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# Effects of three low-volume, high-intensity exercise conditions on affective valence

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# Effects of three low-volume, high-intensity exercise conditions on affective valence

A common barrier to exercise is “lack of time”. Accordingly, interest in low-volume, high-intensity training has grown exponentially since this activity is considered time-efficient. However, the high-intensity nature of this exercise may frequently result in feelings of displeasure creating another barrier for many people. The purpose of this study was to compare affective (pleasure-displeasure) responses to three low-volume, high-intensity exercise conditions, including a novel shortened-sprint protocol. Using a within-subjects, randomised crossover experiment, healthy participants ($N$ = 36) undertook a single bout of: 1) traditional reduced-exertion, high-intensity interval training (TREHIT), 2) a novel, shortened-sprint REHIT (SSREHIT) protocol, and 3) sprint continuous training (SCT). Affect and perceived effort were recorded throughout exercise using the Feeling Scale (FS) and the 15-point Borg Rating of Perceived Exertion (RPE) scale, respectively. Enjoyment was recorded 5 min post-exercise using the Exercise Enjoyment Scale (EES). Differences were found for FS (condition by time interaction: $P = 0.01_{GG}$, $\eta^2 = 0.26$), RPE ($P = 0.01_{GG}$, $\eta^2 = 0.23$), and enjoyment ($P < 0.01$) with all outcomes favouring SSREHIT. Shortened-sprint protocols may diminish feelings of displeasure and might be a time-efficient yet tolerable exercise choice to help motivate some people to increase their physical activity and fitness.

*Keywords*: adherence; affective valence; enjoyment; time-efficient; high-intensity interval training; low-volume

Word count: 4630

## Introduction

Interest in low-volume, high-intensity exercise has become ubiquitous in sport and exercise science research in recent years. Several approaches to this exercise have emerged alongside claims for a role in public health promotion (e.g. Francois & Little, 2015; Jung *et al*., 2015; Rehn, Winett, Wisløff & Rognmo, 2013; Steele *et al*., 2017a). High-intensity, interval training (HIT) is one such approach and is characterised by brief periods of repeated maximal or near-maximal exercise, interspersed with periods of recovery. Proponents emphasise relative time-efficiency as an important practical benefit to increase exercise adherence in those who otherwise would not engage with more time-consuming approaches. The *efficacy* of HIT as a potent means of inducing beneficial biochemical, cellular, and physiological adaptations is clear. Experimental mechanistic investigations (Burgomaster *et al*., 2008; Gibla *et al*., 2006), randomised controlled trials (Heydari *et al*., 2012; Matsuo *et al*., 2013), and meta-analyses (Weston, Taylor, Batterham & Hopkins, 2014; Weston, Wilsøff & Coombes, 2014) attest this point. HIT improves cardiorespiratory fitness which exerts a powerful protective effect against all-cause mortality, with changes from low to intermediate or high fitness considered more important than the overall volume of exercise performed (Ehrman *et al*., 2017; Lee *et al*., 2011; Ross *et al*., 2016). However, what is less clear is how *effective* HIT is likely to be in real-world settings. Concerns have been raised about the likelihood of HIT evoking a high degree of negative affect, or displeasure, which may in-turn lead to an avoidant response with the prospect of future exercise sessions (Hardcastle, Ray, Beale & Hagger, 2014).

Hedonistic theories of motivation, such as dual-mode theory, propose that exercise above a certain intensity threshold relies heavily on anaerobic substrate phosphorylation which results in a cascade of physiological responses that greatly challenge homeostasis (Ekkekakis, Hall & Petruzzello, 2008). These perturbations lead to a dramatic decline in pleasure (Cabanac, 2006; Ekkekakis, 2003), which could in-turn predict long-term exercise adherence (Williams *et al*., 2008; 2012). Thus, one of the reasons for the advocacy of HIT, that it might appeal to individuals who otherwise would not engage with more time-consuming exercise, is juxtaposed with speculation that the potential consequences of high-intensity exercise may pose a significant barrier for many, since people typically choose not to engage in activities that they find overly challenging and aversive (Pollock, 1978). Yet, critiques based on hedonicity have mostly relied on *continuous* exercise above the ventilatory threshold (Del Vecchio, Gentil, Coswig, & Fukuda, 2015; Ekkekakis *et al*., 2008) which may be wholly inappropriate for understanding intensity-affect-adherence relationships associated with HIT, since the intermittent nature of the activity fundamentally alters the exercise experience.

Affective responses observed in response to HIT are varied, explained by diverse protocols in terms of effort, frequency, duration, and recovery associated with the high-intensity periods of exercise. Research has shown HIT can produce affective and enjoyment responses that are similar to those of moderate-intensity continuous exercise (Kilpatrick, Greely, & Collins, 2015) and more pleasant than heavy continuous exercise (Jung *et al*., 2014). Similarly, greater enjoyment and improved confidence to engage with HIT have been reported in comparison to moderate-intensity exercise, despite more negative affective states (Bartlett *et al*., 2011; Kilpatrick *et al*., 2015). Other research has reported lower pleasure and enjoyment for HIT compared to moderate-intensity and heavy continuous exercise (Decker & Ekkekakis, 2017; Oliveira *et al*., 2013). However, the exercise conditions in these studies used intensities requiring sustained anaerobic metabolism, whereas more moderate approaches to HIT with different interval and recovery periods might yield different results.

