

EMOTION REGULATION AND PERFORMANCE

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Abstract

This study used a single blind, within-participant, counterbalanced, repeated measures design to examine the relationship between emotional self-regulation and sport performance. Twenty competitive athletes completed four laboratory-based conditions; familiarization, control, emotion suppression, and non-suppression. In each condition participants completed a 10km cycling time trial requiring self-regulation. In the experimental conditions participants watched an upsetting video prior to performing the cycle task. When participants suppressed their emotional reactions to the video (suppression condition) they completed the cycling task slower, generated lower mean power outputs, and reached a lower maximum heart rate and perceived greater physical exertion than when they were given no self-regulation instructions during the video (non-suppression condition) and received no video treatment (control condition). The findings suggest that emotional self-regulation resource impairment affects perceived exertion, pacing and sport performance and extends previous research examining the regulation of persistence on physical tasks. The results are discussed in line with relevant psychophysiological theories of self-regulation and fatigue and pertinent potential implications for practice regarding performance and well-being are suggested.

Keywords: ego depletion, performance, fatigue, pacing, suppression, self control, strength energy model, dual task paradigm

Emotion regulation and sport performance

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2 Self-regulation refers to any effort by a human being to alter his or her inner states or
3 responses, including actions, thoughts, feelings, and task performances (Baumeister,
4 Heatherton, & Tice, 2007). It has been argued that such efforts are fundamental to human
5 functioning and facilitate individual and cultural flourishing through the promotion of moral,
6 disciplined, and virtuous behaviors and curbing of hostile and aggressive impulses that
7 undermine prosocial behaviors (cf. Bauer & Baumeister, 2011). For example, through self-
8 regulation people can become active agents in the management of their emotional lives and
9 directors of their actions in emotion-eliciting contexts (Koole, van Dillen, & Sheppes, 2011).
10 Indeed, one type of self-regulation of interest to sport and exercise psychologists is that of
11 emotion regulation, which refers to any process that influences the onset, offset, magnitude,
12 duration, intensity, or quality of one or more aspects of the emotional response (McRae,
13 Ochsner, & Gross, 2011). There is growing support for the notion that emotion regulation is
14 important for individual (e.g., Lane, Beedie, Jones, Uphill, & Devonport, 2012; Uphill,
15 McCarthy, & Jones, 2009), team (e.g., Tamminen & Crocker, 2013; Wagstaff & Weston, 2014)
16 and organizational (e.g., Wagstaff, Fletcher, & Hanton, 2012a) performance outcomes in sport.
17 Moreover, research indicates that emotions are discrete experiences that serve socially
18 constructive purposes (see Hanin, 2010; Wagstaff, Fletcher, & Hanton, 2012b). This is not
19 surprising given the substantial literature highlighting the performance implications of emotions
20 experienced before and during sport competition (Hanin, 2010). However, despite the apparent
21 value of emotional self-regulation in sport, a considerable body of research beyond this domain
22 indicates that all acts of self-regulation are “fuelled” by a limited but renewable resource, with
23 repeated self-regulatory effects depleting this resource to compromise subsequent attempts (see
24 Baumeister, Bratslavsky, Muraven, & Tice, 1998). This study aimed to examine the relationship
25 between emotional self-regulation and sport performance.

1 In line with the notion that self-regulation draws on a limited resource, Baumeister and
2 colleagues' strength model (see Baumeister, Vohs, & Tice, 2007) offers an explanation for such
3 decrements and labels the resulting state of impairment as *ego depletion*. An important
4 outstanding issue for the strength model is what, exactly, becomes depleted. This has led
5 researchers to examine possible physiological resources that might explain the ego depletion
6 effect. One candidate has been glucose, the primary fuel for brain function (e.g., Gailliot et al.,
7 2007). However, the role of glucose as an explanation for ego depletion has been criticized
8 mainly because peripheral blood glucose (e.g., finger) does not reflect brain glucose levels and
9 the demand for glucose by self-regulation tasks in the brain is relatively small (Beedie & Lane,
10 2012; Kurzban, 2010). In an attempt to synthesize the varied research on the strength model,
11 Hagger, Wood, Stiff, and Chatzisarantis' (2010) meta-analysis showed effort-induced ego
12 depletion to have a moderate to large effect size (Cohen's $d = .62$) in deteriorating performance
13 on subsequent self-regulation tasks regardless of whether those tasks were in the same (e.g.,
14 emotion regulation-emotion regulation) or different (e.g., emotion regulation-physical
15 regulation) regulatory domain. Importantly, and in contrast to cognitive load, the effects of self-
16 regulation resource depletion are temporary with periods of rest or relaxation being
17 hypothesized to help restore resources and minimize the deleterious effects of depletion on
18 subsequent task performance (Hagger et al., 2010).

19 In line with the global resource perspective proposed by the strength model, the
20 regulation of emotions has been found to reduce performance on subsequent physical and
21 cognitive tasks (e.g., Baumeister et al., 1998; Finkel & Campbell, 2001; Muraven, Tice, &
22 Baumeister, 1998; Schmeichel, Vohs, & Baumeister, 2003). For example, Muraven et al. (1998)
23 found participants who were asked to suppress their emotional expression (i.e., emotion
24 regulation) while watching an emotion-provoking video were subsequently unable to squeeze
25 an isometric handgrip dynamometer for as long as participants who were not given regulatory
26 guidance. Bray, Martin Ginis, Hicks, and Woodgate (2008) later showed that people who

1 performed a brief cognitively effortful task experienced a 50% decrement in maximum
2 voluntary contraction on a handgrip dynamometer compared to controls. Although not directly
3 examining self-regulation or ego depletion, Marcora, Staiano, and Manning (2009) showed that
4 participants' performance (time to exhaustion) on an exercise test was reduced dramatically
5 following a cognitively demanding task compared to a control task. Further, ratings of
6 perceived exertion during exercise were significantly higher following the cognitively
7 demanding task, suggesting that mental fatigue directly led to perceptions of greater effort
8 required to perform the exercise task. Martin Ginis and Bray (2010) later found sedentary
9 participants who were exposed to a cognitively demanding task manipulation generated lower
10 levels of work during a 10 minute cycling task and planned to exert less effort during an
11 upcoming exercise bout, compared with a control group. Due to their sampling of sedentary
12 individuals, Martin Ginis and Bray called for more research examining self-regulation and the
13 physical exercise performance of active individuals.

