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More efficient, perhaps, but at what price? Pleasure and enjoyment responses to high-intensity interval exercise in low-active women with obesity

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ABSTRACT

Objectives: Fewer than 1.5% of women with obesity in the USA are physically active at recommended levels. High-intensity interval exercise (HIIE) has been proposed as a possible solution to the problem of low activity, based on the dual promise of accelerating the accrual of benefits while reducing the time commitment. However, concerns have been raised about the appeal and sustainability of HIIE. The purpose of this study was to compare during-exercise affective valence and post-exercise enjoyment in response to a bout of HIIE and a longer, isocaloric bout of moderate-intensity continuous exercise (MICE).
Design: Within-subjects experiment.
Methods: Low-active women with obesity ($N = 24$) completed one bout of HIIE (3-min warm-up, four 3-min intervals of recumbent cycling at 115% of Watts at the ventilatory threshold, four 2-min periods of active recovery at 85% of Watts at the ventilatory threshold, 5-min cool-down) and one bout of MICE (3-min warm-up, 25 min of recumbent cycling at 90% of Watts at the ventilatory threshold, 5-min cool-down) in counterbalanced order. The Feeling Scale (FS) was administered during exercise and the Physical Activity Enjoyment Scale (PACES) was administered after cool-down.
Results: Differences were found for both FS (condition by time interaction: $p < 0.001$, $\eta^2 = 0.27$) and PACES ($p = 0.04$, $d = -0.38$), with both outcomes favoring MICE.
Conclusions: The lower pleasure and enjoyment associated with HIIE compared to MICE underscore the importance of considering not only physiological adaptations but also the appeal and sustainability of HIIE for low-active women with obesity.

Compliance with physical activity recommendations among American adults remains low, posing a challenge to public-health researchers and practitioners. Objective assessments of physical activity with accelerometry from the National Health and Nutrition Examination Survey ($N = 3522$) show that only 3.2% of American adults accumulate at least 30 min of moderate-intensity physical activity, in bouts of at least 10 min, on at least 5 days per week (Tudor-Locke, Brashear, Johnson, & Katzmarzyk, 2010). Importantly, noncompliance varies by both sex and body-mass-index (BMI) category. Women with obesity, a segment of the population now estimated to comprise 36% of adult women (Flegal, Carroll, Kit, & Ogden, 2012) and projected to comprise 45–52% by 2030 (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011), exhibit the lowest levels of physical activity. Specifically, fewer than 1.5% of women with obesity do the minimum amount of physical activity recommended for health promotion (Tudor-Locke et al., 2010). On average, women with obesity are estimated to perform only 13.8 min of moderate- and 10.8 s of vigorous-intensity physical activity daily (Archer et al., 2013).

The aetiology of this extremely low level of physical activity is unknown and there is presently no evidence base to support practice guidelines for addressing the problem (Ekkekakis, Vazou, Bixby, & Georgiadis, 2016). The dearth of information is reflected in position statements by American (Donnelly et al., 2009) and European (Fogelholm, Stallknecht, & Van Baak, 2006) organizations, which detail how much physical activity adults with obesity should be doing and why but contain no guidance on methods of promotion and implementation that can encourage sustained participation.

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1. Approaches to exercise prescription: tortoise versus hare

Two fundamentally different approaches to exercise prescription have evolved in practice. The traditional approach calls for moderate-intensity continuous exercise (MICE) of prolonged duration. The preference for MICE is based on three main arguments (Smart & Ismail, 2013): (a) it provides an adequate stimulus for clinically meaningful adaptations in cardiometabolic parameters, (b) it entails low risk of injury and other adverse events, and (c) it is presumed to be tolerable for most individuals. Thus, this approach is presently advocated by most scientific bodies. For example, the American College of Sports Medicine (2014) recommends that, for adults with obesity, the intensity should be set initially at 40–60% of oxygen uptake or heart rate reserve and the duration at 30 min, with progression to intensities over 60% and duration of 60 min, as long as participants are "capable and willing" (p. 320).

On the other hand, two characteristics of MICE may contribute to the low participation among adults with obesity. First, critics have noted that "moderate activity provides little metabolic stress and, as a result, confers little improvement in aerobic fitness and minimal weight loss," thus causing frustration and making dropout "a rational decision" (O'Donovan & Shave, 2007, p. 434). Second, since, like most adults, adults with obesity cite "lack of time" as the primary reason for their low activity (e.g., Andersen & Jakicic, 2009), authors have noted that recommendations requiring a minimum daily investment of 30–60 min are "totally unrealistic and largely unattainable for the majority of the populace" (Bird & Hawley, 2012, p. 314).

The alternative approach, namely high-intensity interval exercise (HIIE), was originally developed as a training method for athletes but has been proposed as appropriate for public health in the last decade (e.g., Gaesser & Angadi, 2011; Gibala & McGee, 2008; Gillen & Gibala, 2014; Rehn, Winett, Wisløff, & Rognmo, 2013). This suggestion has had a profound impact on the research literature and exercise programs on a global scale, presumably because of the promise of addressing the two aforementioned limitations of MICE (i.e., accelerating the accrual of benefits while reducing the time commitment). Thus, in recent years, HIIE has been proposed as an appropriate intervention specifically for individuals with obesity (Boutcher, 2011), diabetes (Bird & Hawley, 2012), and the metabolic syndrome (Kessler, Sisson, & Short, 2012). Proponents argue that, by providing a stronger stimulus to the cardiorespiratory system, HIIE may accelerate gains in aerobic capacity compared to MICE (Elliott, Rajopadhyaya, Bentley, Beltrame, & Aromataris, 2015; Milanovic, Sporiš, & Weston, 2015; Weston, Wisløff, & Coombes, 2014). Moreover, HIIE may yield benefits similar to MICE for a range of cardiometabolic parameters, as well as reductions in body mass and waist circumference, but with a shorter time commitment (Hwang, Wu, & Chou, 2011).

2. The great intensity debate

The HIIE-vs-MICE debate has become polarized and heated, with strong opinions being expressed from both sides (Biddle & Batterham, 2015; Del Vecchio, Gentil, Coswig, & Fukuda, 2015; Hardcastle, Ray, Beale, & Hagger, 2014; Holloway & Spriet, 2015; Jung, Little, & Batterham, 2016; Wisløff, Coombes, & Rognmo, 2015). Proponents of HIIT are "convinced that HIIT is superior to MICE" (Juneau, Hayami, Gayda, Lacroix, & Nigam, 2014, p. S403) and "believe that the time to introduce high-intensity exercise to the whole community has come" (Rehn et al., 2013, p. 5). Thus, they assert that "HIIT should play a central role in health activity guidelines to maximize the benefits of physical activity globally" (Wisløff et al., 2015, p. 5216).

