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Age-specific affective responses and self-efficacy to acute high-intensity interval training and continuous exercise in insufficiently active young and middle-aged men

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ABSTRACT

Background/objective: High-intensity interval training (HIIT) has been recognized as an emerging trend in public health promotion, but its age-specific differences in psycho-perceptual responses have yet to be investigated. This study compared the psycho-perceptual responses after a single session of HIIT versus moderate-intensity continuous exercise (MICE) and vigorous-intensity continuous exercise (VICE) in twelve young and twelve middle-aged insufficiently active males respectively.

Methods: Using a randomized cross-over design, participants undertook three main trials consisting of: HIIT (10 x 1-min run at 100% VO_{2max} interspersed with 1-min active recovery), MICE (40-min run at 65% VO_{2max}) and VICE (20-min run at 80% VO_{2max}). Affective responses, self-efficacy and exercise preference were assessed for each trial.

Results: Both HIIT and VICE showed more positive in-task affective responses than MICE in young adults, while middle-aged adults reported more positive responses in both HIIT and MICE than in VICE. However, middle-aged adults displayed significantly lower exercise task self-efficacy scores towards HIIT (42.7 ± 25.3) and VICE (49.2 ± 23.9) than MICE (63.4 ± 18.3 , both $P < 0.01$). Additionally, only 17% of participants in the middle-aged group reported a preference to engage in HIIT as opposed to either MICE (50%) and VICE (33%).

Conclusion: Our finding revealed distinct affective and self-efficacy responses to acute HIIT versus both MICE and VICE in the two age groups which assists in our understanding of how individuals in various age populations perceive HIIT. This information will assist in the design and implementation of effective exercise programs for public health, especially for insufficiently active individuals.

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Introduction

Physical inactivity has been identified as a global pandemic and increases the risk of non-communicable diseases (NCD's) including cardiovascular diseases, cancer and diabetes.¹ In an attempt to reduce premature mortality from NCD's, the World Health Organization (WHO) has set a global target to decrease physical

inactivity by 10% by 2025.¹ Current physical activity (PA) guidelines recommend that individuals accumulate at least 150-min of moderate-intensity continuous exercise (MICE), 75-min of vigorous-intensity continuous exercise (VICE), or a combination of both per week.² Despite the well-documented health benefits associated with regular PA, epidemiological evidence suggests low worldwide compliance to these guidelines² with "lack of time" the most commonly cited barrier to exercise participation.³ An effective exercise protocol with minimal time commitment is therefore warranted to increase PA among the general population.

High-intensity interval training (HIIT), also commonly referred to as "high-intensity interval exercise" (HIIE), has been recognized as an emerging trend in public health promotion.⁴ Historically used

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as a training method by athletes, its recent popularity among the general population is demonstrated in its consistently high rankings in the American College of Sports Medicine Annual Fitness Trend over the past 5 years.⁵ HIIT typically involves repeated bouts of high-intensity workout, interspersed with active or inactive recovery periods and compared to the traditional continuous training approach, involves a substantially reduced training volume and lower time commitment.⁶ For instance, one of the most common models of low volume HIIT (20 min), utilizing 10 intervals of 60 s conducted at maximal/near maximal aerobic capacity interspersed with 60 s recovery at very low intensities, has been shown to be both feasible and efficacious in improving cardiometabolic health in sedentary adults⁷ and in individuals with type 2 diabetes.⁸