14 Recently, a number of sport psychology-specific studies have examined the relationship
15 between self-regulatory strength and physical action performance. Dorris, Power, and Kenefick
16 (2012) argued that due to the highly-practiced nature of sport, athletes' exercise behaviors are
17 substantially different to the handgrip strength and cycling outputs of non-athletic individuals
18 used in initial self-regulation and physical action research (cf. Bray et al., 2008; Muraven et al.,
19 1998). In an attempt to overcome these limitations, Dorris et al. used calisthenic measures of
20 physical action (i.e., press-ups and sit-ups). Using a repeated-measures design, they found a
21 performance decrement (i.e., fewer press-ups, sit-ups) in a sample of athletes following a
22 cognitively demanding task requiring self-regulation than after an easy task. Other research on
23 ego depletion in sport has focused on the impact of self-regulatory manipulation on skilled
24 performance (e.g., Englert & Bertrams, 2012; Furley, Bertrams, Englert, & Delphia, 2013;
25 McEwen, Martin Ginis, & Bray, 2013). To elaborate, Englert and Bertrams (2012) recently
26 found ego depleted individuals to perform worse on basketball free throw and darts tasks as

1 their anxiety increased, whereas no significant relationship was observed for non-depleted
2 participants. McEwen et al. (2013) also examined dart task performance following a cognitive
3 task requiring self-regulation. Using a randomized controlled design they found a significant
4 decline in dart throwing accuracy in the experimental self-regulation depleting condition
5 compared to the baseline and control. Furley et al. (2013) also used a repeated measures design
6 to demonstrate that athletes' ability to focus attention on a computer-based decision making
7 task under distracting conditions relied on the situational availability of self-regulatory strength.
8 The authors concluded that having sufficient regulatory resources in interference rich sport is
9 likely to aid decision making.

10 Collectively, the burgeoning research reviewed above has provided a valuable insight
11 into the relationship between self-regulatory impairment via cognitively-demanding tasks and
12 performance on isometric handgrip strength, calisthenic exercise routines, and skill-based tasks,
13 and the execution of such skills and decision making under pressure. It is surprising, however,
14 that given the importance of regulating emotions in sport highlighted here, that extant research
15 has elided the interplay between *emotional* self-regulation and sport performance. Indeed, it
16 remains to be understood whether emotional self-regulation impacts sport performance. Further,
17 no research has examined the relationship between self-regulation demands and *endurance*
18 sport performance or tasks lasting longer than a few minutes. Indeed, and in line with Dorris et
19 al.'s (2012) critique of such measures, it could be argued that the dependent measures of
20 physical action in extant self-regulation research have limited application to performance in
21 many globalized sports involving gross motor skills (e.g., running, cycling, jumping). To
22 elaborate, in order to maximise their competitive performance, most athletes must execute gross
23 motor skills at an optimal intensity determined by the nature of the task and their own
24 physiological and psychological capabilities. For example, elite athletes use pacing strategies to
25 monitor exercise intensity and ensure that energy-producing capacities are not exhausted before
26 they reach the end of their competition. Therefore, the complex regulatory skill of pacing,

1 incorporating physiological, neurophysiological and perceptual responses during exercise, is a
2 critical factor determining success in middle- and long-duration sporting competitions (Baron,
3 Moullan, Derulle, & Noakes, 2009). Hence, the demand for pacing during cycling performance
4 requires self-regulation. The present study examined the effect of emotional self-regulatory
5 resource manipulation on the performance of a 10km cycling time trial. It was hypothesized that
6 participants' time trial performance would be worse following pre-time trial experimentally
7 manipulated self-regulatory resources than in a control and experimental condition where no
8 self-regulatory demands were imposed.

9 **Method**

10 To address the research question a single-blind, within-subject, repeated measures,
11 counterbalanced design was used. The design had four conditions: familiarization, control,
12 emotion-suppression, and non-suppression conditions.

13 **Participants**

14 Participants ($N = 20$) were undergraduate male ($N = 10$) and female ($N = 10$) students
15 ($Age_{years} M = 21.13, SD = 1.61, Mass_{kg} M = 79.21, SD = 4.24, Height_{cm} M = 178.63, SD =$
16 5.04). The participants all competed in individual, endurance sports (running: $n = 8$, swimming:
17 $n = 6$, rowing: $n = 6$), trained a minimum of 3 times per week, and performed at club ($n = 6$),
18 national ($n = 7$) and international ($n = 7$) levels at the time of data collection. Many researchers
19 favor repeated measures designs because they allow the detection of within-person change
20 across experimental conditions and typically have higher statistical power than cross-sectional
21 and between-groups designs (cf. Marcora et al., 2009; McEwan et al., 2013). However, sample
22 size selection for successful repeated measures designs is difficult (Guo, Logan, Glueck, &
23 Muller, 2013). Hence, a required sample size of 15 was calculated using G*power 3.1 software
24 program, setting power ($1 - \beta$ err prob) at .8, alpha (α err prob) at $p = .05$, and using the effect
25 size ($d_z = .62$) reported in Hagger et al.'s (2010) meta analysis of 83 studies examining the
26 strength model. The sample size in the present study is also comparable to similar research in

1 this area (e.g., $N = 16$; Marcora et al., 2009). In line with Guo et al.'s considerations for power
2 and sample size, one female participant was removed from analysis due to a moderate number
3 of missing values in one condition.

4 Following favorable University Ethics Committee review, participants, none of whom
5 had prior knowledge as to the nature of the study, were recruited via a University notice board
6 advertisement. Participants were informed that the study was an investigation of emotions and
7 performance. This deception was necessary to mask the true purpose of the study. Sampling
8 criteria stipulated that participants had to be aged 18-30 and be involved in regular competitive
9 sport (training or competition 3+ times per week), and frequently ride a bicycle in an attempt to
10 minimize performance variance due to confounding physiological or familiarization factors.
11 Participants undertook a medical screening process prior to the experiment.

