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Over-estimation of required recovery time during repeated sprint exercise with self-regulated recovery

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- 1 **Over-estimation of required recovery time during repeated sprint exercise with self-regulated**
- 2 **recovery.**
- 3

4 **Abstract**

5

6 This study investigated the reliability and accuracy of self-regulated recovery time and performance
7 during repeated sprinting. On four occasions, 14 men (24.5 ± 5.0 y) completed 10 x 6 sec cycle
8 sprints against 7.5% body mass, self-regulating (SR) recovery time to maintain performance.
9 Subjects then repeated the test but with a reduced recovery (RR) of 10% less recovery time. Across
10 the first four trials, there were no between-trial differences in peak power output (PPO) or mean
11 power output (MPO), recovery time, or fatigue index ($P > 0.05$). Random variation in recovery time
12 was reduced across trials 3-4 (CV = 7.5%, 95% confidence limits (CL) = 5.4-12.4%) compared to
13 trials 1-2 (CV = 16.0, 95% CL = 11.4 to 27.0%) and 2-3 (CV = 10.1%, 95% CL = 7.2 to 16.7%), but
14 was consistent across trials for PPO and MPO (between-trials CV \leq 3.3%). There were no trial
15 effects for any performance, physiological, or perceptual measures when comparing SR to RR ($P >$
16 0.05), although heart rate and perceptual measures increased with subsequent sprint efforts ($P <$
17 0.05). Following two familiarisation trials, subjects can reliably self-regulate recovery time to
18 maintain performance during repeated sprints. However, subjects overestimate the amount of
19 recovery time required as reducing this time by 10% had no effect on performance, perceptual or
20 physiological parameters. Self-regulated sprinting is potentially a reliable training tool, particularly
21 for sprint training where maintenance of work is desired. However, over-estimation of required
22 recovery time means that performance improvements may not be achieved if the goal of training is
23 improvement of repeated sprint performance with incomplete recovery.

24

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29 **Key Words:** pacing; power output; self-regulation; fatigue.

30

31 INTRODUCTION

32

33 Repeated sprint exercise is common across many sports and in experimental research (5,15,17).
34 Performance determinants evaluated in repeated sprint tests include speed or power output, and
35 fatigue resistance (18). Quantification of maximum sprint speed/power shows good test-retest
36 reliability (30). Conversely, the best method of quantifying fatigue index (FI) reports a coefficient of
37 variation (CV) of ~30% (16,17). This large variability may hamper understanding of regulatory
38 processes underpinning performance during, and improvements gained from, repeated sprint
39 exercise.

40

41 Pacing tactics may be employed before or soon after exercise begins in a feed-forward fashion, to
42 prevent significant homeostatic disturbance and premature exercise termination (29). Billaut et al.
43 (7) reported that prior knowledge of the required number of sprints influences power output during a
44 repeated sprint protocol, suggesting that anticipatory self-regulated (SR) pacing may happen during
45 repeated sprint exercise. However, self-regulation was confined to power production as the recovery
46 periods between sprints were fixed.

47

48 Glaister et al. (18) further investigated self-regulation of performance during 12 x 30 m running
49 sprints by allowing subjects to choose their own recovery time based on individual perceptions of
50 recovery. Following two familiarisation trials, subjects were able to self-regulate recovery to
51 maintain a consistent performance (mean CV for recovery time between sessions 3-4 of 9.9%).
52 Glaister et al. (18) suggested that these findings justify self-regulation of repeated sprinting as a
53 reliable tool for individuals to quantify their level of fatigue and maintain the quality of repeated
54 sprint sessions. Self-regulation of repeated sprint performance in line with individual physical
55 capabilities would be beneficial in many sport and exercise training scenarios, particularly when
56 individuals train in groups. However, the protocol employed by Glaister et al. (18) could not
57 quantify the accuracy of SR repeated sprinting. Therefore, it could not be determined whether

58 subjects overestimated recovery time to allow them to maintain performance. This should be
59 investigated, as the recovery time chosen would influence the physiological demand experienced
60 during the bout (4). Full recovery, defined for the purposes of the current study as a return to resting
61 metabolic and intramuscular energy status, is not required for repeated sprint performance to be
62 maintained (15). If SR recovery is over-estimated, meaning that subjects give themselves more
63 recovery than is actually necessary to maintain repeated sprint performance, then allowing athletes to
64 self-regulate their performance may not generate the physiological load required to stimulate specific
65 adaptations and performance enhancements, or prepare athletes sufficiently for the demands of
66 competition. This can be experimentally tested by establishing individual SR recovery and then
67 reducing this recovery time in a blinded fashion. If such an approach alters physiological and
68 perceptual responses and impairs repeated sprint performance, it would provide an insight into the
69 accuracy of self-regulating repeated sprinting. Currently, no specific research is available that
70 addresses these issues.