Whilst affective and other perceptual responses to various iterations of HIT are uncertain, several attempts have been made to consider the minimal amount of exercise that can confer health benefits. Metcalfe *et al*. (2011) devised reduced-exertion, HIT (REHIT) with a total duration of 10-min, inclusive of 2 × 10–20-s cycle sprints against a braking force equivalent to 7.5% of body mass. Despite the minimal volume of exercise, maximal oxygen uptake ($\dot{V}O_{2max}$) improved by 12–15% in healthy participants. Studies using type 2 diabetics have shown similar increases (Revdal, Hollekim-Strand, & Ingul, 2016; Ruffino *et al*., 2016). These changes are thought to be caused by activation of molecular signalling pathways that lead to increased gene expression of key transcription coactivators considered important for mitochondria biogenesis and energy metabolism under conditions of both health and disease (Finck & Kelly, 2006; Metcalfe *et al*., 2015). As such, the acceptability of such a minimalist approach to exercise could be important for inactive individuals wanting to improve health outcomes in a time-efficient manner. One further study has used sprint continuous training (SCT), which involves a single sustained maximal effort sprint without rest periods (Harris *et al*., 2014), and found similar improvements in $\dot{V}O_{2max}$. In this study, the volume of high-intensity exercise was work-matched (kJ) to higher-volume HIT protocols. The average total time commitment was ~3.5 min, excluding warm-up and cool down.

Despite the time-efficiency of these exercise choices, the 'peak-end rule' is a psychological heuristic that proposes that memory associated with pleasure or displeasure is influenced by the moment a peak response is experienced (Fredrickson, 2000). For REHIT and SCT the peak moment of displeasure is likely to be proximal to the high-intensity sprints and could influence retrospective evaluations of the activity, impacting motivational factors related to future adherence. Frequently, sprints result in considerable fatigue and feelings of nausea due to metabolic acidosis, particularly in inexperienced inactive individuals, thus duration and recovery between sprints is an important consideration. Perception of exercise is related to muscle resistance to external force but becomes a function of duration when work is extended over time resulting from change in exercise capacity due to fatigue (Cafarelli *et al*., 1977). Currently, there is a paucity of methods for improving the affective experience of low-volume, high-intensity exercise (Zenko, Ekkekakis, & Ariely, 2016), thus protocols with fewer or shorter sprints should be tested.

The affective response is important for the potential role of this type of exercise in health promotion and has not been explored. The challenge is to induce meaningful benefits to health without overly compromising perceptual response, making exercise acceptable and tolerable. Therefore, the objective of the present study was to consider differences between affective responses to three low-volume, high-intensity exercise protocols. Traditional REHIT (TREHIT) and SCT were compared to a novel, shortened-sprint REHIT condition (SSREHIT). The experimental hypothesis was that SSREHIT would result in more favourable affective responses.

## Methods

### *Participants and experimental approach*

Ratings of affective valence were designated the primary outcome variable. An a priori power analysis was performed using G*Power© software (version 3.1.9.2, 2017) for comparison between three dependent means. This was based on an anticipated medium effect size (i.e. 0.5), an alpha criterion of 0.05, and power of 0.8 (1 – beta), which are proportionate with effect size assumptions made in similar studies (e.g. Decker & Ekkekakis, 2017; Kilpatrick *et al*., 2015; Martinez *et al*., 2014). Analysis indicated that a total of 23 participants were required to reach 0.8 statistical power. After institutional ethical approval, a convenience sample of 36 participants (29 males, 7 females; age 22.3 ± 4.7 years; stature, 1.7 ± 0.1 m; body mass, 73.2 ± 12.3 kg; Body Mass Index, 24.2 ± 2.6 kg·m$^2$) were recruited, consisting students (78% of the sample) and office-based employees. Participants were recreationally active (i.e. meeting physical activity guidelines) and healthy, determined via negative responses to a medical screening questionnaire.

Following familiarisation, consisting explanations and demonstrations of the exercise conditions and measures, participants commenced the first exercise training session within one week, undertaking three separate high-intensity exercise conditions: 1) SSREHIT, 2) TREHIT, and 3) SCT, with a minimum of 48 h washout between sessions. A counterbalanced crossover design was used to control for order effects, with the three conditions grouped into six possible orders and participants randomly assigned to these using a random number generator. Participants were instructed to consume their normal diet and asked to refrain from intense physical activity the day before each session delaying participation if they were experiencing fatigue or musculoskeletal injury. They were also instructed to refrain from engaging in any recovery modalities following exercise. Allocation concealment and blinding of assessors who measured outcome measures was not possible.

***Exercise conditions***

All exercise conditions were performed on a Wattbike cycle ergometer (Wattbike Pro, Nottingham, UK) with pedal resistance for the sprints matched and set using the air and magnetic settings to create a flywheel braking force appropriate for peak power generation, as recommended by the manufacturer. Instructions on how to carry out each exercise condition were communicated before and during each session, with standardised verbal encouragement and feedback used throughout sprints to ensure maximal effort. Participants remained in the laboratory for 10-min post-exercise for monitoring of adverse events.

*Traditional REHIT (TREHIT)*

TREHIT was performed as per Metcalfe *et al*. (2011) and totalled 10 minutes of cycling, inclusive of 2 × 20 s maximal effort sprints. Exercise intensities between sprints were low (~60 W). A warm-up (3-min at ~30–60 W) and cool down (3-min at ~30 W) were included within the 10-min session. A schematic overview of TREHIT can be seen in **Figure 1 a**.

