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Original Research

Are Self-Selected Intervals as Effective as Fixed Intervals in Controlling Acute Responses in High-Intensity Interval Resistance Training?

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ABSTRACT

International Journal of Exercise Science 16(4): 1205-1215, 2023. Physical conditioning programs often apply high-intensity resistance training (HIRT), but there is a lack of research investigating the effects of using fixed or self-selected resting intervals between exercises on the performance, relative intensity, and affective perception during this modality of training. This study compared fixed versus self-selected rest intervals in HIRT sessions on cardiorespiratory responses, number of repetitions, and enjoyment perception in trained young men. Sixteen trained males (27.1 ± 3.9 years; 56.6 ± 7.5 mL.kg^{-1}.min^{-1}) performed HIRT circuits with 30-s and self-selected recovery interval. The duration of resting intervals was longer in HIRT performed with fixed than self-selected intervals (14.04 ± 5.82 s; $p < 0.0001$; ES = 3.2). Both sessions elicited similar relative HRR (79.4 ± 6.2 % *vs.* 81.6 ± 4.2 %; $p = 0.14$), VO_2R (43.0 ± 12.2% *vs.* 47.7 ± 9.6%; $p = 0.10$), and enjoyment reflected by scores in the PACES questionnaire (107.9 ± 15.1 *vs.* 109.2 ± 12.8; $p = 0.65$). The total number of repetitions (403.4 ± 45.5 *vs.* 353.1 ± 27.4; $p < 0.01$, ES = 1.3) and caloric expenditure (154.4 ± 28.6 kcal *vs.* 121.4 ± 21.6 kcal; $p < 0.001$, ES = 0.13) were greater in HIRT performed with fixed *vs.* self-selected intervals. In conclusion, HIRT performed with fixed and self-selected rest intervals elicited similar relative intensity and enjoyment perception. However, the number of repetitions and caloric expenditure were greater in sessions performed with fixed 30-s.

KEY WORDS: Circuit-based exercise, cardiorespiratory fitness, energy metabolism, exercise recovery, high-intensity interval training

INTRODUCTION

Interval training (IT) has been recommended for the development of cardiorespiratory fitness since it involves cycles of high intensity efforts above anaerobic threshold (32). A trend in IT has

been the use of low volume workouts, with emphasis on near maximal exertion (25, 38). High-Intensity Interval Training (HIIT) protocols are characterized by the application of *all-out* exercises, interspersed with short periods of recovery (active or passive) (13, 17). A key characteristic of this training is the relatively short total duration, usually no longer than 20 min (13, 17).

An interesting HIIT strategy is the application of circuits combining aerobic stimuli with resistance exercises, which is referred to as High-Intensity Resistance Training (HIRT). The advantage of this training modality is the potential improvement of both cardiorespiratory fitness and muscle strength (5, 6). Among the different training components, the role of rest intervals within HIIT is particularly important, since adequate high intensity cycles depend on adequate recovery – accordingly, rest intervals have been shown to affect the pattern of oxygen consumption (VO_2), heart rate (HR) and lactate production during this training modality (28, 29). Despite the proper manipulation of this variable is essential in any type of circuit, essential points that could assist in the physiological control during HIRT circuits have not yet clarified, especially with regard to the application of self-selected intervals.

A few studies have shown that self-selection of the interval between stimuli can be useful in maintaining high effort intensities, albeit they have applied interval protocols on cycle ergometer and treadmill (22, 27). It should be noted that some aspects from HIRT circuits do not allow us to extrapolate the results from studies carried out in running and cycling to HIRT. Among them, there is a plethora of combinations of exercises and movement patterns, which involve, for instance, pushing, pulling, crouching, and jumping, recruiting different muscle groups in the same exercise session (38, 39). In addition, different exercise orders and execution speeds can be chosen (4). Therefore, the sum of these aspects can affect the physiological and affective responses to exertion differently, in relation to HIIT performed in cyclical activities, such as pedaling and running.