12 **Procedure**

13 Each participant visited the experiment facility a total of four times under ambient
14 conditions. The four visits comprised familiarization, control, emotion-suppression, and non-
15 suppression conditions. Following familiarization participants were randomly allocated to an
16 ABC ($N = 5$), BCA ($N = 5$), CBA ($N = 5$), or CAB ($N = 5$) counterbalancing system to
17 minimize order effects. Data from each participant was collected individually and in private
18 during these visits. Each condition commenced at the same time of day in a sport and exercise
19 physiology laboratory, to minimize any circadian variations and lasted approximately 60
20 minutes on each occasion. A minimum of 48 hours was given to rest between conditions. All
21 participants were given written instructions to drink 35 ml of water per kilogram of body
22 weight, sleep for at least 7 hours, refrain from the consumption of alcohol, and avoid any
23 vigorous exercise the day before each visit. Participants were also instructed to avoid caffeine
24 and nicotine for at least 3 hours before testing and consume a set breakfast (2 slices of toast
25 spread with margarine or butter, 250 ml of orange juice, and a banana) 1 hour before all testing
26 sessions, which were conducted in the morning. At each visit to the lab, participants were asked

1 to complete a pretest checklist to ascertain that they had complied with the instructions given to
2 them. No digressions from the checklist were reported. At the end of their fourth visit,
3 participants were fully-debriefed (including the true purpose of the study).

4 **Familiarization condition.** Following receipt of written informed consent, the
5 participant's height, weight, blood pressure, and blood glucose were measured. Participants
6 then completed demographics pro forma, the subjective fatigue questionnaire, modified Stroop,
7 and the 16-item Brief Mood Introspection Scale (BMIS) to assess mood and arousal (Mayer &
8 Gaschke, 1988). Previous research has found that differences in mood can counteract ego
9 depletion (see Tice, Baumeister, Shmueli & Muraven, 2007); therefore, the BMIS was used as a
10 manipulation check. Participants were then asked to complete a maximal 10km cycling time
11 trial at a fixed-gear (54) on a Veletron RaceMate with the instruction, "cycle ten kilometers as
12 quickly as possible, we will tell you when to start and when you have completed the trial".
13 During the time trial participants wore a face mask to measure V_{O_2} . A cycling task to assess
14 self-regulation was selected due to enhanced control over confounding variables (e.g., unwanted
15 energy-expenditure, technical variation, repeatability) typically associated with other common
16 physical endurance skills (e.g., treadmill running). A distance of 10km was selected due to the
17 need to participants to engage in physical self-regulation (i.e., pacing) for an extended period of
18 time. To elaborate, Corbett, Barwood and Parkhouse (2009) found modifications to pacing
19 strategy to occur following just one bout of exercise for short (i.e., 2km) distance cycling tasks,
20 with no research indicating such learning effects for longer (i.e., 10km) time trials. The
21 optimum pacing strategy requires the presence of an accurate estimate of the power output that
22 can be sustained for the duration of the event. This process has been described as an internal
23 negotiation and requires an estimation of the magnitude of the task remaining, momentary
24 power output and remaining energetic reserves (Baron et al., 2010). When an athlete selects an
25 unsustainable power output for the expected duration of exercise, an early disturbance in
26 physiological homeostasis occurs, which if left unregulated, leads to a decrease in performance

1 (Baron et al., 2010). Heart Rate (T31, Polar, UK) and perceived exertion (RPE; Borg, 1982)
2 were taken at 1, 3, 5, 7 and 9km. On completion of the cycle time trial, a second blood glucose
3 sample was taken before participants completed the modified Stroop and then the BMIS again.

4 **Control condition.** The control condition was identical to the familiarization condition.

5 **Emotion suppression condition.** During the emotion suppression and non-suppression
6 conditions participants were asked to fill out the BMIS and measures of subjective fatigue upon
7 arrival. On finishing the questionnaires participants completed the short modified-Stroop test.
8 Following the Stroop test participants watched a 3 min video excerpt that shows an Asian
9 woman causing herself to throw up and who subsequently eats her own vomit. The video has
10 been found to elicit strong feelings of disgust (DeJong, Peters, & Vanderhallen, 2002; Martijn
11 Tenbült, Merckelbach, Dreezens, & de Vries, 2002). Disgust was preferred over emotions such
12 as joy or sadness because it is relatively easy to elicit in a laboratory situation in an ethically
13 acceptable manner (Gross & Levenson, 1993) and has been found to be a prevalent emotional
14 response to stressors encountered in sport organizations (see Fletcher, Hanton & Wagstaff,
15 2012). Moreover, most people agree about what is disgusting, whereas they often disagree
16 about what is humorous or sad. In line with the procedure of Martijn et al. (2002) participants
17 received the following instructions, “In a moment you will see a video. It is important that you
18 watch the video with attention. The video may evoke an emotional reaction so please be aware
19 that you can signal me to stop the video at any time you wish. If you experience any emotions
20 while watching the video, try not to show them. In other words, try to behave in such a way that
21 other people cannot see what you are feeling. There is a video camera in front of the screen to
22 record your expressions of emotion”. Having informed the participants about the video, the
23 experimenter moved behind a screen and observed the participant through an unobtrusive
24 window in order to react quickly if the participant indicated that the video should be stopped.
25 The participants were seated at a small desk in front of a PC computer with a 16” screen. The

1 following text appeared on the screen: “In 20 seconds the video will start. Use this time to free
2 your mind of all thoughts, feelings, and emotions”.

3 Immediately following the video, the BMIS, the short modified-Stroop test, subjective
4 manipulation check questionnaire, and post-experimental questionnaire were completed.

5 Participants then began the 10km time trial as per the control condition. Physiological (HR,
6 V_{O_2}) and perceptual (RPE) responses were measured at 1, 3, 5, 7, and 9km. Following the time
7 trial, participants completed the BMIS, subjective fatigue and post-experimental questionnaires.

