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Journal of Sports Sciences

Comparison of affective responses during and after low volume high-intensity interval exercise, continuous moderate- and continuous high-intensity exercise in active, untrained, healthy males --Manuscript Draft--

Full Title:	Comparison of affective responses during and after low volume high-intensity interval exercise, continuous moderate- and continuous high-intensity exercise in active, untrained, healthy males
Manuscript Number:	RJSP-2017-0083R2
Article Type:	Original Manuscript
Keywords:	interval training; Intermittent exercise; enjoyment; adherence
Abstract:	<p>This study compared affective responses to low volume high-intensity interval exercise (HIIE), moderate-intensity continuous exercise (MICE) and high-intensity continuous exercise (HICE). Twelve untrained males (VO_{2max} 48.2 ± 6.7 ml·kg⁻¹·min⁻¹) completed MICE (30 min cycle at 85% of ventilatory threshold (VT)), HICE (cycle at 105% of VT matched with MICE for total work), and HIIE (10 x 6 s cycle sprints with 60 s recovery). Affective valence and perceived activation were measured before exercise, post warm-up, every 20% of exercise time, and 1, 5, 10, and 15 min post-exercise. Affective valence during exercise declined by 1.75 ± 2.42, 1.17 ± 1.99, and 0.42 ± 1.38 units in HICE, HIIE, and MICE, respectively, but was not statistically influenced by trial ($P = 0.35$), time ($P = 0.06$), or interaction effect ($P = 0.08$). Affective valence during HICE and HIIE was consistently less positive than MICE. Affective valence post-exercise was not statistically influenced by trial ($P = 0.10$) and at 5 min post-exercise exceeded end-exercise values ($P = 0.048$). Circumplex profiles showed no negative affect in any trial. Affective responses to low volume HIIE are similar to HICE but remain positive and rebound rapidly, suggesting it may be a potential alternative exercise prescription.</p>
Order of Authors:	<p>Ailsa Niven</p> <p>Jacqueline Thow</p> <p>Jack Holroyd</p> <p>Anthony P Turner</p> <p>Shaun Phillips</p>
Response to Reviewers:	<p>Reviewer #1: The revision of the paper is much improved. I have the following remarks:</p> <p>1. response to Reviewer #1 point 9: new text is indicated on L388, but this doesn't seem correct.</p> <p>We apologise if this amendment was overlooked. We have now added this text where we believe the reviewer was referring to (P.16, L391 of anonymised manuscript).</p> <p>2. response to Reviewer #1 point 17: new text is indicated on L492, but this doesn't seem correct.</p> <p>We believe that this amendment was made; however, we have amended the wording to make the statement clearer (P.20, L495 of anonymised manuscript).</p> <p>3. Title: I recommend that the title include the statement 'active, untrained, healthy males'. Incidentally, in the paper, they are described as 'not highly trained', which seems different to me from 'untrained'.</p> <p>The title amendment has been made. Also, for consistency the participants are now referred to as "untrained" in the methodology.</p> <p>4. L392: I would add the word 'young'</p>

	This has been added into the location we believe the reviewer is referring to (P.16, L391 of anonymised manuscript).
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1 **Comparison of affective responses during and after low volume high-intensity**
2 **interval exercise, continuous moderate- and continuous high-intensity exercise**
3 **in active, untrained, healthy males**

4

5 Running title: affective responses to reduced volume high-intensity interval exercise

6

7 **Keywords:** interval training; intermittent exercise; enjoyment; adherence

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26 **Abstract**

27

28 This study compared affective responses to low volume high-intensity interval
29 exercise (HIIE), moderate-intensity continuous exercise (MICE) and high-intensity
30 continuous exercise (HICE). Twelve untrained males ($\dot{V}O_{2\max}$ 48.2 ± 6.7 ml·kg⁻¹·min⁻¹) completed MICE (30 min cycle at 85% of ventilatory threshold (VT)), HICE
31 ¹·min⁻¹) completed MICE (30 min cycle at 85% of ventilatory threshold (VT)), HICE
32 (cycle at 105% of VT matched with MICE for total work), and HIIE (10 x 6 s cycle
33 sprints with 60 s recovery). Affective valence and perceived activation were measured
34 before exercise, post warm-up, every 20% of exercise time, and 1, 5, 10, and 15 min
35 post-exercise. Affective valence during exercise declined by 1.75 ± 2.42 , 1.17 ± 1.99 ,
36 and 0.42 ± 1.38 units in HICE, HIIE, and MICE, respectively, but was not statistically
37 influenced by trial ($P = 0.35$), time ($P = 0.06$), or interaction effect ($P = 0.08$).
38 Affective valence during HICE and HIIE was consistently less positive than MICE.
39 Affective valence post-exercise was not statistically influenced by trial ($P = 0.10$) and
40 at 5 min post-exercise exceeded end-exercise values ($P = 0.048$). Circumplex profiles
41 showed no negative affect in any trial. Affective responses to low volume HIIE are
42 similar to HICE but remain positive and rebound rapidly, suggesting it may be a
43 potential alternative exercise prescription.

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51 **Introduction**

52

53 More than 30% of the worldwide population are insufficiently physically active for
54 health (Hallal, 2012). Lack of time is a commonly cited barrier to completing
55 sufficient physical activity (Aaltonen et al., 2012). Low volume high-intensity interval
56 exercise (HIIE) is brief, repeated bursts of intense or all-out exercise separated by rest
57 or low-intensity exercise, with total intense exercise time ≤ 10 min per session and total
58 session time ≤ 30 min (Gillen & Gibala, 2014). Low volume HIIE can considerably
59 improve aerobic fitness, body composition, and cardiometabolic health in a variety of
60 populations (Babraj et al., 2009; Jakeman, Adamson, & Babraj, 2012; Tjonna et al.,
61 2009). Therefore, low volume HIIE is a time efficient strategy for improving health
62 and fitness (Gillen & Gibala, 2014) that may appeal to individuals with limited time
63 to be active.

64

65 Many HIIE protocols are extremely challenging due to their high-intensity nature
66 (Gillen & Gibala, 2014), which has led to debate around the public health value of
67 HIIE. Several researchers have argued that individuals are unlikely to engage with, or
68 adhere to HIIE (Biddle & Batterham, 2015; Hardcastle, Ray, Beale, & Hagger, 2014),
69 partly because they will find it unpleasant and therefore be unlikely to repeat the
70 experience (Rhodes & Kates, 2015). According to the dual-mode theory of affective
71 responses to exercise (Ekkekakis, 2003), intensity is a key mediator of the affective
72 response. Exercise above the ventilatory threshold (VT) typically leads to more
73 unpleasant affective responses than exercise at and below VT (Astorino et al., 2016;
74 Ekkekakis, Hall, & Petruzzello, 2008; Kilpatrick, Kraemer, Bartholomew, Acevedo,
75 & Jarreau, 2007). However, the dual-mode theory applies to continuous exercise, and

76 the intermittent nature of HIIE with regular recovery opportunities may allow
77 participants to experience more positive affective responses (Jung, Bourne, & Little,
78 2014; Jung, Little, & Batterham, 2016).

79

80 However, an emerging body of literature suggests that HIIE generates less positive
81 affect compared to continuous submaximal exercise (Jung et al., 2014; Oliveira,
82 Slama, Deslandes, Furtado, & Santos, 2013; Saanijoki et al., 2015). Whilst these
83 studies suggest that HIIE is experienced less positively compared with more moderate
84 exercise, findings may be clouded by methodological issues. Some studies (Jung et
85 al., 2014; Saanijoki et al., 2015) standardised continuous intensity exercise to a
86 percentage of peak power (W_{peak}). The relative demands and tolerable duration of
87 exercise are not adequately characterised using this approach, and instead exercise
88 intensity domains should take account of individualised intensity thresholds, such as
89 the VT (Mann, Lamberts, & Lambert, 2013). Additionally, the HIIE protocol used by
90 Jung et al. (2014) was the same duration as their continuous high-intensity protocol,
91 and the protocols of Oliveira et al. (2013), Saanijoki et al. (2015), and Decker and
92 Ekkekakis (2016) lasted ~17-23 min, excluding warm-up and cool-down. This
93 negates the practical attraction of reduced exercise duration with HIIE. Furthermore,
94 the protocols adopted by Saanijoki et al. (2015) and Oliveira et al. (2013) were
95 particularly arduous, making unclear the transferability of the findings to HIIE
96 protocols that may be more palatable.

97

98 There has been a concerted effort to develop low volume HIIE protocols that are
99 efficacious, time efficient, and more palatable (Gillen & Gibala, 2014). Protocols
100 involving 20-60 s of total work within a 7-10 min exercise session can substantially

101 improve aerobic fitness and cardiometabolic health (Adamson, Lorimer, Cobley, &
102 Babraj, 2014; Adamson, Lorimer, Cobley, Lloyd, & Babraj, 2014; Allison, Martin,
103 MacInnis, Gurd, & Gibala, 2016). However, affective responses to these protocols
104 are not well understood. It is plausible that affective responses may be less negative
105 than in previously reported HIIE data, due to shorter and less frequent work bouts
106 (Jung et al., 2014; Martinez, Kilpatrick, Salomon, Jung, & Little, 2015), and larger
107 work-to-rest ratios implying less reliance on anaerobic metabolism relative to session
108 duration. Recent work on the affective responses to HIIE specifically called for
109 research to investigate affective responses to reduced volume HIIE protocols (Decker
110 & Ekkekakis, 2016). While some research has compared affective responses to
111 different volumes of HIIE (Martinez et al., 2015; Wood et al., 2016), a low volume
112 HIIE protocol (i.e. 20-60 s total work) was not used.