Despite the well-documented physiological health benefits of HIIT, research investigating the psycho-perceptual responses to this type of exercise is still in an early stage. Since psycho-perceptual responses can have significant behavioral implications,⁹ a typical public health concern is how the general population, particularly insufficiently active and less fit individuals, perceive HIIT and whether they can comply with it in the long term.¹⁰ Findings to date have been conflicting with some studies reporting positive psycho-perceptions to a single bout of HIIT compared to MICE^{11–13} and VICE,¹⁴ while others reported contradictory findings.¹⁵ In addition, to the best of our knowledge, relatively few studies have been conducted in insufficiently active adults,¹⁴ a primary target of PA health promotion initiatives.¹⁰ Furthermore, the majority of research to date has been conducted in a single age or heterogeneous age group. The age-specific differences in psycho-perceptual responses to HIIT have yet to be investigated. Age has been shown to be an independent predictor to exercise behavior.² Advancing age is associated with a decline in physical capacity which could in turn affect psycho-perceptual responses towards vigorous exercise.¹⁶ Hence, differentiating how individuals in various age populations perceive HIIT is of paramount importance for the design and implementation of effective exercise programs by fitness professionals in public health. The purpose of the present study was to evaluate the age-specific psycho-perceptual responses to a single bout of HIIT versus both MICE and VICE in young and middle-aged insufficiently active adults respectively. It was hypothesized that the psycho-perceptual responses to the trials would differ between the two groups.

Methods

Participants

Twelve young (aged 18–25 yr) and twelve middle-aged (aged 40–59 yr) healthy, insufficiently active males were recruited through advertisements in the university, partner institutions, community centers, and online to participate in the study (see Table 1 for participant demographic characteristics). Inclusion

Table 1
Demographic characteristics of participants.

Variable	Young (n = 12)	Middle-aged (n = 12)
Age (yr)	24.3 ± 1.7**	46.8 ± 7.5
Height (cm)	168.3 ± 5.6	168.4 ± 6.8
Weight (kg)	66.8 ± 15.0	66.4 ± 8.1
Body fat (%)	19.5 ± 6.9	19.9 ± 3.8
BMI (kg m ⁻²)	23.5 ± 4.6	23.4 ± 2.1
VO _{2max} (mL min ⁻¹ kg ⁻¹)	44.9 ± 6.6*	39.5 ± 5.6

Significantly different between groups based on independent sample t-tests:
**P < 0.01; *P < 0.05.

BMI: Body mass index; VO_{2max}: Maximal oxygen uptake.

criteria included engaging in less than 150-min of moderate PA or less than 75-min of vigorous PA per week for more than three months,¹⁷ as assessed by the International Physical Activity Questionnaire (IPAQ).¹⁸ Exclusion criteria included severe high blood pressure ($\geq 180/100$ mmHg), on medication for chronic disease, myocardial infarction, uncompensated heart failure, or unstable angina pectoris over the previous four weeks, as suggested by the current exercise prescription guidelines.¹⁷ The sample size is a reflection of related research¹³ and is based on an anticipated small effect size (i.e., ES = 0.4), with an $\alpha = 0.05$ and a $\beta = 0.20$ (G*Power version 3.0.10). A written informed consent was provided to participants with a detailed explanation of the aim, procedure, benefits and potential risks of the study. The study procedures were submitted and granted by The Ethics Committee at The Chinese University of Hong Kong.

Preliminary testing

During the first laboratory visit, participants' height was measured using a stadiometer (Seca, Leicester). Body weight, body mass index (BMI) and body fat percentage were determined by a body composition analyzer (MC-780MA, Tanita, Japan). Maximal oxygen uptake (VO_{2max}) was determined by a continuous, incremental, graded uphill treadmill running test to volitional exhaustion based on the protocol demonstrated previously by our laboratory.¹⁹ VO_{2max} was considered to be attained when the following standardized criteria were met: (1) a respiratory exchange ratio of greater than or equal to 1.10; (2) failure of heart rate (HR) to increase with increases in workload.¹⁷ HR was recorded continuously during the test using HR telemetry (H7 Sensor, Polar, Finland). Data collected from the VO_{2max} test was used to determine the speed required for the experimental trials.

Familiarization trial

The second visit to the laboratory was a familiarization trial to enable the participants to familiarize with the experimental procedures and to confirm whether the individually prescribed running intensity met the designated percentage VO_{2max} thresholds of each protocol.^{14,20} Participants completed the familiarization trial one week after the VO_{2max} test. This trial required them to complete half of each protocol used in the main trials, with a 30-min rest between protocols. The protocol sequence for the familiarization trial was randomized.