In addition to physiological data, a variable that has been investigated in HIIT is the subjective enjoyment elicited by acute training bouts. Thum et al. (33) claimed that HIIT has challenging and motivating aspects that may promote greater satisfaction and enjoyment during exercise bouts. Aspects such as the shorter duration of training sessions as well as the dynamism of exercise routines might increase the enjoyment perception, in addition to promote adherence in novice or experienced individuals (14, 34). Nonetheless, we could not find prior research investigating the influence of fixed *vs*. self-selected rest intervals on the enjoyment perception in HIRT. Given these unclear questions, the present study aimed to compare the cardiorespiratory responses, energy expenditure, number of repetitions and enjoyment perception during acute HIRT performed with fixed *vs.* self-selected rest intervals in trained young men.

METHODS

Participants

Sample size was calculated using the G*Power software, version 3.1.9.6. (Universitat Düsseldorf, Düsseldorf, Germany), considering a probability level of 0.05, with an effect size of 0.5 for a statistical power of 0.80. The recommended sample size was of 16 participants. Thus, the sample consisted of 16 healthy men aged 20 to 35 years, who practiced mixed exercise modalities for at least six months. Mixed exercise modalities were those practiced in the form of a high intensity circuit, involving resistance and aerobic exercises. The following exclusion criteria were adopted: a) musculoskeletal problems that could limit the practice of exercises performed in the circuits, as well as on treadmill; b) cardiovascular or metabolic disease that could interfere cardiorespiratory outcomes; c) use of medications that could interfere with cardiorespiratory responses to effort. The project was approved by the institutional ethics committee (CAEE: 08275619.6.0000.5289) and before entering the experiment, individuals signed free and informed consents. The present study adhered to the ethical standards of International Journal of Exercise Science (23).

Protocol

Study Design: Data were collected during four visits to the laboratory, interspersed with intervals of 48- to 72 h. On the first visit, subjects answered a structured questionnaire to identify their habitual physical activity and factors potentially limiting exercise performance. Subsequently, eligible participants performed a cardiopulmonary exercise testing (CPET). On the second visit, a familiarization session was conducted to review procedures and exercise technique. During the third and fourth visits, participants performed the experimental HIRT sessions in a randomized order, with resistance exercises applied with either a fixed or self-selected rest interval between bouts. The oxygen uptake, heart rate, number of repetitions, and subjective enjoyment were compared between conditions. Figure 1 shows the experimental design of the study.

Cardiopulmonary Exercise Testing: A treadmill ramp protocol was applied, based on the Matthews's et al questionnaire, to determine maximum oxygen uptake (VO_2max) (20). The initial and final velocities were calculated using the equation proposed by the American College Sports Medicine (ACSM) (1). The protocol was designed to elicit maximal volitional exhaustion within 8 to 12 min (10). Before the test, subjects were monitored until the respiratory quotient and VO_2 values were of approximately 0.75 to 0.85 and 3.5 ml.kg1.min-1, respectively (2). Individuals were encouraged to perform a maximum effort during the CPET, and the highest peak oxygen uptake (VO_2peak) was recorded. Gas exchange analysis was performed through the VO_{2000} gas analyzer (Medical Graphics™, Saint Paul, United States), with data averaged every 20 s. A heart rate monitor (Polar™ RS-800, Kempele, Finland) was used for HR assessment. Maximum CPETs should exhibit at least three out of five criteria: a) maximum voluntary exhaustion; b) grade 9 or 10 on the Borg CR-10 scale; c) 90% of age-predicted maximum HR (HRmax) or HR plateau; d) VO_2 plateau; e) respiratory quotient ≥ 1.10.