113

114 How people feel *after* HIIE may also be of importance, as affect at the end of the task
115 may influence future behaviour (Kahneman, Fredrickson, Schreiber, & Redelmeier,
116 1993). Although in their recent review, Rhodes and Kates (2015) concluded the
117 evidence did not support a relationship between post-exercise affect and future
118 physical activity behaviour, this was based on only nine studies of varying quality with
119 mixed findings, highlighting the need for further research. Further, Rhodes and Kates
120 (2015) acknowledged the counter theoretical argument that the end of the task may be
121 the most powerful affective stimulus (Hargreaves & Stych, 2013; Kahneman et al.).
122 This perspective is important to investigate further because according to dual-mode
123 theory there is likely to be a ‘rebound’ from affective negativity to positivity following
124 exercise, regardless of intensity (Ekkekakis, 2003), and within 1 min following severe-
125 intensity exercise (Ekkekakis, Hall, & Petruzzello, 2005b). Therefore, it is possible

126 that affective responses post-HIIE are similar to responses following exercise at a
127 lower intensity. Limited research has focused on affect post-HIIE with recent studies
128 either not assessing post-exercise affect (Frazao et al., 2016; Saanijoki et al., 2015) or
129 assessing affect at a later point (Jung et al., 2014; Oliveira et al., 2013) and potentially
130 missing the window to document and compare the rebound effect.

131

132 The development of effective, time efficient, and palatable HIIE protocols would be
133 an important step forward for the implementation of HIIE into public health strategies.
134 Efficacy and time efficiency have been established; affective responses during and
135 after these reduced volume protocols have not been well examined. The aim of this
136 study was to compare affective responses during and after low volume HIIE,
137 moderate-intensity continuous exercise (MICE) and high-intensity continuous
138 exercise (HICE). We hypothesised that cardiovascular strain would be similar in the
139 HICE and HIIE trials, and greater than the MICE trial; affective valence would
140 decrease more during HIIE than MICE, but less than during HICE; and post-exercise
141 affective valence would rebound within the same time-frame in all trials.

142

143 **METHODS**

144

145 **Participants**

146

147 Twelve healthy, physically active males participated (mean $\pm$ SD age 25 ± 7 years
148 (range 19-35 years), height 177 ± 7 cm, body mass (BM) 76.5 ± 12.2 kg, maximal
149 oxygen uptake ($\dot{V}O_{2max}$) 48.2 ± 6.7 ml $\cdot$ kg $^{-1}\cdot$ min $^{-1}$, W_{peak} 297 ± 36 W). Participants
150 were generally physically active (≥ 150 min habitual physical activity per week

151 (National Health Service, 2013); physically active for ≥ 30 min on 5 ± 1.6 days per
152 week (range 2-7)), untrained (below the age-gender 90th percentile for $\dot{V}O_{2\max}$
153 (American College of Sports Medicine, 2005)), not participating in/training for a
154 competition or event, and unfamiliar with HIIE. The sample consisted of five
155 University staff members and seven undergraduate students (one computer science,
156 one primary education, and five sport science students). The study was explained to
157 participants, and written informed consent was gained. All work was conducted with
158 the formal approval of the University of Edinburgh, Moray House School of Education
159 Ethics Committee.

160

161 **Baseline trial**

162

163 All sessions took place in the same climate controlled laboratory (temperature 20-
164 21°C, relative humidity 50-55%). In visit one, anthropometric data were collected
165 (BM: model 708; Seca, Hamburg, Germany; standing height: model 245; Seca,
166 Hamburg, Germany), and standardised explanations of the Borg CR-10 Rating of
167 Perceived Exertion (RPE) scale, Feeling Scale (FS, (Hardy & Rejeski, 1989)), and Felt
168 Arousal scale (FAS, (Svebak & Murgatroyd, 1985)) were provided according to the
169 instructions in the original publications. These explanations were briefly reviewed at
170 the beginning of each subsequent session.

171

172 Participants completed a cycle ergometer ramp test to exhaustion (Lode Excalibur,
173 Groningen, Netherlands) to determine $\dot{V}O_{2\max}$ and VT. The ergometer was set in
174 hyperbolic mode and participants were informed that they could cycle at their
175 preferred cadence. Participants cycled for 5 min at 60 W to familiarise themselves

176 with the ergometer. They then dismounted, fitted a heart rate (HR) monitor (Polar
177 Electro, Finland), and were attached to the online gas analyser (Cortex MetaMax 3B,
178 Leipzig, Germany) via a two-way non-rebreathing facemask (7450 Series V2, Hans
179 Rudolph, Kansas, USA). The analyser was calibrated according to manufacturer
180 instructions prior to each use. Participants sat quietly for 5 min then remounted the
181 ergometer and completed the warm-up and first two test stages. The facemask was
182 then removed and participants sat for 5 min.

183

184 The test, adapted from Bergstrom et al. (2013), began at 60 W for 2 min, after which
185 power output increased by 15 W·min⁻¹ until volitional exhaustion or cadence dropped
186 below 60 rev·min⁻¹ for more than 10 s despite strong verbal encouragement.
187 Participants' $\dot{V}O_{2\max}$ was determined as the highest 30 s average, provided that at least
188 two of the following criteria were met: a) $\geq 90\%$ of age-predicted maximum HR; b)
189 respiratory exchange ratio > 1.1 ; c) a plateau in $\dot{V}O_2$ (< 150 ml·min⁻¹ increase during
190 the last 60 s of the test) (Bergstrom et al., 2013). While valid $\dot{V}O_{2\max}$ values can be
191 gained from shorter protocols (Midgley et al., 2008), the primary outcome measure of
192 the test was VT. Therefore, a published VT protocol was chosen.

193

194 The VT was determined using the V-slope method described by Beaver, Wasserman,
195 and Whipp (1986), and defined as the $\dot{V}O_2$ corresponding to the intersection of two
196 linear regression lines plotted below and above the visually determined breakpoint in
197 the $\dot{V}CO_2$ versus $\dot{V}O_2$ relationship (Bergstrom et al., 2013). All resting and warm-up
198 expired gas data was excluded from the analysis, and the data were checked to confirm
199 that there was no hyperventilation at the start of the test. The VT determined from the
200 V-slope method was confirmed by examining plots of the ventilatory equivalents for

201 O_2 ($\dot{V}_E/\dot{V}\text{O}_2$) and CO_2 ($\dot{V}_E/\dot{V}\text{CO}_2$) against $\dot{V}\text{O}_2$ (Davis, Frank, Whipp, & Wasserman,
202 1979). A systematic increase in $\dot{V}_E/\dot{V}\text{O}_2$ without a corresponding increase in $\dot{V}_E/\dot{V}\text{CO}_2$,
203 was the criterion for confirming VT. All VT determinations were undertaken by the
204 same physiologist, and confirmed by a second physiologist. The power output/ $\dot{V}\text{O}_2$
205 regression equation from the maximal test was used to determine the power output
206 associated with $\dot{V}\text{O}_2$ at the VT (Bergstrom et al., 2013).

207

208 **Exercise sessions**

209

210 Participants completed three trials (Figure 1) in a randomised, Latin-square (3 x 3),
211 crossover design. Within-participants, all trials were completed at the same time of
212 day and separated by 3-7 days, with the same researcher and research assistant present.
213 Participants completed a dietary record for 24 h before the first session and replicated
214 this prior to subsequent sessions. They also refrained from strenuous physical or
215 cognitive activity (such as long periods of intense concentration, which can influence
216 perception of exercise difficulty; Marcora, Staiano, & Manning, 2009) and alcohol
217 intake for ≥ 24 h before each session. Adherence to these procedures was confirmed
218 at each visit. Trials began and ended with 2 min cycling at 60 W, followed by an
219 additional 13 min of seated recovery post-exercise (total post-exercise time 15 min).

220

221 *Moderate-Intensity Continuous Exercise*

222

223 Participants cycled for 30 min at a power output equal to 85% of VT, which
224 corresponds to a moderate intensity (Kilpatrick et al., 2007). This trial acted as a

225 control, as measures of affect have previously shown minimal change during
226 continuous exercise at this intensity (Ekkekakis et al., 2008; Kilpatrick et al., 2007).

227

228 *High-Intensity Continuous Exercise*

229

230 Participants cycled at a power output corresponding to 105% of VT, which
231 corresponds to a hard intensity (Kilpatrick et al., 2007). Differences in total work may
232 influence affective responses to exercise (Blanchard, Rodgers, Wilson, & Bell, 2004).
233 Therefore, work done in HICE was the same as that done in MICE. This was achieved
234 by reducing the exercise duration in HICE to account for the higher power output in
235 this trial.