Importantly, these arguments are based on the belief that, besides its cardiometabolic benefits, HIIE "remains popular in the general public" (Jung et al., 2016, p. 2) and is "very enjoyable" (Kilpatrick, Jung, & Little, 2014, p. 14). Authors claim that, compared to MICE, participants report "highest enjoyment" when engaged in HIIE (Kilpatrick et al., 2014, p. 14). Reportedly, this is due to "a decreased subjective feeling of fatigue, breathlessness, and monotony" (Juneau et al., 2014, p. S403). Researchers who share these views have suggested that, due to the intermittent nature of HIIE, the well-characterized negative relationship between exercise intensity and affective responses (Ekkekakis, Parfitt, & Petruzzello, 2011) may not apply in the case of HIIT (Jung et al., 2016).

On the opposite side of the debate, skeptics have pointed out that the evidence in support of HIIE is still evolving. Citing limited evidence on efficacy and safety, the American Heart Association has determined that, for patients with cardiovascular disease, HIIE "cannot yet be broadly recommended" (Fletcher et al., 2013, p. 915). Similarly, other experts have concluded that, for patients with heart failure, "there is currently insufficient evidence to supplant a continuous [MICE] approach with this new [exercise training] model" (Arena, Myers, Forman, Lavie, & Guazzi, 2013, p. 104). Indeed, randomized trials of patients with coronary artery disease and heart failure found no evidence of superiority of HIIE over MICE in cardiovascular outcomes, including maximal aerobic capacity (Conraads et al., 2015; Støylen et al., 2012).

Skeptics have also expressed concerns about HIIE possibly raising the risk of injury, discomfort, nonadherence, and dropout (e.g., De Feo, 2013; Keteyian, 2012). Specifically, HIIE has been found to be associated with a higher rate of adverse events during exercise or within the 24 h postexercise in patients with cardiometabolic diseases, leading reviewers to warn that "caution must be taken" (Levinger et al., 2015, p. 62). Other authors have emphasized that, in considering the benefit-to-risk ratio of high exercise intensity, the effects on parameters beyond the cardiovascular system, such as the health of the brain, should not be overlooked. It is still unknown, for example, how elevated stress hormone levels (e.g., cortisol), changes in electrolyte balance, inflammation, hypoxia, and oxidative stress associated with high-intensity exercise may influence brain structure and function (Tarumi & Zhang, 2015). Lucas, Cotter, Brassard, and Bailey (2015) have also warned that "the potential dangers of [HIIE] to the brain are not trivial," in part due to increasing "the risk of hyperperfusion injury predisposing to stroke or blood-brain barrier breakthrough" (p. 905). Finally, while most available randomized trials are underpowered to investigate differences in adherence, in one trial with inactive overweight and obese adults in a community setting, the researchers attributed the minimal effect of HIIE on aerobic capacity to the higher participant attrition, lower session attendance, and lower percentage of prescribed exercise completed among HIIE participants than those assigned to MICE (Lunt et al., 2014).

3. The appeal of HIIE remains undetermined: methodological challenges

The appeal of HIIE in different populations remains an open empirical question (Jung et al., 2016). Over a decade ago, Coyle (2005) wrote that "a feeling of severe fatigue" is "the 'price' for [the] effectiveness and remarkable time efficiency" of HIIE (p. 1983). Since then, research has focused on two constructs of central importance to how exercise is experienced, namely (a) affective valence (i.e., pleasure versus displeasure), typically rated on a single-item scale during exercise, and (b) enjoyment, typically measured with a multi-item questionnaire after exercise. Both affective valence (Ekkekakis & Dafermos, 2012; Rhodes & Kates,

2015) and enjoyment (Rhodes, Fiala, & Conner, 2009) have been found to be associated with physical activity.

Investigations of affect and enjoyment in response to HIIE sessions among healthy adults have been contradictory. Some authors claim that HIIE "may be a viable alternative to continuous moderate-intensity exercise prescriptions" (Jung, Bourne, & Little, 2014, p. 16). Others have concluded that HIIE "leads to significant increase in negative emotions both during and after the exercise in sedentary subjects," which may in turn "hinder the adherence to physical activity" (Saanijoki et al., 2015, p. 2610).

The apparent inconsistency of experimental results may be due to several methodological differences. First, there is a risk of participant self-selection bias, with most studies having been conducted with young, healthy, active, and fit college students, many enrolled in exercise-science programs. Results based on such samples arguably have limited generalizability to the general adult population, which is characterized by high body mass and low activity. For example, in a study cited nearly 100 times, the authors reported that a bout of HIIE resulted in higher enjoyment scores than a bout of MICE, a finding that was discussed as potentially "relevant for improving exercise adherence" (Bartlett et al., 2011, p. 547). However, the eight young male participants (mean age 25 ± 5 years), despite being described as "recreationally active," had a maximal aerobic capacity above the 95th percentile for their age (57 $ml \cdot kg^{-1} \cdot min^{-1}$). On the other hand, the 28 sedentary men (mean age 47 ± 5 years) studied by Saanijoki et al. (2015) had a maximal aerobic capacity at the 20th percentile for their age on average (34 $ml \cdot kg^{-1} \cdot min^{-1}$). In another study, the men had an average aerobic capacity at the 65th percentile (45 $ml \cdot kg^{-1} \cdot min^{-1}$) but the women at the 15th percentile (28 $ml \cdot kg^{-1} \cdot min^{-1}$) and yet no analyses by gender were reported (Jung et al., 2014).

A second possible contributor to the inconsistency in the results reported thus far is the choice of intensities characterized as "high intensity" in HIIE bouts and as "moderate intensity" in MICE bouts. Intensities are commonly selected without reference to a guiding physiological framework, thus occasionally resulting in misleading conclusions. For example, in one study, because physiological drift and the slow component of oxygen uptake (Jones et al., 2011) were not taken into account, a condition described as "moderate-intensity" continuous exercise was, in fact, performed at consistently higher heart rate than a comparator condition described as "heavy-intensity" interval exercise (Kilpatrick, Greeley, & Collins, 2015). Likewise, a condition described as "heavy-intensity" continuous exercise was, in fact, performed at higher heart rate than a comparator condition described as "severe-intensity" interval exercise. Since conditions described as being of lower intensity were consistently of higher intensity and vice versa, any conclusions framing the study as a comparison between HIIE and MICE must be questioned.