71

72 The aim of this study was to investigate the reliability of SR performance during repeated sprint
73 exercise and the accuracy of this self-regulation. It was hypothesised that following appropriate
74 familiarisation, self-regulation of repeated sprint exercise would allow maintenance of a stable
75 performance level, and that reducing SR recovery duration would impair repeated sprint
76 performance.

77

78 **METHODS**

79

80 Experimental Approach to the Problem

81

82 Learning effects exist between the first two trials of a cycle sprint test (22). Therefore, to ensure
83 sufficient data for familiarisation and reliability analysis, subjects completed four trials (18) each
84 comprising 10 x 6 sec cycle sprints on a Monark 894E mechanically braked cycle ergometer against

85 a 7.5% body mass (BM) resistance. Subjects SR the recovery duration between each sprint with the
86 goal of maintaining a stable power output across all sprints. All subjects maintained sprint
87 performance across the four trials, and therefore took part in a fifth trial. Recovery time was
88 manipulated in a single-blind fashion to investigate the accuracy of SR repeated sprint performance.
89 Each subject's most reliable SR performance from trial 3 or 4 (based on within-trial coefficient of
90 variation (CV) for mean power output (MPO)) was used as the criterion recovery time to manipulate.
91 Each post-sprint recovery time was reduced by 10% (reduced recovery (RR) trial). The ergometer
92 was attached to specialist software (Monark Anaerobic Test Software 3.2.5.5, Vansbro, Sweden) that
93 enabled calculation of peak power output (PPO), MPO, and FI for each sprint. Heart rate (HR),
94 physical ratings of perceived exertion (P-RPE) and measures of task effort awareness (TEA) were
95 recorded during each trial to provide an indication of physiological and psychological strain. Within
96 subjects, all trials were conducted at the same time of day, with a minimum of 3 and maximum of 7
97 days between trials. Subjects completed a food diary for 24 h before the first trial and were
98 instructed to replicate this before each trial, to control for the potential influence of alterations in
99 energy intake on mood state (9) and performance (24). Subjects were asked to consume a light meal
100 at least 2 h before testing. Pre-testing training was not standardised between subjects, but was
101 standardised within subjects by requesting that they refrain from strenuous exercise for at least 24 h
102 before each trial. Adherence to these procedures was verbally confirmed at the beginning of each
103 trial.

104

105 Subjects

106

107 Fourteen healthy, recreationally active males (24.5 ± 5.0 y, 178 ± 8 cm, 80.9 ± 13.2 kg) participated,
108 some of whom had experience of repeated cycle sprinting. Subjects took part in a variety of sports
109 (gym training, climbing, football, hockey, volleyball, martial arts) for a mean weekly duration of 6.5
110 ± 3.9 h and a mean experience level of 8.1 ± 5.3 years. Subjects were informed of the nature of the

111 investigation, after which they gave written informed consent. The study received approval from the
112 Institutional Research Ethics Committee.

113

114 Procedures

115

116 Body mass (BM, kg) and standing height (cm) were recorded using a height stadiometer (Seca model
117 245, Hamburg, Germany) and digital scale (Seca model 708, Hamburg, Germany) respectively while
118 wearing shorts. Subjects then completed a standardised warm-up of 4 min cycling at 60 rpm against
119 a 1 kg resistance, and 3 x 3 s maximal sprints against a 7.5% BM resistance interspersed with 45 s
120 cycling against no resistance. They then dismounted and sat quietly for 3 min prior to the main
121 component of the trial. In each trial, subjects were informed that they were to complete 10 x 6 s
122 cycle sprints, to give maximum effort in each sprint, and to give themselves sufficient recovery so
123 that in all ten sprints they were able to replicate the performance achieved in the criterion sprint
124 (instructions adapted from Glaister et al. (18)). Subjects were instructed to remain seated during all
125 sprints. No external performance feedback was provided but cadence was visible during recovery
126 periods. Vigorous verbal encouragement was provided during every sprint. Subjects were instructed
127 to give a 3 s countdown before starting each sprint, and to factor this into their recovery. Recovery
128 time was defined as the period from the end of the previous sprint until the beginning of the next
129 sprint, immediately following the 3 s countdown. All sprints began from 60 rpm with resistance
130 automatically applied to the flywheel upon reaching 110 rpm.