236

237 *High-Intensity Interval Exercise*

238

239 Participants completed 10 x 6 s all-out cycling efforts against 7.5% of BM,
240 interspersed with 60 s recovery, on a mechanically braked cycle ergometer (Monark
241 Ergomedic 814E, Vansbro, Sweden). The first 50 s of recovery was passive. From
242 50-59 s, participants cycled unloaded at 60 rev·min⁻¹. At 59 s, participants cycled
243 maximally for 1 s unloaded, after which the resistance was added to the flywheel and
244 the 6 s sprint began. This protocol has been shown to substantially improve aerobic
245 capacity, physical function, and metabolic health in untrained adults (Adamson,
246 Lorimer, Copley, & Babraj, 2014; Adamson, Lorimer, Copley, Lloyd, et al., 2014). A
247 laboratory protocol was chosen to standardise the exercise sessions and provide a
248 clearer causal relationship between low volume HIIE and affective responses, and a
249 stronger justification for follow-up work using a more practical field-based protocol.

250 Total session duration, exercise duration, or work performed in HIIE was not matched
251 to MICE and HICE, as one of the attractive characteristics of HIIE is its ability to elicit
252 health and fitness improvements with notably less work and time commitment than
253 continuous submaximal exercise (Babraj et al., 2009).

254

255 During MICE and HICE, the researcher and research assistant remained out of
256 eyesight of the participants and did not communicate with them other than to record
257 in-exercise measurements. This was not possible during HIIE due to the requirement
258 to add and remove resistance to the flywheel, and to instruct the participant to stop and
259 start each sprint. However, no encouragement was provided during HIIE.

260

261 * FIGURE 1 HERE *

262

263 **Measurements**

264

265 Heart rate was recorded throughout at 5 s intervals. The Borg CR-10 scale assessed
266 RPE, as ratio scales provide more accurate insights into perceptual processes during
267 exercise than the 6-20 RPE scale (Borg & Kaijser, 2006; Oliveira et al., 2013).
268 Affective valence (pleasure/displeasure) was assessed using the FS, ranging from -5
269 (very bad) to +5 (very good). Perceived activation was measured using the FAS,
270 ranging from 1 (low arousal) to 6 (high arousal). All scales were administered at rest
271 prior to the warm-up (except RPE), in the last 30 s of the warm-up, every 20% of
272 exercise time, and 1, 5, 10, and 15 min post-exercise (RPE at 1 min post-exercise
273 only). In the HIIE trial, scales were taken immediately following sprints 2, 4, 6, 8,
274 and 10 (still ~20% of exercise duration), due to the logistical problem of collecting

275 this information during an all-out cycling effort. Laminated copies of each scale were
276 held in front of the participant, who was asked to provide a number for each scale
277 according to how they felt at that moment (Oliveira et al., 2013; Saanijoki et al., 2015).

278

279 Data from the FS and FAS were represented in the circumplex model, which describes
280 a combined affective state with respect to activation and valence (Oliveira et al., 2013).

281 This model was used as it includes positive and negative valence, high and low
282 activation states, and is not domain-specific, making it appropriate for assessing affect
283 before, during, and after exercise (Ekkekakis et al., 2008).

284

285 **Statistical analyses**

286

287 Analyses were performed using IBM SPSS Statistics 21 for Windows (IBM Corp.,
288 Chicago, IL). The Shapiro-Wilk test assessed the distribution of all data sets. Work
289 related characteristics of exercise were compared using one-way repeated measures
290 ANOVA and post-hoc pairwise comparisons with the Bonferroni correction.
291 Affective valence and perceived activation during exercise were examined using a
292 two-way (3 trials and 6 time points (warm-up, 20, 40, 60, 80, and 100% of exercise))
293 repeated measures ANOVA. The same variables post-exercise were examined using
294 a two-way (3 trials and 5 time points (100% of exercise, 1, 5, 10, and 15 min post-
295 exercise)) repeated measures ANOVA. Post hoc pairwise comparisons with the
296 Bonferroni correction explored significant main effects. This analysis follows the
297 same approach as Ekkekakis et al. (2008) in a related study. An alpha level of $P <$
298 0.05 was used in all tests except when the Bonferroni correction was applied. Cohen's
299 d effect sizes (ES) for within-participants designs (Lakens, 2013) were calculated for

300 pairwise comparisons and defined as trivial ($d < 0.2$), small ($d \geq 0.2, < 0.5$), medium
301 ($\geq 0.5, < 0.8$), and large ($d \geq 0.8$) (Cohen, 1992).

302

303 **RESULTS**

304

305 **Intensity manipulations**

306

307 Table 1 presents mean performance data and physiological responses from the three
308 trials. By design, MICE and HICE were equal in terms of total work performed and
309 differed statistically in duration and intensity. The MICE and HIIE trials differed
310 statistically across all variables with the exception of mean HR. The HICE and HIIE
311 trials also differed statistically for all variables except RPE.

312

313 * TABLE 1 HERE *

314

315 **During Exercise**

316

317 *Affective valence*

318

319 There were no statistically significant effects of trial ($F_{1,2,13.6} = 1.02, P = 0.350$), time
320 ($F_{1,6,17.8} = 3.57, P = 0.058$), or interaction ($F_{2,6,28.5} = 2.57, P = 0.081$) for affective
321 valence during exercise (Figure 2A). However, differences in affective valence
322 progressively increased during exercise between MICE and HICE (mean difference
323 $0.0 \pm 1.0, d = 0.20$ at warm-up to $1.5 \pm 2.3, d = 0.66$ at 100% of exercise) and MICE
324 and HIIE (mean difference $0.1 \pm 1.1, d = 0.16$ at warm-up to $0.9 \pm 1.6, d = 0.59$ at

100% of exercise). The difference in affective valence between HICE and HIIE was fairly stable over time (mean difference 0.1 ± 1.2 , $d = 0$ at warm-up to 0.6 ± 3.2 , $d = 0.18$ at 100% of exercise). Within-trials, the largest reduction in affective valence (warm-up to 100% of exercise) occurred in HICE (-1.75 ± 2.42 units, $d = 0.72$), followed by HIIE (-1.17 ± 1.99 units, $d = 0.59$) and MICE (-0.42 ± 1.38 units, $d = 0.30$).

Perceived activation

There were statistically significant main effects of trial ($F_{2,22} = 13.91$, $P < 0.001$), time ($F_{1.6,18.3} = 40.12$, $P < 0.001$), and trial x time interaction ($F_{4.1,45.6} = 4.14$, $P = 0.006$) for perceived activation during exercise (Figure 2B). There were no statistical differences between conditions at baseline or warm-up. The MICE and HIIE trials differed statistically throughout exercise, with differences remaining large between 20% ($P = 0.002$, $d = 1.37$) and 100% ($P = 0.002$, $d = 1.36$) of exercise. The MICE and HICE trials differed statistically at 60% ($P = 0.006$, $d = 1.16$), 80% ($P = 0.006$, $d = 1.17$), and 100% ($P = 0.021$, $d = 0.96$) of exercise. The HICE and HIIE trials did not differ statistically at any time (largest difference at 20% of exercise, $P = 0.075$, $d = 0.75$).

* FIGURE 2 HERE *

350 **Post-exercise**

351

352 *Affective valence*

353

354 There were no statistically significant main effects of trial ($F_{1.1,12.5} = 3.09$, $P = 0.100$)
355 or trial x time interaction ($F_{2.4,26.9} = 1.17$, $P = 0.333$) for affective valence post-exercise
356 (Figure 2A). However, there was a main effect of time ($F_{1.3,14.5} = 11.11$, $P = 0.003$).
357 Affective valence was statistically greater 5 ($P = 0.048$, $d = 0.81$), 10 ($P = 0.038$, $d =$
358 0.61) and 15 min ($P = 0.041$, $d = 0.67$) post-exercise compared with 100% of exercise.

359

360 *Perceived activation*

361

362 There were statistically significant main effects of trial ($F_{2,22} = 10.68$, $P = 0.001$), time
363 ($F_{4,44} = 68.0$, $P < 0.001$), and trial x time interaction ($F_{3.1,33.9} = 4.80$, $P = 0.006$) for
364 perceived activation post-exercise (Figure 2B). Perceived activation declined
365 statistically more between 100% of exercise and 5 ($P = 0.013$, $d = 0.86$) and 15 min
366 ($P = 0.008$, $d = 0.93$) post-exercise in HICE vs. MICE, and between 100% of exercise
367 and 5 ($P = 0.002$, $d = 1.20$), 10 ($P = 0.006$, $d = 0.97$), and 15 min ($P = 0.004$, $d = 1.05$)
368 post-exercise in HICE vs. MICE. There were no statistical interactions between HICE
369 and HICE.

370

371 **Circumplex model**

372

373 The patterns of the circumplex model for each trial are in Figure 3. For MICE, low
374 activation and positive affect (associated with a sense of calmness) was observed at

all time points. In HICE, participants ranged from low activation and positive affect (calmness) prior to exercise and for the first 40% of exercise to high activation and positive affect (associated with a sense of energy) from 60-100% of exercise. Post-exercise, participants again experienced low activation and positive affect (calmness). In the HIIE trial, participants experienced low activation and positive affect (calmness) prior to exercise, high activation and positive affect (energy) throughout and immediately following exercise, and low activation and positive affect (calmness) for the remainder of the recovery. At no point during any of the trials did participants experience high activation and negative affect (associated with tension) or low activation and negative affect (associated with tiredness).

