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Affective Adaptation to Repeated Sprint Interval Training and Moderate-Intensity Continuous Training Protocols in Insulin-Resistant Subjects

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ABSTRACT

SAANIJOKI, T., L. NUMMENMAA, M. KOIVUMÄKI, E. LÖYTTYNIEMI, K. K. KALLIOKOSKI, and J. C. HANNUKAINEN. Affective Adaptation to Repeated Sprint Interval Training and Moderate-Intensity Continuous Training Protocols in Insulin-Resistant Subjects. *Med. Sci. Sports Exerc.*, Vol. 50, No. 1, pp. 00–00, 2018. **Introduction**: The aim of this study was to investigate affective responses to repeated sessions of sprint interval training (SIT) in comparison with moderate-intensity continuous training (MICT) in insulin-resistant subjects. **Methods**: Twenty-six insulin-resistant adults (age, 49 (4) yr; 10 women) were randomized into SIT (n = 13) or MICT (n = 13) groups. Subjects completed six supervised training sessions within 2 wk (SIT session, 4–6 × 30 s all-out cycling/4-min recovery; MICT session, 40–60 min at 60% peak work load). Perceived exertion, stress, and affective state were assessed with questionnaires before, during and after each training session. **Results**: Perceived exertion, displeasure, and arousal were higher during the SIT compared with MICT sessions (all P < 0.01). These, however, alleviated similarly in response to SIT and MICT over the 6 d of training (all P < 0.05). SIT versus MICT exercise increased perceived stress and decreased positive affect and feeling of satisfaction acutely after exercise especially in the beginning of the intervention (all P < 0.05). These negative responses declined significantly during the training period: perceived stress and positive activation were no longer different between the training groups after the third, and satisfaction after the fifth training session (P > 0.05). **Conclusions**: The perceptual and affective responses are more negative both during and acutely after SIT compared with MICT in untrained insulin-resistant adults. These responses, however, show significant improvements already within six training sessions, indicating rapid positive affective and physiological adaptations to continual exercise training, both SIT and MICT. These findings suggest that even very intense SIT is mentally tolerable alternative for untrained people with insulin resistance.
Key Words: TYPE 2 DIABETES MELLITUS, INSULIN RESISTANCE, SPRINT INTERVAL TRAINING, PERCEIVED EXERTION, AFFECTIVE VALENCE, AFFECT

Regular physical exercise is a key component for management of type 2 diabetes mellitus (T2DM) (1). The prevailing recommendations for physical activity, that is, minimum of 150 min of moderate-intensity physical activity per week spread over three to five sessions (2), improve glycemic control in individuals with T2DM (3), yet most diabetic patients fail to achieve the required volume. It has been suggested that patients with T2DM would benefit from greater exercise intensities (4). The mounting evidence show that submaximal high-intensity interval training (HIIT) and supramaximal sprint interval training (SIT) elicit comparable or even superior metabolic and cardiovascular improvements as traditional moderate-intensity continuous exercise (MICT) (5–7), and are feasible options also for the prevention and treatment of T2DM (8). HIIT involves alternating short (1–4 min) bouts of activity performed at near-maximal intensity (80%–95% of maximal HR) with recovery periods or light exercise. SIT is a form of HIIT, where the work intervals are shorter (≤30 s) and performed at maximal intensity in "all-out" manner (6). Thus, SIT differs with respect to volume and intensity from HIIT and may represent even more time-efficient alternative for improving cardiovascular fitness. Already 2 wk of SIT improves glycemic control in healthy adults (9–11) and in insulin-resistant

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individuals (12) as well as in patients with T2DM (13). The strenuous nature of SIT, however, has raised concerns regarding its tolerability for sedentary people (14).

Pleasure and enjoyment motivate participation (15,16) and adherence to regular physical exercise (17–19). Moderate-intensity training is associated with positive affective changes (20), whereas higher exercise intensities are usually accompanied with increased negative affect (21). Affective responses of intense intermittent exercise have remained more disputable, most likely due to variety of studied interval training protocols, the age, sex, fitness level, and exercise background of the study participants (22–28). Our previous intervention study showed that SIT versus MICT induced higher perceived exertion, displeasure, and negative affective responses during and acutely after exercise in untrained, healthy, middle-age men, however these negative responses started to decline already within six training sessions (22). To our knowledge, the perceptions of SIT in comparison with MICT have not been assessed in diabetic individuals.

Somatic health may affect the perceptual responses to exercise. For instance, T2DM may increase the feelings of fatigue (29), depression, and anxiety (30), and additionally, rapid fluctuations in blood glucose may cause impaired mood and cognitive functions (31). Because such symptoms can interfere with daily activities as well as exercise tolerance and adherence (29), they could also exaggerate exercise effort (32), and hence exacerbate the aversion of strenuous exercise, such as SIT. Furthermore, obesity and poor cardiorespiratory fitness, which typically coincide with diabetes, may also worsen the decline in affect (33). Although recent findings suggest that HIIT may be a feasible exercise option in individuals with prediabetes (34), the repeated SIT-induced perceptual adaptation in this patient group lacks empirical evidence. Given the positive impact of SIT on insulin sensitivity as well as favorable perceptual responses of shorter high-intensity intervals (35), the aim of the present study was to investigate the affective responses to repeated sessions of SIT in untrained insulin-resistant individuals. As a secondary analysis, the responses were compared with SIT-induced affective responses in inactive but healthy individuals by combining data from our previous study that used similar research design (22). We hypothesized that among insulin-resistant subjects, SIT would cause higher perceived exertion and more negative affect compared with MICT, both during and after exercise, but that these would alleviate over the repeated sessions of exercise. In comparison with healthy individuals, we hypothesized that SIT would result in higher perceived exertion and negative affect among insulin-resistant individuals.