8 **Non-suppression condition.** Participants completed the same protocol as the emotion
9 suppression condition prior to and following the cycling time trial; however, during the video
10 treatment they received no guidance regarding emotion suppression or regulation.

11 **Measures**

12 **Brief mood inspection scale.** A substantial body of self-regulation research (e.g.,
13 Martijn et al., 2002) has used the 16-item BMIS to assess mood and arousal. The BMIS consists
14 of 16 adjectives which measure current mood along valence and arousal dimensions.

15 Specifically, participants indicate the extent to which each item/ adjective (e.g. ‘lively’,
16 ‘drowsy’) describes their present mood. Responses were made on a seven-point Likert scale
17 ranging from 1 (definitely do not feel) to 4 (definitely feel). The items provide four dimensions:
18 Pleasant-Unpleasant (PU), Arousal-Calm (AC), Positive-Tired (PT), Negative-Relaxed (NR).

19 The BMIS mood factors have internal consistencies of .76 to .83 for the respective dimensions
20 (Muraven, 2008) and have demonstrated sufficient validity and reliability ($r = .76$ to $.83$; Mayer
21 & Gaschke, 1988).

22 **Modified Stroop test.** Stroop tests have been used widely in self-regulation research
23 (see Hagger et al., 2010), with short tests predominantly employed to measure cognitive
24 functioning and longer versions of the test commonly used as a depleting task (cf. Xu, Begue, &
25 Bushman, 2012). The short modified-Stroop test used here required participants to tell the
26 experimenter the ink color of each word in a list of 70 words as quickly and accurately as

1 possible. Words and ink colors were mismatched (e.g., YELLOW in blue ink). Participants
2 were told to call out the ink color of each word unless the ink color was red, in which case they
3 were to ignore the ink color and read the text. Thus, participants had to override their impulse to
4 read the text instead of the ink color while remembering the red ink exception. Stroop
5 performance was measured by the number of errors made and time taken to complete the test.
6 Two separate Stroop tests were used, and counterbalanced in this study in order to prevent
7 participants learning the pattern.

8 **Ratings of perceived exertion (RPE).** Participants rated perceived physical exertion
9 (RPE) throughout each cycling time trial using Borg's 15-point scale (Borg, 1982). The ratings
10 range from 6 (very, very light) to 20 (very, very hard), with these scores denoting heart rates
11 ranging from 60-200 beats·min⁻¹ when multiplied by a factor of 10 (Borg, 1982). Participants
12 were asked to indicate what level of exertion they felt they were working at when they reached
13 1km, 3km, 5km, 7km, and 9km.

14 **Subjective fatigue.** The measures used by Martijn et al. (2002) acted as manipulation
15 checks for the experimental conditions in present study. Participants indicated their agreement
16 to 8 statements (I feel tired/ energetic/ fit/ drowsy/ not clear/ exhausted/ I don't feel like doing
17 anything/ I have the feeling I can handle the world) assessed on a 4-point Likert scale.

18 **Post-experimental questionnaire.** Six questions used by Martijn et al. (2002) to verify
19 that the video evoked emotions of disgust and whether participants managed their reactions as
20 instructed were used here. Three items were included to measure aversive reactions to the video
21 ("I almost had to throw up myself"/ "I felt sick"/ "the video was too disgusting to watch").
22 Three items were included to measure adherence to the instructions whilst watching the video
23 ("while watching the video: "I succeeded in not showing my emotions"/ "I continuously tried to
24 hide my emotions"/ "I had trouble not to show my emotions"). All post-experimental items
25 were measured using a four-point Likert scale ranging from 1 (not at all) to 4 (very much so).

1 **Blood glucose.** Blood samples were taken with single-use blood sampling lancets.
2 Blood glucose levels were measured (mmol/L). using an Accu-Chek compact meter. Baseline
3 and post 10km time trial measures were taken in each condition with additional measures taken
4 following manipulation (i.e., post-video) in the suppression and non-suppression conditions.

5 **Data Analysis**

6 Data analysis was completed using PASW (IBM SPSS Statistics, Version 20.0).
7 Following normality tests using the Kolmogorov-Smirnov test, a range of repeated measures
8 ANOVA (e.g., manipulation checks), MANOVA (e.g., effect of condition on dependent
9 variables), independent t-tests (e.g., manipulation checks for learning effect), paired t-tests (e.g.,
10 manipulation checks) were completed in order to test the data for variance and conduct the
11 manipulation tests for the experimental conditions. Audio recordings of debrief interviews were
12 subject to analysis by an independent researcher blinded to the purpose of the study.

13 **Results**

14 **Manipulation checks**

15 **Check on the experimental instructions.** In the suppression condition, the participants
16 indicated that they were generally successful in trying to suppress their emotions ($M = 3.63$, SD
17 $= .76$), that they tried to hide their emotions for the duration of the video ($M = 3.50$, $SD = 1.03$)
18 and that it was reasonably difficult to suppress their emotions during the video ($M = 2.90$, $SD =$
19 1.14). These data indicate that the participants generally followed experimental instructions and
20 the suppression task required self regulatory effort. Moreover, where comparable information is
21 available, the manipulation check data are very similar to extant research using the same video
22 treatment (cf. Martjin et al., 2002; M range = 2.94-3.24).

23 To check the data for learning effects, independent samples t-tests compared participants
24 undertaking suppression followed by the non-suppression (i.e., ABC and BCA) with those
25 receiving the non-suppression followed by the suppression (i.e., CBA and CAB)
26 counterbalancing system. All study variables were included, with no significant differences

1 being observed for the HR, RPE, 10k time, Stroop, glucose, subjective fatigue, or post-
2 experiment questionnaire) between the counterbalancing systems. However, participants who
3 received the suppression condition followed by the non-suppression system reported feeling
4 significantly more loving in the suppression ($M = 2.22$, $SD = 1.20$) than in the non-suppression
5 ($M = 2.00$, $SD = .47$), $t(18) = -0.54$ $p < .001$ condition. This finding was considered an outlier
6 and when viewed amid the other non-significant relationships it was interpreted from these data
7 that no significant learning effect occurred.