131

132 *Trial 1*

133

134 A flow chart summarising the experimental protocol is in Figure 1. Subjects were introduced to the
135 equipment and procedures. They then undertook a single 6 s sprint to familiarise them with the
136 procedure and provide criterion sprint data for comparison with repeated sprint performance.
137 Following the warm up, subjects remounted the ergometer and cycled at 60 rpm against no resistance

138 for 10 s, after which they cycled maximally. The load was automatically added to the ergometer
139 upon reaching 110 rpm, at which time the 6 s sprint began. On completion, participants cycled easily
140 against a 1 kg resistance for 1 min, then dismounted the ergometer and sat quietly for 5 min. The test
141 was repeated to identify whether a maximal effort was achieved in the first sprint. If subjects
142 achieved a lower MPO in test 2, the result of test 1 was taken as MPO. If subjects achieved a MPO
143 in test 2 $\geq 5\%$ greater than test 1, a third test was undertaken. This was repeated as necessary until
144 MPO no longer increased. A 15 min seated recovery followed the criterion sprint test.

145

146 Following the recovery, participants completed the standardised warm up, then remounted the
147 ergometer and cycled at 60 rpm for one minute. The investigator provided a 3 s countdown, after
148 which the subject completed 10 x 6 s cycle sprints against a 7.5% BM resistance with a self-regulated
149 recovery between each sprint. During recovery, participants cycled at 50-60 rpm against no
150 resistance.

151

152 *Trials 2-4*

153

154 Trials 2-4 followed a similar procedure to that of trial 1. However, only the warm up and the 10 x 6 s
155 sprints were completed.

156

157 Following the first four trials, subjects' data were analysed to determine if they successfully
158 maintained sprint performance in each trial. Performance maintenance was defined as:

159

- 160 1. The absence of an obvious pattern of fatigue, determined by visual inspection of PPO and MPO
161 data for each sprint (18), to confirm no continuous drop-off in performance.
- 162 2. A within-trial CV for MPO of 5.2% or less (the upper CV of MPO for this type of exercise
163 (10,18)).

164

165 All subjects successfully maintained performance in the first four trials, and progressed to the final
166 trial.

167

168 *Trial 5*

169

170 In this trial, SR recovery time was manipulated as described above. The 10% reduction in recovery
171 times is greater than the random variation of recovery time previously reported during self-paced
172 recovery of repeated sprints (18). However, prior to the session subjects were informed that their
173 most reliable sprint session was being replicated to investigate repeatability of performance. They
174 were reminded that they should produce their best effort, but this time the investigator would tell
175 them when to begin each sprint. The investigator informed the subject when there was 10 s of a
176 recovery period remaining, and provided a 3 s countdown into the next sprint.

177

178 **Figure 1 here**

179

180 In addition to power data, HR was recorded (Polar S610i, Kempele, Finland) at 5 s intervals
181 throughout each trial. Fatigue index was calculated using the formula (18):

182

183
$$\text{Fatigue index} = (100 \times (\text{total sprint performance} / \text{ideal sprint performance})) - 100$$

184

185 Where total sprint performance = sum of MPO from all sprints, and ideal performance = number of
186 sprints x greatest MPO. Self-regulated recovery duration between each sprint was recorded with a
187 digital stopwatch to the nearest s (11). Physical ratings of perceived exertion and TEA were recorded
188 5 s after every sprint using procedures described by Swart et al. (27). These scales separately
189 quantify physical and psychological effort during exercise, enabling greater insight into the influence
190 of these factors on exercise performance (27).

