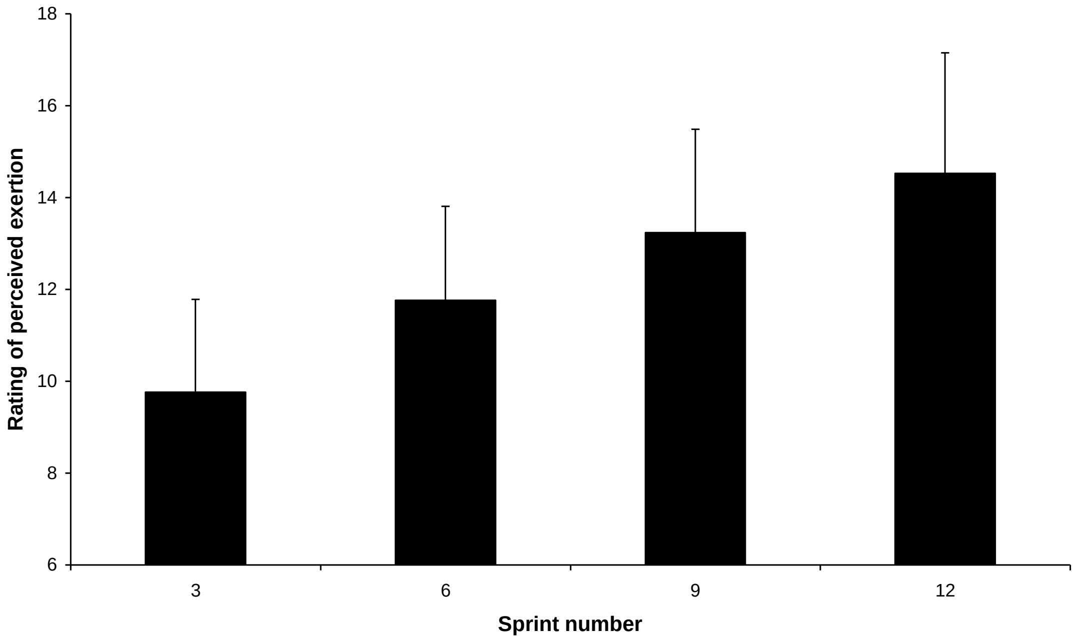

Figure 2. Ratings of perceived exertion during a 12 × 30 m multiple sprint running protocol (*n* = 17) using self-selected recovery periods. Values are means; bars are standard deviations.

Heart Rate Responses

The pattern of the heart rate response to the multiple sprint protocol is presented in Figure 3. Maximum heart rate during the multiple sprint tests was 171.2 ± 10.4 b·min^{-1}, with mean heart rate recovery between sprints being 27.1 ± 9.2 b·min^{-1}. Maximum heart rate during the VO_{2max} tests was 193.1 ± 8.5 b·min^{-1}.

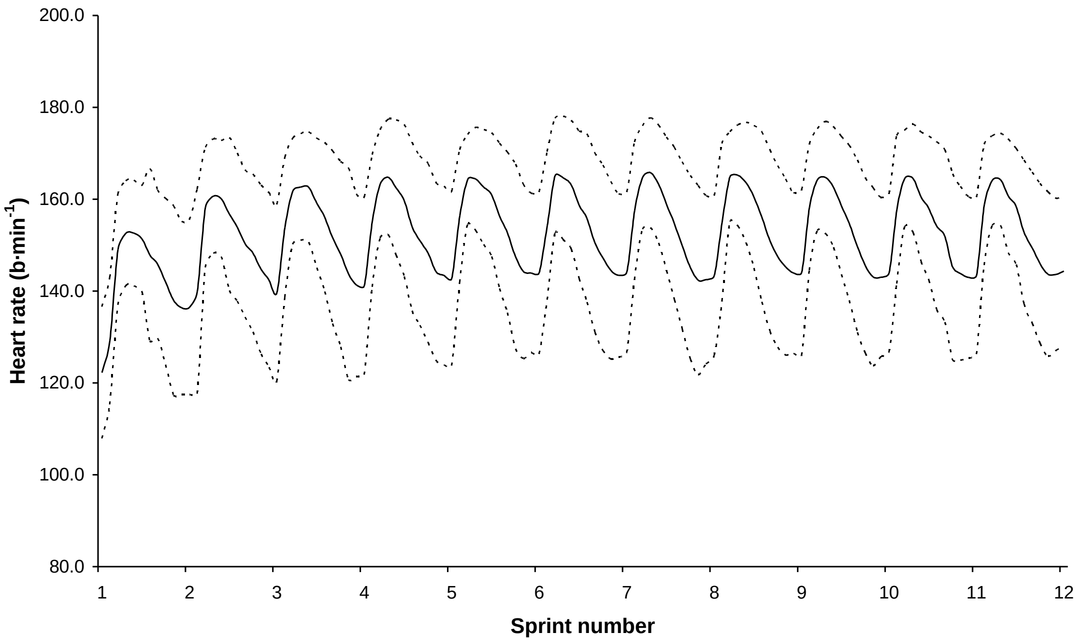

Figure 3. Heart rate response during a 12 × 30 m multiple sprint running protocol (*n* = 17) using self-selected recovery periods. Solid line represents the mean heart rate response; dashed lines represent standard deviations. Note: recovery heart rate data are presented as a percentage of total test time to allow direct comparisons between subjects.

