Edinburgh Research Explorer

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

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:	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 (VO2max 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.
Order of Authors:	Ailsa Niven
	Jacqueline Thow
	Jack Holroyd
	Anthony P Turner
	Shaun Phillips
Response to Reviewers:	Reviewer #1: The revision of the paper is much improved. I have the following remarks: 1. response to Reviewer #1 point 9: new text is indicated on L388, but this doesn't seem correct. 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). 2. response to Reviewer #1 point 17: new text is indicated on L492, but this doesn't seem correct. We believe that this amendment was made; however, we have amended the wording to make the statement clearer (P.20, L495 of anonymised manuscript). 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'. The title amendment has been made. Also, for consistency the participants are now referred to as "untrained" in the methodology. 4. L392: I would add the word 'young'

	This has been added into the location we believe the reviewer is referring to (P.16, L391 of anonymised manuscript).

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

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

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 ($\dot{V}O_{2max}$ 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.

Introduction

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

Many HIIE protocols are extremely challenging due to their high-intensity nature (Gillen & Gibala, 2014), which has led to debate around the public health value of HIIE. Several researchers have argued that individuals are unlikely to engage with, or adhere to HIIE (Biddle & Batterham, 2015; Hardcastle, Ray, Beale, & Hagger, 2014), partly because they will find it unpleasant and therefore be unlikely to repeat the experience (Rhodes & Kates, 2015). According to the dual-mode theory of affective responses to exercise (Ekkekakis, 2003), intensity is a key mediator of the affective response. Exercise above the ventilatory threshold (VT) typically leads to more unpleasant affective responses than exercise at and below VT (Astorino et al., 2016; Ekkekakis, Hall, & Petruzzello, 2008; Kilpatrick, Kraemer, Bartholomew, Acevedo, & 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 $\pm$ 7 years

148   (range 19-35 years), height 177 $\pm$ 7 cm, body mass (BM) 76.5 $\pm$ 12.2 kg, maximal

149   oxygen uptake ($\dot{V}O_{2max}$) 48.2 $\pm$ 6.7 ml·kg^{-1}·min^{-1}, W_{peak} 297 $\pm$ 36 W). Participants

150   were generally physically active ($\geq$ 150 min habitual physical activity per week

151   (National Health Service, 2013); physically active for $\geq$ 30 min on 5 $\pm$ 1.6 days per

152   week (range 2-7)), untrained (below the age-gender 90th percentile for $\dot{V}O_{2max}$

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 $\dot{V}O_{2max}$ 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 $W \cdot min^{-1}$ until volitional exhaustion or cadence dropped

186 below 60 $rev \cdot min^{-1}$ for more than 10 s despite strong verbal encouragement.

187 Participants' $\dot{V}O_{2max}$ 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 $ml \cdot min^{-1}$ increase during

190 the last 60 s of the test) (Bergstrom et al., 2013). While valid $\dot{V}O_{2max}$ 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 ($\dot{V}_E/\dot{V}O_2$) and CO_2 ($\dot{V}_E/\dot{V}CO_2$) against $\dot{V}O_2$ (Davis, Frank, Whipp, & Wasserman,

202   1979). A systematic increase in $\dot{V}_E/\dot{V}O_2$ without a corresponding increase in $\dot{V}_E/\dot{V}CO_2$,

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/$\dot{V}O_2$

205   regression equation from the maximal test was used to determine the power output

206   associated with $\dot{V}O_2$ 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 $\geq$ 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, Cobley, & Babraj, 2014; Adamson, Lorimer, Cobley, 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 ± 1.0, $d = 0.20$ at warm-up to 1.5 ± 2.3, $d = 0.66$ at 100% of exercise) and MICE

324   and HIIE (mean difference 0.1 ± 1.1, $d = 0.16$ at warm-up to 0.9 ± 1.6, $d = 0.59$ at

325   100% of exercise). The difference in affective valence between HICE and HIIE was

326   fairly stable over time (mean difference 0.1 ± 1.2, $d = 0$ at warm-up to 0.6 ± 3.2, $d =$

327   0.18 at 100% of exercise). Within-trials, the largest reduction in affective valence

328   (warm-up to 100% of exercise) occurred in HICE (-1.75 ± 2.42 units, $d = 0.72$),

329   followed by HIIE (-1.17 ± 1.99 units, $d = 0.59$) and MICE (-0.42 ± 1.38 units, $d =$

330   0.30).

331

332   *Perceived activation*

333

334   There were statistically significant main effects of trial ($F_{2,22} = 13.91$, $P < 0.001$), time

335   ($F_{1.6,18.3} = 40.12$, $P < 0.001$), and trial x time interaction ($F_{4.1,45.6} = 4.14$, $P = 0.006$) for

336   perceived activation during exercise (Figure 2B). There were no statistical differences

337   between conditions at baseline or warm-up. The MICE and HIIE trials differed

338   statistically throughout exercise, with differences remaining large between 20% ($P =$

339   0.002, $d = 1.37$) and 100% ($P = 0.002$, $d = 1.36$) of exercise. The MICE and HICE

340   trials differed statistically at 60% ($P = 0.006$, $d = 1.16$), 80% ($P = 0.006$, $d = 1.17$),

341   and 100% ($P = 0.021$, $d = 0.96$) of exercise. The HICE and HIIE trials did not differ

342   statistically at any time (largest difference at 20% of exercise, $P = 0.075$, $d = 0.75$).

343

344   * FIGURE 2 HERE *

345

346

347

348

349

14

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 HIIE vs. MICE. There were no statistical interactions between HICE

369   and HIIE.

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

375   all time points. In HICE, participants ranged from low activation and positive affect

376   (calmness) prior to exercise and for the first 40% of exercise to high activation and

377   positive affect (associated with a sense of energy) from 60-100% of exercise. Post-

378   exercise, participants again experienced low activation and positive affect (calmness).

379   In the HIIE trial, participants experienced low activation and positive affect (calmness)

380   prior to exercise, high activation and positive affect (energy) throughout and

381   immediately following exercise, and low activation and positive affect (calmness) for

382   the remainder of the recovery. At no point during any of the trials did participants

383   experience high activation and negative affect (associated with tension) or low

384   activation and negative affect (associated with tiredness).