191

192 Statistical Analyses

193

194 Between-trials reliability was assessed by calculating changes in the mean, intraclass correlation
195 coefficient (ICC), CV, and 95% limits of agreement (LoA) using published spreadsheets (20,21).
196 One-way repeated measures ANOVA compared mean recovery time between trials 1-4, and PPO and
197 MPO between the criterion sprint and all sprints in the SR and RR trials. Physiological, perceptual,
198 and performance measures from each subject's most reliable repeated sprint trial (based on within
199 trial recovery time) from the first four sessions was compared to the RR trial using a two-way (trial x
200 sprint) ANOVA. The Greenhouse-Geisser adjustment was applied if the assumption of sphericity
201 was violated, and post-hoc Bonferroni correction explored significant main effects. Pearson
202 correlations between sprint number and perceptual responses, and between P-RPE and TEA, were
203 calculated for each subject. Effect sizes for significant main effects from ANOVA analysis were
204 reported as partial eta-squared (η_p^2) and quantified as small (≤ 0.01), medium ($> 0.01, < 0.14$), and
205 large (≥ 0.14 ; 13). Cohen's d effect sizes quantified the magnitude of significant mean differences
206 between trials (small, $d \leq 0.2$; medium, $d > 0.2, < 0.8$; large, $d \geq 0.8$; (12)). Statistical significance
207 was set at $P \leq 0.05$, and data are mean \pm SD unless otherwise stated.

208

209 RESULTS

210

211 Mean results for each performance variable across the four reliability trials are in Table 1. There
212 were no differences across trials for any performance variable ($P > 0.05$). Reliability statistics are in
213 Table 2. Random variation of recovery time (CV and LoA) was substantially reduced when
214 comparing the final pair of trials to earlier pairs of trials. Both MPO and PPO demonstrated ICCs $>$
215 0.95 and CVs $\leq 3.3\%$ in all comparisons. Conversely, there were high levels of random variation in
216 FI.

217

218

Tables 1 & 2 here

219

220 As designed, mean recovery time was significantly reduced in the RR trial compared with the SR
221 trial (86.2 ± 31.6 vs. 95.7 ± 35.2 s, $P < 0.05$, $d = 0.28$), with the reduced recovery time lower than
222 that chosen by each participant in trials 3 and 4. There was no significant effect of sprint number for
223 mean recovery time ($F_{2.69,34.94} = 0.482$, $P > 0.05$, $\eta_p^2 = 0.07$). Power profiles across the SR and RR
224 sprints, and compared to the criterion sprint, are in Figure 2A and B. There was no significant main
225 effect for PPO for trial ($F_{1,13} = 0.134$, $P > 0.05$, $\eta_p^2 = 0.01$) or sprint number ($F_{3.66,47.54} = 0.820$, $P >$
226 0.05 , $\eta_p^2 = 0.06$) and no interaction effect ($F_{4.13,53.74} = 0.973$, $P > 0.05$, $\eta_p^2 = 0.07$). There was no main
227 effect for trial ($F_{1,13} = 1.163$, $P > 0.05$, $\eta_p^2 = 0.08$) or sprint number ($F_{3.01,39.12} = 0.452$, $P > 0.05$, $\eta_p^2 =$
228 0.03) and no interaction effect ($F_{2.78,35.98} = 0.840$, $P > 0.05$, $\eta_p^2 = 0.06$) for MPO. There was no
229 significant difference in MPO between the criterion sprint and any sprint in the SR ($F_{2.76,35.86} =$
230 2.099 , $P > 0.05$, $\eta_p^2 = 0.14$) and RR trials ($F_{2.96,38.53} = 1.161$, $P > 0.05$, $\eta_p^2 = 0.08$). However, PPO in
231 the criterion sprint was significantly greater than PPO in all sprints of the SR trial ($F_{3.396,44.144} = 3.114$,
232 $P < 0.05$, $\eta_p^2 = 0.19$). In the RR trial, PPO in sprints 3-10 was significantly lower than the criterion
233 sprint ($F_{10,130} = 2.621$, $P < 0.05$, $\eta_p^2 = 0.17$).