385

386 * FIGURE 3 HERE *

387

388 **DISCUSSION**

389

This study compared acute affective responses during and after MICE, HICE, and a low volume, time-efficient HIIE protocol in young, physically active, untrained males. Cardiovascular strain was similar between HICE and HIIE, and greater in these trials compared to MICE. During exercise, there were no statistically significant differences in affective responses between conditions or across time. However, differences in affective valence progressively increased during exercise in MICE compared to both HICE and HIIE, with moderate ES reported. The difference in affective valence between HICE and HIIE was fairly stable. Affective valence during exercise demonstrated the largest reduction in HICE, followed by HIIE, with the lowest reduction in MICE. Post-exercise, there were no statistically significant differences

400 between conditions, however at 5 min post-exercise, affective valence statistically
401 exceeded end-exercise values in all trials.

402

403 Differences in total work completed can influence affective responses to exercise,
404 potentially masking any moderating influence of exercise intensity (Blanchard et al.,
405 2004). The MICE and HICE trials involved the same amount of work, but differed
406 statistically in duration and measures of intensity. Therefore, the experimental
407 manipulation of the steady-state protocols based on intensity was successful. The
408 HIIE session involved less total work and was shorter than both steady-state protocols,
409 in line with the suggestion that HIIE is attractive due to its lower work and time
410 commitment (Babraj et al., 2009). Mean power output was statistically greater in the
411 work bouts of HIIE compared to MICE and HICE. Therefore, HIIE represented a
412 notably different exercise challenge than MICE and HICE.

413

414 Although not statistically significant, the difference in affective valence between
415 MICE and HICE, and MICE and HIIE, increased from trivial ES at the onset of
416 exercise to medium ES at 100% of exercise. Affective valence during HICE and HIIE
417 was consistently less positive than MICE, suggesting they are experienced as less
418 pleasurable. The responses in MICE and HICE reinforce the finding that continuous
419 exercise $>VT$ generates less pleasant affective valence than continuous exercise $<VT$
420 (Astorino et al., 2016; Ekkekakis et al., 2008).

421

422 In contrast, the difference in affective valence between HICE and HIIE remained small
423 and stable with increasing duration. Therefore, the current study provides novel data
424 showing that affective valence during a low volume HIIE protocol is similar to HICE.

425 Previous research has reported inconsistent findings on affective responses between
426 HIIE and HICE, perhaps due to methodological issues and the use of different HIIE
427 protocols (Jung et al., 2014; Oliveira et al., 2013; Saanijoki et al., 2015). From both a
428 statistical significance and practical meaningfulness (ES) perspective, the current
429 findings do not support the suggestion of (Jung et al., 2014) that HIIE may be less
430 aversive than HICE. It is important to also note that the affective responses in both
431 trials in the current study did not decrease to a negative level. Furthermore, in the
432 current study the affective valence responses to HIIE were less negative compared to
433 HICE than in the study of Oliveira et al. (2013), which supports the contention that
434 different HIIE protocols can elicit different affective responses (Martinez et al., 2015).
435 Our study provides further evidence that it may be feasible to manipulate HIIE
436 parameters to induce positive (or less negative) affect (Jung et al., 2016), and that for
437 these reasons, HIIE should not be considered inferior to HICE or MICE in its affective
438 responses (Saanijoki et al., 2015).

439

440 The lack of a statistically significant between-trials effect for affective valence during
441 exercise may be due to the larger inter-individual variability in affective valence
442 during HICE and HIIE compared to MICE. Affective responses to HIIE are
443 influenced by physical activity status and training experience (Frazao et al., 2016;
444 Saanijoki et al., 2015), and potentially by individual differences in preference for and
445 tolerance of high-intensity exercise (Ekkekakis, Hall, & Petruzzello, 2005a).
446 Participants in the current study were physically active and not highly trained, which
447 lent some homogeneity to the sample. Nevertheless, habitual physical activity levels
448 were not strictly controlled, therefore it is possible that differences in this variable may
449 have contributed to the greater variability in affective valence in HIIE and HICE.

450 However, the mean $\dot{V}O_{2\max}$ and $\dot{V}O_2$ at percentages of VT data indicate that there was
451 not a large variability in markers of aerobic fitness in the sample. The variability in
452 affective valence during HIIE warrants further study, as identifying factors that can
453 predict exercise preference may lead to more targeted exercise prescription (Ekkekakis
454 et al., 2005a). It should also be considered that the absence of statistical significance
455 for affective valence during exercise may be due to a Type II error related to statistical
456 power. However, our analysis procedures combining inferential statistical results with
457 measures of ES help to mitigate any potential influence of sub-optimal statistical
458 power on data interpretation.

459

460 The circumplex model is a dimensional analysis of affect that incorporates affective
461 valence and perceived activation to give a more complete view of affective responses
462 (Ekkekakis et al., 2008). However, this analysis has had limited consideration in HIIE
463 research, with the exception of Oliveira et al. (2013). The circumplex data for MICE
464 and HICE in the current study are similar to that of Ekkekakis et al. (2008) for running
465 < and >VT. The profile for HIIE did not include negative feeling states at any time,
466 and was similar to HICE. This contrasts with Oliveira et al. (2013), where participants
467 reported negative feeling responses during HIIE with much longer work periods than
468 the current study, but not during their HICE trial. These data further support the
469 suggestion that manipulation of HIIE variables can alter the affective responses to
470 HIIE (Jung et al., 2016; Martinez et al., 2015). These affective alterations may be due,
471 at least partly, to shifts in the dependence on anaerobic metabolism (Oliveira et al.,
472 2013). If low volume HIIE is not perceived more negatively than HICE, and confers
473 meaningful health and fitness improvements (Adamson, Lorimer, Cobley, & Babraj,
474 2014; Adamson, Lorimer, Cobley, Lloyd, et al., 2014), it may represent an attractive

475 alternative form of exercise due to its reduced time commitment. The potential
476 attraction of low volume, time-efficient HIIE is lent further credence by data showing
477 that affective responses to HIIE improve when the exercise is repeated (Saaniyoki et
478 al., 2015).

479

480 In addition to affect during exercise, this study also focused on post-exercise affect as
481 this may have an influence on future behaviour (Kahneman et al., 1993), and has had
482 limited consideration in HIIE research. Our data showed that post-HIIE affective
483 valence improved at the same rate as HICE and MICE. Post-exercise circumplex
484 values for HIIE were also similar to MICE and HICE, reinforcing that the low volume
485 HIIE protocol in the current study did not lead to negative post-exercise affect. The
486 smaller affective rebound at 5 min post-HIIE in our study compared to that of Oliveira
487 et al. (2013) is probably due to the more positive affect reported during HIIE in the
488 current study, meaning the participants had a smaller affective “deficit” from which to
489 rebound. Although further research is required to understand the relationship between
490 post-exercise affect and future behaviour (Hargreaves & Stych, 2013; Jung et al.,
491 2016; Rhodes & Kates, 2015), the findings of the current study suggest that because
492 the post-exercise affective response to HIIE is similar to HICE and MICE then it could
493 have a similar relationship to future behaviour. This lends further support to the
494 suggestion that low volume, time efficient, efficacious HIIE may represent an
495 attractive alternative form of exercise, at least in physically active young men.

496

497 This study recruited relatively young, physically active participants. While this is not
498 a highly trained or athletic sample, caution should be used when attempting to
499 generalise our findings to an inactive and/or older population. However, HIIE

500 protocols very similar to ours have proved efficacious and well tolerated in inactive
501 older people (Adamson, Lorimer, Cobley, & Babraj, 2014; Adamson, Lorimer,
502 Cobley, Lloyd, et al., 2014; Allison et al., 2016). Furthermore, contemporary debate
503 advocates the use of fewer and shorter work bouts in HIIIE protocols for the general
504 population, including older and inactive people (Vollaard & Metcalfe, 2017). Our
505 low-volume HIIIE protocol meets this suggestion. These points, coupled with the
506 justification for our HIIIE protocol described elsewhere in this paper, suggest that the
507 affective responses to the low-volume HIIIE protocol reported in this study may not be
508 notably different in an older or less active population. Of course, this suggestion
509 should be empirically tested.

510

511 We have presented novel data to show that low volume HIIIE with higher relative
512 intensity does not induce more negative affective responses during or after exercise
513 than MICE or HICE. Based on the documented improvement in affect with repeated
514 exposure to HIIIE, low volume, time efficient HIIIE may be an attractive alternative
515 exercise prescription for improving health and fitness.

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525 **Geolocation Information**

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527 The research was conducted in Edinburgh, Scotland. Participants were recruited from
528 the local area. Specific nationalities were not a focus of the research and were not
529 recorded.

530

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532

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534 Edinburgh to support costs associated with a research assistant and advertising for
535 research participants.

536

537 **Disclosure of interest**

538

539 The authors report no conflicts of interest.

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701

702 **FIGURE CAPTIONS**

703

704 Figure 1. Schematic of the experimental protocol. MICE = moderate-intensity
705 continuous exercise; HICE = high-intensity continuous exercise; HIIE = high-intensity
706 interval exercise.