METHODS

The present study was a part of a larger study entitled "The effects of short-time high-intensity interval training on tissue glucose and fat metabolism in healthy subjects and in patients with type 2 diabetes" (NCT01344928). The study was conducted at the Turku PET Centre, University of Turku and Turku University Hospital (Turku, Finland) according to the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of the Hospital District of South-West Finland (decision 95/180/2010 §228).

Subjects. Participants were recruited via local newspaper advertisements. The inclusion criteria consisted of ages 40 to 55 yr, body mass index (BMI) of 18.5 to 35 $kg\cdot m^{-2}$, blood pressure of ≤160/100 mm Hg, sedentary lifestyle (exercise twice a week or less, peak oxygen uptake $\dot{V}O_{2peak}$ $\leq 40\ \cancel{cm}\cdot kg^{-1}\cdot min^{-1}$), and impaired glucose tolerance according to the criteria of the American Diabetes Association (36) and HbA_{1c} less than 7.5 $mmol\cdot L^{-1}$. The exclusion criteria consisted of regular use of tobacco products, significant use of alcohol and a condition that could potentially endanger the participant's health during the study or interfere with the interpretation of the results. After careful interview and medical examination including ECG and oral glucose tolerance test, 26 subjects (age, 49 [4] yr; BMI, 30.5 [2.7] $kg\cdot m^{-2}$, and $\dot{V}O_{2peak}$, 27.2 [4.6] $mL\cdot kg^{-1}\cdot min^{-1}$) met the eligibility criteria and were admitted into the study after providing written informed consent. 17 subjects (6 women) met the criteria of T2DM (36) and the remaining 9 (4 women) subjects met the criteria of prediabetes, having impaired fasting glucose and/or impaired glucose tolerance (36). The sample size is a reflection of related research on perceptual changes in response to repeated exercise (37). Participants were randomized for SIT and MICT with 1:1 allocation ratio, resulting in n = 13 in SIT and n = 13 in MICT group. Two subjects from the SIT group dropped out during the trial, one because of claustrophobic feelings during preintervention imaging procedures and one due to migraine during the first SIT session. Three subjects from the MICT group discontinued the trial due to personal reasons. Thus, 11 subjects in SIT and 10 subjects in MICT group finalized all their assigned training sessions.

In a subsequent analysis, we compared the affective responses to exercise in these insulin-resistant subjects and in age-matched healthy untrained subjects (age, 47 [5] yr; BMI, 26.1 [2.5] $kg\cdot m^{-2}$; and $\dot{V}O_{2peak}$, 34.2 [4.1] $mL\cdot kg^{-1}\cdot min^{-1}$), who underwent similar exercise intervention and of which results have been reported previously (22).

Training intervention. The training intervention consisted of six supervised exercise sessions within 2 wk. The SIT sessions comprised of warm-up and 4 to 6 × 30 s all out cycling efforts with 4 min recovery between bouts (Monark 894E, Vansbro, Sweden). The number of bouts was increased from four to five, and further to six after every other training session. Each bout started with a few seconds acceleration to maximal cadence without resistance, followed by a sudden increase of the load (10% of fat free mass in kg) and maximal cycling for 30 s. Participants were familiarized with SIT training during screening phase (2 × 30 s sprints). The MICT group performed continuous aerobic cycling for 40 to 60 min (Tunturi E85; Tunturi Fitness, Almere, The Netherlands) at the intensity of 60% of peak workload. Training duration was increased from 40 to 50 min and further to 60 min after every other session. Blood lactate concentration was measured from capillary samples before and within 1 min after each training session.

Questionnaires and other measurements. The perceptual and affective responses induced by exercise were assessed as previously described (22). Briefly, Borg's RPE 6 to 20 scale and self-assessment manikin (SAM) rating scale (38) were administered repeatedly during each training session (before training session and after each sprint in the SIT group and in every 10 min in the MICT group) to assess participants' subjective exertion and feelings of affective valence (pleasantness versus unpleasantness) and arousal (calm versus excited). With RPE scale, the participants were instructed as follows: "While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you. Borg's rating scale ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number from the scale that best describes your level of exertion at that specific time point." SAM is a nine-point pictorial assessment technique to measure core affect, and it is easy to administer during exercise. Only the valence and arousal scales of SAM were used in the present study, with following instructions: "We want you to rate how pleasant or unpleasant you feel at certain time points. These caricatures show facial expressions ranging from very happy to very unhappy. Very happy face reflects feelings such as extreme happiness, pleasantness, or, hopefulness. Very unhappy face reflects feelings such as extreme sadness, displeasure, upset, or irritation. Choose the caricature that best describes your level of pleasure at that specific time point. We also want you to rate how calm or aroused you feel at certain time points. These caricatures show physical signs ranging from sleepiness (eyes closed) to extreme activation (heart pounding). Sleepy caricature reflects very low activation state such as extreme calmness, relaxation, sleepiness or slowness. Heart ponding caricature reflects very high activation state such as extreme excitement, enthusiasm, restlessness or anger. Choose the caricature that best describes your level of arousal at that specific time point."