Experimental trials

One week after the familiarization trial, participants completed one of the three experimental trials on a standardized treadmill (Pulsar 3p, h/p/cosmos, Germany) in a randomized and counter-balanced order. The HIIT protocol consisted of 10 bouts of 1-min run at 100% VO_{2max} separated by 1-min active recovery at 50% VO_{2max}. The total exercise trial time was 20-min in duration. The MICE protocol consisted of 40-min running at 65% VO_{2max}. The VICE protocol consisted of 20-min running at 80% VO_{2max}. The energy expenditure (EE) was estimated via indirect calorimetry assuming a non-protein respiratory exchange ratio.²¹ EE of HIIT and VICE were matched, whereas MICE was not (Table 2). It should be noted that the current methodological approach was adapted from a number of previous studies^{11,13,22} to reflect on the relative low-volume and time-efficient nature of HIIT and VICE as compared to the traditional high-volume and long-duration nature of MICE, providing greater real-life implications. HR was monitored continuously during the exercise using heart rate telemetry (H7 Sensor, Polar, Finland). All participants performed a 2-min warm up at 50%

Table 2
Mean physiological responses during HIIT, MICE and VICE.

	Young (n = 12)			Middle-aged (n = 12)		
	HIIT	VICE	MICE	HIIT	VICE	MICE
EE(kJ)	931 ± 78	932 ± 75	1437 ± 152*	907 ± 123	931 ± 135	1534 ± 180*
Mean HR (bpm)	170 ± 10 (W) 157 ± 12 (R)	162 ± 10	144 ± 12*	158 ± 9 (W) 146 ± 10 (R)	156 ± 9	139 ± 8*
BLa (mmol/L)						
Before	1.1 ± 0.2	1.2 ± 0.3	1.1 ± 0.3	1.2 ± 0.3	1.0 ± 0.2	1.1 ± 0.2
After	6.2 ± 0.6	5.9 ± 0.5	2.2 ± 0.2*	5.6 ± 0.6	5.6 ± 0.5	2.0 ± 0.2*

BLa: Blood lactate; EE: Energy expenditure; HIIT: High-intensity interval training; HR: Heart rate; MICE: Moderate-intensity continuous exercise; R: Rest period; VICE: Vigorous-intensity continuous exercise; W: Work period.

*P < 0.05 vs. MICE and VICE respectively.

VO_{2max} and a 2-min cool down at self-selected light intensity (determined in the first trial and kept constant for subsequent trials). No external stimuli (e.g. music, television and mobile devices) and verbal encouragement were given in all trials. The three trials were performed one week apart and each time participants arrived at the laboratory same time of the day (between 8:00 to 11:00 a.m.) to eliminate any circadian effects.

Dietary and exercise training control

Participants were requested to avoid strenuous exercise, caffeine and alcohol 24-hr before all experimental trials. They were also asked to report their past 24-hr food intake after completion of the first trial and then consume the same food the day before all subsequent trials.

Psycho-perceptual measurements

Affective responses

Affect is defined as an instinctive mood response that is elicited without significant thought,²³ measured using the Feeling Scale (FS).²⁴ The FS is a single-item, 11-point bipolar rating scale that indicates affective valence (pleasure and displeasure) and ranges from -5 (very bad) to +5 (very good). The FS has been employed for measuring affective responses in recent HIIT studies.^{14,20} Participants were asked to rate their baseline affective responses right before exercise (i.e., baseline). To assess in-task affect, the FS was also administered at 10 time points (i.e., 15%, 20%, 35%, 40%, 55%, 60%, 75%, 80%, 95% and 100% of exercise completed). Following a similar methodological approach used in previous studies,^{11,20} these time points were chosen to incorporate both interval and recovery periods during the HIIT protocol and were standardized across trials to account for the difference in duration.

Exercise task self-efficacy

Self-efficacy is the conviction and belief that one can successfully perform a given task.^{25,26} Participants' self-efficacy was assessed via a 5-item questionnaire²⁷ designed to determine their confidence to repeat each exercise trial. The questionnaire was presented to the participants at 1-hr post-exercise. The 5-items included the stem, "How confident are you that you can ... "perform (one to five) bout of exercise per week for the next 4 weeks that is just like the one you completed today?" Responses were scored as a percentage of 0% (Not at all) to 100% (Extremely confident) in 10% increments. The self-efficacy scale demonstrated good internal consistency (α 's = 0.9) in the present study.