*Shortened-sprint REHIT (SSREHIT)*

SSREHIT was designed to match the total time spent completing high-intensity exercise as per TREHIT (i.e. 40-s). However, with the aim of reducing affective response, the time was fractionalised into smaller periods. Thus, participants performed 8 × 5 s maximal effort sprints, with low-intensity effort (~60 W) cycling between sprints, within a 10-min session. Again, this was inclusive of a warm-up (3-min at ~30–60 W) and cool down (2-min at ~30 W) (**Figure 1 b**).

*Sprint continuous training (SCT)*

Due to the other exercise conditions using disparate protocols, it was not possible to work match SCT. However, the total duration of the "extended sprint" was similar to previous studies (i.e. Harris *et al*., 2014; Whyte *et al*., 2013). SCT consisted a total of 8 minutes cycling, inclusive of a warm-up (3-min at ~30–60 W), a 3-min extended sprint, and a cool down (2-min at ~30 W) (**Figure 1 c**). During the extended sprint, participants were encouraged to pedal with maximal effort whilst considering the duration of the sprint. Thus, an element of "pacing" was inherent to this. There was no requirement to reduce the braking force to ensure maintenance of an appropriate cadence (> 50 rpm), because the Wattbike measures force applied through the cranks onto the chain and is independent of cadence, with power uninfluenced by resistance from the magnetic or airbrake systems.

***Measures***

*Affect (pleasure-displeasure)*

Affect was assessed using the single-item, 11-point Feeling Scale (FS) (Hardy & Rejeski, 1989) which ranges from – 5 "very bad" to + 5 "very good", with anchors designated for 0 ("neutral") and all odd integers in between. The stem "How do you currently feel?" was used to measure pleasure throughout exercise at 25%, 50%, 75%, and 100% of bout completion for all conditions (**Figure 1 a-c**). These times were selected to capture a representative depiction throughout each condition including responses during or shortly after sprints, and immediately upon exercise cessation. The FS was presented to participants using a visual cue card at each time point to ensure accurate reference to the scale.

*Rating of perceived exertion*

Perceived intensity of effort for each condition was monitored using the 15-point rating of perceived exertion (RPE) Borg scale (Borg, 1970). The scale ranges from 6 "no exertion" to 20 "maximal exertion" with anchors designated for all odd integers in between. As for recording of affect, RPE was measured using a visual cue card throughout exercise at 25%, 50%, 75%, and 100% of bout completion, using the stem "How hard are you working at this moment in time?"

*Enjoyment*

Enjoyment was assessed for each condition using the single-item, 7-point Exercise Enjoyment Scale (EES) (Stanley & Cumming, 2009). Anchors are given at every integer, ranging from 1 "not at all" to 7 "extremely". The EES was used following the stem, "Use the following scale to indicate how much you enjoyed this exercise session," and was recorded 5-min post-exercise.

***Statistical analyses***

Statistical analyses were carried out using IBM SPSS Statistics version 24 (IBM, Armonk, USA) with the criterion for statistical significance set at $P < 0.05$. Possible covariates (age and body mass) and factors (sex) – that were not part of the main experimental manipulation but could influence the dependent variable – were included in a preliminary analysis to check for independence of the predictor variable and were found to be non-significant. After checking test assumptions, including normality using the Shapiro-Wilk test, data were analysed in two phases.

For the first phase, a two-way (condition [3] × time [4]) repeated measures analysis of variance (RMANOVA) was conducted for FS and RPE, applying the Greenhouse-Geisser correction when the sphericity assumption was violated. Significant main effects were considered using post-hoc Bonferroni-corrected pairwise comparisons to control for familywise error rate. In addition, a one-way RMANOVA was conducted to examine differences in enjoyment. Effect sizes were quantified using the partial eta squared ($\eta^2$) statistic with the magnitude of difference considered as small (< 0.1), medium (0.1–0.3), or large (> 0.5).

The second phase used separate one-way RMANOVA's to assess differences in FS and RPE for the three exercise conditions for each time point (i.e. 25%, 50%, 75%, and 100% of bout completion). For post-hoc analyses, familywise error rate was controlled using Bonferroni corrections. The Cohen's *d* was used to assess effect size, with differences considered as trivial (< 0.20), small (0.20–0.49), moderate (0.50–0.79), or large (> 0.80).

## Results

### *Descriptive data*

All participants completed the three conditions (no dropouts) as allocated with outcome measures obtained from all participants for FS, RPE, and EES. Several adverse events, defined as any untoward occurrence that happened during the conduct of the study, were reported. Seven incidences of mild to moderate nausea or light headedness were reported for REHIT, five for SSREHIT, and three for SCT. Additionally, two participants vomited following REHIT and one participant vomited after SSREHIT. There were no instances of syncope or musculoskeletal injuries in response to any of the conditions. All adverse events were classified as not serious as per National Institute for Health Research Good Clinical Practice guidelines.