The Perceived Stress Questionnaire (PSQ) (39), the Positive and Negative Affect Schedule (PANAS) (40) and a visual analogue scale (VAS) (separate scales for tension, irritation, pain, exhaustion, satisfaction and motivation to exercise) with extreme statements anchored at each end (i.e., not at all irritated to extremely irritated) were administered before and within 5 min after each training session to measure changes in experienced stress and pleasant versus unpleasant emotions. Participants were asked to respond to each scale in terms of how they felt at that moment.

$\dot{V}O_{2peak}$ test was performed as previously described in details by Kiviniemi et al. (41) on a bicycle ergometer (Ergoline 800s; VIASYS Healthcare, Germany) before the intervention and about 96 h after the last training session at the Paavo Nurmi Centre, University of Turku, Turku, Finland. The test started at 50 W and followed by an increase of 30 W every 2 min until volitional exhaustion. Ventilation and gas exchange were measured (Jaeger Oxycon Pro; VIASYS Healthcare) and reported as the mean value per minute. The peak respiratory exchange ratio was ≥1.17, and the peak blood lactate concentration, measured from capillary samples immediately and 1 min after exhaustion (analyzed using YSI 2300 Stat Plus; YSI Incorporated Life Sciences, Yellow Springs, OH), was ≥7.4 $mmol \cdot L^{-1}$ for all the tests. The highest 1-min mean value of oxygen consumption was defined as $\dot{V}O_{2peak}$. Peak workload ($Load_{peak}$) was calculated as an average workload during the last 2 min of the test and used as a measure of maximal performance. Body composition was measured by bioimpedance monitor (InBody 720; Mega Electronics Ltd., Kuopio, Finland).

Statistical analyses. Statistical analyses were performed using SAS System for Windows 9.3 (SAS Institute Inc., Cary, NC). The training adaptations ($\dot{V}O_{2peak}$ test results) were assessed with hierarchical linear mixed model with training (preintervention vs postintervention) as within- subjects factor and group (SIT vs MICT) as between-subjects factor. Because of positively and negatively skewed distributions, PANAS negative, tension, and irritation values were log-transformed, pain was square root -transformed, and motivation $\cancel{\chi^2}$-transformed before statistical analyses. The changes **AQ2** in the parameters measured during exercise (RPE, valence, and arousal) were analyzed with hierarchical linear mixed model where bout (preexercise score and 1–4 maximal sprints in the SIT group, and preexercise score and 10-, 20-, 30-, and 40-min time intervals in the MICT group) and training session (1–6) were used as within-subjects factors and group as between-subjects factor. These time points were selected for analysis, since they were completed across all six sessions of training. Unstructured covariance structure was used for bout and compound symmetry covariance structure for session. The diabetes status (T2DM/prediabetes) and sex were used as additional between factors for the analyses. The changes in the parameters measured before and after every training session (PSQ, PANAS and VAS scores, and lactate) were analyzed with hierarchical linear mixed model including session (1–6) and time (preexercise vs postexercise) as within-factors and group (SIT vs MICT) as between-factor. Unstructured covariance structure was used for session and compound symmetry covariance structure for time. The diabetes status (T2DM/prediabetes) and sex were used as additional main factors for the analyses. Subjects with one value and another missing (drop outs, technical problems) are included in this model, thus model-based mean (SAS least square means) values are reported for all the parameters. Linear model was **AQ3** used to test the association between the affective parameters and the changes in $\dot{V}O_{2peak}$ and $Load_{peak}$. Model included the mean value of the PSQ, PANAS, and VAS scores measured before every training session as covariate and group as between-subject factor and the change in $\dot{V}O_{2peak}$ and $Load_{peak}$ as the dependent variables. An alpha level of $P \leq 0.05$ and two-side tests was used in all statistical testing.

In the subsequent analyses, the affective measures were compared between insulin-resistant subjects from this study to previously reported results in age-matched healthy untrained men (22). Statistical analyses for RPE, valence, and arousal values after the fourth maximal sprint in the SIT groups and after 40 min in the MICT groups (because those were measured in all six sessions) were performed using hierarchical mixed linear model with unstructured covariance structure, including one within-factor (sessions), two between-factors [diabetes status (healthy or insulin-resistant) and group (SIT or MICT)], and their interaction terms. To avoid too complicated statistical model, analyses for PSQ, PANAS and VAS scores, and lactate were performed separately for the values measured before and after the exercise sessions. Also, these were analyzed using hierarchical mixed linear model with unstructured covariance structure, including one within-factor (sessions), two between-factors [diabetes status (healthy or insulin-resistant) and group (SIT or MICT)], and their interaction terms. The measurements for healthy subjects were performed between March 2011 and February 2013 and for insulin-resistant subjects between February 2013 and November 2015.

RESULTS

Insulin-resistant subject characteristics and training efficacy. The SIT and MICT groups were well matched T1 at the baseline, based on the whole-body parameters (Table 1). Body mass, BMI, and fat-free mass remained unchanged after 2 wk of training whereas fat percent reduced (P = 0.018, time). $Load_{peak}$ was improved in both groups (P < 0.001, time); however, the response of $\dot{V}O_{2peak}$ was different between SIT and MICT (P = 0.050 for group–time interaction), and only SIT improved $\dot{V}O_{2peak}$ (P = 0.013 for training effect in SIT). Lactate was higher after SIT than MICT (P < 0.001 for group–time interaction, least squares means ± SE: SITpre = 1.33 ± 0.28; SITpost = 14.22 ± 0.29; MICTpre = 1.26 ± 0.26; MICTpost = 3.89 ± 0.26) (see Table, Supplemental Digital Content 1, Summary of the results of the linear mixed model, http://links.lww.com/MSS/B29).