Perceived exertion

Rating of perceived exertion (RPE) was assessed using the Borg Category-Ratio 10 Scale (CR-10).²⁸ The scale ranges from 0 to 10 with anchors ranging from "No exertion at all" (0) to "Maximal exertion" (10). Participants were asked to rate their exertion at baseline and at 10 in-task time points together with the affective response assessment (i.e., FS).

Exercise preference

At the end of the final exercise trial, participants were asked to indicate their exercise preference based on their experience of all three exercise trial. The question asked; "If it were entirely up to you, which of the three exercise trials (i.e., HIIT/VICE/MICE) you performed would you prefer most?" Responses were analyzed individually. This question was adapted from two previous studies.^{11,13}

Blood lactate concentration

Blood lactate concentration (BLa) was recorded before and immediately after exercise in all trials. Capillary blood samples were acquired from the fingertips with a portable analyzer (Lactate Plus, Nova Biomedical, Waltham, Massachusetts).

Statistical analysis

Data was presented as means ± SD, using SPSS for Windows (Version 20) for analysis. A series of two-way analyses of variance (ANOVA) with repeated measures was used to determine the main effect of exercise modes and time respectively, and their interaction for RPE, affective responses and BLa. In addition, a series of one-way ANOVA with repeated measures was conducted to examine self-efficacy. Post hoc pairwise comparisons were conducted using Least Significant Difference (LSD) corrections. Independent sample t-tests were used to compare the demographic characteristics of the participants in the two age groups. The significance level (*P*-value) was set at 0.05. Effect size (ES) were calculated using Cohen's *d* to indicate the magnitude of mean difference where appropriate.²⁹ Scores of 0.2, 0.5 and > 0.8 were considered small, moderate and large effect sizes respectively.

Results

Exercise intensity

All participants were able to complete all trials successfully. Table 2 summarizes the physiological responses to all trials. The total energy expenditure (EE) during exercise was significantly

different between HIIT and MICE, VICE and MICE (both $P < 0.001$, $ES \geq 2.0$; Table 2), while the EE in HIIT and VICE was matched. BLA was similar at baseline for all trials ($P > 0.05$), but was higher in HIIT and VICE (both $P < 0.05$, $ES \geq 2.0$) than MICE in both age groups immediately after exercise.

Affective responses

In the young adult group, the FS scores were higher at 95% and 100% of exercise completed in HIIT and VICE than in MICE (both $P < 0.05$, $ES \geq 0.4$), indicating a more positive affective response towards the end of exercise session. However, HIIT showed no difference with VICE at any time point ($P > 0.05$; Fig. 1a). In the middle-aged adult group, both HIIT and MICE reported higher FS scores from 40% of exercise completed onwards than VICE (both $P < 0.05$, $ES \geq 0.5$), suggesting a more positive affective response than VICE, while HIIT did not differ with MICE across the exercise session ($P > 0.05$; Fig. 1b).

Exercise task self-efficacy

No significant difference was observed in exercise task self-efficacy for all three exercise trials in the young adult group (HIIT: 44.1 ± 27.9 vs. VICE: 51.4 ± 25.3 vs. MICE: 45.1 ± 25.6 , all $P > 0.05$). Middle-aged adults displayed significantly lower exercise task self-efficacy scores towards HIIT (42.7 ± 25.3) and VICE (49.2 ± 23.9) than MICE (63.4 ± 18.3 , both $P < 0.01$, $ES \geq 0.6$) based upon pairwise comparison. No difference was found between HIIT and VICE ($P > 0.05$).