***Affect (pleasure-displeasure)***

RMANOVA revealed a significant main effect of condition for FS ($F_{2, 70}$ = 54.66, $P$ = 0.01, $\eta^2$ = 0.61). FS ratings were lower (greater displeasure) during TREHIT and SCT compared to SSREHIT (both $P$ = 0.001), in addition to being lower for SCT compared to TREHIT ($P$ = 0.005). There was also a main effect of time ($F_{2.2, 77.08}$ = 197.29, $P = 0.01_{GG}$, $\eta^2$ = 0.85) with an apparent quadratic trend. FS ratings declined across time in all three conditions, but the decrease was larger in the TREHIT and SCT conditions compared to SSREHIT (at 50%, 75%, and 100% of bout duration, all $P$ = 0.001). The lowest values occurred at 75% of bout duration for all three conditions with FS values of 1.4 ± 1.7 ("fairly good"), -0.2 ± 1.9 (near "neutral") and -0.9 ± 1.5 ("fairly bad") reported for SSREHIT, TREHIT and SCT, respectively. There was also a significant condition × time interaction effect ($F_{4.57, 159.91}$ = 12.55, $p = 0.01_{GG}$, $\eta^2$ = 0.26). This indicates that the condition had different effects on FS depending on the time point (% bout completion). **Figure 2** indicates that steeper slopes of change were evident for TREHIT and SCT compared to SSREHIT. These data are summarised in **table 1**.

***Rating of perceived exertion***

RMANOVA showed a significant main effect of condition for RPE ($F_{2, 70}$ = 33.02, $p$ = 0.01, $\eta^2$ = 0.46). RPE was higher during TREHIT and SCT compared to SSREHIT (both $P$ = 0.001). There was also a main effect of time ($F_{2.27, 79.44}$ = 307.89, $p = 0.01_{GG}$, $\eta^2$ = 0.90) with peak RPE occurring at 75% of bout duration for all three conditions with values of 13.9 ± 1.5 ("somewhat hard"), 15.5 ± 1.7 ("hard") and 16.4 ± 1.6 (nearly "very hard") reported for

SSREHIT, TREHIT and SCT, respectively. SSREHIT was perceived to be less strenuous than TREHIT and SCT at 50%, 75%, and 100% of bout duration (all $P < 0.05$). There was also a significant condition × time interaction effect ($F_{4.01,\ 143.09} = 10.31$, $p = 0.01_{GG}$, $\eta^2 = 0.23$). Examining **Figure 3**, the increase in RPE was steeper for TREHIT and SCT than for SSREHIT. These data are summarised in **table 1**.

### *Enjoyment*

RMANOVA revealed a main effect between the conditions for enjoyment ($F_{2,\ 70} = 73.12$, $P = 0.01$, $\eta^2 = 0.68$). EES ratings were higher for SSREHIT (5.2 ± 1.1, "quite a bit") compared to TREHIT (4.2 ± 1.4, "moderately", $P = 0.001$, $d = 0.79$) and SCT (3.4 ± 1.3, "slightly", $P = 0.001$, $d = 1.49$), and ratings were also higher for TREHIT compared to SCT ($P = 0.001$, $d = 0.59$).

## Discussion

The premise for advocating low-volume, high-intensity exercise as a means of achieving a more active lifestyle is predicated on the assumption that overcoming the most commonly cited barrier to exercise – "lack of time" – will lead to greater exercise adherence. However, the intensity of effort for this type of exercise could similarly discourage participation if it is deemed overly strenuous. Fundamentally, whether low-volume, high-intensity exercise is efficacious and safe, yet at the same time appealing, tolerable, and sustainable will be decisive in terms of its effectiveness in real-world settings and as a public health strategy. To the authors knowledge this is the first study to empirically compare affective responses between different low-volume, high-intensity exercise conditions.

The main finding was that SSREHIT was more enjoyable, with lower RPE, and more favourable affective responses compared to TREHIT and SCT. Although affect decreased throughout all conditions (i.e. diminishing pleasure over time), the slopes of change were steeper during TREHIT and SCT, illustrated by significant and meaningful condition × time interactions for FS. These data provide preliminary evidence to suggest that shorter sprints do not compromise affective response to the same degree as longer sprints, and therefore could reduce the likelihood of evoking a high degree of negative affect, which could in-turn improve exercise adherence. SSREHIT and TREHIT were matched for total time spent completing high-intensity exercise, yet despite the reduced recovery time between sprints, FS was more favourable for SSREHIT. This suggests perception is related to the duration of individual sprints rather than the number of high-intensity sprints.

Pleasure and displeasure responses are an important part of the exercise experience. The dual-mode theory describes such affective response to *continuous* exercise, where intensities above the ventilatory threshold are accompanied by a cascade of physiological responses that dramatically challenge maintenance of homeostasis (Ekkekakis *et al*., 2008). Responses to intermittent exercise may be inherently different, thus the aim of the current study was to compare affective responses for approaches to low-volume, high-intensity exercise. It was deemed unnecessary to include a traditional continuous exercise condition because affective response to this type of exercise is well known (e.g. peak negative responses in the region of 1 to 2.3 FS units; Decker & Ekkekakis, 2017; Jung *et al*., 2014; Kilpatrick *et al*., 2015). In comparison to these studies, the peak negative FS response for SSREHIT was similar to responses for moderate-intensity continuous exercise and was more favourable than for higher-volume HIT (e.g. Decker & Ekkekakis, 2017).