Problems are also evident in studies cited as supporting the conclusion that HIIE is experienced as less pleasant than MICE. For example, in one such study, each 2-min high-intensity interval consisted of exercise at 100% of peak oxygen uptake, while recovery periods lasted for only 57 ± 10 s (Oliveira, Slama, Deslandes, Furtado, & Santos, 2013). However, it is well established that exercise in the "severe" range of intensity (i.e., from the level of critical power to peak oxygen uptake) can only be sustained for a few minutes and this range of tolerance is further shortened with repeated bouts and short recovery periods (Bailey, Vanhatalo, Wilkerson, DiMenna, & Jones, 2009; Coats et al., 2003; Ferguson et al., 2007). The diminished tolerance in such protocols is presumed to be due to the depletion of high-energy phosphate and glycogen stores in muscles, as well as the incomplete removal of metabolites and restoration of pH levels (Jones, Vanhatalo, Burnley, Morton, & Poole, 2010). Thus, despite the fact that the (male) participants in the study by Oliveira et al. (2013) were young (24 ± 4 years) and fit (48 ± 7 $ml \cdot kg^{-1} \cdot min^{-1}$, 75th percentile), it is perhaps unsurprising that more than half (8 of 15) could not complete the HIIE condition.

A third issue that has likely contributed to the inconsistency in previous results is the relative duration of the HIIE and MICE sessions. HIIE sessions have been compared to MICE sessions that were as short as 20 min (Kilpatrick et al., 2015; Martinez, Kilpatrick, Salomon, Jung, & Little, 2015) or as long as 40 min (Jung et al., 2014; Saanijoki et al., 2015) or even 50 min (Bartlett et al., 2011). Moreover, since the main argument supporting the promotion of HIIE in the domain of public health is its time efficiency (e.g., Bird & Hawley, 2012; Gibala & McGee, 2008; Gillen & Gibala, 2014), one would expect HIIE sessions to be compared to MICE sessions that are longer. However, some studies have compared HIIE and MICE sessions of equal duration (e.g., Kilpatrick et al., 2015) or even HIIE sessions that were longer than MICE (Martinez et al., 2015).

A fourth potential contributor to the inconsistencies in previous results is the method of affect assessments. Previous research has established that ratings of pleasure-displeasure track changes in exercise intensity closely, reliably worsen over time when the intensity exceeds the ventilatory threshold, and exhibit a robust positive rebound when the exercise stops or the intensity is reduced (Ekkekakis et al., 2011). Therefore, for the assessment protocol to faithfully represent the presumably dynamic changes in pleasure-displeasure during a bout of HIIE, ratings must be obtained from participants at least at the highest point of the "peaks" (i.e., at the end of recovery periods) and the lowest point of the "valleys" (i.e., at the end of the high-intensity intervals). However, in some studies, ratings were obtained at the midpoint of the interval and recovery periods (Jung et al., 2014), thus missing the peaks and valleys and misrepresenting the shape of the affective response. In other studies, ratings were obtained only after the high-intensity intervals, thus capturing the affective response to the cessation of intense exercise rather than the response to the high-intensity intervals themselves (Oliveira et al., 2013; Saanijoki et al., 2015). Finally, in studies in which ratings were obtained "during the last 15 s" (Kilpatrick et al., 2015, p. 247) or "during the last 10 s" (Martinez et al., 2015, p. 141) of the high-intensity intervals, the *bipolar* rating scale of pleasure-displeasure was presented side-by-side with a *unipolar* scale of enjoyment, asking respondents to "indicate how much you are enjoying this exercise session." This juxtaposition, and the associated variance transfer, may have introduced a biasing effect on ratings of pleasure-displeasure. In particular, the phrase "how much you are enjoying" (a typical example of a "loaded" or "leading" question) and the instruction to rate the degree of enjoyment without permitting respondents to indicate any degree of aversion may have negatively impacted the validity of pleasure-displeasure assessments during exercise.

Thus far, the affective and enjoyment responses to HIIE and MICE among low-active adults with obesity or other cardiometabolic risk factors have not been compared in a study specifically designed and powered for this purpose. In a study of only 8 patients with type 2 diabetes (mean age 63 years, mean BMI 32 $kg \cdot m^{-2}$), the anticipated enjoyment of future HIIE sessions was rated highly (~8 out of 9, with 9 being "very enjoyable") but there was no comparison to MICE (Little et al., 2011). A study of 19 young, sedentary, overweight or obese men (mean age 23 years, mean BMI 31 $kg \cdot m^{-2}$), whose maximal aerobic capacity (35 $ml \cdot kg^{-1} \cdot min^{-1}$) was "poor" (bottom 20% for their age), showed that repeated 1-min intervals at 100% of maximal capacity yielded nearly fivefold larger declines in pleasure (6.9 versus 1.4-point drop on an 11-point scale) than intervals at 70% (Boyd, Simpson, Jung, & Gurd, 2013). On the other hand, there was no difference in anticipated enjoyment

("How enjoyable would it be for you to do high-intensity interval training 3 days per week?"), with both groups averaging more than 6 out of 7 (with 7 being "extremely enjoyable"). Finally, in a study of 10 overweight or obese adults (8 women), with mean age of 41 years, mean BMI of 36 $kg \cdot m^{-2}$, and estimated maximal aerobic capacity of 22 $ml \cdot kg^{-1} \cdot min^{-1}$ (i.e., "very poor"), the authors concluded that "there were no significant differences" (p. 838) for either during-exercise affective valence or post-exercise enjoyment between HIIE and MICE conditions (Little, Jung, Wright, Wright, & Manders, 2014). The lack of a statistically significant difference, however, was likely due to the low statistical power afforded by the small sample, since there was a medium-size difference in the ratings of during-exercise valence ($d = 0.56$) and a small-to-medium difference in post-exercise enjoyment ($d = 0.28$), both in favor of MICE.

4. The present study

While there is no universal definition of HIIE, the core feature of HIIE is the alternation between (a) intervals of "'all-out' effort" or an intensity "close to that which elicits VO_{2peak} (i.e., >90% of VO_{2peak})," lasting "from a few seconds to up to several minutes" and (b) periods of passive or active recovery ("rest or low-intensity exercise") lasting "up to a few minutes" (Gibala & McGee, 2008, p. 58). To appropriately calibrate the intensity and the volume of HIIE bouts for different populations, it has been suggested that "future studies should examine modified interval-based approaches" (Gibala & McGee, 2008, p. 62). This call has led to the emergence of two broad categories of HIIE (Kessler et al., 2012): (a) "sprint interval training" (SIT) typically involves 4–6 cycles of 30-s bursts at "all out" (i.e., maximal or supramaximal) intensity, whereas (b) "aerobic interval training" (AIT) typically involves 4–6 cycles of exercise at 80–95% of maximal capacity, each lasting for 3–4 min. Because of reports of nausea and light-headedness during sessions of SIT (e.g., Richards et al., 2010), the present study focused on AIT.