385

386   * FIGURE 3 HERE *

387

388   **DISCUSSION**

389

390   This study compared acute affective responses during and after MICE, HICE, and a

391   low volume, time-efficient HIIE protocol in young, physically active, untrained males.

392   Cardiovascular strain was similar between HICE and HIIE, and greater in these trials

393   compared to MICE. During exercise, there were no statistically significant differences

394   in affective responses between conditions or across time. However, differences in

395   affective valence progressively increased during exercise in MICE compared to both

396   HICE and HIIE, with moderate ES reported. The difference in affective valence

397   between HICE and HIIE was fairly stable.   Affective valence during exercise

398   demonstrated the largest reduction in HICE, followed by HIIE, with the lowest

399   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 $\dot{V}O_{2max}$ 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

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

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

This study recruited relatively young, physically active participants. While this is not
a highly trained or athletic sample, caution should be used when attempting to
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 HIIE protocols for the general

504   population, including older and inactive people (Vollaard & Metcalfe, 2017). Our

505   low-volume HIIE protocol meets this suggestion. These points, coupled with the

506   justification for our HIIE protocol described elsewhere in this paper, suggest that the

507   affective responses to the low-volume HIIE 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 HIIE 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 HIIE, low volume, time efficient HIIE may be an attractive alternative

515   exercise prescription for improving health and fitness.

516

517

518

519

520

521

522

523

524

Geolocation Information

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

Funding

Disclosure of interest

The authors report no conflicts of interest.

550   **REFERENCES**

551

552   Aaltonen, S., Leskinen, T., Morris, T., Alen, M., Kaprio, J., Liukkonen, J., & Kujala,

553   U. (2012). Motives for and barriers to physical activity in twin pairs discordant

554   for leisure time physical activity for 30 years. *International Journal of Sports*

555   *Medicine, 33*(2), 157-163. doi: 10.1055/s-0031-1287848

556   Adamson, S. B., Lorimer, R., Cobley, J. N., & Babraj, J. A. (2014). Extremely short-

557   duration high-intensity training substantially improves the physical function

558   and self-reported health status of elderly adults. *Journal of American Geriatric*

559   *Society, 62*(7), 1380-1381. doi: 10.1111/jgs.12916

560   Adamson, S. B., Lorimer, R., Cobley, N. J., Lloyd, R., & Babraj, J. (2014). High

561   Intensity Training Improves Health and Physical Function in Middle Aged

562   Adults. *Biology, 3*(2), 333-344. doi: 10.3390/biology3020333

563   Allison, M. K., Martin, B. J., MacInnis, M. J., Gurd, B., & Gibala, M. J. (2016). Brief,

564   Intense Intermittent Stair Climbing Is A Practical, Time-Efficient Method To

565   Improve Cardiorespiratory Fitness: 2157 Board #309 June 2, 3: 30 PM - 5: 00

566   PM. *Med   Sci   Sports   Exerc,   48*(5   Suppl   1),   609.   doi:

567   10.1249/01.mss.0000486830.80107.b2

568   American, College, of, Sports, & Medicine. (2005). *ACSM's Guidelines for Exercise*

569   *Testing and Prescription* (7th ed.). Baltimore (ML): Lippincott Williams and

570   Wilkins.

571   Astorino, T. A., Schubert, M. M., Palumbo, E., Stirling, D., McMillan, D. W., Gallant,

572   R., & Dewoskin, R. (2016). Perceptual Changes in Response to Two Regimens

573   of Interval Training in Sedentary Women. *Journal of Strength and*

574 *Conditioning   Research,   30*(4),   1067-1076.   doi:

575   10.1519/JSC.0000000000001175

576 Babraj, J. A., Vollaard, N. B., Keast, C., Guppy, F. M., Cottrell, G., & Timmons, J. A.

577   (2009). Extremely short duration high intensity interval training substantially

578   improves insulin action in young healthy males. *BMC Endocrine Disorders,*

579   *9*(3), 1-8. doi: Artn 310.1186/1472-6823-9-3

580 Beaver, W. L., Wasserman, K., & Whipp, B. J. (1986). A new method for detecting

581   anaerobic threshold by gas exchange. *J Appl Physiol (1985), 60*(6), 2020-2027

582 Bergstrom, H. C., Housh, T. J., Zuniga, J. M., Traylor, D. A., Camic, C. L., Lewis, R.

583   W., . . . Johnson, G. O. (2013). The Relationships Among Critical Power

584   Determined From a 3-Min All-Out Test, Respiratory Compensation Point, Gas

585   Exchange Threshold, and Ventilatory Threshold. *Research Quarterly for*

586   *Exercise and Sport, 84*(2), 232-238. doi: 10.1080/02701367.2013.784723

587 Biddle, S. J. H., & Batterham, A. M. (2015). High-intensity interval exercise training

588   for public health: a big HIT or shall we HIT it on the head? *International*

589   *Journal of Behavioral Nutrition and Physical Activity, 12*(95), 1-8. doi:

590   10.1186/s12966-015-0254-9

591 Blanchard, C. M., Rodgers, W. M., Wilson, P. M., & Bell, G. J. (2004). Does equating

592   total volume of work between two different exercise conditions matter when

593   examining exercise-induced feeling states? *Research Quarterly for Exercise*

594   *and Sport, 75*(2), 209-215

595 Borg, E., & Kaijser, L. (2006). A comparison between three rating scales for perceived

596   exertion and two different work tests. *Scandinavian Journal of Medicine &*

597   *Science in Sports, 16*(1), 57-69. doi: 10.1111/j.1600-0838.2005.00448.x

598   Cohen, J. (1992). A Power Primer. *Psychological Bulletin, 112*(1), 155-159. doi: Doi

599   10.1037/0033-2909.112.1.155

600   Davis, J. A., Frank, M. H., Whipp, B. J., & Wasserman, K. (1979). Anaerobic

601   Threshold Alterations Caused by Endurance Training in Middle-Aged Men.

602   *Journal of Applied Physiology, 46*(6), 1039-1046

603   Decker, E. S., & Ekkekakis, P. (2016). More efficient, perhaps, but at what price?

604   Pleasure and enjoyment responses to high-intensity interval exercise in low-

605   active women with obesity. *Psychology of Sport and Exercise, 28*, 1-10. doi:

606   http://dx.doi.org/10.1016/j.psychsport.2016.09.005

607   Ekkekakis, P. (2003). Pleasure and displeasure from the body: Perspectives from

608   exercise. *Cognition & Emotion, 17*(2), 213-239. doi:

609   10.1080/02699930244000282

610   Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005a). Some like it vigorous:

611   Measuring individual differences in the preference for and tolerance of

612   exercise intensity. *Journal of Sport & Exercise Psychology, 27*(3), 350-374

613   Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005b). Variation and homogeneity in

614   affective responses to physical activity of varying intensities: an alternative

615   perspective on dose-response based on evolutionary considerations. *Journal of*

616   *Sports Sciences, 23*(5), 477-500. doi: 10.1080/02640410400021492

617   Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2008). The relationship between

618   exercise intensity and affective responses demystified: To crack the 40-year-

619   old nut, replace the 40-year-old nutcracker! *Annals of Behavioral Medicine,*

620   *35*(2), 136-149. doi: 10.1007/s12160-008-9025-z

621   Frazao, D. T., de Farias, L. F., Dantas, T. C. B., Krinski, K., Elsangedy, H. M., Prestes,

622   J., . . . Costa, E. C. (2016). Feeling of Pleasure to High-Intensity Interval

623   Exercise Is Dependent of the Number of Work Bouts and Physical Activity

624   Status. *Plos One, 11*(3), e0152752. doi: 10.1371/journal.pone.0153986

625   Gillen, J. B., & Gibala, M. J. (2014). Is high-intensity interval training a time-efficient

626   exercise strategy to improve health and fitness? *Applied Physiology and*

627   *Nutrition and Metabolism, 39*(3), 409-412. doi: 10.1139/apnm-2013-0187

628   Hallal, P., Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. (2012). Global

629   physical activity levels: surveillance progress, pitfalls, and prospects. *The*

630   *Lancet, 380*(9838), 247-257

631   Hardcastle, S. J., Ray, H., Beale, L., & Hagger, M. S. (2014). Why sprint interval

632   training is inappropriate for a largely sedentary population. *Frontiers in*

633   *Psychology, 5*(1505), 1-3. doi: 10.3389/fpsyg.2014.01505

634   Hardy, C. J., & Rejeski, W. J. (1989). Not What, but How One Feels - the

635   Measurement of Affect during Exercise. *Journal of Sport & Exercise*

636   *Psychology, 11*(3), 304-317

637   Hargreaves, E. A., & Stych, K. (2013). Exploring the peak and end rule of past

638   affective episodes within the exercise context. *Psychology of Sport and*

639   *Exercise, 14*(2), 169-178. doi: 10.1016/j.psychsport.2012.10.003

640   Jakeman, J., Adamson, S., & Babraj, J. (2012). Extremely short duration high-intensity

641   training substantially improves endurance performance in triathletes. *Applied*

642   *Physiology and Nutrition and Metabolism, 37*(5), 976-981. doi:

643   10.1139/h2012-083

644   Jung, M. E., Bourne, J. E., & Little, J. P. (2014). Where Does HIT Fit? An

645   Examination of the Affective Response to High-Intensity Intervals in

646   Comparison to Continuous Moderate- and Continuous Vigorous-Intensity

647 Exercise in the Exercise Intensity-Affect Continuum. *PLoS ONE, 9*(12),

648 e114541. doi: 10.1371/journal.pone.0114541

649 Jung, M. E., Little, J. P., & Batterham, A. M. (2016). Commentary Why sprint interval

650 training is inappropriate for a largely sedentary population. *Frontiers in*

651 *Psychology, 6*(1999), 1-3. doi: 10.3389/fpsyg.2015.01999

652 Kahneman, D., Fredrickson, B. L., Schreiber, C. A., & Redelmeier, D. A. (1993).

653 When more pain is preferred to less - adding a better end. . *Psychological*

654 *Science, 4*(6), 401-405. doi: 10.1111/j.1467-9280.1993.tb00589.x

655 Kilpatrick, M., Kraemer, R., Bartholomew, J., Acevedo, E., & Jarreau, D. (2007).

656 Affective responses to exercise are dependent on intensity rather than total

657 work. *Medicine and Science in Sports and Exercise, 39*(8), 1417-1422. doi:

658 10.1249/mss.0b013e31806ad73c

659 Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative

660 science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology,*

661 *4*(863), 1-12. doi: ARTN 86310.3389/fpsyg.2013.00863

662 Mann, T., Lamberts, R. P., & Lambert, M. I. (2013). Methods of Prescribing Relative

663 Exercise Intensity: Physiological and Practical Considerations. *Sports*

664 *Medicine, 43*(7), 613-625. doi: 10.1007/s40279-013-0045-x

665 Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical

666 performance in humans. *Journal of Applied Physiology, 106*(3), 857-864. doi:

667 10.1152/japplphysiol.91324.2008

668 Martinez, N., Kilpatrick, M. W., Salomon, K., Jung, M. E., & Little, J. P. (2015).

669 Affective and Enjoyment Responses to High-Intensity Interval Training in

670 Overweight-to-Obese and Insufficiently Active Adults. *Journal of Sport &*

671 *Exercise Psychology, 37*(2), 138-149. doi: 10.1123/jsep.2014-0212

672 National Health Service, S. (2013). Scottish Physical Activity Screening Question

673   (SCOT-PASQ). Scotland.