Peak negative responses were observed during or immediately after high-intensity sprints at 75% of bout completion in all three conditions. However, pleasure remained higher for SSREHIT with a large effect size (1.4 ± 1.7 FS units, “fairly good”) compared to TREHIT (-0.1 ± 1.9, “neutral”, $P$ = 0.01, $d$ = 0.83) and SCT (-0.8 ± 1.6, “fairly bad”, $P$ = 0.01, $d$ = 1.15). For SSREHIT, affective responses were more favourable than reported in some research on higher-volume HIT (Decker & Ekkekakis, 2017; Jung *et al*., 2014), but less favourable than others (Kilpatrick *et al*., 2015; Martinez *et al*., 2015). However, in these studies affect was recorded upon cessation of activity which reduces comparison to the current study, where responses were recorded during activity. It is reasonable to expect responses to be different, because there is a general shift in affective valence toward pleasure, regardless of intensity of effort, after the cessation of exercise. Also, dose-response effects may occur during exercise and then dissipate before post-exercise measurements of affect are recorded (Ekkekakis *et al*., 2008). Regardless, it has been suggested that minimising displeasure is key to achieving optimal behaviour (Cabanac, 2006). Therefore, it is unlikely that the SCT protocol used in the present study would be adhered to by most people in the long-term. However, responses relating to perception of displeasure were minimised during SSREHIT and TREHIT, so these may be genuinely time-efficient and tolerable approaches to exercise and a viable alternative to higher-volume exercise recommendations. Shorter sprints may provide additional benefit in this regard.

In their original study, Metcalfe *et al*. (2011) reported improvements in $\dot{V}O_{2max}$ in healthy but sedentary participants despite modest required effort (RPE 13 ± 1), whereas others observed higher values (17 ± 1) using the same protocol in recreationally active participants (Haines, 2015). More recently, REHIT was well tolerated in inactive men and women (Metcalfe *et al*., 2016) and in men with type 2 diabetes (Ruffino *et al*., 2016). However, in these studies RPE was again recorded at the end of training sessions with participants asked to retrospectively consider effort for the whole training session, not just the high-intensity sprints. It is important to consider that even if most of the time during REHIT is spent at a low-intensity, the high-intensity sprints could produce negative perceptual responses of which the magnitude could impact motivational factors related to future adherence. Indeed, the peak-end rule contests that memory associated with pleasure-displeasure responses are influenced by the moment a distinct peak is experienced, with the duration having little effect. As for FS, peak RPE occurred at 75% of bout completion in all conditions and was more favourable for SSREHIT (13.9 ± 1.5) with large effect sizes compared to TREHIT (15.5 ± 1.7, $P = 0.01$, $d = -1$) and SCT (16.4 ± 1.6, $P = 0.01$, $d = -1.61$).

An important yet rarely considered issue when measuring theoretical constructs such as RPE, is that they are understood using arbitrary scales for which considerable interpretation and subjective thought processes influence results. Perceived exertion, or effort, is a cognitive feeling of work associated with voluntary actions during exercise, and is influenced by anticipatory regulation comprising efferent output such as awareness of central motor commands to recruit muscle motor units (Pageaux, 2016; Tucker, 2009). However, it is a common and inaccurate assumption that afferent feedback from homeostatic disturbance also contributes significantly to perception of effort (Marcora, 2009). Perceptions of "effort" and "discomfort" might be conflated if instructions given to participants do not clearly emphasise narrow definitions (i.e. perception of effort during exercise is independent of afferent feedback from skeletal muscles), reducing validity when implementing RPE scales. In the current study, participants were encouraged to pedal at maximal intensity for all three exercise conditions, which theoretically should have elicited maximal perceptions of effort. However, observed values were lower than maximal and varied between conditions suggesting that the measure of RPE might not be reflective of the intended construct. A possible explanation for this is that participants anchored their RPE values with discomfort or did not fully understand what they were rating. Furthermore, it is not clear how affect is influenced by perceived effort or discomfort, although the FS aims to measure core affect which is a neurophysiological state consciously accessible as a simple primitive non-reflective feeling (Russell and Feldman Barrett, 2009). Participants are able to differentiate between effort and discomfort during resistance training using novel scales (Steele *et al*., 2017b), but current research has not attempted to verify this finding in response to high-intensity repeated sprints. Examination of this issue would improve understanding of the role these perceptions have in regulating exercise intensity providing practical information on exercise tolerance (Abbiss *et al*., 2015; Steele *et al*., 2017b).

Similarly, although affective valence and enjoyment overlap, they are not identical constructs. Indeed, an assumption of dual-mode theory is that there exists a distinction between core affect, such as hedonistic pleasure or pain, and more distinct emotional experiences such as enjoyment that require cognitive appraisal and appreciation of the totality of the experience (Russell & Barrett, 1999; Wankel, 1993). Research has revealed varied enjoyment responses for HIT compared to moderate-intensity continuous exercise (e.g. Decker & Ekkekakis, 2017; Jung *et al*., 2015; Kilpatrick *et al*., 2015; Oliveira *et al*., 2013; Thum, Parsons, Whittle & Astorino, 2017). In the current study, post-exercise enjoyment was higher for SSREHIT (5.2 ± 1.1 EES units, “quite a bit”) compared to TREHIT (4.2 ± 1.4, “moderately”, $P = 0.01$, $d = 0.79$), and SCT (3.4 ± 1.3, “slightly”, $P = 0.01$, $d = 1.49$). This is in-line with the findings of Martinez *et al*. (2015) who reported greater enjoyment for shorter intervals over longer ones. It remains speculative why high-intensity intermittent exercise can result in more favourable affective and enjoyment responses compared to continuous exercise. The nature of the activity may provide a succession of positive accomplishments as high-intensity bouts are completed and breaking the activity into smaller bursts could make the activity appear more manageable preventing monotony. In the SSREHIT condition it is possible that the sprints were of insufficient duration to induce the physiological responses that are associated with more negative affective and enjoyment responses.