Affect and perception of exertion during exercise in insulin-resistant subjects. The results are summarized in Figure 1 and in the supplemental content (see Table, F1 Supplemental Digital Content 2, summary of the linear mixed model results, http://links.lww.com/MSS/B30). Perceived exertion (Fig. 1A) and arousal (Fig. 1C) increased and valence (Fig. 1B) decreased more in the SIT than MICT group during the training sessions (all P < 0.05 for group–bout interaction). Perceived exertion (P < 0.001, session) and arousal (P = 0.024 for session–bout interaction) experienced during the exercise sessions decreased and affective valence increased (P < 0.001, session) over the training period, but the effect was similar for SIT and MICT (Fig. 1D–1F).

Affective responses before and after exercise and during the training intervention in insulin-resistant subjects. Affective responses before and after exercise and during the training intervention are summarized in Figure 2 and in the supplemental content (see Table, F2 Supplemental Digital Content 1, summary of the linear mixed model results, http://links.lww.com/MSS/B29). MICT sessions did not affect perceived stress (PSQ), but SIT sessions increased it. PSQ remained unaltered during the training period in the MICT group, but post-SIT stress declined toward the end of the training intervention (P = 0.035 for group–session–time interaction; Fig. 2A). PSQ scores were significantly higher after the first two SIT sessions than after the first two MICT sessions (all P < 0.05); however, from the third exercise session, the difference of PSQ-ratings after exercise was no longer significant between SIT and MICT (P > 0.05). In parallel, PANAS-positive score decreased after the SIT sessions in the beginning of the intervention, but started to increase over the training period, whereas in the MICT group PANAS-positive score was higher after the training yet declining toward the end of the intervention (P = 0.014 for group–session–time interaction; Fig. 2B). PANAS-positive score was significantly lower after the first two SIT sessions

TABLE 1. Subject characteristics and training adaptations in the SIT and MICT groups.

	HIIT		MICT		*P*		
	Pre	Post	Pre	Post	Group	Time	Group–Time
n	13	11	13	10			
Men/women, *n*	9/4	7/4	7/6	6/4	0.69[a]		
T2DM/prediabetes, *n*	11/2	10/1	6/7	4/6	0.097[a]		
Age, yr	49 (47–51)		49 (46–51)		0.85[b]		
Height, cm	173 (168–179)		172 (167–176)		0.61[b]		
Weight, kg	88.9 (80.6–97.2)	88.4 (80.1–96.7)	91.5 (84.5–98.6)	91.1 (84.0–98.1)	0.62	0.083	0.95
BMI	30.5 (28.5–32.5)	30.3 (28.4–32.3)	31.0 (29.4–32.7)	30.8 (29.2–32.5)	0.69	0.07	0.83
Fat, %	34.8 (31.4–38.5)	33.8 (30.5–37.5)	33.8 (30.8–36.9)	32.9 (30.0–36.0)	0.67	**0.018**	0.87
AQ4 FFM, kg	57.0 (51.8–62.2)	57.6 (52.4–62.8)	59.6 (55.0–64.2)	59.8 (55.2–64.5)	0.49	0.11	0.54
$\dot{V}O_{2peak}$, L·min^{-1}	2.26 (1.99–2.53)	2.36 (2.1–2.63)	2.47 (2.24, 2.71)	2.43 (2.19–2.67)	0.43	0.43	**0.039**
$\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	25.7 (23.2–28.2)	27.0 (24.6–29.5)*	27.0 (24.9–29.2)	26.9 (24.6–29.1)**	0.72	0.12	**0.05**
$Load_{peak}$, W	173 (153–193)	187 (167–207)	190 (173–208)	201 (183–219)	0.24	<**0.001**	0.48

The results are presented as means (95% CI) for age and height. For all other parameters the results are presented as model-based means (95% CI). Group *P* value indicates whether there is a level difference between the groups, time *P* value displays the mean change between premeasurements and postmeasurements and group–time *P* value indicates whether the mean changes are different between the groups.
Significant differences are printed in boldface.
[a]Fisher exact test at baseline.
[b]*t* test
* HIIT time effect, *P* = 0.013.
** MICT time effect, *P* = 0.75.
AQ5 95% CI, 95% confidence interval.