234

235

Figure 2 here

236

237 Perceptual responses to the SR and RR trials are in Figure 3A and B. There was no main effect of
238 trial (P-RPE; $F_{1,13} = 0.034$, $P > 0.05$, $\eta_p^2 = 0.0$ and TEA; $F_{1,13} = 0.074$, $P > 0.05$, $\eta_p^2 = 0.0$) and no
239 interaction effect between trials over time (P-RPE; $F_{3.05,39.70} = 0.920$, $P > 0.05$, $\eta_p^2 = 0.07$ and TEA;
240 $F_{9,117} = 0.750$, $P > 0.05$, $\eta_p^2 = 0.06$). However, there was a significant time effect for both P-RPE
241 ($F_{1.43,18.62} = 27.590$, $P < 0.05$, $\eta_p^2 = 0.68$) and TEA ($F_{1.42,18.44} = 21.950$, $P < 0.05$, $\eta_p^2 = 0.63$). The
242 relationship between sprint number and perceived physical and psychological stress demonstrated
243 wide inter-individual variability in the SR (P-RPE: $r^2 = 0.07$ - 0.98 , TEA: $r^2 = 0.21$ - 0.88) and RR (P-
244 RPE: $r^2 = 0.08$ - 0.92 , TEA: $r^2 = 0.0$ - 0.94) trials. Similarly, the relationship between P-RPE and TEA

245 was $r^2 = 0.28-1.0$ in the SR trial and $r^2 = 0-0.98$ in the RR trial. Heart rate showed no main effect of
246 trial ($F_{1,10} = 0.949$, $P > 0.05$, $\eta_p^2 = 0.09$) or interaction effect ($F_{2,78,27.83} = 0.708$, $P > 0.05$, $\eta_p^2 = 0.07$),
247 but there was a main effect of time ($F_{3,54,35.35} = 41.269$, $P < 0.05$, $\eta_p^2 = 0.81$; Figure 4).

248

249

Figure 3 here

250

251 **DISCUSSION**

252

253 Following two familiarisation sessions, subjects were able to maintain repeated sprint performance
254 with relatively stable SR recovery periods. Reducing SR recovery duration by 10% did not impair
255 maintenance of repeated sprint performance or affect psycho-physiological ratings. Therefore,
256 subjects over-estimated required recovery time between sprints.

257

258 Table 2 shows a notable improvement in the reliability of SR recovery time between trials 1-2, 2-3,
259 and 3-4. The high CV and low ICC for SR recovery time between trials 1-2 compared with trials 2-3
260 and 3-4 supports the suggestion of Hopkins et al. (22) that learning effects are evident between at
261 least the first two trials of cycle sprint tests. The reliability of SR recovery between trials 3-4 in the
262 current study (CV = 7.5%, ICC = 0.97) is better than that reported by Glaister et al. (18) across the
263 same trials (CV = 9.9%, ICC = 0.83), and is also below the imposed 10% reduction of recovery time
264 in the RR trial. Better reliability may relate to the exercise mode (running vs. cycling), or to the
265 subjects used in the current study, some of whom had experience of repeated cycle sprinting. It
266 should also be considered that maintenance of repeated sprint performance depends on sprint
267 duration (1). Therefore, varying sprint duration may influence the ability to self-regulate
268 performance. This should be considered when comparing results between studies, and may represent
269 an interesting avenue for further research.

270

271 Glaister et al. (18) reported a progressive increase in RPE during repeated sprints, despite a stable
272 performance. This was attributed to subjects giving themselves just enough recovery between
273 sprints. In the current study, P-RPE and TEA scores progressively increased throughout both trials,
274 with no significant between-trials differences. The present findings support the observation that
275 while a self-selected recovery will allow performance to be maintained, perceived exertion
276 progressively increases. However, the present findings do not support the suggestion that subjects
277 pace recovery to give just enough time to maintain performance, as when recovery time was reduced
278 by 10% performance was still maintained.

279

280 In the current study, P-RPE was almost identical at the end of exercise in the SR and RR trials.
281 However, the peak values (~15) in the current study and that of Glaister et al. (18) likely do not
282 reflect the highest tolerable values that subjects could have attained. This is reinforced by the
283 moderate peak TEA values in both trials. Short-duration sprinting is fuelled by phosphocreatine
284 (PCr; ~50%) and glycolysis (~40%), with a progressive aerobic contribution as sprint number
285 increases (6). The duration of the recovery periods in the current study would likely have enabled a
286 continued large contribution of PCr to subsequent sprints, as the half-time of PCr resynthesis in
287 adults is ~27 s (28). Therefore, progressive intramuscular acidosis associated with the glycolytic
288 contribution to the sprints may explain the progressive increase in P-RPE and TEA (18). It has also
289 been shown that the aerobic contribution to repeated sprinting increases as the number of sprints
290 progresses (8). Increased aerobic contribution would require an increased cardiorespiratory demand,
291 increasing afferent feedback and potentially elevating RPE and TEA. The potential impact of
292 increased intramuscular acidosis and cardiorespiratory demand may also explain the variable
293 individual relationship between sprint number and perceived physical and psychological stress, as
294 between-subjects differences in aerobic fitness and muscle morphology may have modulated
295 metabolic responses (19,29) and, hence, perceptual responses to the sprints. Blood lactate
296 concentration was not measured in this study due to the large variability in blood lactate measures
297 and the greater reliance on PCr as a fuel during repeated sprinting. Therefore, further investigation is