Several limitations should be considered when interpreting the findings of this study. The three exercise conditions were not work matched which limits comparison between protocols, although the difference in total work is unlikely to be the most salient consideration in relation to perception of exercise because a core principle of dual-mode theory is that intensity of effort, not duration or work completed, drives the affective response (Kilpatrick, Kraemer, Bartholomew, Acevedo & Jarreau, 2007; Kilpatrick *et al*., 2015). This also improves ecological validity, because participants had more flexibility and autonomy as they would in a real-world setting. Also, to capture a more complete depiction of perceptual responses, measurements were taken at standardised time points throughout each condition. Peak affect and RPE occurred at 75% of bout completion, but due to each condition using a different protocol, this was measured upon cessation of the extended sprint for SCT but shortly after cessation of sprints for SSREHIT and TREHIT. This could lead to underestimation of response for SSREHIT and TREHIT although it is unlikely that the physiological effects of the sprints dissipated in the short time before outcomes were recorded.

Although baseline fitness was not assessed, the participants were relatively young and met the physical activity guidelines limiting generalisability, particularly to those who are inactive or who have chronic disease. Future research should address affective response to SSREHIT in these populations. Consideration should also be given to the specific cycle ergometer used in this study. The Wattbike allows for a very rapid transition from low-intensity cycling to pedalling with a high electromagnetic braking force permitting generation of high peak power within the first few seconds of the high-intensity sprints, which may be required to elicit the metabolic adaptations associated with HIT (Whyte *et al*., 2013). However, it is not clear if other cycle machines or leisure facility bikes could be used to perform REHIT as effectively.

In conclusion, this study highlights that perceptual responses to SSREHIT, in terms of affect, effort, and enjoyment were more favourable compared to TREHIT and SCT. Affective valence remained positive throughout exercise, although heterogeneity in individual responses should be considered. By reducing the duration of the high-intensity sprints, it is possible that SSREHIT could be a genuinely time-efficient, appealing, and tolerable form of exercise to combat the burden of physical inactivity. Moving forward, physiological adaptations to SSREHIT should be monitored through longitudinal research to see if such approaches can confer the same health benefits as higher-volume HIT. A key challenge remains to translate current evidence to practical approaches that are both tolerable and time-efficient in real-world settings.

**Disclosure of interest**

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## Tables

**Table 1** Comparison of outcome measures for the three low-volume, high-intensity training conditions.

| | SSREHIT | REHIT | SCT | SSREHIT vs REHIT *P* = | SSREHIT vs REHIT *d* = | SSREHIT vs SCT *P* = | SSREHIT vs SCT *d* = | REHIT vs SCT *P* = | REHIT vs SCT *d* = |
|---|---|---|---|---|---|---|---|---|---|
| **FS** | | | | | | | | | |
| 25% | 3.9 ± 1.1 | 3.9 ± 0.6 | 3.8 ± 0.6 | NS | 0 | NS | 0.11 | NS | 0.17 |
| 50% | 2.6 ± 1.7 [a, b] | 1.7 ± 1.3 [c] | 1.4 ± 0.9 [c] | 0.01 | 0.59 | 0.01 | 0.88 | 0.51 | 0.27 |
| 75% | 1.4 ± 1.7 [a, b] | -0.1 ± 1.9 [b, c] | -0.8 ± 1.6 [a, c] | 0.01 | 0.83 | 0.01 | 1.15 | 0.03 | -0.55 |
| 100% | 1.5 ± 1.9 [a, b] | 0 ± 1.7 [b, c] | -0.5 ± 1.5 [a, c] | $0.01_{GG}$ | 0.83 | $0.01_{GG}$ | 1.17 | $0.02_{GG}$ | 0.31 |
| Average | 2.3 ± 1.2 | 1.4 ± 1.9 | 1 ± 2.1 | - | - | - | - | - | - |
| **RPE** | | | | | | | | | |
| 25% | 7.9 ± 1.1 | 8.3 ± 1.7 | 7.9 ± 1 | NS | -0.28 | NS | 0 | NS | 0.29 |
| 50% | 12 ± 1.7 [a, b] | 12.6 ± 1.8 [b] | 13.5 ± 1.5 [a, c] | 0.04 | -0.34 | 0.01 | -0.94 | 0.4 | -0.54 |
| 75% | 13.9 ± 1.5 [a, b] | 15.5 ± 1.7 [b, c] | 16.4 ± 1.6 [a, c] | 0.01 | -1 | 0.01 | -1.61 | 0.01 | -0.55 |
| 100% | 12.1 ± 2 [a, b] | 13.2 ± 2.1 [b] | 13.5 ± 2.3 [a, c] | 0.01 | -0.11 | 0.01 | -0.23 | 0.49 | -0.12 |
| Average | 11.5 ± 2.5 | 12.4 ± 3 | 12.8 ± 3.6 | - | - | - | - | - | - |
| **EES** | 5.2 ± 1.1 [a, b] | 4.2 ± 1.4 [b, c] | 3.4 ± 1.3 [a, c] | 0.01 | 0.79 | 0.01 | 1.49 | 0.01 | 0.59 |
| **Blood Lactate** (mmol/L$^{-1}$) | 13.1 ± 3.5 | 13.5 ± 3.5 | 13 ± 3.2 | NS | -0.11 | NS | 0.03 | NS | 0.15 |
| **Total Work** (kJ) | 507.2 ± 66.6 [a, b] | 470.4 ± 71.2 [b, c] | 438.5 ± 64.9 [a, c] | 0.01 | 0.53 | 0.01 | 1.04 | 0.01 | 0.47 |

Note: Data are presented as mean ± standard deviations.