8 **Aversive reaction to the video.** A repeated measures multivariate ANOVA
9 (MANOVA) showed no difference in aversive reactions between the experimental
10 conditions $F(1, 17) = 0.27$, $p = .85$, $\eta^2 = .05$. A repeated measures ANOVA was conducted
11 to test the condition by time ratings of disgust. There was a significant effect of watching
12 the video manipulation on ratings of disgust ($F(1, 18) = 58.05$, $p < .001$; $\eta^2 = .76$) with
13 ratings of disgust being significantly higher after participants watched the video than
14 before in the suppression ($M = 1.21$, $SD = .42$ vs $M = 3.53$, $SD = 1.12$) and non-
15 suppression ($M = 1.26$, $SD = .56$ vs $M = 3.32$, $SD = 1.34$) conditions respectively. There
16 was no significant difference in ratings of disgust between experimental conditions
17 ($F(1,18) = 0.38$, $p = .55$; $\eta^2 = .02$) and no significant interaction for time*condition $F(1,18)$
18 $= 0.33$, $p = .31$; $\eta^2 = .06$.

19 **Mood.** A repeated measures multivariate ANOVA (MANOVA) showed no effect
20 of time $F(1, 18) = 0.51$, $p = .73$, $\eta^2 = .12$, condition $F(1, 18) = 0.81$, $p = .54$, $\eta^2 = .18$, and
21 no condition*time interaction $F(1, 18) = 1.87$, $p = .17$, $\eta^2 = .33$ for mood. This indicates
22 that participants did not experience differing mood prior to or during the course of
23 experimental conditions, and thus, makes it unlikely that any difference in self-regulation
24 can be attributed to mood.

1 **Subjective fatigue.** A repeated measures MANOVA revealed no effect for
2 condition on pre-experimental measures of subjective fatigue $F(1, 18) = 0.66, p = .43, \eta^2 =$
3 $.04$.

4 **Disguising the true nature of the study.** As far as can be inferred from the
5 debrief interviews, participants considered the main goal of the study to be “the
6 repeatability of performance on a cycling task”.

7 **Cognitive functioning.** A 2x2 repeated measures ANOVA with Bonferoni
8 correction revealed a main effect for condition*time interaction on Stroop time $F(1, 18) =$
9 $11.17, p < .01, \eta^2 = .38$. The pairwise comparisons showed participants to take
10 significantly longer to complete the Stroop test after watching the video than they did
11 before this manipulation ($M = 4.45, p = .03, d = .23$). A main effect was also revealed for
12 condition*time interaction on Stroop mistakes $F(1, 18) = 11.06, p = .02, \eta^2 = .27$. The
13 pairwise comparisons showed participants to make significantly more mistakes on the
14 Stroop test after watching the video than they did before this manipulation ($M = -.82, p <$
15 $.01, d = .39$). In the absence of a video in the control condition, a comparison before and
16 after the cycle time trial was conducted and showed no difference in Stroop completion
17 time ($M = 70.16, SD = 11.62$ vs $M = 68.26, SD = 11.80$), $t(18) = 1.69, p = .11; d = .16$ or
18 mistakes ($M = .94, SD = .71$ vs $M = 1.26, SD = .81$), $t(18) = 1.68, p = .11; d = .41$.
19 Therefore, we can conclude that emotion suppression elicited a statistically significant
20 reduction in cognitive functioning. Table 1 provides a summary of the Stroop test results
21 for each condition.

22 **Effect of emotion self-regulation on main dependent variables**

23 A repeated measures MANOVA and univariate post-hoc tests were conducted to
24 establish if there were significant main effects for condition on dependant variables. The results
25 showed there was a multivariate effect between conditions for 10k cycle time, maximum heart
26 rate, RPE, power output, and peak Vo₂, Wilks' Lambda $F(10, 34) = 7.23, p < .001, \eta^2 = .69$.

1 Univariate tests also indicated there was an effect of condition on 10k cycle time $F(2, 20) = 4.8$,
2 $p = .02$, $\eta^2 = .33$, power output $F(2, 20) = 41.47$, $p < .001$, $\eta^2 = .81$, perceived exertion $F(2, 20)$
3 $= 5.90$, $p = .01$, $\eta^2 = .37$, and maximum heart rate $F(2, 20) = 6.51$, $p < .01$, $\eta^2 = .39$. However,
4 univariate tests revealed no effect of condition on peak Vo2 $F(2, 20) = 2.08$, $p = .15$, $\eta^2 = .17$ or
5 blood glucose $F(2, 20) = 1.13$, $p = .34$, $\eta^2 = .10$.

6 **Physical performance.** Post hoc tests using the Bonferoni correction revealed
7 cycle time was significantly slower in the suppression ($M = 18.42$, $SD = 1.14$) than the
8 control ($M = 17.82$, $SD = 1.08$), significant at $p = <.01$ ($d = .52$), and non-suppression (M
9 $= 18.00$, $SD = 1.22$) conditions, significant at $p = .02$ ($d = .41$). The pairwise comparison
10 between the control and non-suppression conditions was non-significant ($M = -.59$, $p =$
11 $.12$, $d = .06$). Therefore, we can conclude that emotion suppression elicited a statistically
12 significant reduction in 10km cycling time trial performance.

13 **Power output.** Post hoc tests with the Bonferoni correction revealed power was
14 significantly lower in the emotion suppression condition ($M = 163.30$, $SD = 7.70$) than the
15 control ($M = 170.40$, $SD = 9.33$), $p < .01$ ($d = 1.44$) and non-suppression condition ($M =$
16 169.98 , $SD = 10.85$), $p < .01$ ($d = 1.78$), respectively, indicating that power was reduced
17 after suppressing emotions during the video task. No difference in power output was
18 observed between the control and non-suppression conditions ($M = -1.16$, $p = .89$, $d =$
19 $.20$). Thus, we can conclude that emotion suppression elicited a statistically significant
20 reduction in power output. Figure 1 shows the mean power output findings for each
21 condition.