298 required to elucidate these suggestions. Similar P-RPE, TEA, and HR between the SR and RR trials
299 reinforces that when subjects are permitted to select their own recovery, they over-estimate the
300 recovery required to maintain performance by at least 10%.

301

302 Deception of the number of sprints (with known sprint and recovery duration) to be performed can
303 significantly reduce PPO and work performed from the first sprint, suggesting the presence of a
304 pacing strategy based on factors including the number of sprints required (7). From a practical
305 perspective, pacing during repeated sprint exercise may impair training quality and fitness
306 adaptations. In the SR trial, subjects produced a significantly lower PPO from sprint one compared
307 with the criterion sprint. It therefore appears that when subjects were aware that they had to perform
308 multiple sprints, even with a self-selected recovery, they produced submaximal power from the onset
309 of exercise despite being asked to perform maximally. Submaximal power production could be the
310 result of an anticipatory pacing strategy based on knowledge of the number of sprints to be
311 completed (7), or it may be that experience of completing repeated 6 sec sprints enabled the subjects
312 to pace differently within each sprint, achieving a lower PPO but maintaining MPO (Figure 2A and
313 B). In the current study, it is not possible to determine the relative prevalence of these hypotheses.
314 Billaut et al. (7) did not employ a single criterion sprint. Therefore, the true maximal performance of
315 their subjects was unknown, meaning inferences regarding pacing strategies could only be made by
316 comparing between-trials sprint performance during exercise. By comparing repeated sprint
317 performance to that of a single sprint, this study provides the first evidence for sub-optimal
318 performance from the onset of a known bout of repeated sprinting in recreationally trained subjects.
319 This finding reinforces the presence of a pacing strategy based either on anticipation of the number of
320 sprints to be completed and/or based on prior experience of the repeated sprint protocol.

321

322 It is well known that the type of pacing strategy employed during exercise is influenced by previous
323 related exercise experience (2,25) and the performance level of the subject (23). Possible
324 determinants of the pacing strategies used by different standards of athlete include differences in

325 physiological and psychological parameters (3,23), and the learnt aspect of pacing that is developed
326 through experience (14). The current study used recreationally trained subjects. Therefore, it cannot
327 be conclusively asserted that using SR recovery in more highly trained and/or experienced athletic
328 populations would generate the same findings as reported in the current study, or would be a useful
329 strategy for athletes. Future research should explore the influence and efficacy of SR recovery in
330 more elite populations.

331

332 In conclusion, following two familiarisation trials repeated cycle sprinting performance can be
333 reliably maintained when subjects self-regulated recovery. However, subjects also over-estimate by
334 at least 10% the recovery time needed to maintain sprint performance.

335

336 **PRACTICAL APPLICATIONS**

337

338 Self-regulated recovery appears to be a reliable option for maintaining the quality of repeated sprint
339 exercise and resisting fatigue. This has particular practical relevance when training groups of
340 individuals with differing repeated sprint abilities. Coaches could employ SR repeated sprinting as a
341 method of maintaining sprint quality tailored to individual performance, rather than using a single
342 fixed recovery period, which may not suit the ability of all individuals. However, this study has
343 demonstrated that individuals over-estimate the recovery time needed for maintenance of
344 performance. Many sporting situations require repeated bouts of effort with minimal recovery (26).
345 Therefore, if a goal of training is to prepare for this situation, then allowing individuals to self-
346 regulate recovery may not stimulate the necessary metabolic adaptations for performance
347 improvement. Coaches should be aware of the potential benefits and limitations of SR repeated
348 sprinting, and consider the use of SR recovery within the context of specific training aims. The
349 findings of this study should also be treated as population specific, until subsequent work has been
350 conducted in more elite populations to investigate whether or not high performing athletes display
351 similar responses to SR repeated sprint exercise.