Thus, the purpose of the present study was to compare the effects of a session of HIIE/AIT and a session of MICE on during-exercise affective valence and post-exercise enjoyment in low-active women with obesity. Previous research has shown that women with obesity report lower levels of pleasure across the entire range of exercise intensity than their non-obese counterparts (Ekkekakis, Lind, & Vazou, 2010) and the difference may grow larger at higher intensities (da Silva et al., 2011). Thus, when asked to choose between higher intensity or longer duration, more women with obesity choose lower intensity, even if this means exercising for a longer period of time (Fogelholm, Kukkonen-Harjula, Nenonen, & Pasanen, 2000). On the other hand, according to anecdotal accounts from a study of patients with the metabolic syndrome (mean age 55 years, mean BMI 30 $kg \cdot m^{-2}$), participants "found it motivating to have a varied procedure to follow" whereas participants in a moderate-intensity walking condition "found it 'quite boring' to walk continuously during the whole exercise period" (Tjønna et al., 2008, p. 352). Intermittent activity is also perceived as more rewarding or enjoyable than continuous activity by non-obese children (Barkley, Epstein, & Roemmich, 2009) and fit young adults (e.g., Bartlett et al., 2011). Thus, given the contradictory prior evidence, no directional hypothesis regarding the affective and enjoyment responses to a session of HIIE/AIT and a session of MICE could be formulated.

5. Methods

5.1. Participants

An initial power analysis assuming an effect size of $d = 0.6$ for a comparison between two dependent means on the primary outcome, namely ratings of affective valence (pleasure-displeasure) during exercise (Ekkekakis et al., 2010), and alpha of 0.05, indicated that 24 participants were required to reach 80% statistical power. Participants were recruited via (a) invitations e-mailed to all faculty, staff, and students of a large university in the Midwestern United States and (b) fliers posted throughout the community and campus, distributed at local super-markets, and inserted into the local Sunday newspaper.

Our goal was to evaluate the potential of HIIE/AIT as an exercise intervention among women with obesity exercising in unsupervised settings rather than under medical supervision. Thus, we targeted recruitment to asymptomatic participants with no more than two cardiovascular risk factors (i.e., obesity and sedentary lifestyle) and, therefore, no more than "moderate" risk (ACSM, 2014). Specifically, the inclusion criteria were (a) age of 18–54 years, (b) obesity (BMI $\geq$ 30 $kg \cdot m^{-2}$), (c) fewer than 30 min of moderate-intensity physical activity per day on most days of the week, based on responses to a 7-day physical activity recall interview, (d) no reported change in physical activity habits over the past 6 months, (e) a medical examination in the last 12 months that revealed no contraindications to vigorous exercise, (f) "apparently healthy" status determined by negative responses to all questions on the Physical Activity Readiness Questionnaire (Thomas, Reading, & Shephard, 1992), and (g) no current injuries or ailments. Exclusion criteria were smoking, hypertension, dyslipidemia, impaired fasting glucose, and use of any medication that could influence cardiovascular or metabolic responses to exercise, consistent with the risk stratification criteria specified by ACSM (2014).

Of 488 women who expressed interest, 38 met eligibility criteria. Of those, 7 did not schedule or attend their first session and 1 had a change in health status prior to enrollment that prevented participation. Of the 30 individuals enrolled, 6 dropped out due to the following reasons: injury unrelated to the study (n = 2); discomfort from the face mask (n = 2); personal reasons (n = 1); inability to complete the HIIE/AIT session (n = 1). Thus, 24 women were included in the analyses (see Table 1 for demographic and anthropometric characteristics).

5.2. Measures

5.2.1. Affective valence

The core affective dimension of affective valence (i.e., pleasure-displeasure) was designated the primary outcome variable. It was assessed with the Feeling Scale (FS; Hardy & Rejeski, 1989). The FS

Table 1
Descriptive statistics (*M* ± *SD*) for demographic, anthropometric, and physiological characteristics of the participants (*N* = 24).

	M ± *SD*
Age (years)	39.25 ± 11.23
Age Range (years)	19–53
Height (cm)	164.15 ± 7.19
Body Mass (kg)	94.20 ± 12.81
Body Fat (%)	44.00 ± 4.27
Body Mass Index ($kg \cdot m^{-2}$)	34.96 ± 4.46
Obesity Class I, II, III (n_I, n_{II}, n_{III})	11, 11, 2
Systolic Blood Pressure (mmHg)[a]	127.06 ± 12.77
Diastolic Blood Pressure (mmHg)[a]	79.42 ± 9.80
Baseline Heart Rate ($beats \cdot min^{-1}$)[a]	76.21 ± 10.66
VO_2peak ($L \cdot min^{-1}$)	1.77 ± 0.31
VO_2peak ($mL \cdot kg^{-1} \cdot min^{-1}$)	19.05 ± 3.67
Ventilatory Threshold ($L \cdot min^{-1}$)	1.08 ± 0.16
Ventilatory Threshold ($ml \cdot kg^{-1} \cdot min^{-1}$)	11.64 ± 2.12
Ventilatory Threshold (%VO_2peak)	61.57 ± 6.24

[a] Average of two measurements, prior to the HIIE/AIT and MICE bouts.

is an 11-point, single-item, bipolar rating scale commonly used for the assessment of affective responses during exercise. The scale ranges from −5 to +5. Anchors are provided at zero ("Neutral") and at all odd integers, ranging from "Very Good" (+5) to "Very Bad" (−5).

5.2.2. Enjoyment

Post-exercise enjoyment was designated a secondary outcome. It was assessed with the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991). The PACES consists of 18 semantic-differential items, with the opposites separated by a 7-point scale (e.g., 1: "I enjoy it"; 7: "I hate it"). Respondents are instructed to "rate how [they] feel at the moment about the physical activity [they] have been doing." Validation studies have shown a negative correlation with boredom and a significant prediction of choice between different activities (Kendzierski & DeCarlo, 1991). In the present study, the internal consistency of the questionnaire was high (Cronbach's alpha coefficient of 0.98 and 0.97 after MICE and HIIE/AIT, respectively).