674 Oliveira, B. R. R., Slama, F. A., Deslandes, A. C., Furtado, E. S., & Santos, T. M.

675   (2013). Continuous and High-Intensity Interval Training: Which Promotes

676   Higher Pleasure? *Plos One, 8*(11), e79965. doi: ARTN

677   e7996510.1371/journal.pone.0079965

678 Rhodes, R. E., & Kates, A. (2015). Can the Affective Response to Exercise Predict

679   Future Motives and Physical Activity Behavior? A Systematic Review of

680   Published Evidence. *Annals of Behavioral Medicine, 49*(5), 715-731. doi:

681   10.1007/s12160-015-9704-5

682 Saanijoki, T., Nummenmaa, L., Eskelinen, J. J., Savolainen, A. M., Vahlberg, T.,

683   Kalliokoski, K. K., & Hannukainen, J. C. (2015). Affective Responses to

684   Repeated Sessions of High-Intensity Interval Training. *Medicine and Science*

685   *in Sports and Exercise, 47*(12), 2604-2611. doi:

686   10.1249/Mss.0000000000000721

687 Svebak, S., & Murgatroyd, S. (1985). Metamotivational Dominance - a Multimethod

688   Validation of Reversal Theory Constructs. *Journal of Personality and Social*

689   *Psychology, 48*(1), 107-116. doi: Doi 10.1037/0022-3514.48.1.107

690 Tjonna, A. E., Stolen, T. O., Bye, A., Volden, M., Slordahl, S. A., Odegard, R., . . .

691   Wisloff, U. Aerobic interval training reduces cardiovascular risk factors more

692   than a multitreatment approach in overweight adolescents. *Clinical Science,*

693   *116*(4), 317-326

694 Vollaard, N. B. J., & Metcalfe, R. S. (2017). Research into the Health Benefits of

695   Sprint Interval Training Should Focus on Protocols with Fewer and Shorter

696   Sprints. *Sports Medicine*. doi: 10.1007/s40279-017-0727-x

697 Wood, K. M., Olive, B., LaValle, K., Thompson, H., Greer, K., & Astorino, T. A.

698   (2016). Dissimilar Physiological and Perceptual Responses between Sprint

699   Interval Training and High-Intensity Interval Training. *Journal of Strength and*

700   *Conditioning Research, 30*(1), 244-250. doi: 10.1519/Jsc.0000000000001042

701

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.

714

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.

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 Ailsa Niven[1], Jacqueline Thow[2], Jack Holroyd[3], Anthony P. Turner[4], and Shaun M.

8 Phillips[5]

9

10 [1]Institute for Sport, Physical Education, and Health Sciences, University of

11 Edinburgh, Scotland, 0131 6516679, ailsa.niven@ed.ac.uk; [2]Sportscotland Institute

12 of Sport, Stirling, Scotland, jacki.thow@googlemail.com; [3]Institute for Sport,

13 Physical Education, and Health Sciences, University of Edinburgh, Scotland,

14 s1121440@sms.ed.ac.uk; [4]Institute for Sport, Physical Education, and Health

15 Sciences, University of Edinburgh, Scotland, 0131 6516003, tony.turner@ed.ac.uk;

16 [5]Institute for Sport, Physical Education, and Health Sciences, University of

17 Edinburgh, Scotland, 0131 6514110, shaun.phillips@ed.ac.uk.

18

19 **Corresponding Author:**

20 Dr Shaun Phillips; University of Edinburgh, Institute for Sport, Physical Education,

21 and Health Sciences, St Leonards Land, Holyrood Road, Edinburgh, EH88AQ

22 Tel: 0131 651 4110, Fax: 0131 651 6521, Email: shaun.phillips@ed.ac.uk

23

25

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 ($\dot{V}O_{2max}$ 48.2 $\pm$ 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 $\pm$ 2.42, 1.17 $\pm$ 1.99,

36 and 0.42 $\pm$ 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.

44

45

46

47

48

49

50

Introduction

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

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

4

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·kg^{-1}·min^{-1}, W_{peak} 297 ± 36 W). Participants

150 were generally physically active ($\geq$ 150 min habitual physical activity per week

151   (National Health Service, 2013); physically active for $\geq$ 30 min on 5 $\pm$ 1.6 days per

152   week (range 2-7)), untrained (below the age-gender 90th percentile for $\dot{V}O_{2max}$

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 $\dot{V}O_{2max}$ 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 $W \cdot min^{-1}$ until volitional exhaustion or cadence dropped

186 below 60 $rev \cdot min^{-1}$ for more than 10 s despite strong verbal encouragement.

187 Participants' $\dot{V}O_{2max}$ 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 $ml \cdot min^{-1}$ increase during

190 the last 60 s of the test) (Bergstrom et al., 2013). While valid $\dot{V}O_{2max}$ 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

8

201 O_2 ($\dot{V}_E/\dot{V}O_2$) and CO_2 ($\dot{V}_E/\dot{V}CO_2$) against $\dot{V}O_2$ (Davis, Frank, Whipp, & Wasserman,

202 1979). A systematic increase in $\dot{V}_E/\dot{V}O_2$ without a corresponding increase in $\dot{V}_E/\dot{V}CO_2$,

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/$\dot{V}O_2$

205 regression equation from the maximal test was used to determine the power output

206 associated with $\dot{V}O_2$ 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 $\geq$ 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

9

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

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

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, Cobley, & Babraj, 2014; Adamson, Lorimer, Cobley, 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 ± 1.0, $d = 0.20$ at warm-up to 1.5 ± 2.3, $d = 0.66$ at 100% of exercise) and MICE

324   and HIIE (mean difference 0.1 ± 1.1, $d = 0.16$ at warm-up to 0.9 ± 1.6, $d = 0.59$ at

13

325 100% of exercise). The difference in affective valence between HICE and HIIE was

326 fairly stable over time (mean difference 0.1 ± 1.2, $d = 0$ at warm-up to 0.6 ± 3.2, $d =$

327 0.18 at 100% of exercise). Within-trials, the largest reduction in affective valence

328 (warm-up to 100% of exercise) occurred in HICE (-1.75 ± 2.42 units, $d = 0.72$),

329 followed by HIIE (-1.17 ± 1.99 units, $d = 0.59$) and MICE (-0.42 ± 1.38 units, $d =$

330 0.30).

331

332 *Perceived activation*

333

334 There were statistically significant main effects of trial ($F_{2,22} = 13.91$, $P < 0.001$), time

335 ($F_{1.6,18.3} = 40.12$, $P < 0.001$), and trial x time interaction ($F_{4.1,45.6} = 4.14$, $P = 0.006$) for

336 perceived activation during exercise (Figure 2B). There were no statistical differences

337 between conditions at baseline or warm-up. The MICE and HIIE trials differed

338 statistically throughout exercise, with differences remaining large between 20% ($P =$

339 0.002, $d = 1.37$) and 100% ($P = 0.002$, $d = 1.36$) of exercise. The MICE and HICE

340 trials differed statistically at 60% ($P = 0.006$, $d = 1.16$), 80% ($P = 0.006$, $d = 1.17$),

341 and 100% ($P = 0.021$, $d = 0.96$) of exercise. The HICE and HIIE trials did not differ

342 statistically at any time (largest difference at 20% of exercise, $P = 0.075$, $d = 0.75$).