352

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466

467 **Figure Captions**

468

469 **Figure 1.** Flow diagram summarising the experimental protocol.

470

471 **Figure 2.** Peak power output (A) and mean power output (B) across the criterion sprint (C) and
472 repeated sprint efforts with self-regulated recovery (filled circles) and reduced recovery (open
473 circles). * significantly greater than sprints 1-10 in the SR trial ($P < 0.05$); ** significantly greater
474 than sprints 3-10 in the RR trial ($P < 0.05$).

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476 **Figure 3.** Physical ratings of perceived exertion (A) and task effort and awareness ratings (B)
477 following each sprint effort in the self-regulated (filled circles) and reduced recovery (open circles)
478 trials. † Significant main effect of sprint number ($P < 0.05$).

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483 **Table 1.** Mean (\pm SD) performance variables across the four trials of self-regulated repeated sprint
484 exercise.

	Trial 1	Trial 2	Trial 3	Trial 4
Recovery time (s)	90.3 \pm 26.8	92.4 \pm 35.5	94.8 \pm 33.1	96.1 \pm 33.8
Mean power output (W.kg ⁻¹)	10.93 \pm 1.18	10.79 \pm 1.21	10.76 \pm 1.28	10.84 \pm 1.16
Peak power output (W.kg ⁻¹)	12.53 \pm 1.75	12.25 \pm 1.61	12.22 \pm 1.69	12.20 \pm 1.56
Fatigue index (%)	3.3 \pm 1.4	4.1 \pm 1.8	4.5 \pm 2.0	3.9 \pm 1.7

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501 **Table 2.** Pairwise reliability of performance variables during self-regulated repeated sprint exercise.

		Δ Mean	ICC	CV	95% LoA
Recovery time (s)	Trial 1 to 2	2.14 (-10.57 to 14.86)	0.79 (0.48 to 0.93)	16.0 (11.4 to 27.0)	1.77 \pm 44.83
	Trial 2 to 3	2.36 (-7.15 to 11.87)	0.94 (0.82 to 0.98)	10.1 (7.2 to 16.7)	2.38 \pm 33.60
	Trial 3 to 4	1.36 (-3.80 to 6.51)	0.97 (0.90 to 0.99)	7.5 (5.4 to 12.4)	2.00 \pm 17.55
Mean power output (W.kg ⁻¹)	Trial 1 to 2	-0.13 (-0.37 to 0.11)	0.96 (0.87 to 0.99)	2.7 (1.9 to 4.4)	-0.15 \pm 0.84
	Trial 2 to 3	-0.03 (-0.25 to 0.19)	0.97 (0.90 to 0.99)	2.4 (1.8 to 4.0)	-0.05 \pm 0.76
	Trial 3 to 4	0.08 (-0.08 to 0.24)	0.98 (0.94 to 0.99)	1.9 (1.3 to 3.0)	0.10 \pm 0.55
Peak power output (W.kg ⁻¹)	Trial 1 to 2	-0.29 (-0.64 to 0.07)	0.96 (0.87 to 0.99)	3.3 (2.4 to 5.3)	-0.28 \pm 1.27
	Trial 2 to 3	-0.03 (-0.31 to 0.24)	0.97 (0.91 to 0.99)	2.7 (1.9 to 4.3)	-0.06 \pm 0.96
	Trial 3 to 4	-0.01 (-0.18 to 0.15)	0.99 (0.97 to 1.00)	1.6 (1.2 to 2.6)	0.00 \pm 0.56
Fatigue index (%)	Trial 1 to 2	0.75 (-0.43 to 1.93)	0.42 (-0.12 to 0.77)	47.8 (32.7 to 87.6)	0.57 \pm 3.92
	Trial 2 to 3	0.41 (-0.47 to 1.29)	0.72 (0.33 to 0.90)	33.9 (23.6 to 60.1)	0.65 \pm 2.48
	Trial 3 to 4	-0.61 (-1.84 to 0.63)	0.46 (-0.07 to 0.79)	47.3 (32.4 to 86.6)	-0.64 \pm 4.37

502 ICC = intraclass correlation coefficient; CV = coefficient of variation; 95% LoA = 95% Limits of Agreement; Values in parentheses are 95% confidence

503 limits.