5.2.3. Perceived exertion

The perception of exertion during exercise was another secondary outcome. It was assessed with the extensively validated Rating of Perceived Exertion (RPE; Borg, 1998), a 15-point scale ranging from 6 ("No exertion at all") to 20 ("Maximal exertion").

5.2.4. Descriptive assessments

Additional anthropometric and physiological assessments were carried out to characterize the sample and provide manipulation checks. Specifically, body mass and body composition were measured with a bioelectrical impedance analyzer with integrated electronic scale (model BF-626, Tanita, Tokyo, Japan). Stature was measured with a wall-mounted stadiometer. Oxygen uptake (VO_2) was measured with a metabolic cart (model TrueOne 2400, ParvoMedics, Salt Lake City, UT, USA), calibrated before each use.

5.3. Procedures

5.3.1. Experimental design

The study included three sessions of stationary recumbent cycling, a non-weight-bearing modality appropriate for adults with obesity: (a) an incremental test to volitional termination, to determine VO_{2peak} and ventilatory threshold (VT), (b) a session of HIIE/AIT, and (c) an isocaloric session of MICE, the latter two performed in computer-determined random and counterbalanced order.

5.3.2. Incremental exercise test

The first session included a familiarization period, intended to make participants feel comfortable in the laboratory environment and give them an opportunity to ask questions. Additionally, all participants read and signed an informed consent document, approved by the Institutional Review Board, in which the purpose of the study was described generically as "investigation of physiological and psychological responses to exercise." The participants were then fitted with a nose-and-mouth breathing face mask (model 8920/30, Hans Rudolph, Kansas City, MO, USA), equipped with an ultralow-resistance one-way valve (model 2700, Hans Rudolph). A gel sealant (model 7701, Hans Rudolph) was applied to the face mask to prevent air leaks. The exercise test was performed on a recumbent cycle ergometer (Corival Recumbent, Lode BV, Groningen, Netherlands) equipped with a wide, well-cushioned seat. Participants began cycling against a workload of 20 W for 3 min, followed by a 10 $W \cdot min^{-1}$ ramp until volitional termination. The highest 60-s average of VO_2 was designated VO_{2peak}.

5.3.3. VT determination

Gas exchange data were analyzed offline to determine the VT, using the three-method procedure proposed by Gaskill et al. (2001) and computerized by Ekkekakis, Lind, Hall, and Petruzzello (2008). The three methods included (a) the V-slope, based on a change in slope in the relationship between VCO_2 and VO_2, (b) the method of ventilatory equivalents, based on a rise in V_E/VO_2 without a concurrent rise in V_E/VCO_2, and (c) the method of excess CO_2, based on an increase in excess CO_2 from steady state. All data were converted to 20-s averages before analysis to reduce noise. Three experienced investigators analyzed the data independently. Determination of the VT required agreement between at least two of the three.

5.3.4. Workload determination

Energy expenditure is a central consideration in exercise interventions for adults with obesity. Although it has been suggested that the higher intensity of HIIE should raise excess post-exercise oxygen consumption and, thus, result in total 24-h energy expenditure (TEE) matching that associated with MICE, the increase in TEE resulting from bouts of HIIE may be small (e.g., ~10%, Sevits et al., 2013). Consequently, it remains unclear whether HIIE can raise TEE to the same extent as MICE (Hazell, Olver, Hamilton, & Lemon, 2012; Kelly, King, Goerlach, & Nimmo, 2013; Skelly et al., 2014). Thus, given the focus of the present study on obesity, the bouts of HIIE/AIT and MICE were designed to be isocaloric, consistent with other studies of participants with obesity and the metabolic syndrome (Martins et al., 2016; Tjønna et al., 2008).

Equating caloric expenditure was accomplished with extensive pilot-testing, taking into account several competing considerations and addressing the methodological issues identified in the introduction. Specifically: (a) the session of MICE had to last ~30 min (as per physical activity recommendations; Haskell et al., 2007) and be performed at an intensity that would allow the low-active participants to complete the session without stopping, (b) the high-intensity intervals had to reach intensities consistent with HIIT (~90% VO_{2peak}), (c) the duration of the high-intensity intervals had to be tolerable for four repetitions, (d) the intensity of the HIIE active-recovery periods had to be low enough to allow participants sufficient recovery before the next high-intensity interval and, at the same time, high enough to make a substantial contribution to the overall energy expenditure of the session, and (e) the HIIT session had to be shorter than MICE.

Based on evidence on the relation between exercise intensity and pleasure-displeasure, the intensities were set in relation to the VT (Ekkekakis et al., 2011). Specifically, the session of MICE consisted of (a) 3-min warm-up (20 Watts), (b) 25 min of cycling at 90% of the Watts corresponding to the VT (to attenuate the slow component of VO_2 and reduce drift), and (c) 5-min cool-down (20 Watts). The session of HIIT consisted of (a) 3-min warm-up (20 Watts), (b) alternation between four 3-min intervals of cycling at 115% of the Watts corresponding to the VT and four 2-min periods of active recovery at 85% of the Watts corresponding to the VT (total of 20 min), and (c) 5-min cool-down (20 Watts).

5.3.5. Outcome assessment protocol

The self-report rating scales were kept out of the field of vision during exercise and were presented (on laminated posters) only at predetermined intervals. Participants indicated their choices by pointing to a number and the researcher confirmed their choices by reading the number in a neutral tone of voice. During the HIIE/AIT bout, the FS and RPE were administered (in random order, to prevent systematic variance transfer) during the last 15 s of each high-intensity and active-recovery period (a total of 8 times, at min 2:00, 5:00, 7:00, 10:00, 12:00, 15:00, 17:00, 20:00). During the MICE bout, the FS and RPE were administered (also in randomized order) in the last 15 s of each 2:30-min period (a total of 10 times, at min 2:30, 5:00, 7:30, 10:00, 12:30, 15:00, 17:30, 20:00, 22:30, 25:00). In order to compare responses at equivalent time points despite the different durations of the HIIE/AIT and MICE bouts, the 10 data points from the MICE bout were divided in two sets of 5 and a second-degree polynomial regression was fitted to each segment (for each participant). The regression parameters were then used to estimate the FS and RPE values at the following eight percentages of bout duration (matching the assessment time points during the HIIE/AIT bout): 10%, 25%, 35%, 50%, 60%, 75%, 85%, and 100%. Additionally, the FS was administered immediately prior to each exercise bout, immediately after the bout, immediately after the cool-down, and 10, 20, and 30 min after exercise. The PACES was administered immediately after the cool-down in both conditions.