707

708 Figure 2. Feeling state (A) and felt arousal (B) at baseline, during, and after exercise
709 for all trials. MICE = moderate-intensity continuous exercise; HICE = high-intensity
710 continuous exercise; HIIE = high-intensity interval exercise. * Significantly greater
711 than 100% of exercise in all trials; ** Significantly lower in MICE vs. HIIE; ***
712 Significantly lower in MICE vs. HICE; † Significantly greater reduction in HICE vs
713 MICE; ‡ Significantly greater reduction in HIIE vs. MICE.

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715 Figure 3: Affective circumplex model applied to the MICE, HICE, and HIIE sessions.
716 MICE = moderate-intensity continuous exercise; HICE = high-intensity continuous
717 exercise; HIIE = high-intensity interval exercise.

Comparison of affective responses during and after low volume high-intensity interval exercise, continuous moderate- and continuous high-intensity exercise in active, untrained, healthy males

Running title: affective responses to reduced volume high-intensity interval exercise

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Keywords: interval training; intermittent exercise; enjoyment; adherence

Abstract

This study compared affective responses to low volume high-intensity interval exercise (HIIE), moderate-intensity continuous exercise (MICE) and high-intensity continuous exercise (HICE). Twelve untrained males ($\dot{V}O_{2\max}$ 48.2 ± 6.7 ml·kg⁻¹·min⁻¹) completed MICE (30 min cycle at 85% of ventilatory threshold (VT)), HICE (cycle at 105% of VT matched with MICE for total work), and HIIE (10 x 6 s cycle sprints with 60 s recovery). Affective valence and perceived activation were measured before exercise, post warm-up, every 20% of exercise time, and 1, 5, 10, and 15 min post-exercise. Affective valence during exercise declined by 1.75 ± 2.42 , 1.17 ± 1.99 , and 0.42 ± 1.38 units in HICE, HIIE, and MICE, respectively, but was not statistically influenced by trial ($P = 0.35$), time ($P = 0.06$), or interaction effect ($P = 0.08$). Affective valence during HICE and HIIE was consistently less positive than MICE. Affective valence post-exercise was not statistically influenced by trial ($P = 0.10$) and at 5 min post-exercise exceeded end-exercise values ($P = 0.048$). Circumplex profiles showed no negative affect in any trial. Affective responses to low volume HIIE are similar to HICE but remain positive and rebound rapidly, suggesting it may be a potential alternative exercise prescription.

51 Introduction

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53 More than 30% of the worldwide population are insufficiently physically active for
54 health (Hallal, 2012). Lack of time is a commonly cited barrier to completing
55 sufficient physical activity (Aaltonen et al., 2012). Low volume high-intensity interval
56 exercise (HIIE) is brief, repeated bursts of intense or all-out exercise separated by rest
57 or low-intensity exercise, with total intense exercise time ≤ 10 min per session and total
58 session time ≤ 30 min (Gillen & Gibala, 2014). Low volume HIIE can considerably
59 improve aerobic fitness, body composition, and cardiometabolic health in a variety of
60 populations (Babraj et al., 2009; Jakeman, Adamson, & Babraj, 2012; Tjonna et al.,
61 2009). Therefore, low volume HIIE is a time efficient strategy for improving health
62 and fitness (Gillen & Gibala, 2014) that may appeal to individuals with limited time
63 to be active.

64

65 Many HIIE protocols are extremely challenging due to their high-intensity nature
66 (Gillen & Gibala, 2014), which has led to debate around the public health value of
67 HIIE. Several researchers have argued that individuals are unlikely to engage with, or
68 adhere to HIIE (Biddle & Batterham, 2015; Hardcastle, Ray, Beale, & Hagger, 2014),
69 partly because they will find it unpleasant and therefore be unlikely to repeat the
70 experience (Rhodes & Kates, 2015). According to the dual-mode theory of affective
71 responses to exercise (Ekkekakis, 2003), intensity is a key mediator of the affective
72 response. Exercise above the ventilatory threshold (VT) typically leads to more
73 unpleasant affective responses than exercise at and below VT (Astorino et al., 2016;
74 Ekkekakis, Hall, & Petruzzello, 2008; Kilpatrick, Kraemer, Bartholomew, Acevedo,
75 & Jarreau, 2007). However, the dual-mode theory applies to continuous exercise, and

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76 the intermittent nature of HIIE with regular recovery opportunities may allow
77 participants to experience more positive affective responses (Jung, Bourne, & Little,
78 2014; Jung, Little, & Batterham, 2016).

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80 However, an emerging body of literature suggests that HIIE generates less positive
81 affect compared to continuous submaximal exercise (Jung et al., 2014; Oliveira,
82 Slama, Deslandes, Furtado, & Santos, 2013; Saanijoki et al., 2015). Whilst these
83 studies suggest that HIIE is experienced less positively compared with more moderate
84 exercise, findings may be clouded by methodological issues. Some studies (Jung et
85 al., 2014; Saanijoki et al., 2015) standardised continuous intensity exercise to a
86 percentage of peak power (W_{peak}). The relative demands and tolerable duration of
87 exercise are not adequately characterised using this approach, and instead exercise
88 intensity domains should take account of individualised intensity thresholds, such as
89 the VT (Mann, Lamberts, & Lambert, 2013). Additionally, the HIIE protocol used by
90 Jung et al. (2014) was the same duration as their continuous high-intensity protocol,
91 and the protocols of Oliveira et al. (2013), Saanijoki et al. (2015), and Decker and
92 Ekkekakis (2016) lasted ~17-23 min, excluding warm-up and cool-down. This
93 negates the practical attraction of reduced exercise duration with HIIE. Furthermore,
94 the protocols adopted by Saanijoki et al. (2015) and Oliveira et al. (2013) were
95 particularly arduous, making unclear the transferability of the findings to HIIE
96 protocols that may be more palatable.

97
98 There has been a concerted effort to develop low volume HIIE protocols that are
99 efficacious, time efficient, and more palatable (Gillen & Gibala, 2014). Protocols
100 involving 20-60 s of total work within a 7-10 min exercise session can substantially

101 improve aerobic fitness and cardiometabolic health (Adamson, Lorimer, Cobley, &
102 Babraj, 2014; Adamson, Lorimer, Cobley, Lloyd, & Babraj, 2014; Allison, Martin,
103 MacInnis, Gurd, & Gibala, 2016). However, affective responses to these protocols
104 are not well understood. It is plausible that affective responses may be less negative
105 than in previously reported HIIE data, due to shorter and less frequent work bouts
106 (Jung et al., 2014; Martinez, Kilpatrick, Salomon, Jung, & Little, 2015), and larger
107 work-to-rest ratios implying less reliance on anaerobic metabolism relative to session
108 duration. Recent work on the affective responses to HIIE specifically called for
109 research to investigate affective responses to reduced volume HIIE protocols (Decker
110 & Ekkekakis, 2016). While some research has compared affective responses to
111 different volumes of HIIE (Martinez et al., 2015; Wood et al., 2016), a low volume
112 HIIE protocol (i.e. 20-60 s total work) was not used.

113

114 How people feel *after* HIIE may also be of importance, as affect at the end of the task
115 may influence future behaviour (Kahneman, Fredrickson, Schreiber, & Redelmeier,
116 1993). Although in their recent review, Rhodes and Kates (2015) concluded the
117 evidence did not support a relationship between post-exercise affect and future
118 physical activity behaviour, this was based on only nine studies of varying quality with
119 mixed findings, highlighting the need for further research. Further, Rhodes and Kates
120 (2015) acknowledged the counter theoretical argument that the end of the task may be
121 the most powerful affective stimulus (Hargreaves & Stych, 2013; Kahneman et al.).
122 This perspective is important to investigate further because according to dual-mode
123 theory there is likely to be a ‘rebound’ from affective negativity to positivity following
124 exercise, regardless of intensity (Ekkekakis, 2003), and within 1 min following severe-
125 intensity exercise (Ekkekakis, Hall, & Petruzzello, 2005b). Therefore, it is possible

126 that affective responses post-HIIE are similar to responses following exercise at a
127 lower intensity. Limited research has focused on affect post-HIIE with recent studies
128 either not assessing post-exercise affect (Frazao et al., 2016; Saanijoki et al., 2015) or
129 assessing affect at a later point (Jung et al., 2014; Oliveira et al., 2013) and potentially
130 missing the window to document and compare the rebound effect.

131

132 The development of effective, time efficient, and palatable HIIE protocols would be
133 an important step forward for the implementation of HIIE into public health strategies.
134 Efficacy and time efficiency have been established; affective responses during and
135 after these reduced volume protocols have not been well examined. The aim of this
136 study was to compare affective responses during and after low volume HIIE,
137 moderate-intensity continuous exercise (MICE) and high-intensity continuous
138 exercise (HICE). We hypothesised that cardiovascular strain would be similar in the
139 HICE and HIIE trials, and greater than the MICE trial; affective valence would
140 decrease more during HIIE than MICE, but less than during HICE; and post-exercise
141 affective valence would rebound within the same time-frame in all trials.

