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Original Research

Affective Responses to Repeated Endurance Training Sessions with Different Intensities: A Randomized Trial

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ABSTRACT

International Journal of Exercise Science 15(5): 152-165, 2022. The purpose was to examine differences in affective responses to repeated sessions of endurance training with different intensities in healthy adults. Thirty young, healthy, and recreationally physically active adults (50% women, age 24.4 ± 6.0 years, VO_{2max} 48.6 ± 7.4 $ml^{-1} \cdot kg^{-1} \cdot min^{-1}$, BMI 23.5 ± 2.4 $kg \cdot m^2$) performed a VO_{2max} test. They were randomized to four sessions of either high intensity sprint interval training (SPRINT, n=10, 5 · 30-sec at >95 of HR_{peak}, 4-min recovery between intervals), high intensity aerobic interval training (HAIT, n=10, 4 · 4-min at ~90% of HR_{peak}, 4-min recovery between intervals) or moderate intensity continuous training (MIT, n=10, 50-min at ~75% HR_{peak}). Assessment during and after each session included HR, La^-, Borg ratings of perceived exertion (RPE), affective state (positive/negative), valence (pleasure/displeasure), arousal (calmness/excitement), tension, irritation, pain, exhaustion, satisfaction, and motivation. HR, La^- and Borg RPE were higher in SPRINT and HAIT compared to MIT ($p < 0.001$), no differences between SPRINT and HAIT. Displeasure and arousal were greater in SPRINT compared to HAIT ($p < 0.05$) and MIT ($p < 0.001$). Within each session, between-group effects showed that SPRINT differed from HAIT and MIT on valence ($p < 0.01$) and arousal ($p < 0.01$), and MIT differed from HAIT and SPRINT on La^- ($p < 0.001$) and HR ($p < 0.001$). In conclusion, repeated sessions of HAIT produced similar physiological responses as SPRINT, and similar affective responses as MIT.

KEY WORDS: Endurance training, exercise psychology, exercise adherence, mental health, exercise physiology

INTRODUCTION

Low physical fitness is one of the major risk factors for mortality (19), hence it is important to find exercise routines that are both effective in improving physical fitness and that can easily be adhered to. High-intensity interval training has been found superior to moderate intensity endurance training (MIT) concerning improvement of e.g. VO_{2max} in various populations (13, 29), and the time-efficiency of such training is suggested to counteract for lack of time as the most prominent barrier for physical activity and exercise (3). Such training has also been among the top five most popular fitness trends since 2014 according to the American College of Sports

Medicine annual global fitness trend survey (35). Despite this popularity, high intensity training has been argued to be difficult to conduct due to high levels of discomfort and perceived exertion during the exercise (26), and because acute affective responses to exercise predict long-term exercise behaviour (21). Hence, Ekkekakis et al. (11) has argued that the intensity-affect relationship must be taken into consideration in the exercise prescription guidelines.

The dual-mode theory presents a framework for the relationship between exercise intensity and affective responses (11). According to this theory, exercise with intensities up to ventilatory threshold (i.e., the point where a marked increase in the V_E/VO_2 ratio occur and accumulation of lactate starts, i.e., ~85% of VO_{2max} or ~90% of HR_{max}) improves or increases the positive affects such as joy, pleasantness and excitement (9). When the exercise intensity reaches the ventilator threshold, the affective response to exercise becomes more heterogenous with some experiencing increase and others experiencing decrease in pleasure (1, 5). According to Ekkekakis et al. (11), the supra-threshold intensity, or maximal intensity, will for most people increase affects such as discomfort, irritation, and pain. The findings on various training intensity levels' impact on enjoyment are uncertain, as Kriel et al. (20), found lower enjoyment and Jung et al. (17) found greater enjoyment of a single session of sprint intervals compared to continuous moderate-to-vigorous intensity training among inactive adults. The differences in both duration and intensity of the continuous training in the two studies can explain this diversity in findings. Oliveira et al. (25) concluded in a meta-analysis that high intensity interval training and MIT had similar effects on affective responses and a small beneficial effect of high intensity interval training compared to MIT on enjoyment. Two more recently published reviews (one scoping review and one meta-analysis) found more negative affective responses during high intensity interval training compared to continuous moderate and/or vigorous exercise (24, 31), yet the interval training was perceived as more enjoyable (24).