5.3.6. Statistical analyses

Data were analyzed with condition-by-time repeated-measures analyses of variance (ANOVAs). When the sphericity assumption was violated, the Greenhouse-Geisser correction was applied to the degrees of freedom. Significant interactions were followed by Bonferroni-corrected pairwise comparisons.

6. Results

6.1. Manipulation check

A comparison of the caloric expenditures of the HIIE/AIT (M = 197 kcal) and MICE (M = 203 kcal) sessions was non-significant, t (23) = −1.33, p = 0.198, d = −0.22. As shown in Fig. 1, during the HIIE/AIT bout, %VO_{2peak} averaged 90.12% ± 12.96% during the high-intensity intervals (where ≥ 91% VO_{2max} is considered "near maximal to maximal"; ACSM, 2014, p. 165) and 64.92% ± 11.12% during the periods of active recovery (where 64% VO_{2max} is the upper boundary of "moderate" intensity). The overall average was 77.52% ± 11.16%. During the MICE bout, %VO_{2peak} was 66.11% ± 10.04%, with a drift from 61.59% ± 12.05% at 2:30 to 69.57% ± 13.58% at 25:00. During HIIE/AIT, %VO_2 at VT averaged 146.21% ± 13.14% during the high-intensity intervals and 105.37% ± 14.57% during the periods of active recovery. The overall average was 125.79% ± 11.73%. During MICE, %VO_2 at VT averaged 109.66% ± 19.10%, with a drift from 100.18% ± 17.61% at 2:30 to 113.69% ± 23.56% at 25:00.

6.2. Affective valence

A 2 (Conditions) by 9 (Time points: pre, 10%, 25%, 35%, 50%, 60%, 75%, 85%, 100% of bout duration) repeated-measures ANOVA on FS showed a main effect of Condition, $F(1, 23) = 14.42$, $p < 0.05$, $\eta^2 = 0.39$, a main effect of Time, $F(2.66, 61.11) = 34.92$, $p < 0.001$, $\eta^2 = 0.60$, and a Condition by Time interaction, $F(3.29, 75.68) = 8.48$, $p < 0.001$, $\eta^2 = 0.27$. Post-hoc tests showed FS to be significantly lower during HIIE/AIT than MICE at the end of each high-intensity interval, 25% (d = −0.78), 50% (d = −0.95), 75% (d = −0.76), and 100% (d = −0.69) of bout duration. FS ratings declined during the bouts in both conditions but the decrease was larger during HIIE/AIT (−3.46 ± 2.04 units) than MICE (−2.25 ± 1.62 units), t (23) = 2.37, p = 0.026. Specifically, during MICE, the decrease from baseline was significant ($p < 0.0014$, after Bonferroni correction) at 60% (d = 0.84), 75% (d = 1.01), 85% (d = 1.18), and 100% (d = 1.43), whereas, during HIIE/AIT, the decrease was significant at 25% (d = 1.28), 35% (d = 0.92), 50% (d = 1.56), 60% (d = 1.26), 75% (d = 1.61), 85% (d = 1.26), and 100% (d = 1.92). At the final assessment, FS ratings averaged slightly below zero in the HIIE/AIT condition (−0.04 ± 1.94, where 0 is "neutral" and −1 is "fairly bad") but were still positive in MICE (1.13 ± 1.34, where 1 is "fairly good"). The conditions did not differ before or after the bouts. These data are illustrated in Fig. 2, panel a.

6.3. Enjoyment

A paired t-test on PACES scores showed a significant difference between conditions, t (23) = −2.14, p = 0.04, d = −0.38, with higher scores after MICE (90.79 ± 22.60) than after HIIE/AIT (82.25 ± 21.76).

6.4. Perceived exertion

A 2 (Conditions) by 8 (Time points: 10%, 25%, 35%, 50%, 60%, 75%, 85%, 100% of bout duration) repeated-measures ANOVA on RPE showed a main effect of Condition, $F(1, 23) = 6.24$, p < 0.001, $\eta^2 = 0.21$, a main effect of Time, $F(3.32, 76.37) = 71.34$, $p < 0.001$, $\eta^2 = 0.76$, and a Condition by Time interaction, $F(3.4, 78.05) = 34.25$, $p < 0.001$, $\eta^2 = 0.60$. Post-hoc tests showed RPE to be significantly higher during MICE at 10% (d = −0.66) and during HIIE/AIT at the end of each high-intensity interval, namely 25% (d = 1.41), 50% (d = 1.37), 75% (d = 1.17), and 100% (d = 1.40) of bout duration. Compared to 10%, RPE increased significantly ($p < 0.0018$, after Bonferroni correction) at each time point during MICE, from 25% (d = −0.39) to 100% (d = −1.08). While the increases from 10% during HIIE/AIT across the recovery periods were of similar magnitude to those observed during MICE, from 35% (d = −0.71) to 85% (d = −1.15), the increases during the high-intensity intervals were much larger, from 25% (d = −2.27) to 100% (d = −3.25). At the final assessment, the average RPE was 15.21 ± 1.79 in HIIE/AIT

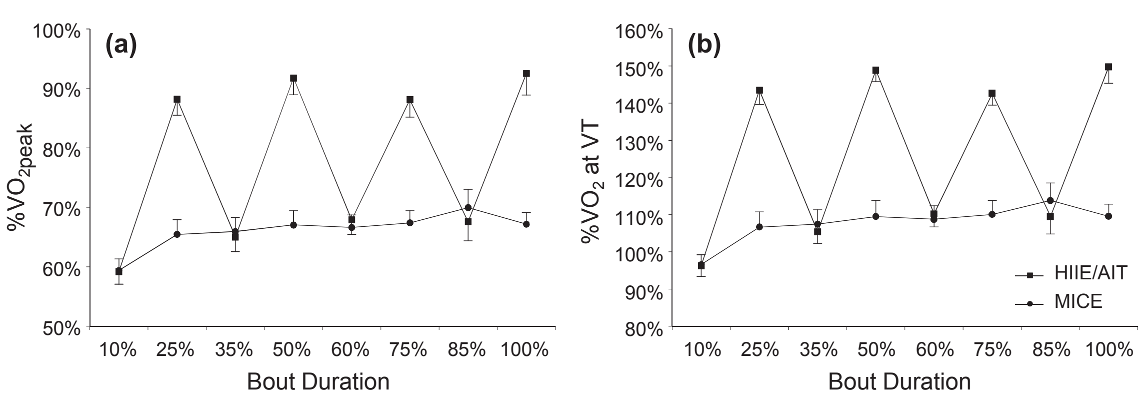

Fig. 1. Percentages of peak oxygen uptake (VO_2peak, panel a) and the oxygen uptake corresponding to the ventilatory threshold (VO_2 at VT, panel b) achieved during the HIIE/AIT and MICE bouts.