DISCUSSION

The aims of the present study were to investigate the process of self-selected recovery in a multiple sprint test with a view to using self-selected recovery time as a means of reliably quantifying an individual's ability to resist fatigue in this type of exercise. Despite having no external reference of elapsed time, the results showed that following the completion of two familiarization trials, participants were able to maintain sprint performance with a relatively short and consistent recovery. These findings compare well with those of Glaister *et al.* (11) which showed a relatively small amount of fatigue in individuals performing 12 × 30 m sprints repeated at 65 s intervals, particularly when compared with the same protocol repeated at 35 s intervals. Nevertheless, despite the absence of fatigue in the present study, RPE values suggest that although individuals felt they had recovered sufficiently to enable sprint performance to be maintained, they were progressively finding the test more difficult. Given that subjects were instructed to give themselves sufficient recovery time to enable sprint performance to be maintained, it is difficult to elucidate on the reasons for this response or to speculate on what would have happened to performance if the number of sprints had been extended. It is however, possible that the steady increase in RPE reflected the fact that subjects were only just giving themselves sufficient recovery time based upon the fact that they knew the number of sprints they were required to perform. As such, increasing or decreasing the number of sprints may have resulted in the same RPE response across the trial.

The energetics of a sprint as short as that performed in the present study are reported to be fuelled primarily by phosphocreatine (PCr) degradation and anaerobic glycolysis, with the former providing the larger (~ 60%) contribution (7,15). As sprints are repeated, the ability to maintain performance is determined by the ability to return to homeostasis during the intervening recovery periods. Since PCr off-kinetics follow a biexponential pattern of resynthesis with peak resynthesis rates of around 1.3 mmol·kg dry muscle^{-1}·s^{-1} (16), it would appear that the recovery periods chosen by the subjects in the present study would have been sufficient to allow PCr to continue to make the same contribution to ATP provision throughout each sprint. Moreover, with such a relatively short time-course, anaerobic glycolysis would not be impaired by glycogen availability, although a corresponding increase in acidosis may have impaired the rate of ATP provision. Unfortunately, since neither muscle nor blood pH levels were evaluated in this investigation, this latter point remains speculative, and is an issue requiring further investigation. However, the idea of a progressive increase in acidosis is plausible given the magnitude of the glycolytic contribution to each sprint and the much slower rate of intramuscular pH recovery relative to that of PCr (7). Indeed, an increase in acidosis, along with a number of other mediating factors (such as muscle damage), also provide a possible explanation for the progressive increase in RPE observed throughout each test.

The duration of the recovery periods chosen by the subjects had a much more distinct effect on heart rate than the fixed, and considerably shorter, recovery periods used in previous research (8). In fact, in multiple sprint tests with 10 s recovery periods, the recovery of heart rate between sprints has been shown to be barely identifiable (8). However, despite individual differences in the duration of the recovery periods, the correlation between recovery duration and VO_{2max} was poor. In effect, although the rapid phase of post-exercise recovery is fuelled by aerobic metabolism (ATP and PCr resynthesis, and restoration of muscle and blood oxygen stores), those individuals with the greatest capacity to utilize oxygen did not typically choose the shortest recovery periods. One of the main limitations with this study is that the duration of the self-selected recovery periods was likely to have, in-part, been influenced by the sprinting ability of each subject. In effect, those subjects with the fastest sprint times were likely to have encountered the largest amount of physiologic/metabolic strain and as such required a longer recovery time compared with their less anaerobic counterparts, regardless of their level of aerobic fitness. Whilst this argument cannot be substantiated from the data collected in this investigation, it is a confounding factor which may explain why the correlation between recovery duration and VO_{2max} was lower than anticipated.

PRACTICAL APPLICATIONS

The results of the present study show that following the completion of two familiarization trials, the ability to maintain sprinting performance in a series of repeated sprints can be self-regulated by an athlete to a high degree of accuracy without the need for external timepieces. These findings have two main practical applications: First, for those athletes involved in multiple sprint sports, the use of self-selected recovery periods provides an alternative and reliable approach to quantifying an individual's ability to recover between sprints (and thereby resist fatigue) in this type of activity. Secondly, if the goal of a sprint training session is to maintain quality, the use of self-selected recovery periods provides coaches, who would otherwise use fixed recovery periods, with a way of maintaining that quality tailored to the ability of each athlete.

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