Inconsistent conceptualizing of the term *high intensity interval training* unfortunately flaws existing literature. This term is used on intervals varying from 30-sec maximal sprints to intervals up to 4-6 minutes per bout at an intensity of 85% - 95% of HR_{max} or HR_{peak} (16). Using the dual-mode theory, some of these intensity levels might not be sufficiently severe and demanding to create the variation in affective responses. The duration and intensity of the breaks between each interval also vary a great deal. To account for this complexity, Stork et al. (32) compared the affective responses to single sessions of sprint intervals (SPRINT) (i.e., 3 · 20-sec all-out sprints with 2-min recovery) with high intensity aerobic intervals (HAIT) (10 · 1-min at 85-90% of HR_{max}) and MIT (i.e., 45-min at 70-75% of HR_{max}) in young, inactive adults. This study showed higher negative affects and physiological responses, yet similar positive affects in the two interval regimes compared to MIT. For follow-up, MIT was reported used more frequently among the participants compared to SPRINT with no differences between MIT and HAIT. Bartlett et al. (2) found that one single bout of HAIT (i.e., 6 · 3-min at 90% of VO_{2max} with 3-min recovery breaks at 50% of VO_{2max}) were perceived more enjoyable than MIT (i.e., 50-min at 70% of VO_{2max}). The findings from Bartlett et al. (2) and Stork et al. (32) indicate possible differences in affective responses of SPRINT and HAIT. Furthermore, many of the aforementioned studies only use one single bout of exercise, which is inadequate for controlling for a possible learning effect of the exercise intensity. Saanijoki et al. (33) performed a trial with repeated sessions, and found equal physiological responses between sprint intervals (i.e., 4-6 · 30-sec maximal sprint with 4-min recovery between sprints) and MIT (i.e., 40-60 min at 60% W_{peak}), yet with more negative affective responses to the sprint intervals. Although the negative affective responses seemed to adjust with repeated sessions, as this research group also found in another study with inactive insulin-resistant adults (34), the findings raised concern about adherence challenges to such interval training over time. To be able to say anything about adherences and possible influence on behaviour, there is a need for conducting studies with repeated sessions and with intensity levels below, proximal to and above the ventilatory threshold.

The aim of this study was to examine acute affective responses during and after a series of endurance training sessions with moderate continuing, submaximal intervals and supramaximal interval training intensities. Based on existing knowledge, we expected higher levels of lactate, heart rate and perceived exertion with higher training intensity. We hypothesized that the training sessions would increase negative affects, displeasure, tension, irritation, and exhaustion more in SPRINT compared to HAIT and MIT, and in HAIT compared to MIT. Further, we hypothesized that satisfaction and motivation were reduced in SPRINT compared to HAIT and MIT, and in HAIT compared to MIT.

METHODS

The methods of this study are reported in accordance with the CONSORT guidelines for reporting of nonpharmacological randomized controlled trials (RCT) (4). The research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (23). Eligible participants received written information about the study and gave their written consent to participation. The study was evaluated by the Regional Committee for Ethics in Medical Research in South-East Norway (ID 2017/113), approved by Norwegian Data Protection Services (ID 53755) and registered in ClinicalTrials.gov (NCT03081520).

Participants

The study was conducted in a sample of healthy, young adults. Inclusion criteria were age 18-40 years, BMI 16-30, and exercise <3 times/week. Exclusion criteria were athletes, performing high-intensity interval training within the past 3 months, smoking and/or snuffing, injuries not compatible with running, and/or pregnancy. Recruitment was performed through advertising on posters in the local region, stands at campus and through social media. A total of 39 volunteered for participation in the study, of these 30 were found eligible (Figure 1).

Protocol

We used an experimental design with randomization of participants to one of three intervention arms. We used stratified randomization where participants were stratified on sex. The allocation of participants was implemented by participants' selecting sealed envelopes after completing the VO_{2max} test, a total of 10 sealed envelopes were prepared for each intervention arm. Two of the authors (MK and AE) enrolled participants and assigned them to the intervention. The two other authors (SBS and MR) were blinded to the participants' allocation. To calculate power, we used results from SAMR valence and arousal derived from Saanijoki et al. (33) as basis. The sample size was calculated using the software G*Power 3.1 (12). We conducted F-test ANOVA repeated measures within-between subjects' interaction, power of 0.80, F-value 0.3, significance level of .05 and two measurements. This calculation showed a need for 30 participants in order to reach a power of 0.80.