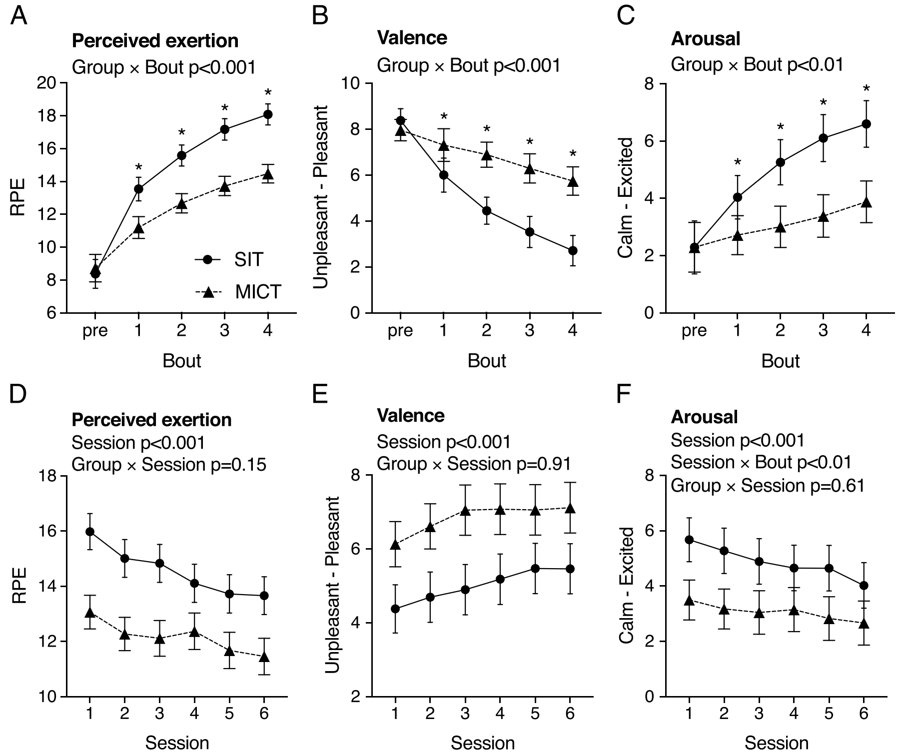
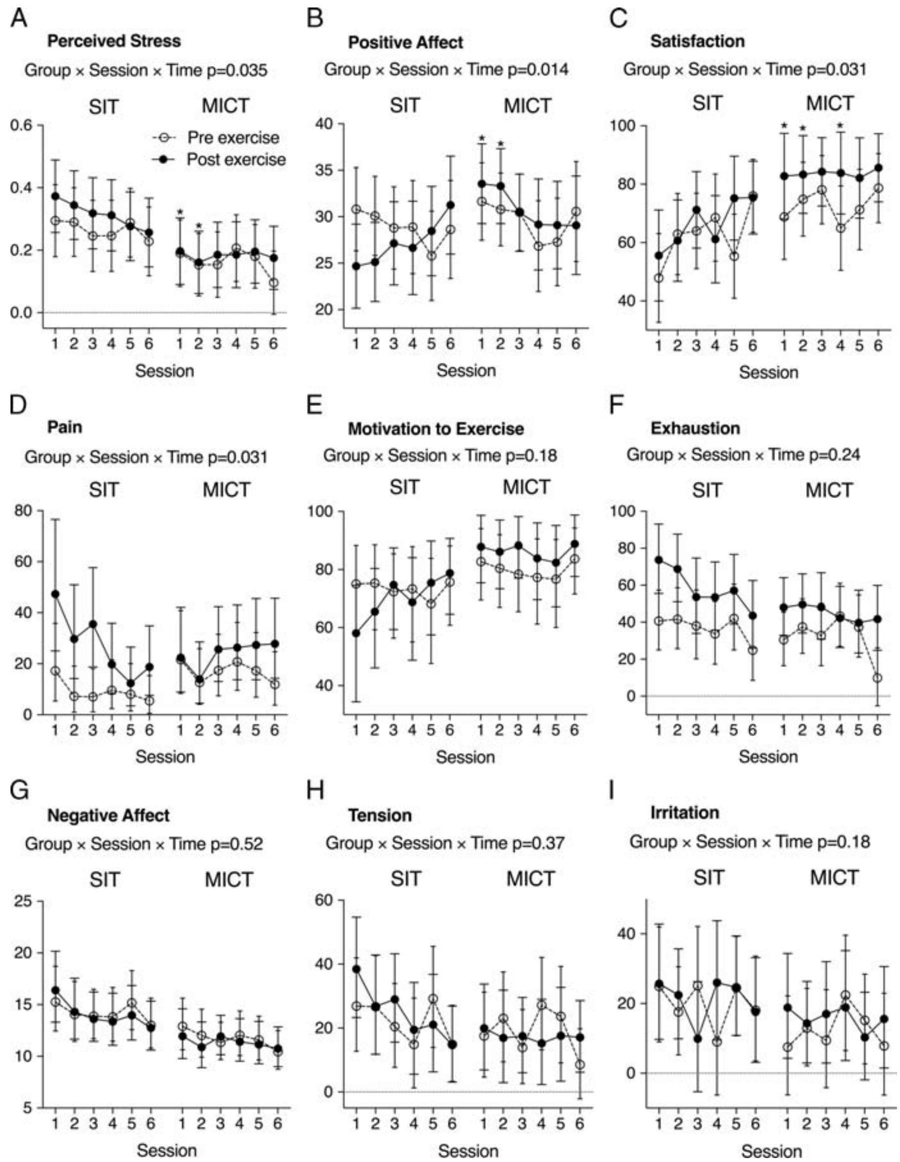


FIGURE 1—RPE (A), affective valence (B) and arousal (C) during exercise in insulin-resistant subjects. In the SIT group assessments were made before exercise and after every 30-s bout, in the MICT group assessments were made before exercise and in every 10 min. Only the first four bouts have been included for the analysis, because these were completed across all six sessions of training. *SIT significantly differs from MICT ($P < 0.05$). Changes of RPE (D), valence (E) and arousal (F) during the training intervention (six training sessions). No significant interaction of session and group was observed; however, the groups are plotted separately for visual purpose. The values are least squares means and the error bars represent 95% confidence intervals.