22 **Perceived exertion.** Pairwise comparisons revealed perceived exertion to be
23 significantly higher in the suppression condition ($M = 16.34$, $SD = .64$) than the control (M
24 $= 15.17$, $SD = 1.06$) and non-suppression ($M = 15.34$, $SD = 1.02$) conditions ($ps < .01$, $d =$
25 1.06 , $d = .72$). As expected, pairwise comparisons revealed no significant difference in

1 mean exertion between the control and non-suppression conditions ($M = -.66, p = .11, d =$
2 $.36$). Figure 2 shows the mean RPE findings for each condition.

3 **Peak heart rate.** Pairwise comparisons revealed peak heart rate to be significantly
4 lower in the suppression ($M = 178.84, SD = 8.89$) than both the control ($M = 186.42, SD =$
5 7.45), $p = .03$ ($d = .80$), and the non-suppression conditions ($M = 185.12, SD = 7.00$), $p =$
6 $.04$ ($d = .57$) conditions respectively. Pairwise comparisons showed no difference in peak
7 heart rate between the control and non-suppression conditions ($M = 2.36, p = .13, d = .03$).

8 **Blood Glucose.** Repeated measures ANOVAs with a Bonferoni correction tested
9 for variance in blood glucose across condition with no difference in pre-experimental
10 manipulation (i.e., pre-video) glucose levels observed $F(2, 36) = 0.05, p = .94$ ($d = .06$). A
11 number of paired t-tests revealed a significant reduction in blood glucose following the
12 experimental manipulation for the suppression condition ($M = 4.25, SD = .94$ vs $M = 3.92,$
13 $SD = .91$), $t(18) = 2.61, p = .02; d = .36$. No difference was observed for the non-
14 suppression ($M = 4.22, SD = .86$ vs $M = 4.06, SD = .87$), $t(18) = 1.46, p = .16; d = .18$
15 condition.

16 Discussion

17 The present study is the first to examine the effects of emotional self-regulatory
18 impairment on endurance gross motor physical tasks. Specifically, this study examined the
19 effect of an effortful emotional self-regulation manipulation on a subsequent familiar
20 physical endurance self-regulation task (i.e., performance of a 10km cycling time trial)
21 compared to control and non-emotional self-regulation demanding conditions in a sample
22 of competitive sport performers. The findings indicated that following 3 minutes of
23 effortful self-regulation participants completed a 10km cycling time trial slower, generated
24 lower mean power outputs, reached a lower maximum heart rate and reported higher
25 ratings of perceived exertion during exercise than when they were given no self-regulation
26 guidance for the same emotion-eliciting treatment and a control. Moreover, no differences

1 in 10km trial time, power output, perceived exertion, or maximum heart rate or oxygen
2 uptake were observed between the control and non-suppression conditions.

3 The findings presented here support and significantly extend previous research
4 highlighting the impact of self-regulation on physical action. Specifically, the findings here
5 provide further support for previous findings that self-regulatory demands impair subsequent
6 physical self-regulatory efforts using cognitively demanding and handgrip endurance tasks
7 (e.g., Bray et al., 2008; Martin Ginis & Bray, 2010; Muraven et al., 1998) and calisthenic
8 exercise routines (e.g., Dorris et al., 2012). Additionally, the extant research is extended in two
9 ways. First, as an initial examination of the effects of *emotional* self-regulation on sport
10 performance, this study furthers knowledge on the role of emotional experience and regulation
11 in performance environments. Indeed, such findings will be of interest to researchers examining
12 the relationship between emotions prior to and during competition (e.g., anxiety, anger) and
13 their regulation and performance. Given research has found sport organizations to impose
14 chronic expectations and requirements for emotional suppression on performers (e.g., Wagstaff
15 et al., 2012a), the present findings have implications for well-being and performance. Although
16 further research is required to test such possibilities, it is possible that self-regulatory demands
17 impact performance and well-being through increased likelihood of emotion regulation failure
18 (e.g., conflict, poor relationships, choking) and behaviors associated with self-regulatory failure
19 (e.g., violence, doping, substance abuse, cheating). Additional considerations relate to the
20 prioritisation between external environmentally-imposed expectations for self-regulation (e.g.,
21 media duties, athlete-coach transactions) and one's internal self-determined desires or
22 preferences (e.g., the expression of emotions experienced, reappraisal of emotions). That is, the
23 demands for and engagement in acts of self-regulation might be mediated by both cognitive
24 appraisal and motivational components (cf. Beedie & Lane, 2012). Necessarily, research is
25 required to explore such avenues of enquiry, which might also consider the mediating role of
26 individual difference (e.g., personality) and emotion (e.g., intensity or type of emotion

1 experienced) variables on the regulation-performance relationship. Further, researchers might
2 examine the relationship between chronic demands for emotional self-regulation and
3 components of burnout such as emotional exhaustion (see Maslach & Jackson, 1981) or
4 antecedents of their onset such as emotional labor (see Brotheridge & Grandey, 2002).

5 A second way this study extends current research is through the demonstration of an
6 effect of impaired self-regulatory resources on an *endurance* task directly related to sport
7 performance. The findings provide an empirical base for assumptions that self-regulation
8 impairment can debilitate sport performance based on the measurement of physical tasks lasting
9 longer than a few minutes. Such findings are consistent with Marcora et al. (2009) who also
10 observed reduced time-to-exhaustion, greater perceived exertion, and no effect for
11 cardiovascular responses on a cycling task following a cognitively demanding manipulation.
12 When considered amidst the extant research, the present findings suggest that endurance sport
13 performance requires sufficient conscious self-regulation resource allocation in order to
14 optimise power output (i.e., pacing) over the duration of training and competition (cf., Baron et
15 al., 2009; Dorris et al., 2012). Indeed, such findings highlight opportunities for multidisciplinary
16 and crossover psychophysiological research.