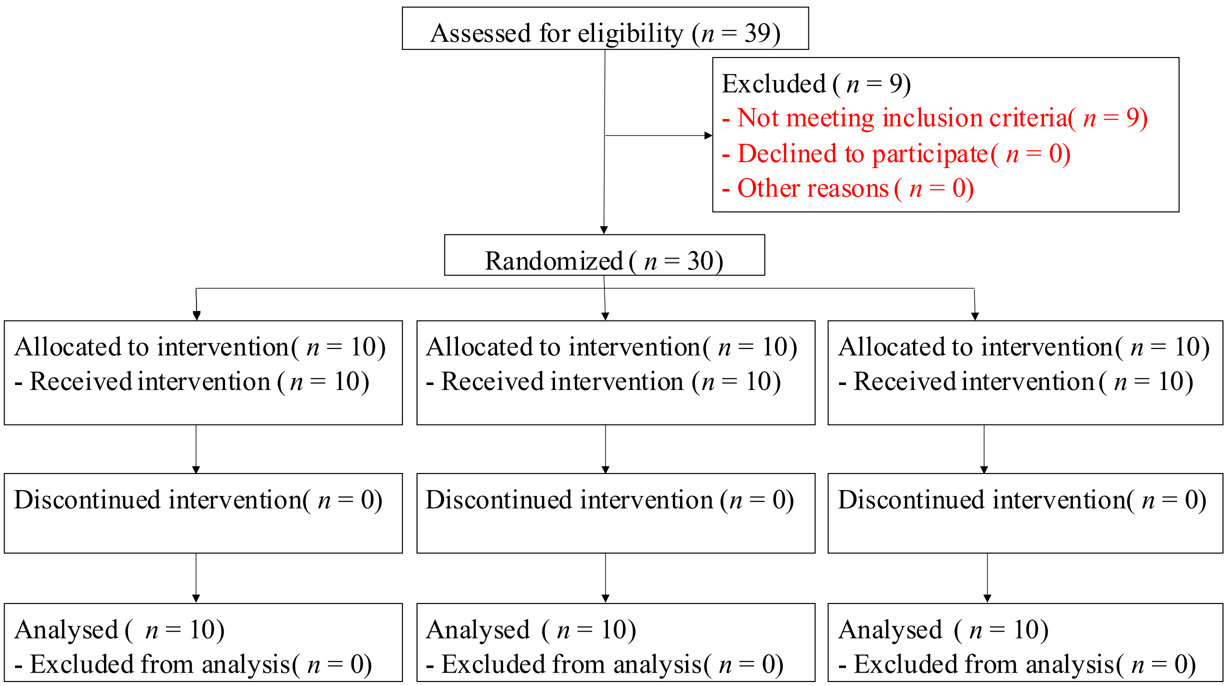

Figure 1. Flow chart of the study.

The four training sessions were conducted within eight days with 1-2 days in between (Wednesday, Friday, Monday, Wednesday). All intervention arms were conducted with running on treadmill (Woodway PPS55, Waukesha, WI, USA). For the SPRINT and HAIT interventions, 10 minutes of warm-up at 65-70% of HR_{peak} and 5 minutes of cool-down at ~70% of HR_{peak} was conducted. The SPRINT intervention was conducted with 5 · 30-sec sprint intervals at >95% of HR_{peak} with 4 minutes recovery at ~70% of HR_{peak} between each interval. To reach intensity of >95% of HR_{peak} in the intervals, the last minute of each recovery period was used to increase intensity to the required level. The first interval was considered a warm-up interval, thus we only obtained measures from the last four bouts. The HAIT was conducted with 4 · 4 minutes intervals at ~90% of HR_{peak} with 3 minutes recovery of approximately 70% of HR_{peak} between each interval. The MIT was conducted with 50 minutes running at ~75% of HR_{peak}. Two researchers (MK and AE) were supervising each session for each participant. All participants conducted the sessions individually and in the laboratory facilities.

Assessments included anthropometrics, self-reported perceived exertion, VO_{2max}, speed, blood lactate, heart rate, and affective responses. Height was measured with a wall-mounted measuring tape and measured to the nearest 0.1 cm. Body weight was measured on a Tefal

Sensitive Computer scale (Pp 6010, France) and measured to the nearest 0.1 kg. BMI was calculated as weight in kilograms divided by height in squared meters ($kg \cdot m^{-2}$). Borg Ratings of Perceived Exertion (RPE) 6-20 scale (18) was used for self-assessment of perceived exhaustion during each session. Borg RPE was obtained immediately after each interval in the SPRINT and HAIT groups, and every 10 minutes in the MIT group. An incremental VO_{2max} test was conducted with running on treadmill (Woodway PPS55, Waukesha, WI, USA). The ergospirometry test system Vmax Spectra (Sensor Medics, Yourba Linda, USA) was used to measure oxygen uptake. The test protocol included 10 minutes of warm-up, then the incremental test began with intensity at approximately ~70%–80% of HR_{peak} with 3% inclination for females and 5% inclination for males. Speed was increased with 1 $km \cdot h^{-1}$ every minute until 14 $km \cdot h^{-1}$ (females) or 15 $km \cdot h^{-1}$ (males). Following this, the inclination increased by 0.5% every 30 second until criteria for VO_{2max} were reached. The criteria for VO_{2max} were voluntary exhaustion, a plateau in VO_2 despite increase in workload, RER ≥ 1.05, and blood lactate above 8 $mmol \cdot L^{-1}$. These criteria have also been used in previous studies (14, 30). VO_{2max} was defined as the average of the two highest continuous VO_2 measurements during the test, i.e., 40s. The length of the test ranged between 6 and 10 min. Arcary Lactate Pro LT-1710-analyzer (Arcary Inc., Kyoto, Japan) was used to obtain blood lactate levels. Lactate was obtained after each bout/interval in SPRINT and HAIT, and every 10 minutes in MIT. HR was measured using Polar RS100 (Polar, Tempele, Finland). HR_{peak} was determined as the highest measured HR at the end of the VO_{2max} test. HR levels were continuously observed during all training sessions, and the recorded HR at end of each bout/interval in SPRINT and HAIT, and every 10 minutes in MIT was used for the analysis. The self-report questionnaire Positive and Negative Affect Schedule (PANAS) (8, 37) was used to assess different state feelings and emotions and were distributed to the participants immediately before and after each session. PANAS consists of 10 items covering positive affects (i.e., excited, enthusiastic) and 10 items covering negative affects (i.e., distressed and upset). The items were rated on a 5-point Likert scale from 1 (Very slightly or not at all) to 5 (Extremely). Sumscores for the subscales positive affects and negative affects were calculated. Cronbach's alpha was .82 for PANAS positive subscale and .85 for PANAS negative subscale. Immediately before and after each training session, the participants completed a VAS with separate scales for tension, irritation, pain, exhaustion, satisfaction and motivation adapted from Saanijoki et al. (33). The VAS lines were 100 mm, and values for each scale is given in mm. Affective dimensions during each session were obtained by the self-assessment manikin rating scale (SAM) (6), for this study the panels of valence (displeasure/pleasure) and arousal (calmness/excitement) were used. Higher score on valence indicated pleasure, whereas higher score on arousal indicated excitement. The SAM was distributed to the participants following each bout/interval in the SPRINT and HAIT group, and every 10 minutes in the MIT group.