than after the first two MICT sessions ($P < 0.05$), but from the third exercise session the difference of positive affect after exercise was no longer significant between SIT and MICT. Satisfaction was higher after versus before the training in the MICT group throughout the intervention, whereas in the SIT group, both preexercise and postexercise satisfaction increased throughout the training period ($P = 0.031$ for group–session–time interaction; Fig. 2C). Between the training modes, satisfaction was significantly lower after the first two and the fourth SIT sessions than after the corresponding MICT sessions (all $P < 0.05$), but from the fifth exercise session no significant differences were observed ($P > 0.05$). Pain increased in both groups after the training sessions but more in the SIT group, however also pain alleviated in the SIT group during the training period ($P = 0.033$ for group–session–time interaction; Fig. 2D). After MICT, motivation to exercise increased more than after SIT ($P = 0.006$ for group–time interaction). Pretraining ratings of motivation to exercise declined during the training period until the last training session, but posttraining ratings increased during the intervention similarly between the groups ($P = 0.047$ for session–time interaction) (Fig. 2E). Exhaustion was higher after than before the training sessions ($P = 0.003$, time) and varied between the training sessions ($P = 0.002$, session) without significant interactions (Fig. 2F). PANAS-negative score and feeling of tension varied between the training sessions ($P = 0.006$ and 0.008, session, respectively) (Figs. 2G and H). Exercise did not significantly affect the feeling of irritation (Fig. 2I). No significant associations were found between the acute exercise responses in affect and the changes in lactate, $\dot{V}O_{2peak}$ or $Load_{peak}$ (correlation data not shown).

Comparison of the affective responses between the insulin-resistant subjects and the healthy subjects. The results are summarized in Figures 3 and 4 F3 F4 and in the supplemental content (see Table, Supplemental Digital Content 3, Summary of the results of the linear mixed model for perceived exertion, valence, and perceived arousal, http://links.lww.com/MSS/B31; and Table, Supplemental Digital Content 4, Summary of the results of the linear mixed model for PSQ, PANAS, and visual analog scale parameters, http://links.lww.com/MSS/B32). Perceived exertion and arousal values after the fourth maximal SIT sprint and after 40 min of MICT were not different between the healthy and insulin-resistant subjects (Fig. 3A and C). However, in the same time points the difference in valence between SIT and MICT was significantly larger in the insulin-resistant subjects than in the healthy subjects ($P = 0.018$ for group–diabetes status interaction) so that pleasantness after four bouts of SIT was lower in the insulin-resistant subjects compared to healthy subjects (2.5 vs 3.9), but higher after 40 min of MICT (5.9 vs 5.1, respectively) over the training sessions (Fig. 3B).



AQ6 **FIGURE 2—Affective responses before and after SIT and MICT sessions in insulin-resistant subjects. *Post-value of MICT is significantly different (*P* < 0.05) from corresponding post-value of SIT. The values are least squares means and the error bars represent 95% confidence intervals.**

The pretraining ratings of PSQ, PANAS, and VAS parameters were analyzed separately from posttraining ratings. Exhaustion before the training sessions varied differently between the healthy and insulin-resistant subjects and SIT and MICT (P = 0.047 for session–group–diabetes status interaction) during the intervention, but showed a decreasing trend toward the end of the training period so that all the groups were less exhausted before the last than before the first training session (Fig. 4A). Also, the feelings of irritation before the training sessions varied differently between the healthy and insulin-resistant subjects and SIT and MICT (P = 0.047 for session–group–diabetes status interaction) during the intervention, but it did not differ significantly between the first and last training sessions. Pain ratings before training sessions varied differently between the healthy and insulin-resistant subjects during the training intervention independently of training mode (P = 0.017 for session–diabetes status interaction). The initial pain ratings in the first training session were higher in insulin resistant than in healthy subjects; however, preexercise pain ratings alleviated only in insulin-resistant subjects over the course of intervention (Fig. 4B). No other differences in pretraining affect ratings between healthy and insulin-resistant subjects were observed.

The posttraining ratings of PSQ, PANAS, and VAS were considered to reflect the affective state stimulated by experienced exercise session. After SIT, PANAS-positive scores significantly increased over the course of the intervention in the insulin-resistant subjects while remaining unaltered among healthy subjects, whereas after MICT, PANAS-positive score decreased in both healthy and insulin-resistant subjects during the intervention (P = 0.002 for session–group–diabetes

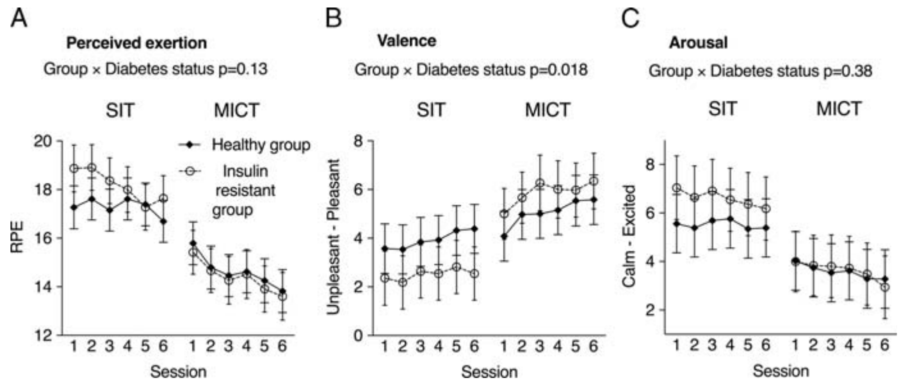


FIGURE 3—RPE (A), affective valence (B) and arousal (C) after the fourth bout of SIT and after 40 min of MICT in healthy and insulin-resistant groups. The exercise sessions are illustrated separately for visual purpose. The values are least squares means and the error bars represent 95% confidence intervals.

status interaction) (Fig. 4C). Post-SIT pain ratings remained unchanged within healthy subjects but decreased significantly in the insulin-resistant subjects during the intervention, whereas after MICT, the pain ratings did not change over the training period neither in healthy nor insulin-resistant subjects (P = 0.005 for session–group–diabetes status interaction) (Fig. 4D). No other differences in posttraining affect ratings between healthy and insulin-resistant subjects were observed.