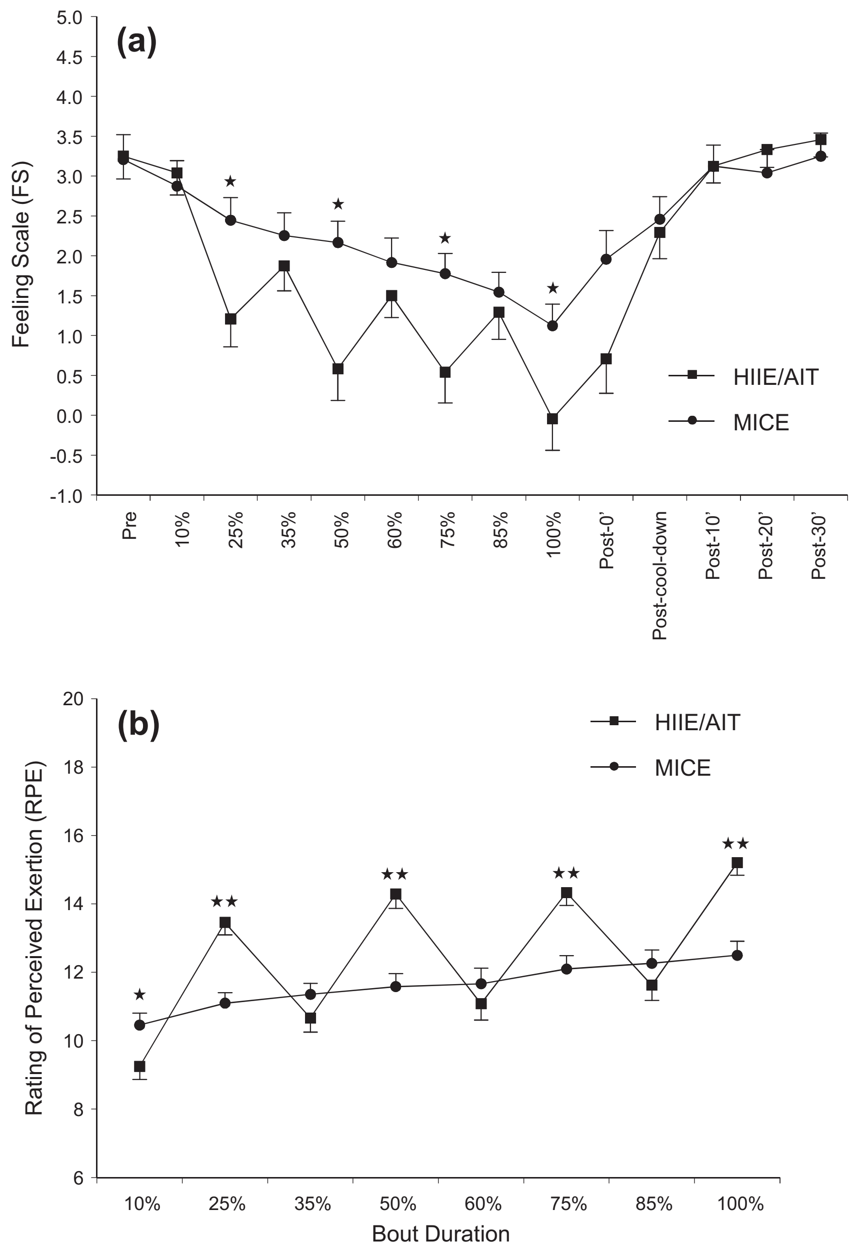

Fig. 2. Feeling Scale scores (FS, panel a) and ratings of perceived exertion (RPE, panel b) in response to the HIIE/AIT and MICE bouts. Note: For FS, *$p < 0.0055$ (for the comparison between conditions after Bonferroni adjustment). For RPE, *$p < 0.00625$ (for the comparison between conditions after Bonferroni adjustment); **$p < 0.001$.

(where 15 is "hard/heavy") compared to 12.50 ± 2.00 in MICE (where 11 is "light" and 13 is "somewhat hard"). These data are illustrated in Fig. 2, panel b.

7. Discussion

In the contemporary exercise-science, medical, and public-health literatures, HIIE is widely described as a promising approach to exercise prescription that can accelerate the accrual of fitness and health benefits while also circumventing the primary perceived barrier to exercise participation, namely lack of time. However, since most exercise-induced adaptations are quickly reversible following nonadherence or dropout, the success of this method in the realm of public health hinges on whether it can be shown to be not only effective and safe but also appealing, tolerable, and sustainable in the long run. In anticipation of pragmatic trials with adequate post-intervention follow-ups that can evaluate adherence, research has focused on how the pleasure and enjoyment responses to HIIE compare to those resulting from traditional MICE. The purpose of the present study was to address this question by focusing on women with obesity, a growing segment of the adult population characterized by alarmingly low levels of physical activity.

The results suggest that, in the present sample, and with the specific HIIE/AIT and MICE protocols tested in this study, the HIIE/AIT bout was experienced as significantly harder, less pleasant, and less enjoyable than MICE. While the women also reported increasing levels of perceived exertion and diminishing levels of pleasure during MICE, the slopes of change over time were steeper during HIIE/AIT than MICE, leading to significant and meaningful condition by time interactions in both FS ($\eta^2 = 0.27$) and RPE ($\eta^2 = 0.60$).

The mean FS score during the bout of MICE was 2.00 ± 1.22, whereas the mean score during HIIE/AIT was 1.25 ± 1.47, resulting in a 0.75-unit difference and a “medium” effect ($d = 0.56$). During HIIE, however, focusing on the average rating may be misleading. Although the ratings during the periods of active recovery (1.93 ± 1.29) did not differ from those during MICE ($d = 0.06$), ratings during the high-intensity intervals (0.57 ± 1.78) showed a 1.43-unit difference or a “large” effect ($d = 0.94$). Based on evidence on the association between during-exercise affective valence and physical activity behavior, these differences are likely consequential. Prospective studies with healthy low-active adults (18–65 years, mean BMI 28 $kg \cdot m^{-2}$) have shown that a 1-unit difference in FS ratings during exercise can translate to 38–41 min (Williams et al., 2008) or 15–29 min of additional at-least moderate-intensity physical activity per week (Williams, Dunsiger, Jennings, & Marcus, 2012). While FS scores after the HIIE/AIT and MICE bouts did not differ, the evidence suggests that post-exercise affective valence is not significantly associated with physical activity (Ekkekakis & Dafermos, 2012; Rhodes & Kates, 2015).