Statistical Analysis

The software IBM SPSS 26.0 (IBM, USA) was used for the statistical analyses. One-way ANOVA with Bonferroni post hoc test was conducted to determine differences in baseline values between the three groups. Two analyses of GLM repeated measurement were used to determine within-group and between-group differences in physiological and affective responses 1) throughout the four exercise sessions, and 2) between bouts within each session. Factors were 1) sessions and 2) bouts, and measures for both analyses were HR, La^-, speed, and SAMR scores. PANAS scores and VAS scores were only included in analysis of the sessions. Group (SPRINT, HAIT or MIT) was selected as between-subject factor with Bonferroni post hoc test. We report F-value and effect size (Partial Eta Squared), which was classified as small (.01), medium (.06) and large (.14) based on recommendations from Miles et al. (22). Significance level was .05.

RESULTS

There were no differences in age, BMI, or $VO_{2\ max}$ among participants in the three intervention arms (Table 1). Age range of the sample was 19-39 years and BMI ranged from 19-29 $kg{\cdot}m^{-2}$. Divided into gender across groups, VO_{2max} (mean (SD)) was higher in males (52.6 (8.2) $ml^{-1}{\cdot}kg^{-1}{\cdot}min^{-1}$) compared to females (44.7 (3.7) $ml^{-1}{\cdot}kg^{-1}{\cdot}min^{-1}$) ($t$ = 3.3, p = 0.002). Baseline momentary affective state showed no between-group differences for PANAS positive or PANAS negative subscales (Table 1).

Table 1. Descriptive data obtained at baseline.

	SPRINT (n = 10)	HAIT (n = 10)	MIT (n = 10)	F	p-value
	Mean (SD)	Mean (SD)	Mean (SD)		
Gender, *male/female*	5/5	6/4	4/6		
Age, *yrs*	22.3 (2.9)	26.0 (7.6)	24.9 (6.5)	1.00	0.38
BMI, $kg{\cdot}m^{-2}$	22.3 (2.7)	23.8 (1.4)	24.3 (2.7)	1.98	0.16
VO_{2max}, $ml^{-1}{\cdot}kg^{-1}{\cdot}min^{-1}$	49.0 (6.0)	49.3 (6.7)	47.5 (9.7)	0.16	0.85
HR_{peak}, $beats{\cdot}min^{-1}$	201.4 (4.7)	196.9 (8.8)	196.6 (8.7)	1.23	0.31
PANAS positive‡	30.9 (2.9)	28.7 (6.6)	32.5 (4.6)	1.48	0.25
PANAS negative‡	17.2 (5.4)	15.2 (4.4)	14.9 (2.8)	0.83	0.45

Note: SPRINT: high intensity sprint interval training. HAIT: high intensity aerobic interval training. MIT: moderate intensity continuous training. BMI: body mass index. HR: heart rate. PANAS: Positive and Negative Affect Schedule. ‡Data obtained immediately prior to the warm-up of the VO_{2max} testing.

SPRINT and HAIT had higher mean La^- levels, HR and Borgs RPE compared to MIT ($p < 0.001$, Table 2). Speed during the training sessions differed between all three groups ($p < 0.001$, Table 2). The affective responses before and after each session showed that PANAS positive for each session improved more in the SPRINT group compared to the MIT group, with no difference between HAIT and MIT (Table 2). There was a large overall within-group effect on VAS exhaustion and VAS pain, and a trend for effect on VAS tension (p = 0.07). No effects were found for VAS satisfaction or VAS motivation (Table 2). The affective responses during each session, assessed by SAM, showed a large overall within-group effect on both valence and arousal (Table 2). Between-group effects were found for the SPRINT group compared to HAIT and MIT, no differences were found between HAIT and MIT (Table 2).

Table 2. Between-group differences in responses to four repeated sessions of training protocol with different intensities. Values represent Group x Time (session) calculated by GLM repeated measurements.