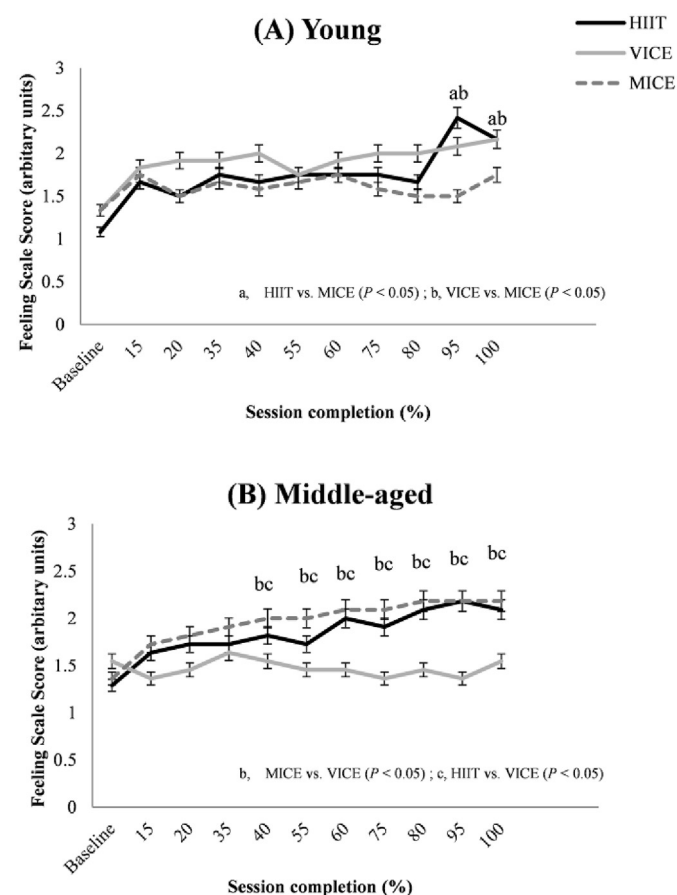


Fig. 1. In-task affective responses (Feeling Scale) (a) Young Adults and (b) Middle-aged adults.

Perceived exertion

Both age groups responded similarly. RPE increased significantly across the exercise session in all trials ($P < 0.01$ for both groups). HIIT and VICE induced significantly higher RPE than MICE ($P < 0.01$ for both groups, $ES \geq 2.0$). An interaction effect was also found ($P < 0.01$ for both groups), indicating the increase of RPE across time was more rapid in HIIT and VICE compared to MICE (Fig. 2a and b) regardless of age groups.

Exercise preference

Our results showed that 33% (4 out of 12) of the young adults preferred HIIT, 67% (8 out of 12) preferred VICE, while none chose MICE as their preference. 17% of participants (2 out of 12) in the middle-aged group reported a preference to engage in HIIT as opposed to either MICE (50%; 6 out of 12) and VICE (33%; 4 out of 12).

Discussion

Psycho-perceptual responses to exercise training have attracted significant attention over recent years. The findings of the present study suggest that the affective responses and self-efficacy to HIIT and continuous exercise (CE) differed among young and middle-