17 Consistent with the potential for the results to inform a range of fields of human
18 functioning, the findings are consistent with a number of theories in psychophysiology. Indeed,
19 these data provide further support for the perspective that self-regulation is guided by a global
20 resource incorporating cognitive, physical and emotional components (cf. Muraven &
21 Baumeister, 2000), but that this resource does not appear to be fully explained by a reduction in
22 blood glucose (Beedie & Lane, 2012; Kurzban, 2010). Another notable finding relates to the
23 significantly lower max heart rate values but higher ratings of effort observed in the suppression
24 condition compared to the other conditions. These data appear to indicate that participants were
25 less willing or less able to exert effort to optimally self-regulate in the suppression condition.
26 Hence, the findings support the global resource component of the strength model and provide

1 initial empirical support for Beedie and Lane's (2012) resource allocation extension of this
2 model. To elaborate, Beedie and Lane do not dispute the important role of glucose as a resource
3 involved in self-regulation, but suggest that regulatory failure is due to the prioritized allocation
4 of glucose to relevant body sites rather than insufficient resources per se. Participants in the
5 present study reported significantly higher ratings of perceived exertion during a self-regulatory
6 exercise task despite generating lower levels of power output following regulatory
7 manipulation. The findings are also consistent with the psychobiological model of exercise
8 performance (see Marcora, 2008). This effort-based decision-making model of endurance
9 performance postulates that time-to-exhaustion is determined by perceived exertion and
10 potential motivation, or the maximum effort and individual is willing to expend to satisfy a
11 goal. In testing this model, Marcora et al. (2009) proposed two potential explanations for why
12 mentally fatigued participants report higher perceived exertion. First, such deficits might affect
13 central processing of the sensory inputs generating perception of effort during exercise. Second,
14 mental fatigue might directly affect the cortical centers involved in the cognitive aspects of
15 central motor command, the primary sensory input for perceived exertion. Marcora et al.
16 hypothesize that the anterior cingulate cortex might be a likely candidate for this, due to this
17 being an area where motor control, homeostatic drive, emotion, and cognition converge.
18 Evidently, further research is required to understand the complex interplay between self-
19 regulation and functioning. Such work will likely require a consideration of neurological,
20 physiological and psychological factors and has application to the areas of self-regulation,
21 pacing, persistence, fatigue, performance, and wellbeing.

22 Beyond the perceived novelty and significance of the study alluded to above, there are
23 several strengths aligned with the rigor of the present study. The use of a controlled,
24 counterbalanced, repeated measures design with a familiarization and various manipulation
25 checks augment the argument that a priori self-regulatory demands accounted for performance
26 differences across condition. The within-participant repeated measures design used here

1 ameliorates potential obstacles associated with between-group designs (e.g., homogeneity of
2 groups, large sample size requirements, individual differences) and appears to offer an
3 alternative to the between-group, dual task design typically used in self-regulation research. In
4 the present study, the dual task paradigm remains but is embedded within the experimental
5 conditions whilst providing a familiarization and control against which to compare. In addition
6 to the study design, the use of endurance sport performance as a self-regulation task is
7 perceived to be a strength of the present study. Given that many sports require *pacing* of
8 physical exertion during time-bound competitions which have clearly defined end-points, this
9 study arguably better represents sport performance than previous research using measurements
10 of handgrip endurance or calisthenic *persistence*.

11 Despite the perceived value of the findings discussed above there are a few limitations
12 allied with the present study. First, using the same video manipulation in the suppression and
13 non-suppression conditions may have caused an order effect regarding the intensity of disgust
14 experienced by participants (i.e., reduced disgust the second time they watched the video).
15 Second, the repeated measures design may have prompted participants to conserve regulatory
16 resources in expectation of subsequent regulatory demands. However, the counterbalancing
17 system appears to have buffered against these effects. To elaborate, manipulation checks
18 showed non-significant differences between the ratings of disgust in response to the video,
19 difficulty in suppressing emotional expression, and the absence of regulatory requirements in
20 the non-suppression condition between the four counterbalancing systems. Third, the sampling
21 of participants who were regular, but not competitive cyclists, might have been a limitation.
22 While these sampling factors might have increased the risk of between-condition variance, it is
23 believed that the sampling of endurance athletes and within-participant, repeated measures
24 design reduced the likelihood of such confounds. A fourth consideration relates to glucose
25 measurement. Although blood was sampled near the brain here (i.e., the earlobe), such sampling
26 provides measures of peripheral blood glucose rather than brain glucose. Beedie and Lane

1 (2012) have argued that periphery blood glucose measurements are problematic. Hence, future
2 research might seek more sensitive and reliable measures of blood glucose, such as brain
3 glucose (e.g., Masden et al., 1995). A final limitation is that the video manipulation used here
4 was not sport specific, thus limiting ecological validity. However, and in line with other self-
5 regulation research (e.g., Englert & Bertrams, 2012), it was perceived important to apply an
6 established task to manipulate self-regulation. Future research in this area should seek to use
7 sport-specific manipulations of emotional self-regulation and consider using a range of videos
8 with similar emotion-eliciting effects such as performance feedback, selection, or sport injuries.

9 In view of the findings and in consideration of the strengths and limitations alluded to
10 above, several applied implications are proposed. Expressly, it is important for practitioners to
11 make sport performers and organizations aware that tasks requiring emotion regulation close to
12 competition (e.g., impression management, interaction with fans, media interviews) may affect
13 perceived exertion, pacing, and ultimately, performance outcomes. Moreover, sport
14 psychologists might make efforts to make individuals in such domains aware that self-
15 regulation requirements originate from a variety of sources such as thought-suppression,
16 decision-making, and concentration (cf., Baumeister et al., 2007) with likely similar outcomes
17 for endurance performance. Such implications are also likely to be relevant in other professional
18 domains requiring emotion regulation and physical endurance including military operations,
19 medical and emergency services, and manual employment. Hence, occupational and
20 organizational psychologists might consider similar practical recommendations for other
21 performance domains, especially those requiring physical exertion.