DISCUSSION

Our main finding was that the levels of perceived exertion and arousal increased and pleasantness decreased during both exercise modes, but as hypothesized, significantly more steeply during SIT compared with MICT sessions in insulin-resistant untrained adults. Perceived exertion alleviated and pleasantness increased toward the end of the training period and not differently between the training modes, suggesting that repeated sessions of exercise resulted in affective adaptation, the process of weakening of emotional responses over time. Furthermore, SIT acutely increased perceived stress and pain, and decreased positive affect more than MICT especially in the beginning of the training period. As the intervention progressed, perceived stress and pain experienced after SIT alleviated and positive affect and satisfaction increased to the level comparable to MICT. Our findings suggest that in the beginning of training SIT feels worse than MICT during and acutely after the exercise session. However, mental and physiological adaptations occur already within a few exercise sessions leading to similar affective responses after both SIT and MICT. Consequently, even very strenuous SIT appears to be a tolerable training method for insulin-resistant adults.

SIT-induced affective responses in people with insulin resistance have not been previously investigated. Previous research shows that interval training (SIT/HIIT) is physiologically a feasible alternative to MICT in the prevention and treatment of T2DM (8). Given that affective responses influence future physical activity behavior, at least during MICT (18), understanding SIT-induced perceptual and affective changes is important when evaluating the feasibility of SIT for T2DM patients. Higher exercise intensity parallels with higher exertion and displeasure during exercise (20,22,23,26). In line with our previous findings in healthy individuals (22), already the second bout of SIT increased ratings of perceived exertion and displeasure to higher level than what was observed during 40 min of MICT in insulin-resistant subjects. Similarly, affective valence, that is, pleasure, has consistently

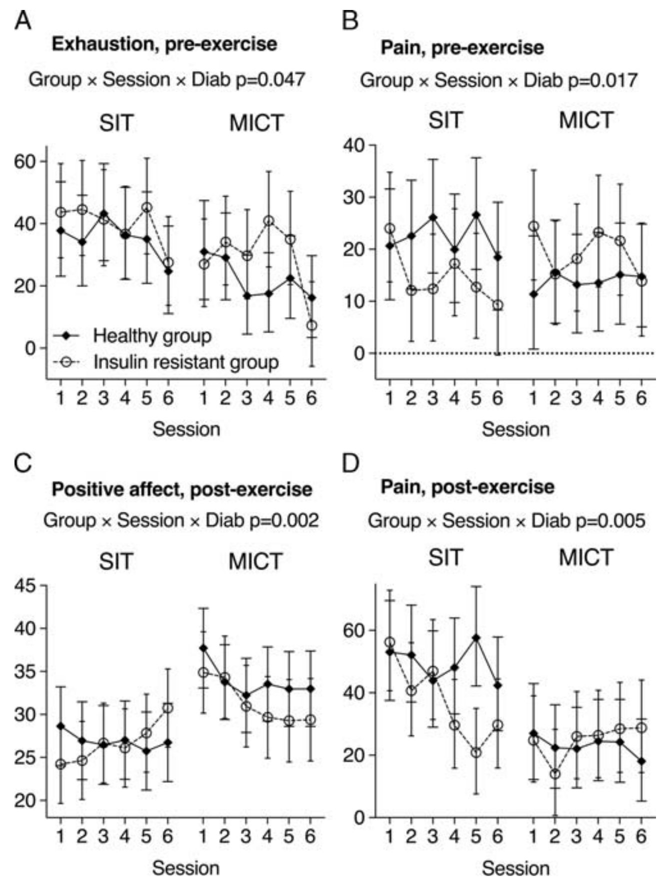


FIGURE 4—Affective responses before (A and B) and after (C and D) SIT and MICT in healthy and insulin-resistant subjects. The values are least squares means and the error bars represent 95% confidence intervals.

been reported lower also during HIIT versus MICT in inactive lean (26) and obese individuals (23) and in recreationally active individuals (25). Perceptual and affective responses to exercise may, at least partly, be determined by metabolic and cardiovascular strain, as perceived exertion has been associated with higher lactate and ventilation as well as with HR (42), which also has been linked to more negative feelings (43). Significantly higher blood lactate concentration after SIT than MICT indicates considerably larger contribution from anaerobic metabolism for energy production in SIT, as of course can be expected. Somewhat elevated lactate levels also after MICT suggests that, despite being performed at the intensity of only 60% of peak workload, MICT intensity was close to vigorous for these subjects. However, in the present study, we did not observe associations between blood lactate concentration and perceived exertion or affective measures. Interestingly, although SIT and HIIT induce similar negative perceptual and affective responses in comparison with MICT, it has been suggested that shorter-duration interval bouts may be more tolerable for novice exercisers (35). Perceptual responses and enjoyment have been found more positive during shorter than longer intervals in inactive obese individuals (35,44), thus speculatively, sprint bouts even shorter than 30 s might be favored over few minutes of intervals.