			SPRINT vs HAIT	SPRINT vs MIT	HAIT vs MIT
	F	ES	Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Borg RPE	21.55***	0.62	1.17 (-0.54, 2.87)	4.25 (2.54, 5.96)***	3.08 (1.38, 4.79)***
La⁻, *mMol ·min⁻¹*	29.60***	0.69	1.30 (-0.55, 3.14)	5.33 (3.48, 7.17)***	4.03 (2.19, 5.87)***
HR, *beats ·min⁻¹*	47.19***	0.78	3.35 (-6.52, 13.21)	34.07 (24.20, 43.93)***	30.72 (20.85, 40.58)***
Speed, *km ·h⁻¹*	57.72***	0.81	5.48 (2.95, 8.00)	10.64 (8.11, 13.17)***	5.16 (2.64, 7.69)***
PANAS positive	4.76*	0.26	0.85 (-1.84, 3.54)	3.15 (0.46, 5.84)*	2.30 (-0.39, 4.99)
PANAS negative	0.87	0.06	0.53 (-1.41, 2.46)	1.00 (-0.93, 2.93)	0.48 (-1.46, 2.41)
VAS tension, *mm*	3.02	0.18	15.83 (-8.94, 40.59)	23.35 (-1.42, 48.11)	7.53 (-17.24, 32.29)
VAS irritation, *mm*	1.45	0.10	7.88 (-6.26, 22.01)	8.40 (-5.73, 22.53)	0.53 (-13.61, 14.66)
VAS exhaustion, *mm*	11.07***	0.45	23.60 (1.61, 45.59)*	40.35 (18.36, 62.34)***	16.75 (-5.24, 38.74)
VAS satisfaction, *mm*	0.45	0.03	-2.85 (-24.25, 18.55)	4.98 (-16.42, 26.37)	7.83 (-13.57, 29.22)
VAS pain, *mm*	5.31*	0.28	19.13 (0.21, 38.04)*	22.33 (3.41, 41.24)*	3.20 (-15.72, 22.12)
VAS motivation, *mm*	1.68	0.11	4.98 (-7.54, 17.49)	8.98 (-3.54, 21.49)	4.00 (-8.52, 16.52)
SAM arousal	10.38***	0.44	0.73 (0.07, 1.39)*	1.17 (0.51, 1.83)**	0.44 (-0.22, 1.10)
SAM valence	8.82***	0.40	-0.78 (-1.49, -0.07)*	-1.15 (-1.86, -0.43)**	-0.37 (-1.08, 0.34)

Note: *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$. SPRINT: Sprint interval group. HAIT: High intensity Aerobic Interval group. MIT: Moderate Intensity Training group. RPE: Ratings of Perceived Exertion. HR: heart rate. PANAS: Positive and Negative Affect Schedule. VAS: Visual Analogue Scale. SAM: Self-Assessment Manikin rating scale.

Bout-to-bout course of physiological and affective responses during the training sessions: Analyzing mean value from each bout during the training session, we found a within-group effect of Group ·Time on La⁻ ($p < 0.001$) and SAMR valence ($p = 0.01$). There was a Group ·Time effect on La- between all four assessment times, between assessment time 1 vs 2 and 3 vs 4 on HR, and between assessment time 2 vs 3 for SAMR arousal (Figure 2-5). Between-group effects showed that SPRINT differed from HAIT and MIT on SAMR arousal (Figure 2) and valence (Figure 3), and MIT differed from HAIT and SPRINT on La⁻ (Figure 4), and HR (Figure 5).