343

344 * FIGURE 2 HERE *

345

346

347

348

349

14

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 HIIE vs. MICE. There were no statistical interactions between HICE

369 and HIIE.

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

16

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.

17

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.

18

450   However, the mean $\dot{V}O_{2max}$ 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

19

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 (Saanijoki 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 HIIE protocols for the general

504 population, including older and inactive people (Vollaard & Metcalfe, 2017). Our

505 low-volume HIIE protocol meets this suggestion. These points, coupled with the

506 justification for our HIIE protocol described elsewhere in this paper, suggest that the

507 affective responses to the low-volume HIIE 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 HIIE 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 HIIE, low volume, time efficient HIIE may be an attractive alternative

515 exercise prescription for improving health and fitness.

516

517

518

519

520

521

522

523

524

525 **Geolocation Information**

526

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

531 **Funding**

532

536

537 **Disclosure of interest**

538

539 The authors report no conflicts of interest.

540

541

542

543

544

545

546

547

548

549

550 **REFERENCES**

551

552 Aaltonen, S., Leskinen, T., Morris, T., Alen, M., Kaprio, J., Liukkonen, J., & Kujala,

553   U. (2012). Motives for and barriers to physical activity in twin pairs discordant

554   for leisure time physical activity for 30 years. *International Journal of Sports*

555   *Medicine, 33*(2), 157-163. doi: 10.1055/s-0031-1287848

556 Adamson, S. B., Lorimer, R., Cobley, J. N., & Babraj, J. A. (2014). Extremely short-

557   duration high-intensity training substantially improves the physical function

558   and self-reported health status of elderly adults. *Journal of American Geriatric*

559   *Society, 62*(7), 1380-1381. doi: 10.1111/jgs.12916

560 Adamson, S. B., Lorimer, R., Cobley, N. J., Lloyd, R., & Babraj, J. (2014). High

561   Intensity Training Improves Health and Physical Function in Middle Aged

562   Adults. *Biology, 3*(2), 333-344. doi: 10.3390/biology3020333

563 Allison, M. K., Martin, B. J., MacInnis, M. J., Gurd, B., & Gibala, M. J. (2016). Brief,

564   Intense Intermittent Stair Climbing Is A Practical, Time-Efficient Method To

565   Improve Cardiorespiratory Fitness: 2157 Board #309 June 2, 3: 30 PM - 5: 00

566   PM. *Med Sci Sports Exerc, 48*(5 Suppl 1), 609. doi:

567   10.1249/01.mss.0000486830.80107.b2

568 American, College, of, Sports, & Medicine. (2005). *ACSM's Guidelines for Exercise*

569   *Testing and Prescription* (7th ed.). Baltimore (ML): Lippincott Williams and

570   Wilkins.

571 Astorino, T. A., Schubert, M. M., Palumbo, E., Stirling, D., McMillan, D. W., Gallant,

572   R., & Dewoskin, R. (2016). Perceptual Changes in Response to Two Regimens

573   of Interval Training in Sedentary Women. *Journal of Strength and*

574   *Conditioning   Research,   30*(4),   1067-1076.   doi: 575   10.1519/JSC.0000000000001175

576   Babraj, J. A., Vollaard, N. B., Keast, C., Guppy, F. M., Cottrell, G., & Timmons, J. A.

577   (2009). Extremely short duration high intensity interval training substantially

578   improves insulin action in young healthy males. *BMC Endocrine Disorders,*

579   *9*(3), 1-8. doi: Artn 310.1186/1472-6823-9-3

580   Beaver, W. L., Wasserman, K., & Whipp, B. J. (1986). A new method for detecting

581   anaerobic threshold by gas exchange. *J Appl Physiol (1985), 60*(6), 2020-2027

582   Bergstrom, H. C., Housh, T. J., Zuniga, J. M., Traylor, D. A., Camic, C. L., Lewis, R.

583   W., . . . Johnson, G. O. (2013). The Relationships Among Critical Power

584   Determined From a 3-Min All-Out Test, Respiratory Compensation Point, Gas

585   Exchange Threshold, and Ventilatory Threshold. *Research Quarterly for*

586   *Exercise and Sport, 84*(2), 232-238. doi: 10.1080/02701367.2013.784723

587   Biddle, S. J. H., & Batterham, A. M. (2015). High-intensity interval exercise training

588   for public health: a big HIT or shall we HIT it on the head? *International*

589   *Journal of Behavioral Nutrition and Physical Activity, 12*(95), 1-8. doi:

590   10.1186/s12966-015-0254-9

591   Blanchard, C. M., Rodgers, W. M., Wilson, P. M., & Bell, G. J. (2004). Does equating

592   total volume of work between two different exercise conditions matter when

593   examining exercise-induced feeling states? *Research Quarterly for Exercise*

594   *and Sport, 75*(2), 209-215

595   Borg, E., & Kaijser, L. (2006). A comparison between three rating scales for perceived

596   exertion and two different work tests. *Scandinavian Journal of Medicine &*

597   *Science in Sports, 16*(1), 57-69. doi: 10.1111/j.1600-0838.2005.00448.x

24

598   Cohen, J. (1992). A Power Primer. *Psychological Bulletin, 112*(1), 155-159. doi: Doi

599   10.1037/0033-2909.112.1.155

600   Davis, J. A., Frank, M. H., Whipp, B. J., & Wasserman, K. (1979). Anaerobic

601   Threshold Alterations Caused by Endurance Training in Middle-Aged Men.

602   *Journal of Applied Physiology, 46*(6), 1039-1046

603   Decker, E. S., & Ekkekakis, P. (2016). More efficient, perhaps, but at what price?

604   Pleasure and enjoyment responses to high-intensity interval exercise in low-

605   active women with obesity. *Psychology of Sport and Exercise, 28*, 1-10. doi:

606   http://dx.doi.org/10.1016/j.psychsport.2016.09.005

607   Ekkekakis, P. (2003). Pleasure and displeasure from the body: Perspectives from

608   exercise. *Cognition & Emotion, 17*(2), 213-239. doi:

609   10.1080/02699930244000282

610   Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005a). Some like it vigorous:

611   Measuring individual differences in the preference for and tolerance of

612   exercise intensity. *Journal of Sport & Exercise Psychology, 27*(3), 350-374

613   Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005b). Variation and homogeneity in

614   affective responses to physical activity of varying intensities: an alternative

615   perspective on dose-response based on evolutionary considerations. *Journal of*

616   *Sports Sciences, 23*(5), 477-500. doi: 10.1080/02640410400021492

617   Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2008). The relationship between

618   exercise intensity and affective responses demystified: To crack the 40-year-

619   old nut, replace the 40-year-old nutcracker! *Annals of Behavioral Medicine,*

620   *35*(2), 136-149. doi: 10.1007/s12160-008-9025-z

621   Frazao, D. T., de Farias, L. F., Dantas, T. C. B., Krinski, K., Elsangedy, H. M., Prestes,

622   J., . . . Costa, E. C. (2016). Feeling of Pleasure to High-Intensity Interval

623   Exercise Is Dependent of the Number of Work Bouts and Physical Activity

624   Status. *Plos One, 11*(3), e0152752. doi: 10.1371/journal.pone.0153986

625 Gillen, J. B., & Gibala, M. J. (2014). Is high-intensity interval training a time-efficient

626   exercise strategy to improve health and fitness? *Applied Physiology and*

627   *Nutrition and Metabolism, 39*(3), 409-412. doi: 10.1139/apnm-2013-0187

628 Hallal, P., Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. (2012). Global

629   physical activity levels: surveillance progress, pitfalls, and prospects. *The*

630   *Lancet, 380*(9838), 247-257

631 Hardcastle, S. J., Ray, H., Beale, L., & Hagger, M. S. (2014). Why sprint interval

632   training is inappropriate for a largely sedentary population. *Frontiers in*

633   *Psychology, 5*(1505), 1-3. doi: 10.3389/fpsyg.2014.01505

634 Hardy, C. J., & Rejeski, W. J. (1989). Not What, but How One Feels - the

635   Measurement of Affect during Exercise. *Journal of Sport & Exercise*

636   *Psychology, 11*(3), 304-317

637 Hargreaves, E. A., & Stych, K. (2013). Exploring the peak and end rule of past

638   affective episodes within the exercise context. *Psychology of Sport and*

639   *Exercise, 14*(2), 169-178. doi: 10.1016/j.psychsport.2012.10.003

640 Jakeman, J., Adamson, S., & Babraj, J. (2012). Extremely short duration high-intensity

641   training substantially improves endurance performance in triathletes. *Applied*

642   *Physiology and Nutrition and Metabolism, 37*(5), 976-981. doi:

643   10.1139/h2012-083

644 Jung, M. E., Bourne, J. E., & Little, J. P. (2014). Where Does HIT Fit? An

645   Examination of the Affective Response to High-Intensity Intervals in

646   Comparison to Continuous Moderate- and Continuous Vigorous-Intensity

647   Exercise in the Exercise Intensity-Affect Continuum. *PLoS ONE, 9*(12),

648   e114541. doi: 10.1371/journal.pone.0114541

649 Jung, M. E., Little, J. P., & Batterham, A. M. (2016). Commentary Why sprint interval

650   training is inappropriate for a largely sedentary population. *Frontiers in*

651   *Psychology, 6*(1999), 1-3. doi: 10.3389/fpsyg.2015.01999

652 Kahneman, D., Fredrickson, B. L., Schreiber, C. A., & Redelmeier, D. A. (1993).

653   When more pain is preferred to less - adding a better end. . *Psychological*

654   *Science, 4*(6), 401-405. doi: 10.1111/j.1467-9280.1993.tb00589.x

655 Kilpatrick, M., Kraemer, R., Bartholomew, J., Acevedo, E., & Jarreau, D. (2007).

656   Affective responses to exercise are dependent on intensity rather than total

657   work. *Medicine and Science in Sports and Exercise, 39*(8), 1417-1422. doi:

658   10.1249/mss.0b013e31806ad73c

659 Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative

660   science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology,*

661   *4*(863), 1-12. doi: ARTN 86310.3389/fpsyg.2013.00863

662 Mann, T., Lamberts, R. P., & Lambert, M. I. (2013). Methods of Prescribing Relative

663   Exercise Intensity: Physiological and Practical Considerations. *Sports*

664   *Medicine, 43*(7), 613-625. doi: 10.1007/s40279-013-0045-x

665 Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical

666   performance in humans. *Journal of Applied Physiology, 106*(3), 857-864. doi:

667   10.1152/japplphysiol.91324.2008

668 Martinez, N., Kilpatrick, M. W., Salomon, K., Jung, M. E., & Little, J. P. (2015).

669   Affective and Enjoyment Responses to High-Intensity Interval Training in

670   Overweight-to-Obese and Insufficiently Active Adults. *Journal of Sport &*

671   *Exercise Psychology, 37*(2), 138-149. doi: 10.1123/jsep.2014-0212

672　National Health Service, S. (2013). Scottish Physical Activity Screening Question

673　　　　(SCOT-PASQ). Scotland.

674　Oliveira, B. R. R., Slama, F. A., Deslandes, A. C., Furtado, E. S., & Santos, T. M.

675　　　　(2013). Continuous and High-Intensity Interval Training: Which Promotes

676　　　　Higher　Pleasure?　*Plos　One,　8*(11),　e79965.　doi:　ARTN

677　　　　e7996510.1371/journal.pone.0079965

678　Rhodes, R. E., & Kates, A. (2015). Can the Affective Response to Exercise Predict

679　　　　Future Motives and Physical Activity Behavior? A Systematic Review of

680　　　　Published Evidence. *Annals of Behavioral Medicine, 49*(5), 715-731. doi:

681　　　　10.1007/s12160-015-9704-5

682　Saanijoki, T., Nummenmaa, L., Eskelinen, J. J., Savolainen, A. M., Vahlberg, T.,

683　　　　Kalliokoski, K. K., & Hannukainen, J. C. (2015). Affective Responses to

684　　　　Repeated Sessions of High-Intensity Interval Training. *Medicine and Science*

685　　　　*in　Sports　and　Exercise,　47*(12),　2604-2611.　doi:

686　　　　10.1249/Mss.0000000000000721

687　Svebak, S., & Murgatroyd, S. (1985). Metamotivational Dominance - a Multimethod

688　　　　Validation of Reversal Theory Constructs. *Journal of Personality and Social*

689　　　　*Psychology, 48*(1), 107-116. doi: Doi 10.1037/0022-3514.48.1.107

690　Tjonna, A. E., Stolen, T. O., Bye, A., Volden, M., Slordahl, S. A., Odegard, R., . . .

691　　　　Wisloff, U. Aerobic interval training reduces cardiovascular risk factors more

692　　　　than a multitreatment approach in overweight adolescents. *Clinical Science,*

693　　　　*116*(4), 317-326

694　Vollaard, N. B. J., & Metcalfe, R. S. (2017). Research into the Health Benefits of

695　　　　Sprint Interval Training Should Focus on Protocols with Fewer and Shorter

696　　　　Sprints. *Sports Medicine*. doi: 10.1007/s40279-017-0727-x

697 Wood, K. M., Olive, B., LaValle, K., Thompson, H., Greer, K., & Astorino, T. A.

698   (2016). Dissimilar Physiological and Perceptual Responses between Sprint

699   Interval Training and High-Intensity Interval Training. *Journal of Strength and*

700   *Conditioning Research, 30*(1), 244-250. doi: 10.1519/Jsc.0000000000001042

701

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.

714

715 Figure 3: Affective circumplex model applied to the MICE, HICE, and HIIE sessions.

716 MICE = moderate-intensity continuous exercise; HICE = high-intensity continuous

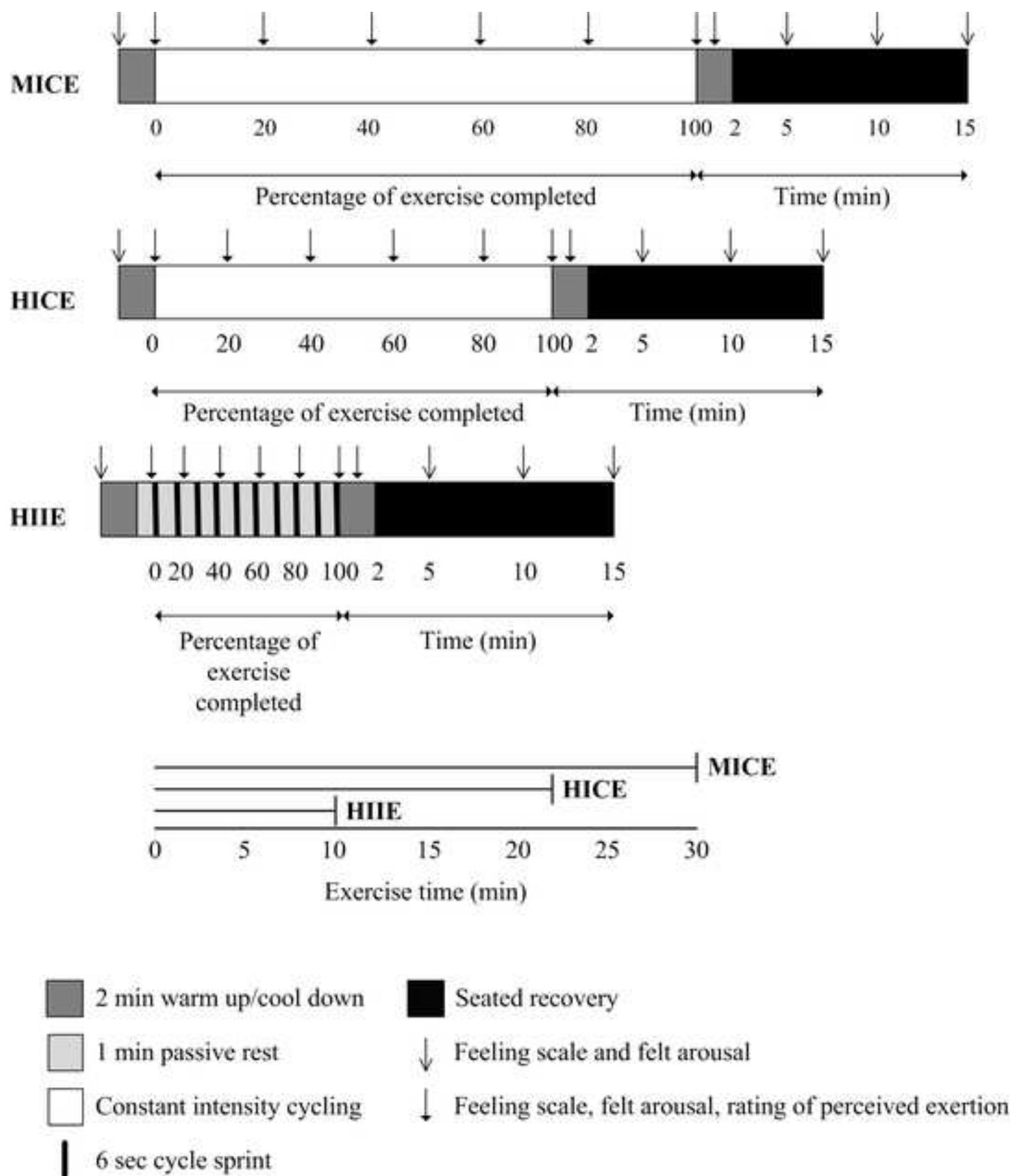717 exercise; HIIE = high-intensity interval exercise.