[a] Statistically significant in comparison to REHIT ($p < 0.05$)

[b] Statistically significant in comparison to SCT ($p < 0.05$)

[c] Statistically significant in comparison to SSREHIT ($p < 0.05$)

Abbreviations: *d* = Cohen's *d*, EES = exercise enjoyment scale, FS = Feeling Scale, GG = Greenhouse-Geisser, NS = not statistically significant, REHIT = reduced-exertion, high-intensity interval training, RPE = rating of perceived exertion, SCT = sprint continuous training, SSREHIT = shortened-sprint, reduced-exertion, high-intensity interval training

**Figure 1**

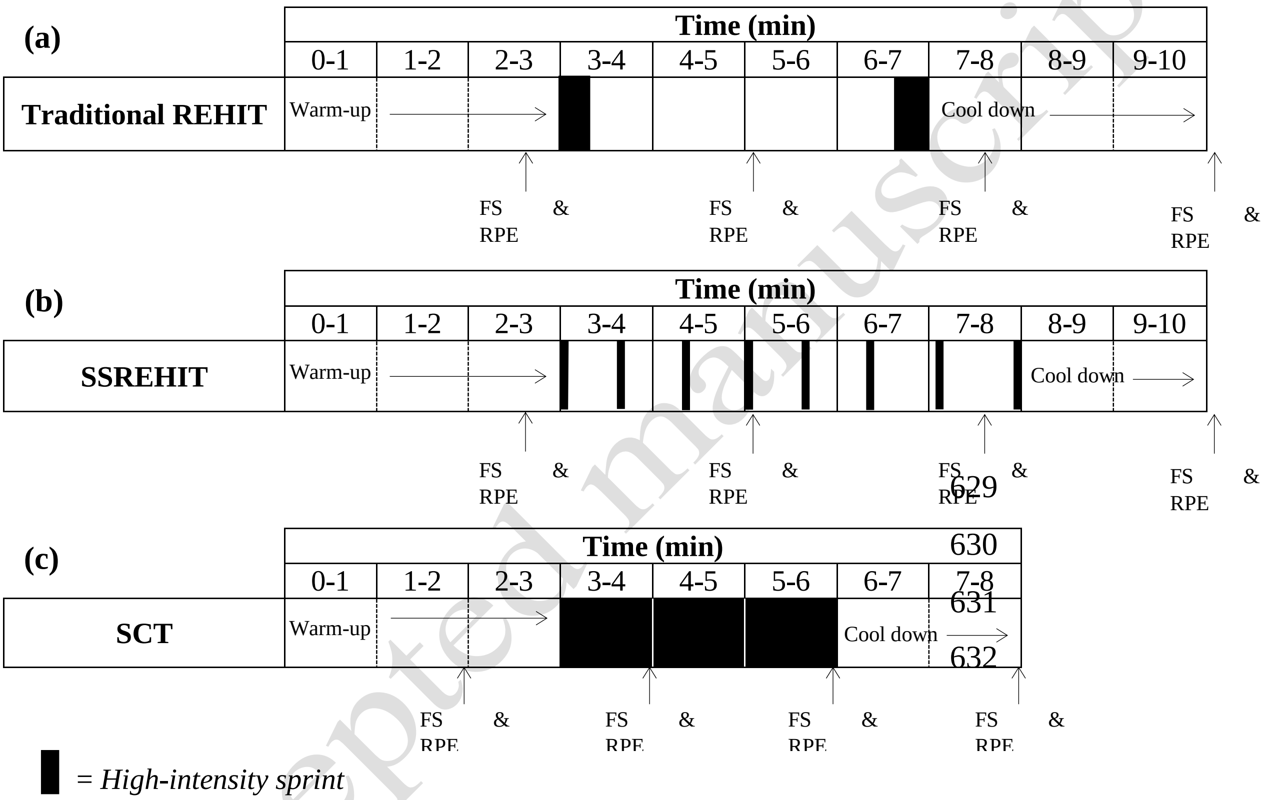


**Figure 2**

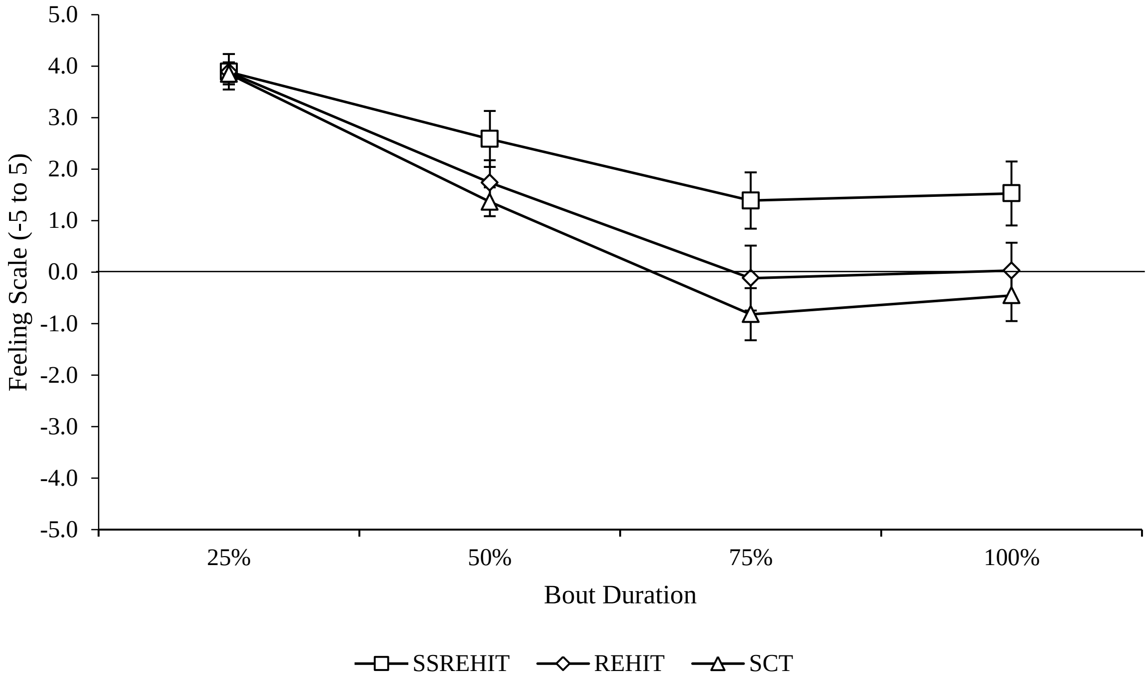
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
Feeling Scale (-5 to 5)
25%
50%
75%
100%
Bout Duration
SSREHIT
REHIT
SCT

**Figure 3**

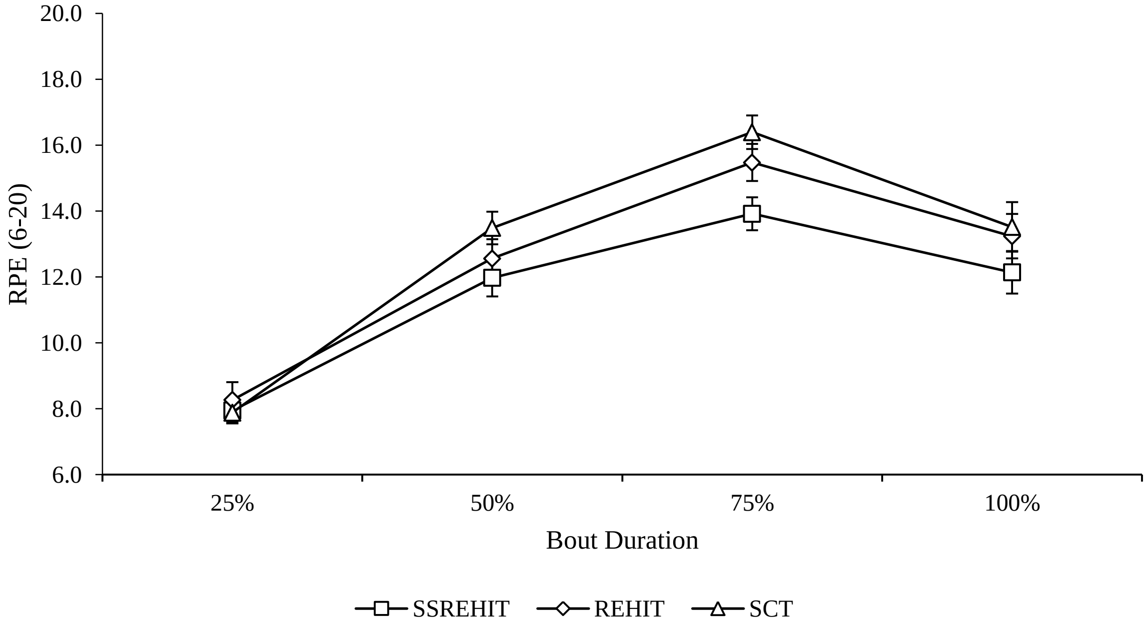
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
RPE (6-20)
25%
50%
75%
100%
Bout Duration
SSREHIT
REHIT
SCT

***Figure 1*** Schematic overview of the three exercise conditions. Abbreviations: FS = feeling scale; REHIT = reduced-exertion high-intensity interval training, RPE = rating of perceived exertion; SCT = sprint continuous training; SSREHIT = shortened-sprint, reduced-exertion, high-intensity interval training

***Figure 2*** Feeling Scale (FS) responses during the three low-volume, high-intensity training conditions. Abbreviations: REHIT = reduced-exertion, high-intensity interval training, SCT = sprint continuous training, SSREHIT = shortened-sprint, reduced-exertion, high-intensity interval training. Note: Data are presented as mean ± 95% confidence intervals.

***Figure 3*** Rating of Perceived Exertion (RPE) responses during the three low-volume, high-intensity training conditions. Abbreviations: REHIT = reduced-exertion, high-intensity interval training, RPE = Rating of Perceived Exertion, SCT = sprint continuous training, SSREHIT = shortened-sprint, reduced-exertion, high-intensity interval training. Note: Data are presented as mean ± 95% confidence intervals.