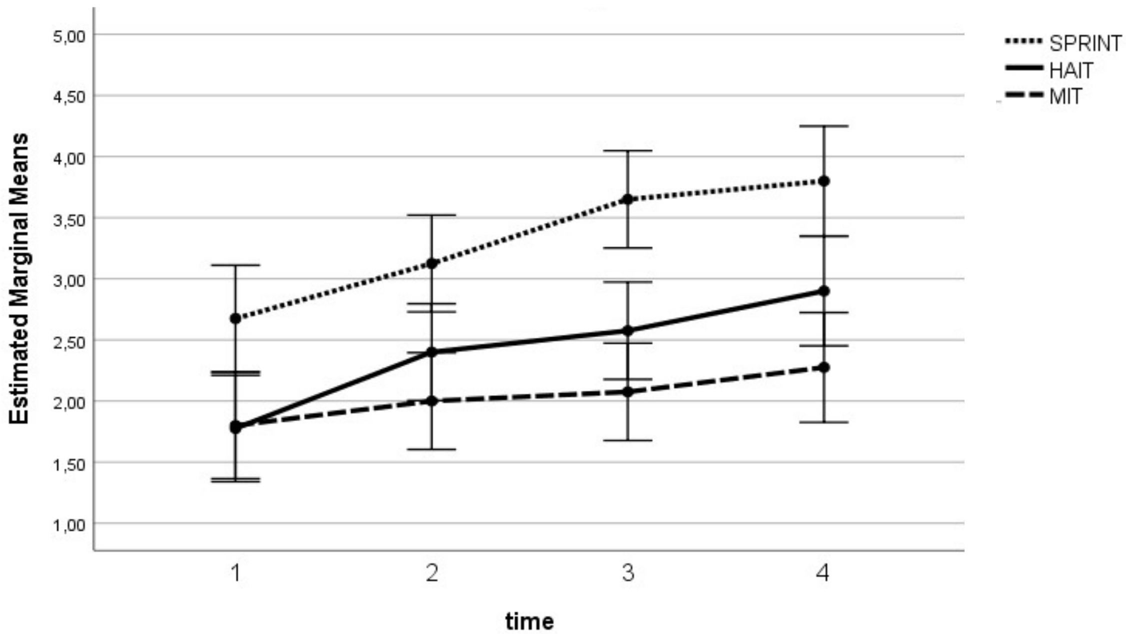

Figure 2. Bout-to-bout responses in SAMR arousal (1 = calm to 5 = exited) during the training sessions. Error bars represent 95% CI. Group · Time (Bout): $p = 0.154$. Between-group: $F = 10.3$***. Bonferroni post hoc: SPRINT vs HAIT: $p = 0.006$**. SPRINT vs MIT: $p = 0.001$**. HAIT vs MIT: $p = 1.00$.

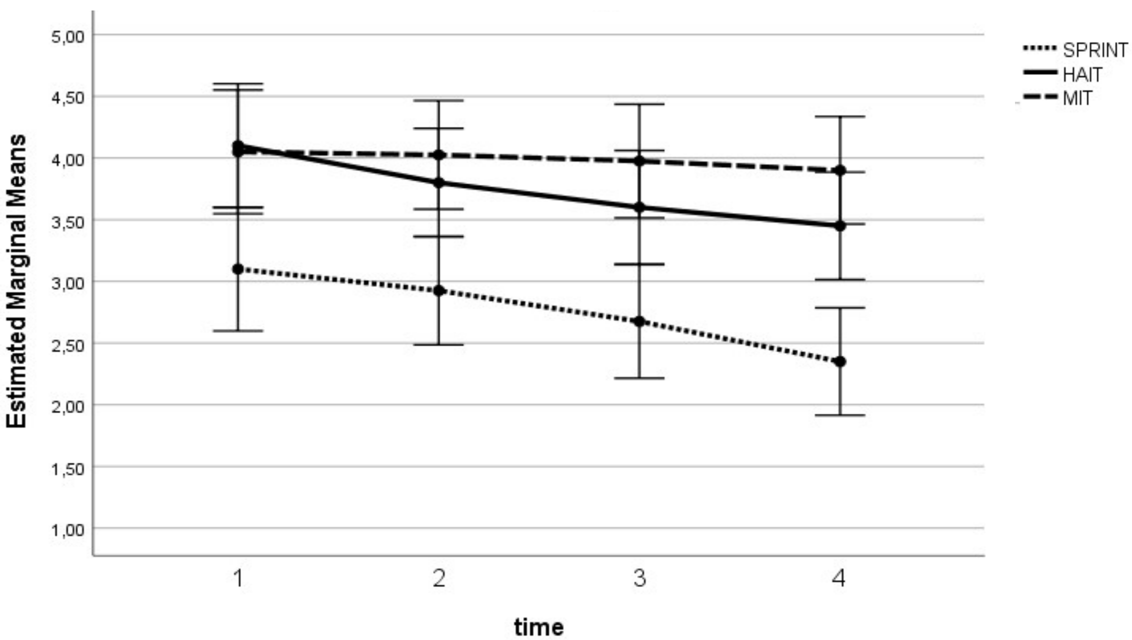

Figure 3. Bout-to-bout responses of SAMR valence (1 = displeasant to 5 = pleasant) during the training sessions. Error bars represent 95% CI. Group · Time (Bout): $p = 0.004$**. Between-group: $F = 12.5$***. Bonferroni post hoc: SPRINT vs HAIT: $p = 0.006$**. SPRINT vs MIT: $p < 0.001$***. HAIT vs MIT: $p = 0.49$.