As the affective and perceptual responses regarding the first bout exposure might promote MICT over SIT, the development of these responses over time and repeated sessions of SIT have remained less documented. Considering the adoption of a new exercise routine, it is intriguing that perceived exertion, arousal, and displeasure experienced during exercise attenuate regardless of the training mode already within six training sessions as shown here and previously in healthy sedentary middle-age men (22). These findings accord also with a previous work demonstrating attenuated perceived exertion and leg pain in response to 6 d of SIT in young active individuals (45). Such alleviations are likely due to rapid adaptations in physiological systems, such as metabolic, neuromuscular, cardiovascular, and respiratory systems, as well as improvements in pain tolerance and in psychological and cognitive elements. Furthermore, we found that stress and pain were significantly higher, and AQ7 positive affect and satisfaction were significantly lower after the first sessions of SIT than MICT, but the disparities in these measures were, in fact, abolished after three exercise sessions. The notable drop in post-SIT ratings of pain, as well as the clear increase in positive affect over six exercise sessions in addition to growing exercise motivation after SIT may indicate that exercise enjoyment increases in response to repeated SIT. Importantly, SIT does not seem to worsen the feelings of fatigue and pain in insulin-resistant subjects, which might compromise regular exercise. These positive affective adaptations to repeated training likely facilitates exercise adherence, as found previously in people with prediabetes, who were able to maintain regular HIIT program independently for 1 month after a brief supervised laboratory intervention (34). Yet, further research investigating the complex and dynamic elements of long-term adherence to SIT is required, because the decision-making and psychological factors that underlie the initiation of a new exercise pattern are not necessarily the same that help to sustain the routine (46,47).

Our secondary finding was that untrained insulin-resistant and healthy individuals show relatively similar affective responses during SIT and MICT, yet adaptation to repeated SIT appears somewhat more positive in insulin-resistant subjects than healthy subjects. Diabetes is typically accompanied with obesity and low cardiorespiratory fitness, which may in part exacerbate the aversion for physical activity and exercise. Higher exercise intensities may elicit more negative perceptual changes (21), and the changes are even more negative among sedentary and overweight individuals compared with healthy lean subjects (33). Reckoning with this and that T2DM is often associated with increased pain (48) as well as additional feelings of fatigue (29), we expected SIT to induce higher perceived exertion and displeasure in the group of insulin-resistant subjects compared with our previous cohort of healthy sedentary subjects. In line with our hypothesis, we found that subjective pleasantness during SIT sessions was markedly lower among insulin-resistant than in healthy subjects, and opposite was found in pleasantness during MICT. In contrast, no differences in perceived exertion, arousal, or lactate between healthy and insulin-resistant subjects were observed despite significantly lower cardiorespiratory fitness and higher BMI in the insulin-resistant group. Somewhat surprisingly, we observed signs of more positive adaptation to SIT among insulin-resistant than healthy subjects over the training period. The decrease of preexercise pain ratings in the insulin-resistant group points to well-established beneficial effects of exercise on pain management (49). Interestingly, post-SIT ratings of pain decreased and positive affect increased more in insulin-resistant than healthy subjects over six exercise sessions, whereas post-MICT ratings of positive affect decreased in both groups. Individual variability in metabolic strain induced by exercise may explain some of the differences between healthy and insulin-resistant subjects, although no correlations were found between affective responses and physiological measures $\dot{V}O_{2max}$, lactate, or BMI. Nevertheless, these findings suggest that SIT may be at least equally well, if not even better, adopted by untrained insulin-resistant than healthy individuals.

Several issues limited the present study. We examined the affective responses only during and immediately after exercise, which limits our interpretation of the result only to these time points. The sample size in the present study was relatively small, and men and women as well as T2DM and prediabetic subjects were not equally divided between the SIT and MICT groups. Both were used as factors in the analyses, but because of small subgroups of men/women and T2DM/prediabetes, we did not test the interactions between other factors and cannot therefore say whether the training responses were different between men and women, for example. Because there may be differences in exercise affect between men and women (50), this should be investigated in the future in larger groups of subjects. Additionally, the sample size calculations of the whole project were based on physiological variables, while they were the primary outcome measures of the larger project. Thus, no power analysis was performed specifically for affective parameters. Given the fluctuating nature of affect, all changes observed in perceptual and affective measures may not be induced purely by exercise. However, for example, for the Borg scale, reliability (alpha) of the first workbout RPE measurements (first bout of SIT/10 min of MICT) across sessions was 0.90, suggesting high level of consistency across subjects. It must also be noted that our study did not include a nonexercise control group. However, the main purpose of this study was to compare the effects of SIT and MICT directly. The exercise intervention of six training sessions was short, warranting more research on the long-term development of SIT-induced affective responses over time. Finally, the training sessions were performed individually in laboratory conditions under supervision and encouragement. Because social support from family and personal trainer is a dominant factor in exercise adoption and maintenance within diabetics (47), and positive feedback during SIT has been linked to higher exercise enjoyment and satisfaction (51), whether SIT can be initiated, adopted, and sustained independently in real life by inactive, overweight to obese people with T2DM or prediabetes remain elusive and require further investigation.

CONCLUSIONS

When comparing first bout exposure of SIT and MICT, SIT undeniably increases perceived exertion, displeasure, and arousal more during exercise, and increases perceived stress, pain and decreases positive affect more acutely after exercise in untrained, overweight to obese insulin-resistant adults. However, the negative affective responses after exercise improve significantly within a few training sessions to the level comparable with MICT, and perceived exertion and displeasure during exercise decline in both exercise modes in response to repeated training. These findings are encouraging in regard of tolerability of SIT, and support the potential feasibility of even very intense SIT as an alternative exercise strategy to untrained people with insulin resistance.

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