142

143 **METHODS**

144

145 **Participants**

146

147 Twelve healthy, physically active males participated (mean $\pm$ SD age 25 ± 7 years
148 (range 19-35 years), height 177 ± 7 cm, body mass (BM) 76.5 ± 12.2 kg, maximal
149 oxygen uptake ($\dot{V}O_{2max}$) 48.2 ± 6.7 ml $\cdot$ kg $^{-1}\cdot$ min $^{-1}$, W_{peak} 297 ± 36 W). Participants
150 were generally physically active (≥ 150 min habitual physical activity per week

(National Health Service, 2013); physically active for ≥ 30 min on 5 ± 1.6 days per week (range 2-7)), untrained (below the age-gender 90th percentile for $\dot{V}O_{2\max}$ (American College of Sports Medicine, 2005)), not participating in/training for a competition or event, and unfamiliar with HIIIE. The sample consisted of five University staff members and seven undergraduate students (one computer science, one primary education, and five sport science students). The study was explained to participants, and written informed consent was gained. All work was conducted with the formal approval of the University of Edinburgh, Moray House School of Education Ethics Committee.

Baseline trial

All sessions took place in the same climate controlled laboratory (temperature 20-21°C, relative humidity 50-55%). In visit one, anthropometric data were collected (BM: model 708; Seca, Hamburg, Germany; standing height: model 245; Seca, Hamburg, Germany), and standardised explanations of the Borg CR-10 Rating of Perceived Exertion (RPE) scale, Feeling Scale (FS, (Hardy & Rejeski, 1989)), and Felt Arousal scale (FAS, (Svebak & Murgatroyd, 1985)) were provided according to the instructions in the original publications. These explanations were briefly reviewed at the beginning of each subsequent session.

Participants completed a cycle ergometer ramp test to exhaustion (Lode Excalibur, Groningen, Netherlands) to determine $\dot{V}O_{2\max}$ and VT. The ergometer was set in hyperbolic mode and participants were informed that they could cycle at their preferred cadence. Participants cycled for 5 min at 60 W to familiarise themselves

176 with the ergometer. They then dismounted, fitted a heart rate (HR) monitor (Polar
177 Electro, Finland), and were attached to the online gas analyser (Cortex MetaMax 3B,
178 Leipzig, Germany) via a two-way non-rebreathing facemask (7450 Series V2, Hans
179 Rudolph, Kansas, USA). The analyser was calibrated according to manufacturer
180 instructions prior to each use. Participants sat quietly for 5 min then remounted the
181 ergometer and completed the warm-up and first two test stages. The facemask was
182 then removed and participants sat for 5 min.

183
184 The test, adapted from Bergstrom et al. (2013), began at 60 W for 2 min, after which
185 power output increased by 15 W·min⁻¹ until volitional exhaustion or cadence dropped
186 below 60 rev·min⁻¹ for more than 10 s despite strong verbal encouragement.
187 Participants' $\dot{V}O_{2\max}$ was determined as the highest 30 s average, provided that at least
188 two of the following criteria were met: a) $\geq 90\%$ of age-predicted maximum HR; b)
189 respiratory exchange ratio > 1.1 ; c) a plateau in $\dot{V}O_2$ (< 150 ml·min⁻¹ increase during
190 the last 60 s of the test) (Bergstrom et al., 2013). While valid $\dot{V}O_{2\max}$ values can be
191 gained from shorter protocols (Midgley et al., 2008), the primary outcome measure of
192 the test was VT. Therefore, a published VT protocol was chosen.

193
194 The VT was determined using the V-slope method described by Beaver, Wasserman,
195 and Whipp (1986), and defined as the $\dot{V}O_2$ corresponding to the intersection of two
196 linear regression lines plotted below and above the visually determined breakpoint in
197 the $\dot{V}CO_2$ versus $\dot{V}O_2$ relationship (Bergstrom et al., 2013). All resting and warm-up
198 expired gas data was excluded from the analysis, and the data were checked to confirm
199 that there was no hyperventilation at the start of the test. The VT determined from the
200 V-slope method was confirmed by examining plots of the ventilatory equivalents for

O₂ ($\dot{V}_E/\dot{V}O_2$) and CO₂ ($\dot{V}_E/\dot{V}CO_2$) against $\dot{V}O_2$ (Davis, Frank, Whipp, & Wasserman, 1979). A systematic increase in $\dot{V}_E/\dot{V}O_2$ without a corresponding increase in $\dot{V}_E/\dot{V}CO_2$, was the criterion for confirming VT. All VT determinations were undertaken by the same physiologist, and confirmed by a second physiologist. The power output/ $\dot{V}O_2$ regression equation from the maximal test was used to determine the power output associated with $\dot{V}O_2$ at the VT (Bergstrom et al., 2013).

Exercise sessions

Participants completed three trials (Figure 1) in a randomised, Latin-square (3 x 3), crossover design. Within-participants, all trials were completed at the same time of day and separated by 3-7 days, with the same researcher and research assistant present. Participants completed a dietary record for 24 h before the first session and replicated this prior to subsequent sessions. They also refrained from strenuous physical or cognitive activity (such as long periods of intense concentration, which can influence perception of exercise difficulty; Marcora, Staiano, & Manning, 2009) and alcohol intake for ≥ 24 h before each session. Adherence to these procedures was confirmed at each visit. Trials began and ended with 2 min cycling at 60 W, followed by an additional 13 min of seated recovery post-exercise (total post-exercise time 15 min).

Moderate-Intensity Continuous Exercise

Participants cycled for 30 min at a power output equal to 85% of VT, which corresponds to a moderate intensity (Kilpatrick et al., 2007). This trial acted as a

control, as measures of affect have previously shown minimal change during continuous exercise at this intensity (Ekkekakis et al., 2008; Kilpatrick et al., 2007).

227

228 *High-Intensity Continuous Exercise*

229

Participants cycled at a power output corresponding to 105% of VT, which corresponds to a hard intensity (Kilpatrick et al., 2007). Differences in total work may influence affective responses to exercise (Blanchard, Rodgers, Wilson, & Bell, 2004). Therefore, work done in HICE was the same as that done in MICE. This was achieved by reducing the exercise duration in HICE to account for the higher power output in this trial.

236

237 *High-Intensity Interval Exercise*

238

Participants completed 10 x 6 s all-out cycling efforts against 7.5% of BM, interspersed with 60 s recovery, on a mechanically braked cycle ergometer (Monark Ergonomic 814E, Vansbro, Sweden). The first 50 s of recovery was passive. From 50-59 s, participants cycled unloaded at 60 rev·min⁻¹. At 59 s, participants cycled maximally for 1 s unloaded, after which the resistance was added to the flywheel and the 6 s sprint began. This protocol has been shown to substantially improve aerobic capacity, physical function, and metabolic health in untrained adults (Adamson, Lorimer, Cobley, & Babraj, 2014; Adamson, Lorimer, Cobley, Lloyd, et al., 2014). A laboratory protocol was chosen to standardise the exercise sessions and provide a clearer causal relationship between low volume HIIE and affective responses, and a stronger justification for follow-up work using a more practical field-based protocol.

250 Total session duration, exercise duration, or work performed in HIIE was not matched
251 to MICE and HICE, as one of the attractive characteristics of HIIE is its ability to elicit
252 health and fitness improvements with notably less work and time commitment than
253 continuous submaximal exercise (Babraj et al., 2009).

254

255 During MICE and HICE, the researcher and research assistant remained out of
256 eyesight of the participants and did not communicate with them other than to record
257 in-exercise measurements. This was not possible during HIIE due to the requirement
258 to add and remove resistance to the flywheel, and to instruct the participant to stop and
259 start each sprint. However, no encouragement was provided during HIIE.

260

261 * FIGURE 1 HERE *

262

263 **Measurements**

264

265 Heart rate was recorded throughout at 5 s intervals. The Borg CR-10 scale assessed
266 RPE, as ratio scales provide more accurate insights into perceptual processes during
267 exercise than the 6-20 RPE scale (Borg & Kaijser, 2006; Oliveira et al., 2013).
268 Affective valence (pleasure/displeasure) was assessed using the FS, ranging from -5
269 (very bad) to +5 (very good). Perceived activation was measured using the FAS,
270 ranging from 1 (low arousal) to 6 (high arousal). All scales were administered at rest
271 prior to the warm-up (except RPE), in the last 30 s of the warm-up, every 20% of
272 exercise time, and 1, 5, 10, and 15 min post-exercise (RPE at 1 min post-exercise
273 only). In the HIIE trial, scales were taken immediately following sprints 2, 4, 6, 8,
274 and 10 (still ~20% of exercise duration), due to the logistical problem of collecting

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275 this information during an all-out cycling effort. Laminated copies of each scale were
276 held in front of the participant, who was asked to provide a number for each scale
277 according to how they felt at that moment (Oliveira et al., 2013; Saanijoki et al., 2015).

278
279 Data from the FS and FAS were represented in the circumplex model, which describes
280 a combined affective state with respect to activation and valence (Oliveira et al., 2013).
281 This model was used as it includes positive and negative valence, high and low
282 activation states, and is not domain-specific, making it appropriate for assessing affect
283 before, during, and after exercise (Ekkekakis et al., 2008).