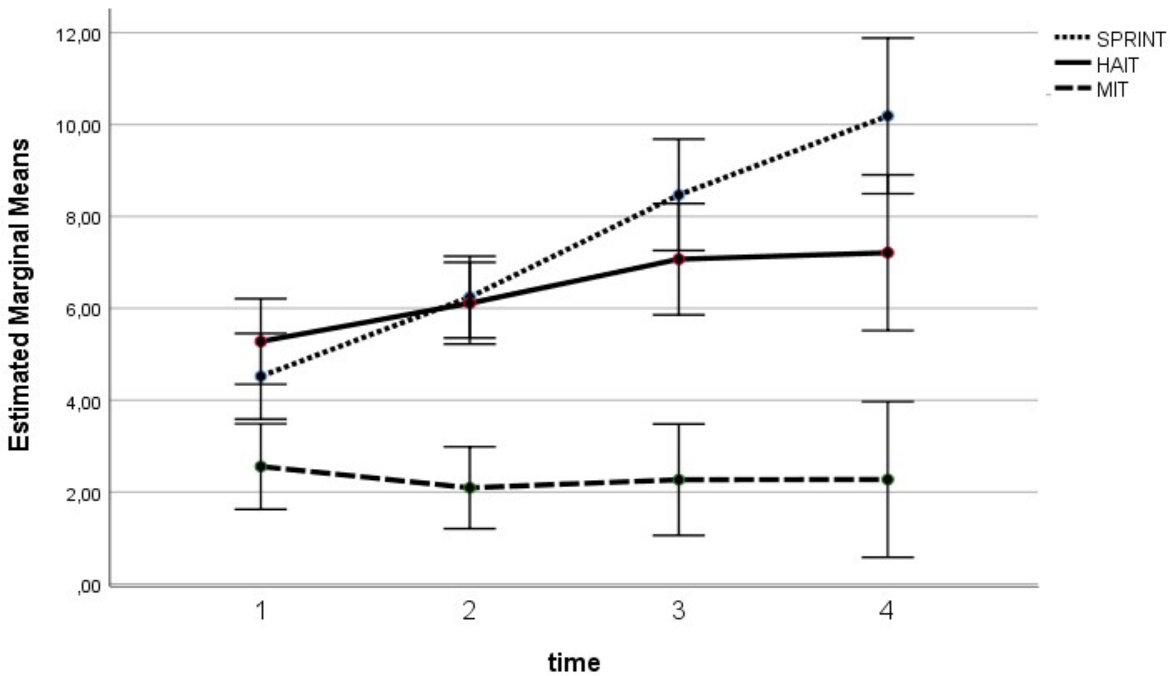

Figure 4. Bout-to-bout responses of lactate (mMol ·min⁻¹) during the training sessions. Error bars represent 95% CI. Group · Time (Bout): $p < 0.001$***. Between-group: $F = 27.3$***. Bonferroni post hoc: SPRINT vs HAIT: $p = 0.62$. SPRINT vs MIT: $p < 0.001$***. HAIT vs MIT: $p < 0.001$***.

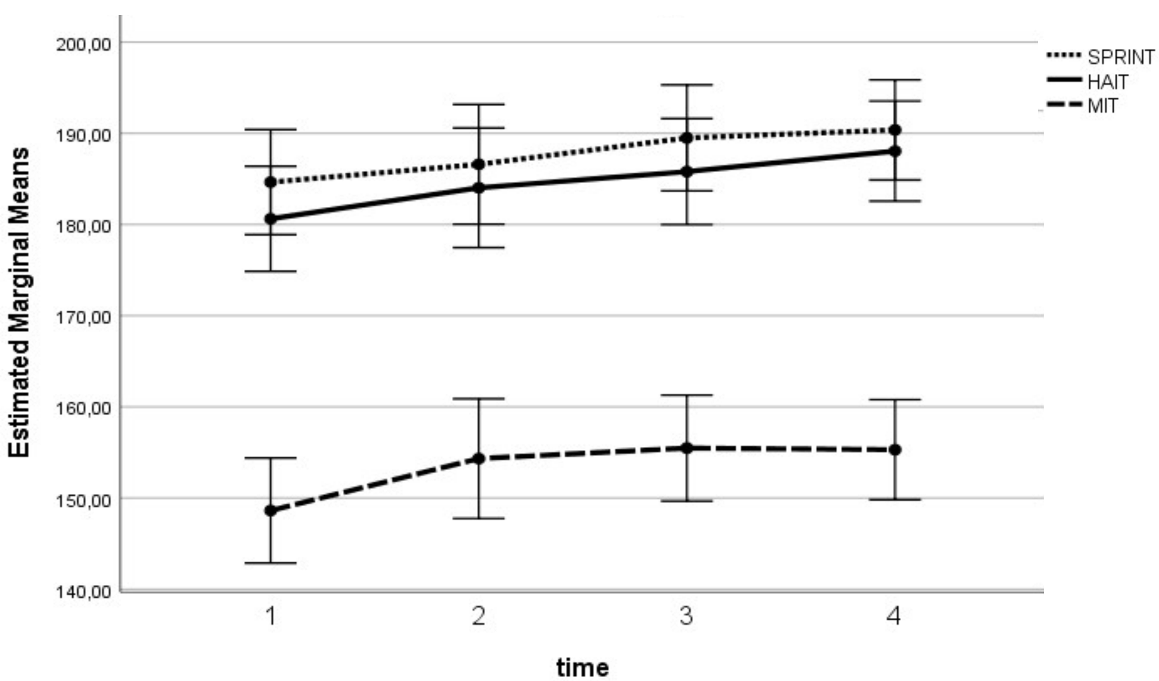

Figure 5. Bout-to-bout responses of heart rate (beats ·min⁻¹) during the training sessions. Error bars represent 95% CI. Group · Time (Bout): $p = 0.234$. Between-group: $F = 12.5$***. Bonferroni post hoc: SPRINT vs HAIT: $p = 1.00$. SPRINT vs MIT: $p < 0.001$***. HAIT vs MIT: $p < 0.001$***.