Table 1

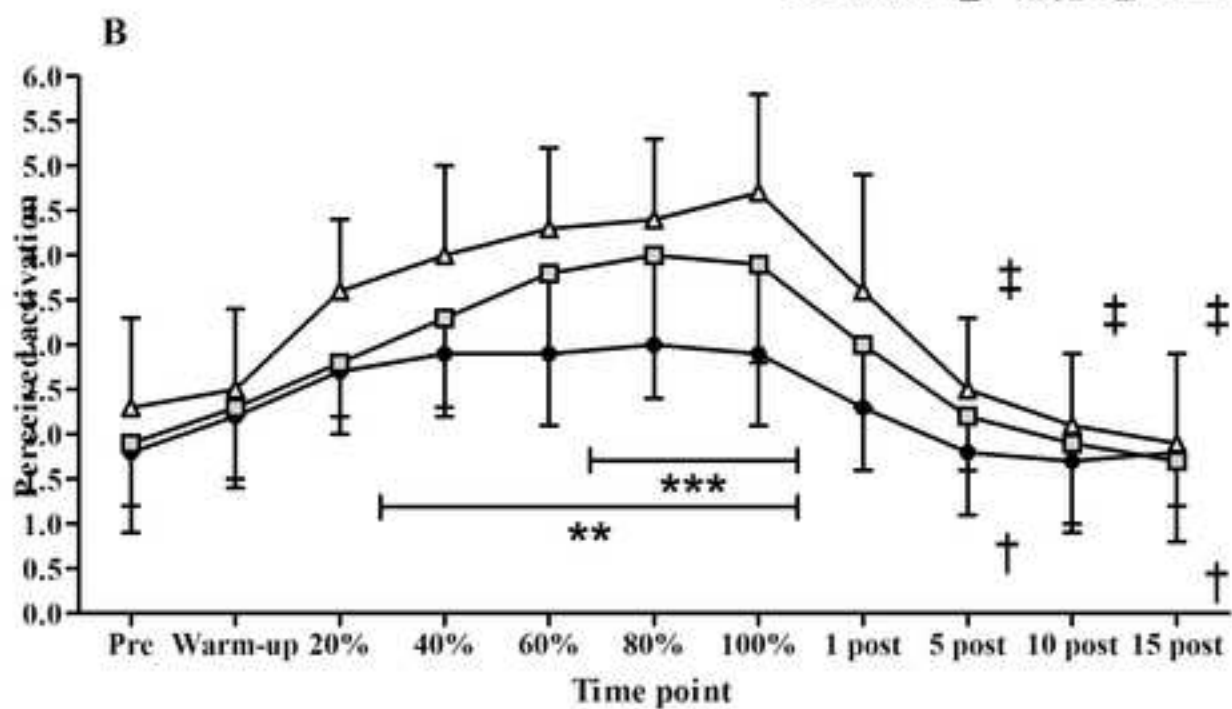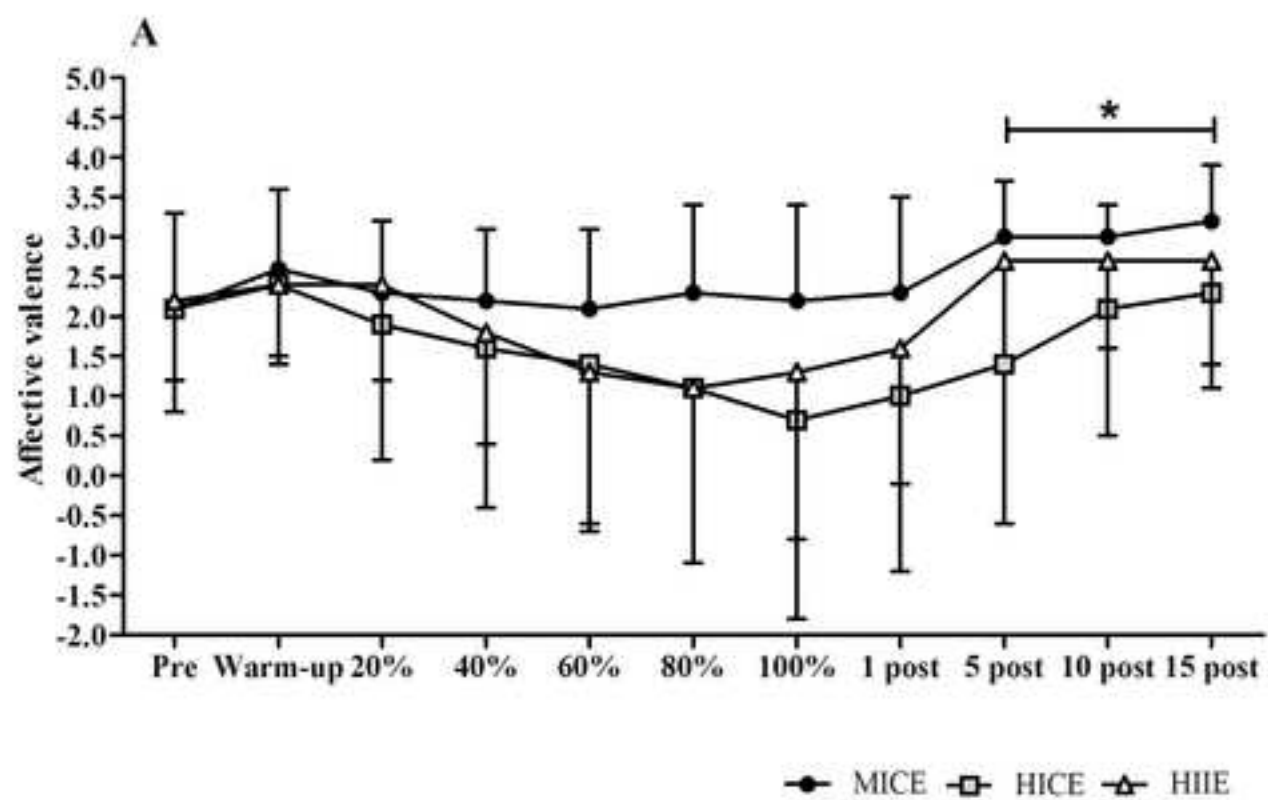TABLE 1. Comparison of the three exercise trials.

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

$d = 2.33$ $d = 2.26$ $d = 0.41$

Data are mean ± 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

MICE

0   20   40   60   80   100 2   5   10   15

Percentage of exercise completed   Time (min)

HICE

0   20   40   60   80   100 2   5   10   15

Percentage of exercise completed   Time (min)

HIIE

0 20 40 60 80 100 2   5   10   15

Percentage of
exercise
completed

Time (min)

|— MICE
|— HICE
|— HIIE

0   5   10   15   20   25   30

Exercise time (min)

2 min warm up/cool down   Seated recovery

1 min passive rest   ↓ Feeling scale and felt arousal

Constant intensity cycling   ↓ Feeling scale, felt arousal, rating of perceived exertion

6 sec cycle sprint

Figure

Figure