22 The study presented here offers an insight into the potentially debilitating role emotional
23 self-regulation (i.e., emotion suppression) might have for endurance sport performance. Such
24 findings are salient given the apparent importance of such acts in the sport domain (see Lane et
25 al., 2012; Tamminen & Crocker, 2013; Uphill et al., 2009; Wagstaff et al., 2012a). However,
26 much remains to be examined within the domain of self-regulation. Some of the most exciting

1 research opportunities appear to lie within the regulation of emotion and the incorporation of
2 neurobiology, physiology, and psychology expertise. For example, research is required to
3 examine recovery from self-regulatory resource depletion, the mediating role of numerous
4 variables towards the understanding of resource allocation, and the development of
5 interventions to ameliorate or overcome the potentially debilitating effects of resource demands
6 (cf., Baumeister, Gailliot, DeWall, & Oaten, 2006). Indeed, it would appear that sport and
7 exercise scientists are ideally placed to be offer expertise toward the development of subsequent
8 research agendas. Overall, the opportunities for future enquiry to assist the crystallization of
9 self-regulation theory and the development of meaningful applied interventions indicate that
10 this area holds fruitful prospects.

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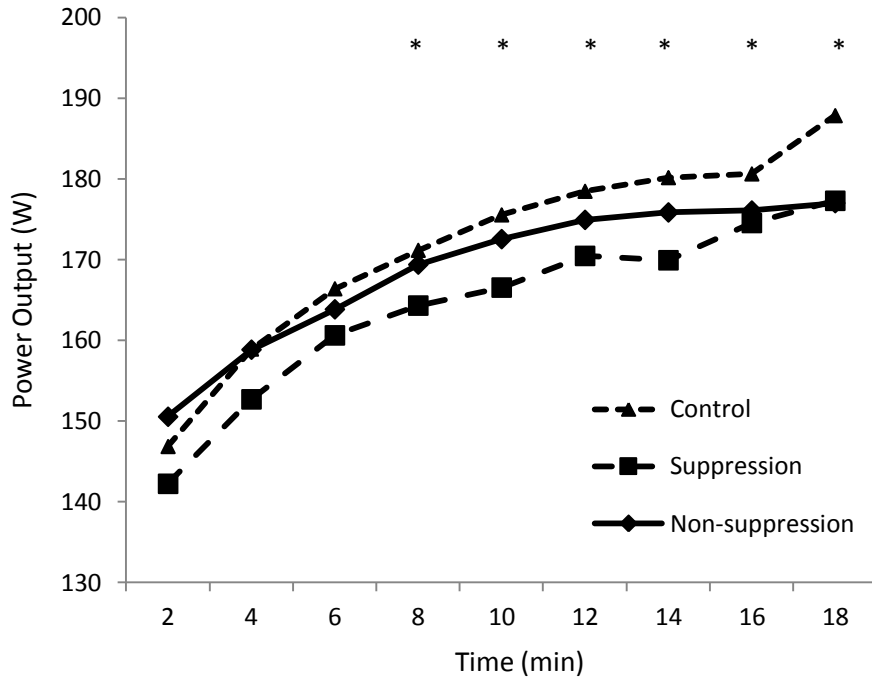
1 **Figure Captions**

2 **Figure 1.** Mean power output during 10km cycling time trials

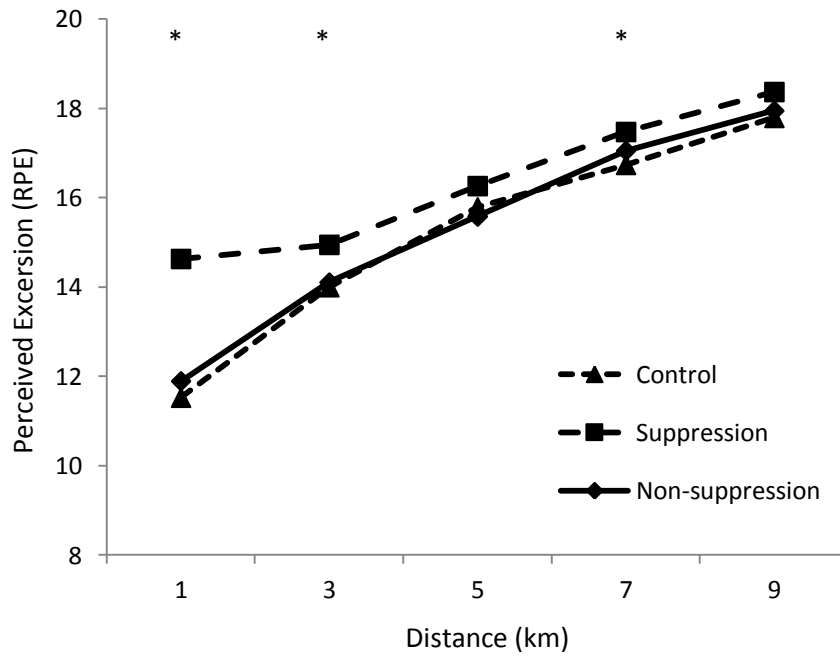
3 **Figure 2.** Mean ratings of perceived exertion during 10km cycling time trials

4 **Table 1.** Means and standard deviations for performance time, cognitive functioning, peak heart
5 rate and peak oxygen consumption during 10km cycling time trials

1



2



3

Condition	Control		Emotion suppression		Non-suppression	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Cycle time (mins)	17.82	1.08	18.42	1.14	18.00	1.22
Stroop time (secs)						
pre-experiment/video	70.16	11.62	70.68	11.61	69.63	9.80
post-video	-	-	77.79	12.11	69.95	9.51
Stroop errors						
pre-experiment/video	.94	.71	.89	.99	.84	.89
post-video	-	-	2.47	1.93	.89	.74
Power output (Watts)	170.40	9.33	163.30	7.70	169.98	10.85
Perceived Exertion (RPE)	15.17	1.06	16.34	.64	15.34	1.02
Peak heart rate (bpm)	186.42	7.45	178.84	8.89	185.42	7.00
Peak Vo2 (l/min)	4.42	.58	4.20	.41	4.41	.59
Blood glucose (mmol/L)						
pre-experiment/video	4.27	.67	4.25	.94	4.22	.86
post-video	-	-	3.92	.91	4.06	.87
post-cycle	3.77	.80	3.31	.82	3.47	.76