284 285 **Statistical analyses**

286
287 Analyses were performed using IBM SPSS Statistics 21 for Windows (IBM Corp.,
288 Chicago, IL). The Shapiro-Wilk test assessed the distribution of all data sets. Work
289 related characteristics of exercise were compared using one-way repeated measures
290 ANOVA and post-hoc pairwise comparisons with the Bonferroni correction.
291 Affective valence and perceived activation during exercise were examined using a
292 two-way (3 trials and 6 time points (warm-up, 20, 40, 60, 80, and 100% of exercise))
293 repeated measures ANOVA. The same variables post-exercise were examined using
294 a two-way (3 trials and 5 time points (100% of exercise, 1, 5, 10, and 15 min post-
295 exercise)) repeated measures ANOVA. Post hoc pairwise comparisons with the
296 Bonferroni correction explored significant main effects. This analysis follows the
297 same approach as Ekkekakis et al. (2008) in a related study. An alpha level of $P <$
298 0.05 was used in all tests except when the Bonferroni correction was applied. Cohen's
299 d effect sizes (ES) for within-participants designs (Lakens, 2013) were calculated for

pairwise comparisons and defined as trivial ($d < 0.2$), small ($d \geq 0.2, < 0.5$), medium ($\geq 0.5, < 0.8$), and large ($d \geq 0.8$) (Cohen, 1992).

RESULTS

Intensity manipulations

Table 1 presents mean performance data and physiological responses from the three trials. By design, MICE and HICE were equal in terms of total work performed and differed statistically in duration and intensity. The MICE and HIIE trials differed statistically across all variables with the exception of mean HR. The HICE and HIIE trials also differed statistically for all variables except RPE.

* TABLE 1 HERE *

During Exercise

Affective valence

There were no statistically significant effects of trial ($F_{1,2,13.6} = 1.02, P = 0.350$), time ($F_{1,6,17.8} = 3.57, P = 0.058$), or interaction ($F_{2,6,28.5} = 2.57, P = 0.081$) for affective valence during exercise (Figure 2A). However, differences in affective valence progressively increased during exercise between MICE and HICE (mean difference $0.0 \pm 1.0, d = 0.20$ at warm-up to $1.5 \pm 2.3, d = 0.66$ at 100% of exercise) and MICE and HIIE (mean difference $0.1 \pm 1.1, d = 0.16$ at warm-up to $0.9 \pm 1.6, d = 0.59$ at

100% of exercise). The difference in affective valence between HICE and HIIE was fairly stable over time (mean difference 0.1 ± 1.2 , $d = 0$ at warm-up to 0.6 ± 3.2 , $d = 0.18$ at 100% of exercise). Within-trials, the largest reduction in affective valence (warm-up to 100% of exercise) occurred in HICE (-1.75 ± 2.42 units, $d = 0.72$), followed by HIIE (-1.17 ± 1.99 units, $d = 0.59$) and MICE (-0.42 ± 1.38 units, $d = 0.30$).

331

332 *Perceived activation*

333

There were statistically significant main effects of trial ($F_{2,22} = 13.91$, $P < 0.001$), time ($F_{1.6,18.3} = 40.12$, $P < 0.001$), and trial x time interaction ($F_{4.1,45.6} = 4.14$, $P = 0.006$) for perceived activation during exercise (Figure 2B). There were no statistical differences between conditions at baseline or warm-up. The MICE and HIIE trials differed statistically throughout exercise, with differences remaining large between 20% ($P = 0.002$, $d = 1.37$) and 100% ($P = 0.002$, $d = 1.36$) of exercise. The MICE and HICE trials differed statistically at 60% ($P = 0.006$, $d = 1.16$), 80% ($P = 0.006$, $d = 1.17$), and 100% ($P = 0.021$, $d = 0.96$) of exercise. The HICE and HIIE trials did not differ statistically at any time (largest difference at 20% of exercise, $P = 0.075$, $d = 0.75$).

343

344 * FIGURE 2 HERE *

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350 **Post-exercise**

351

352 *Affective valence*

353

354 There were no statistically significant main effects of trial ($F_{1.1,12.5} = 3.09$, $P = 0.100$)
355 or trial x time interaction ($F_{2.4,26.9} = 1.17$, $P = 0.333$) for affective valence post-exercise
356 (Figure 2A). However, there was a main effect of time ($F_{1.3,14.5} = 11.11$, $P = 0.003$).
357 Affective valence was statistically greater 5 ($P = 0.048$, $d = 0.81$), 10 ($P = 0.038$, $d =$
358 0.61) and 15 min ($P = 0.041$, $d = 0.67$) post-exercise compared with 100% of exercise.

359

360 *Perceived activation*

361

362 There were statistically significant main effects of trial ($F_{2,22} = 10.68$, $P = 0.001$), time
363 ($F_{4,44} = 68.0$, $P < 0.001$), and trial x time interaction ($F_{3.1,33.9} = 4.80$, $P = 0.006$) for
364 perceived activation post-exercise (Figure 2B). Perceived activation declined
365 statistically more between 100% of exercise and 5 ($P = 0.013$, $d = 0.86$) and 15 min
366 ($P = 0.008$, $d = 0.93$) post-exercise in HICE vs. MICE, and between 100% of exercise
367 and 5 ($P = 0.002$, $d = 1.20$), 10 ($P = 0.006$, $d = 0.97$), and 15 min ($P = 0.004$, $d = 1.05$)
368 post-exercise in HICE vs. MICE. There were no statistical interactions between HICE
369 and HICE.

370

371 **Circumplex model**

372

373 The patterns of the circumplex model for each trial are in Figure 3. For MICE, low
374 activation and positive affect (associated with a sense of calmness) was observed at

all time points. In HICE, participants ranged from low activation and positive affect (calmness) prior to exercise and for the first 40% of exercise to high activation and positive affect (associated with a sense of energy) from 60-100% of exercise. Post-exercise, participants again experienced low activation and positive affect (calmness). In the HIIE trial, participants experienced low activation and positive affect (calmness) prior to exercise, high activation and positive affect (energy) throughout and immediately following exercise, and low activation and positive affect (calmness) for the remainder of the recovery. At no point during any of the trials did participants experience high activation and negative affect (associated with tension) or low activation and negative affect (associated with tiredness).

* FIGURE 3 HERE *

DISCUSSION

This study compared acute affective responses during and after MICE, HICE, and a low volume, time-efficient HIIE protocol in young, physically active, untrained males. Cardiovascular strain was similar between HICE and HIIE, and greater in these trials compared to MICE. During exercise, there were no statistically significant differences in affective responses between conditions or across time. However, differences in affective valence progressively increased during exercise in MICE compared to both HICE and HIIE, with moderate ES reported. The difference in affective valence between HICE and HIIE was fairly stable. Affective valence during exercise demonstrated the largest reduction in HICE, followed by HIIE, with the lowest reduction in MICE. Post-exercise, there were no statistically significant differences

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400 between conditions, however at 5 min post-exercise, affective valence statistically
401 exceeded end-exercise values in all trials.

402

403 Differences in total work completed can influence affective responses to exercise,
404 potentially masking any moderating influence of exercise intensity (Blanchard et al.,
405 2004). The MICE and HICE trials involved the same amount of work, but differed
406 statistically in duration and measures of intensity. Therefore, the experimental
407 manipulation of the steady-state protocols based on intensity was successful. The
408 HIIE session involved less total work and was shorter than both steady-state protocols,
409 in line with the suggestion that HIIE is attractive due to its lower work and time
410 commitment (Babraj et al., 2009). Mean power output was statistically greater in the
411 work bouts of HIIE compared to MICE and HICE. Therefore, HIIE represented a
412 notably different exercise challenge than MICE and HICE.

413

414 Although not statistically significant, the difference in affective valence between
415 MICE and HICE, and MICE and HIIE, increased from trivial ES at the onset of
416 exercise to medium ES at 100% of exercise. Affective valence during HICE and HIIE
417 was consistently less positive than MICE, suggesting they are experienced as less
418 pleasurable. The responses in MICE and HICE reinforce the finding that continuous
419 exercise >VT generates less pleasant affective valence than continuous exercise <VT
420 (Astorino et al., 2016; Ekkekakis et al., 2008).

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422 In contrast, the difference in affective valence between HICE and HIIE remained small
423 and stable with increasing duration. Therefore, the current study provides novel data
424 showing that affective valence during a low volume HIIE protocol is similar to HICE.

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425 Previous research has reported inconsistent findings on affective responses between
426 HIIE and HICE, perhaps due to methodological issues and the use of different HIIE
427 protocols (Jung et al., 2014; Oliveira et al., 2013; Saanijoki et al., 2015). From both a
428 statistical significance and practical meaningfulness (ES) perspective, the current
429 findings do not support the suggestion of (Jung et al., 2014) that HIIE may be less
430 aversive than HICE. It is important to also note that the affective responses in both
431 trials in the current study did not decrease to a negative level. Furthermore, in the
432 current study the affective valence responses to HIIE were less negative compared to
433 HICE than in the study of Oliveira et al. (2013), which supports the contention that
434 different HIIE protocols can elicit different affective responses (Martinez et al., 2015).
435 Our study provides further evidence that it may be feasible to manipulate HIIE
436 parameters to induce positive (or less negative) affect (Jung et al., 2016), and that for
437 these reasons, HIIE should not be considered inferior to HICE or MICE in its affective
438 responses (Saanijoki et al., 2015).