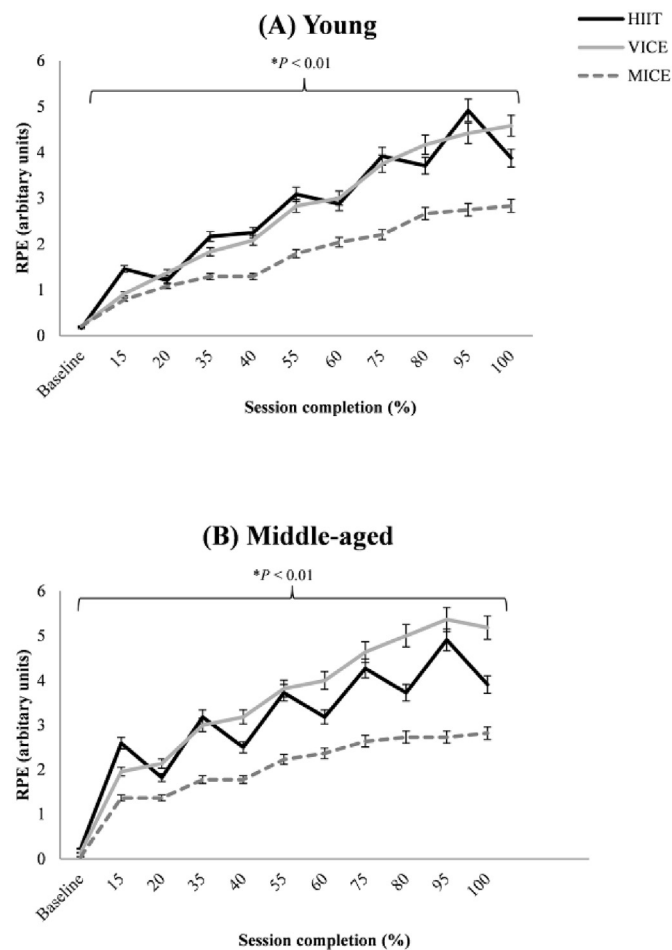


Fig. 2. Rating of perceived exertion (RPE) (a) Young Adults and (b) Middle-aged adults. *An interaction effect indicating that the increase across time was more rapid in HIIT and VICE vs. MICE.

aged adults. To the best of our knowledge, this is the first study to evaluate the psycho-perceptual responses in different age populations to HIIT and CE.

Affect, commonly measured by the FS, is an important determinant of exercise participation and adherence.³⁰ A one-unit increase in FS scores after a single session of exercise has been shown to be associated with an additional 38 min of PA per week at 6 months in sedentary individuals.³¹ The Dual-Mode Theory²³ suggests that both interoceptive (e.g., respiratory or muscular) cues and cognitive cues, such as self-efficacy, can jointly influence affective responses to exercise (i.e., the feeling of pleasure). The balance between these two determinants shifts as a function of exercise intensity. Cognitive cues predominate at intensities below the metabolic threshold and result in pleasurable feelings. Conversely, interoceptive cues are more dominant at intensities above the metabolic threshold (i.e., VT) and result in unpleasant feelings. Hence, exercise intensity that relies on the anaerobic metabolic pathway (i.e., vigorous exercise) can have short-term but substantially more negative effects on affect than exercise performed at a moderate intensity. In particular, vigorous CE has been proposed to induce greater feelings of displeasure³² and psychological distress,³³ which, in turn can reduce exercise participation and adherence.^{23,32} In the present study, RPE and BLA were significantly higher in HIIT and VICE than MICE in both age groups, suggesting that participants were exercising at an intensity close to, or even above their metabolic threshold. Based on the aforementioned Dual-Mode Theory, these two trials theoretically should elicit more negative affective responses than MICE, with an increasing reliance on anaerobic metabolism.³⁰ However, HIIT induced a more positive affective response than MICE in young adults and VICE in middle-aged adults. A possible explanation for our finding may be the fact that HIIT's built-in recovery periods can ease the displeasure experienced during workout periods by reducing boredom and developing a sense of accomplishment after each interval, which subsequently increases overall positive feelings.¹² This view is supported by Jung et al.¹¹ who reported that HIIT (1-min at 100% W_{peak} interspersed with 1-min 20% W_{peak} for 20 min) was more pleasurable than VICE (80% W_{peak} for 20 min) when assessed after the session in insufficiently active young and middle aged adults. Yet, HIIT appeared to be less pleasurable than MICE (40% W_{peak} for 40 min) performed in the same study. More recently, another study involving recreationally active participants¹³ aged between 18 and 49 years also reported that affect was lower in HIIT (eight 1-min bouts of cycling at 85% W_{peak} interspersed with 1-min 25% W_{peak}) than MICE (45% W_{peak} for 20 min). While these findings seem somewhat contradicting to our current result where the affect of HIIT was higher than MICE in the young adult group, it should be noted that the aforementioned two studies^{11,13} have been conducted in a relatively heterogeneous population encompassing both young and middle aged adults and do not differentiate between different age groups. Hence, we suggest that the inconsistency of findings could be at least partly attributed to a possible age-specific response as reported in our current study.