DISCUSSION

The main findings of this study were that HAIT produced similar physiological responses as SPRINT and similar affective responses as MIT, whereas SPRINT and MIT differed on positive affect, exhaustion, pain, valence, and arousal. The higher levels of displeasure (valence) and excitement (arousal) in SPRINT versus MIT was similar to findings from Saanijoki et al. (33), and the differences occurred already from bout one in the training sessions. Following the rationale of the dual-mode theory, this difference is likely due to the differences in exercise intensity. On contrary to the latter study, the present study showed that PANAS positive improved more over the training sessions in SPRINT compared to MIT. This score was obtained after completion of each session, and a potential explanation for this might be an adaptation to the intervals and a feeling of relief, excitement, and self-efficacy about mastering the intervals. However, this finding is in accordance with the meta-analyses of Oliveira et al. (25) and Niven et al. (24) that concluded with an overall effect of interval training compared to MIT on enjoyment. The sample of physically active young adults might influence on this result as such groups have shown greater exercise-induced improvement in mood compared to sedentary groups (15), and the VO_{2max} indicate that our sample was above average age adjusted values in cardiorespiratory fitness (27). According to the dual-mode theory, cognitive parameters such as self-efficacy impact on the affective responses to exercise (11, 24). The participants' exercise experience, physical fitness and hence self-efficacy in exercise might therefore make them more prone to training at very vigorous intensities such as the SPRINT training regime. This can also be the explanation for the lack of Group · Time effects on PANAS negative subscale score, VAS motivation, and VAS satisfaction. There is also a potential ceiling effect on motivation and satisfaction as the sample in our study were physically active yet with no recent experience in high intensity interval training.

The physiological responses (La^- and HR) positively correlated with feelings of irritation (VAS) and SAMR arousal, whereas HR was negatively correlated with SAMR valence (i.e., higher HR indicating more displeasure). In addition to the previously discussed possible explanations for the Time · Group effect on PANAS positive score, a reasonable explanation for this finding might be the timing of PANAS positive assessment. PANAS was assessed before start and after ending of the session, hence the post-session assessment was assessed approximately five minutes after ending of the final bout in the SPRINT and HAIT groups. These minutes might therefore have been sufficient for the trained participants recover from the high levels of exhaustion and displeasure, hence simultaneously assessment of valence and PANAS might have revealed different results. We must also acknowledge that although the La^- measures indicate that HAIT exceeded the ventilatory and lactate threshold, the intensity level was still within acceptable range and hence less demanding compared to the SPRINT. Further, the long recovery periods between each interval/bout in the SPRINT and HAIT training influenced on the overall exercise intensity, and hence likely on affective state post-training. Exercise at intensities around the ventilatory threshold has also shown great inter-individual variability in affective responses (11), and it is the supra-threshold or maximal intensities that provides the greatest reduction in positive affects (11). We can therefore speculate that only a small increase in intensity of the intervals in the HAIT group, i.e., from 90% of HR_{peak} to 92-93% of HR_{peak}, might have generated affective responses more similar to the SPRINT group. As shown in Figure 5, the HR data can imply that the SPRINT and HAIT groups had more similar intensity in the final bout. The lactate levels shown in Figure 4 indicate however that the two intensity levels were of practical difference although not statistically different. Other affective responses might also have been revealed with shorter recovery breaks between each interval in both SPRINT and HAIT groups.

Strengths and limitations: The strengths include the randomized design, stratification on sex, the use of validated assessment, the participants' adherence to the training sessions, close monitoring of each training session by two researchers (AE and MK), and the prospective design accounts for the bias of adaptation to the training regime. Our choice of F-value effect size might have underpowered the sample; thus, sample size might be a limitation of our study. Lack of assessment of personal preferences in exercise intensity is a limitation because such preferences might influence on tolerance and acceptability of the various exercise intensities (10). The initial PANAS scores reported in Table 1 were comparable to normative scores from a large, non-clinical sample (8), however it is a limitation with our study that we did not obtain information about the participants' general mental health and well-being. Further, the findings are limited by use of only self-report of affective responses, and single post-exercise affect measure. We also acknowledge that assessment i.e., during the last 15 seconds of each bout in HAIT and SPRINT might have provided different affective responses compared to assessment immediately after finishing the bouts (7). More sophisticated methods such as EEG or fMRI might provide more accurate findings of affective responses during the intervals in SPRINT and HAIT, and during the course of MIT.

Implications of the findings. Scientific impact of the findings includes a better understanding of the relation between physiological and psychological responses to exercise at different intensities. HAIT performed at an intensity of ~90% of HR_{peak} seems to be superior both in physiological and affective responses, which are important for the motivation and adherence to exercise. The effect on PANAS positive in the most vigorous exercise intensity is interesting and warrants further research. However, PANAS might be inadequate for capturing the full circumplex of affects (28), thus future research need to include assessments of both high and low activation. There is also a need for studies who examine how small increases in intensity (i.e., from ~90% to 92-93% of HR_{peak}) might affect the intensity-affect relationship, studies with longer follow-up to examine potential effects on exercise adherence, and studies that explore the affective responses of HAIT in addition to SPRINT and MIT in more sedentary samples.

In conclusion, repeated sessions of HAIT showed similar physiological responses to repeated session of SPRINT and similar affective responses to repeated sessions of MIT. Our hypothesis of different physiological responses in SPRINT and HAIT compared to MIT were thus confirmed, whereas the affective responses only differed between SPRINT and MIT on some of the measurements. Our hypothesis that affective responses would differ between all three intervention groups was therefore rejected.

ACKNOWLEDGEMENTS

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