439
440 The lack of a statistically significant between-trials effect for affective valence during
441 exercise may be due to the larger inter-individual variability in affective valence
442 during HICE and HIIE compared to MICE. Affective responses to HIIE are
443 influenced by physical activity status and training experience (Frazao et al., 2016;
444 Saanijoki et al., 2015), and potentially by individual differences in preference for and
445 tolerance of high-intensity exercise (Ekkekakis, Hall, & Petruzzello, 2005a).
446 Participants in the current study were physically active and not highly trained, which
447 lent some homogeneity to the sample. Nevertheless, habitual physical activity levels
448 were not strictly controlled, therefore it is possible that differences in this variable may
449 have contributed to the greater variability in affective valence in HIIE and HICE.

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450 However, the mean $\dot{V}O_{2\max}$ and $\dot{V}O_2$ at percentages of VT data indicate that there was
451 not a large variability in markers of aerobic fitness in the sample. The variability in
452 affective valence during HIIE warrants further study, as identifying factors that can
453 predict exercise preference may lead to more targeted exercise prescription (Ekkekakis
454 et al., 2005a). It should also be considered that the absence of statistical significance
455 for affective valence during exercise may be due to a Type II error related to statistical
456 power. However, our analysis procedures combining inferential statistical results with
457 measures of ES help to mitigate any potential influence of sub-optimal statistical
458 power on data interpretation.

459
460 The circumplex model is a dimensional analysis of affect that incorporates affective
461 valence and perceived activation to give a more complete view of affective responses
462 (Ekkekakis et al., 2008). However, this analysis has had limited consideration in HIIE
463 research, with the exception of Oliveira et al. (2013). The circumplex data for MICE
464 and HICE in the current study are similar to that of Ekkekakis et al. (2008) for running
465 < and >VT. The profile for HIIE did not include negative feeling states at any time,
466 and was similar to HICE. This contrasts with Oliveira et al. (2013), where participants
467 reported negative feeling responses during HIIE with much longer work periods than
468 the current study, but not during their HICE trial. These data further support the
469 suggestion that manipulation of HIIE variables can alter the affective responses to
470 HIIE (Jung et al., 2016; Martinez et al., 2015). These affective alterations may be due,
471 at least partly, to shifts in the dependence on anaerobic metabolism (Oliveira et al.,
472 2013). If low volume HIIE is not perceived more negatively than HICE, and confers
473 meaningful health and fitness improvements (Adamson, Lorimer, Cobley, & Babraj,
474 2014; Adamson, Lorimer, Cobley, Lloyd, et al., 2014), it may represent an attractive

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475 alternative form of exercise due to its reduced time commitment. The potential
476 attraction of low volume, time-efficient HIIE is lent further credence by data showing
477 that affective responses to HIIE improve when the exercise is repeated (Saaniyoki et
478 al., 2015).

479
480 In addition to affect during exercise, this study also focused on post-exercise affect as
481 this may have an influence on future behaviour (Kahneman et al., 1993), and has had
482 limited consideration in HIIE research. Our data showed that post-HIIE affective
483 valence improved at the same rate as HICE and MICE. Post-exercise circumplex
484 values for HIIE were also similar to MICE and HICE, reinforcing that the low volume
485 HIIE protocol in the current study did not lead to negative post-exercise affect. The
486 smaller affective rebound at 5 min post-HIIE in our study compared to that of Oliveira
487 et al. (2013) is probably due to the more positive affect reported during HIIE in the
488 current study, meaning the participants had a smaller affective “deficit” from which to
489 rebound. Although further research is required to understand the relationship between
490 post-exercise affect and future behaviour (Hargreaves & Stych, 2013; Jung et al.,
491 2016; Rhodes & Kates, 2015), the findings of the current study suggest that because
492 the post-exercise affective response to HIIE is similar to HICE and MICE then it could
493 have a similar relationship to future behaviour. This lends further support to the
494 suggestion that low volume, time efficient, efficacious HIIE may represent an
495 attractive alternative form of exercise, at least in physically active young men.

496
497 This study recruited relatively young, physically active participants. While this is not
498 a highly trained or athletic sample, caution should be used when attempting to
499 generalise our findings to an inactive and/or older population. However, HIIE

1 500 protocols very similar to ours have proved efficacious and well tolerated in inactive
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3 501 older people (Adamson, Lorimer, Copley, & Babraj, 2014; Adamson, Lorimer,
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5 502 Copley, Lloyd, et al., 2014; Allison et al., 2016). Furthermore, contemporary debate
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7 503 advocates the use of fewer and shorter work bouts in HIIIE protocols for the general
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9 504 population, including older and inactive people (Vollaard & Metcalfe, 2017). Our
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11 505 low-volume HIIIE protocol meets this suggestion. These points, coupled with the
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13 506 justification for our HIIIE protocol described elsewhere in this paper, suggest that the
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15 507 affective responses to the low-volume HIIIE protocol reported in this study may not be
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17 508 notably different in an older or less active population. Of course, this suggestion
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19 509 should be empirically tested.
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26 511 We have presented novel data to show that low volume HIIIE with higher relative
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28 512 intensity does not induce more negative affective responses during or after exercise
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30 513 than MICE or HICE. Based on the documented improvement in affect with repeated
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32 514 exposure to HIIIE, low volume, time efficient HIIIE may be an attractive alternative
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34 515 exercise prescription for improving health and fitness.
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525 **Geolocation Information**

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527 The research was conducted in Edinburgh, Scotland. Participants were recruited from
528 the local area. Specific nationalities were not a focus of the research and were not
529 recorded.

530

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532

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536

537 **Disclosure of interest**

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539 The authors report no conflicts of interest.

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702 **FIGURE CAPTIONS**

703
704 Figure 1. Schematic of the experimental protocol. MICE = moderate-intensity
705 continuous exercise; HICE = high-intensity continuous exercise; HIIE = high-intensity
706 interval exercise.

707
708 Figure 2. Feeling state (A) and felt arousal (B) at baseline, during, and after exercise
709 for all trials. MICE = moderate-intensity continuous exercise; HICE = high-intensity
710 continuous exercise; HIIE = high-intensity interval exercise. * Significantly greater
711 than 100% of exercise in all trials; ** Significantly lower in MICE vs. HIIE; ***
712 Significantly lower in MICE vs. HICE; † Significantly greater reduction in HICE vs
713 MICE; ‡ Significantly greater reduction in HIIE vs. MICE.

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715 Figure 3: Affective circumplex model applied to the MICE, HICE, and HIIE sessions.
716 MICE = moderate-intensity continuous exercise; HICE = high-intensity continuous
717 exercise; HIIE = high-intensity interval exercise.

TABLE 1. Comparison of the three exercise trials.

	MICE	HICE	HIIE	MICE vs. HICE	MICE vs. HIIE	HICE vs. HIIE
Duration (min)	30.0 ± 0.0	22.1 ± 1.2	10.0 ± 0.0	<i>P</i> < 0.001 <i>d</i> = 6.42	<i>P</i> < 0.001*	<i>P</i> < 0.001 <i>d</i> = 9.79
Power (W)	130.3 ± 23.0	176.1 ± 23.3	774.3 ± 118.3	<i>P</i> < 0.001 <i>d</i> = 11.18	<i>P</i> < 0.001 <i>d</i> = 2.73	<i>P</i> < 0.001 <i>d</i> = 2.68
Peak Power (W)	-	-	809.6 ± 127.1	-	-	-
Work (kJ)	234.6 ± 41.3	234.6 ± 41.3	46.5 ± 7.1	<i>P</i> = 1.0 <i>d</i> = 0	<i>P</i> < 0.001 <i>d</i> = 2.61	<i>P</i> < 0.001 <i>d</i> = 2.61
VO _{2max} (%)	55.1 ± 4.5	68.3 ± 5.5	-	<i>P</i> < 0.001 <i>d</i> = 10.43	-	-
Heart rate (b.min ⁻¹)	137 ± 15	159 ± 12	147 ± 12	<i>P</i> < 0.001 <i>d</i> = 1.65	<i>P</i> = 0.14 <i>d</i> = 0.65	<i>P</i> = 0.008 <i>d</i> = 1.11
Peak HR	146 ± 14	167 ± 13	158 ± 10	<i>P</i> = 0.001 <i>d</i> = 1.58	<i>P</i> = 0.049 <i>d</i> = 0.82	<i>P</i> = 0.032 <i>d</i> = 0.89
RPE	3.2 ± 0.9	5.4 ± 1.2	6.0 ± 1.6	<i>P</i> < 0.001	<i>P</i> < 0.001	<i>P</i> = 0.55

$$d = 2.33 \quad d = 2.26 \quad d = 0.41$$

Data are mean $\pm$ SD. Power and work in the HIIE trial calculated from sprint bouts only. Peak power in the HIIE trial is the mean of the highest 1 sec average power output from each sprint. Heart rate data in the HIIE trial is mean HR from the beginning of sprint 1 to the completion of sprint 10. Peak HR in the HIIE trial is highest 5 sec average HR attained. * ES not calculated for this comparison due to absence of variation in the two data sets.

Figure

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