The difference in post-exercise enjoyment approached a “medium” effect ($d = -0.38$). A meta-analysis of 45 studies using semantic-differential measures of enjoyment, including the PACES, yielded an average correlation of $r = 0.44$ with physical activity behavior. This approximates a “large” effect size (i.e., $r = 0.50$), making enjoyment the strongest known correlate of physical activity (Rhodes et al., 2009).

Although a robust difference in RPE between HIIE/AIT and MICE was to be expected, it is noteworthy that the difference between the average RPE during MICE (12.29 ± 2.87) and that during the high-intensity intervals of HIIE/AIT (14.32 ± 1.73) was 2.03 units, representing a “large” effect ($d = -0.86$). In a previous study of women with obesity who had undergone an exercise weight-loss intervention, RPE during a bout of walking was associated with reduced physical activity and increased weight regain one year after the intervention (each 0.5-unit increase in RPE was associated with a 1-kg weight regain; Brock et al., 2010).

A fuller understanding of the possible implications of the observed differences in affective valence and enjoyment for physical activity behavior requires placing them in the context of previous research on behavioral decision making. Studies on painful medical procedures and other unpleasant stimuli has demonstrated that the retrospective evaluation of such episodes does not reflect either the total or the average level of pleasure-displeasure experienced during the episodes. Instead, research has shown that, while the duration of the episode appears to be of minimal importance (Fredrickson & Kahneman, 1993), three features of the affective experience are most consequential: (a) the magnitude of the (positive or negative) affective peak(s), (b) the slope (rate of change) of affect during the episode, and (c) the affect at the end of the episode (Ariely, 1998; Ariely & Carmon, 2000; Ariely & Zauberman, 2003; Redelmeier & Kahneman, 1996). Assuming that post-exercise enjoyment represents a global evaluation of the preceding bout, it is noteworthy that the difference in PACES scores between HIIE/AIT and MICE were significantly correlated with the difference in negative peaks in FS ratings ($r = 0.50$, $p = 0.013$), the difference in FS slopes ($r = 0.58$, $p = 0.003$), the difference in FS ratings just before the end of the bouts ($r = 0.46$, $p = 0.025$), and the difference in FS ratings immediately after the bouts ($r = 0.59$, $p = 0.002$). In each of these important features of the affective experience of exercise, the HIIE/AIT bout yielded more negative results than the MICE bout, namely a larger negative peak (3.63 ± 2.03 vs 2.54 ± 1.50, $t = 2.85$, $p = 0.009$, $d = 0.61$), a steeper negative slope over time (−0.14 ± 0.10 vs −0.07 ± 0.06, $t = -3.18$, $p = 0.004$, $d = -0.82$), lower FS ratings just before the end of the bout (−0.04 ± 1.94 vs 1.13 ± 1.33, $t = 3.04$, $p = 0.006$, $d = 0.70$), and lower FS ratings immediately after the bout (0.71 ± 2.12 vs 1.96 ± 1.76, $t = 2.90$, $p = 0.008$, $d = 0.64$).

The challenge of offering adults with obesity exercise experiences that are pleasant (or at least not unpleasant) has been discussed in the literature (Ekkekakis et al., 2016, 2010; Mattsson, Larsson, & Rössner, 1997). Consistent with previous studies of women with obesity (Ekkekakis et al., 2010; Hulens, Vansant, Lysens, Claessens, & Muls, 2001), the peak aerobic capacity of the participants in the present sample, expressed relative to their body mass, was “very poor” compared to age-group norms (i.e., bottom 5%; American College of Sports Medicine, 2014). Just as importantly, their VT occurred, on average, at less than 3.5 metabolic equivalent units (METs). To put this figure in perspective, examples of activities corresponding to 3.5 METs and, therefore, exceeding the average VT of the women in this sample, include such casual everyday activities as walking at 2.8–3.2 miles per hour on a level, firm surface without carrying extra weight, washing the car, cleaning windows, preparing food, using a leaf blower, picking fruit off trees, and fishing from a standing position. These examples illustrate the challenge faced by exercise professionals, and adults with obesity themselves, in finding exercise or physical activity opportunities likely to yield pleasant (or at least non-unpleasant) experiences. Moreover, the present data show that, while the workload for the MICE bout was set below (90%) the Watts corresponding to VT, the participants could not maintain %VO_2-at-VT steady, resulting in a drift to 113.69% within 25 min. Thus, while the bout started within the “moderate” range of intensity (61.59% VO_{2peak}), it ended at the low end of the “vigorous” range (69.57% VO_{2peak}) in terms of VO_2, though not in terms of RPE (12.50). Given the sensitivity of pleasure-displeasure ratings to intensities exceeding the VT (Ekkekakis et al., 2011), the gradual decline of FS scores during MICE (up to −2.25 units from baseline) is cause for concern but in line with previous evidence (da Silva et al., 2011; Ekkekakis et al., 2010).

In evaluating the data reported herein, readers must take into account the limitations of the study. Neither the sample of participants nor the methods described here can be considered representative of all “women with obesity” or “HIIE” in general. The participants represent a select sample of adult women who, despite their obesity and low activity levels, were free of chronic diseases and medication. Women with obesity encountered in clinical practice may have more than two risk factors and, thus, may exhibit even less tolerance to both HIIE and MICE. Likewise, given the abundance of possible HIIE protocols, the protocol used in the present study should be considered as only one of a multitude of possible options. Other combinations of intervals and recovery periods may yield different results. In particular, if keeping energy expenditure equal to MICE is not required, so-called “low-volume” HIIE, with shorter high-intensity intervals and longer and/or lower-intensity recovery periods, warrants attention. Future studies should also expand the scope of the present investigation to samples of men, adults with different health and fitness profiles, and, importantly, intervention programs with long-term monitoring of adherence and dropout patterns.

In conclusion, in a sample of low-active women with obesity, a bout of HIIE/AIT was rated as less pleasant and less enjoyable than an isocaloric bout of MICE. These results underscore the importance of considering the appeal and sustainability of high-intensity exercise.

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