Our exercise preference result also showed an age-specific difference. All of the young adult participants preferred to engage in either HIIT (33%) or VICE (67%), but not MICE (0%). On the contrary, the middle-aged adults tended to favor MICE the most (50%), followed by VICE (33%) and HIIT (17%). Previous studies have generally suggested a stronger participant preference for HIIT in comparison to MICE,^{11,13} but no study has yet reported an overall greater preference for MICE or VICE over HIIT.⁹ Thus, to the best of our knowledge, the present study is the first to highlight that both MICE and VICE can be preferred to HIIT in insufficiently active participants when age is taken into account. This preference result is also

in line with the relatively positive affective responses observed for VICE in young adult groups and MICE in middle-aged adult groups.

Self-efficacy, the conviction and belief that one can successfully perform a given task^{25,26} has been demonstrated as an important predictor of adoption and maintenance of exercise behavior, especially in less physically active adults.²⁵ In the present study, middle-aged adults displayed significantly lower exercise task self-efficacy scores towards HIIT and VICE than MICE, while no significant difference was observed in the young adult group. Previous research has suggested a reciprocal relationship between self-efficacy and affective responses.¹¹ Relatively better affective responses for HIIT and MICE over VICE and higher self-efficacy for participating in HIIT and MICE than VICE has been reported among insufficiently active adults.¹¹ This relationship, however, was not evident in the current study and this may be partially explained by the demands of the exercise session. Self-efficacy has been found to be most strongly related to affect during vigorous exercise in young adults³⁴ and during moderate-intensity exercise in healthy older adults.³⁵ It is possible that the intensity of HIIT imposed in this investigation may have been perceived as overly challenging for insufficiently active middle-aged adults and thus may have weakened the strength of the self-efficacy-affect relationship. Advancing age is associated with a decline in aerobic and strength capacities and an increase in adiposity^{36,37} which negatively affects an individual's physiological functional capacity, defined as the ability to perform physical tasks of daily living.³⁷ In the present study, VO_{2max} was on average 13.9% lower in the middle-aged adults than the young adult group. One major exercise barrier for older adults is the perception that exercise will be tiring, causing concerns for their health and safety.¹⁶ It can be postulated that the insufficiently active middle-aged adults with low physiological functional capacity may have had lower exercise-related self-efficacy to partake in an acute bout of high intensity exercise thus providing a real barrier to future participation in HIIT. Nevertheless, it should be noted that the present study was an acute study and self-efficacy may change following a longer period of engagement in an exercise intervention. Giving older adults the opportunity to successfully complete high-intensity interval workouts may raise mastery expectations²⁶ and promote a sense of accomplishment, which could positively influence their perception of HIIT. Future research examining the long-term psycho-perceptual changes and adherence to HIIT in this population is warranted.

This study has several strengths including employing a within-subject, randomized cross-over design to investigate the psycho-perceptual responses to HIIT versus CE in two age groups respectively. In addition, the HIIT protocol employed in the current study encapsulated the low-volume and time-efficient nature of HIIT, which provide more real-life implications when compared to longer-duration moderate-intensity CE. Limitations of the study included a lack of direct comparison between the two age groups, as such inter-group comparison would require a much greater sample size than the existing within-subject design. The current findings on the age-specific responses should therefore be interpreted with caution. We do believe, however, that the current data can provide insight for future studies to use other statistical approaches to explore how different demographic populations respond psychologically to HIIT. In addition, only male participants were recruited in this study to avoid potential sex-related confounding factors and thus future studies comparing individuals of different sexes are warranted.

Conclusion

Distinct affective responses and self-efficacy to acute HIIT versus both MICE and VICE were observed in insufficiently active younger

and middle-aged male adults. Both HIIT and VICE showed more positive in-task affective responses than MICE in young adults, while middle-aged adults reported more positive responses in both HIIT and MICE than in VICE. However, middle-aged adults displayed significantly lower exercise task self-efficacy scores towards HIIT and VICE than MICE. Differentiating how individuals in various age populations perceive HIIT is of paramount importance for the design and implementation of effective exercise programs for public health. Further investigations on the long-term adherence to HIIT are warranted.

Conflicts of interest statement

The authors have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2018.09.002>.

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