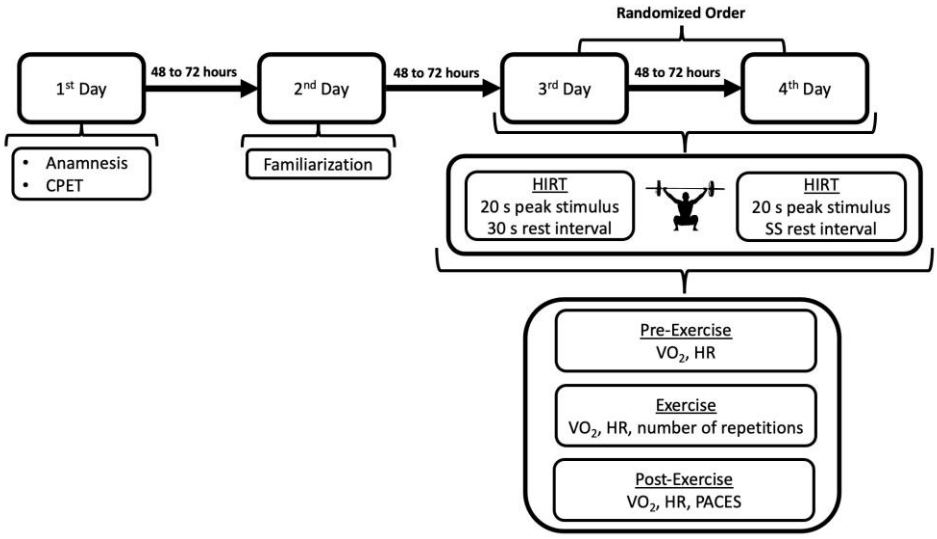

Figure 1. Experimental Design

Measurement of oxygen consumption and heart rate at rest and during HIRT sessions: Resting VO_2 was measured for 30 min before exercise sessions according to strict recommendations published elsewhere (8), including abstention from physical exercise, alcoholic drinks, and caffeinated beverages for 24 hours, and fasting for 8 h before the test. In the laboratory, subjects laid supine in a quiet place, using the facemask during 10 min for adaptation. After this, the VO_2 was assessed for 30 min during which subjects should avoid sudden movements. The resting value corresponded to the average of data within the last 5 min in steady state (coefficient of variation < 10% for VO_2 and carbon dioxide production - VCO_2). This procedure was necessary for calculating the energy expenditure of exercise sessions (9). The HR was also monitored for 30 min, with the average of the last 5 min being recorded as the resting value.

The energy expenditure during HIRT sessions was measured by monitoring VO_2 and VCO_2 using the telemetric VO_{2000} gas analyzer device (Medical Graphics™, Saint Paul, United States). The equipment was previously calibrated according to the manufacturer's instructions. Heart rate was also continuously measured (Polar™ RS-800, Kempele, Finland) and heart rate reserve (HRR) was calculated. Energy expenditure was calculated using the equation proposed by Weir (35) at baseline and after the exercise sessions.

Exercise Sessions: Each session began with a warm-up consisting of a passage through the circuit, with loads applied in the familiarization session. After warming up, individuals were given a minute to position themselves in the place where the exercises were conducted. The HIRT circuit consisted of the following exercises: 1) Thruster; 2) Swing; 3) Unilateral Snatch; 4) Mountain Climber. All exercises were performed in each of the four rounds of HIRT sessions, with 20-s duration for peak bouts. Subjects were verbally motivated to perform as many repetitions as possible. The number of repetitions performed was obtained by filming the HIRT sessions. Rest intervals were of 30 s (fixed interval) or self-selected. Self-selected intervals were recorded for each exercise, but the participants were blinded for this procedure. An interval of

48 to 72 h was given between sessions, and individuals were instructed not to perform additional exercises during the whole experiment.

Physical Activity Enjoyment Scale (PACES): Ten minutes following each HIRT session, subjects completed the PACES questionnaire to assess subjective enjoyment (17). The instrument consists of eighteen items arranged on a bipolar scale with scores ranging from 1 to 7. Higher scores indicate higher enjoyment, within a range of 18-126 points.

Statistical Analysis

Data normality was confirmed by the Shapiro-Wilk test. All data are presented as mean ± standard deviation. Intraclass correlations were calculated to ensure that HR and VO_2 assessed in resting conditions and pre-exercise were similar. To compare absolute and relative HRR, oxygen uptake reserve (VO_2R), and the number of repetitions within rounds and between HIRT conditions, 2-way ANOVAs with repeated measures were applied, with a statistical significance set at $p \leq 0.05$, followed by Bonferroni post hoc verifications in the event of significant F ratios. Differences between conditions for overall HRR and VO_2R, total session and interval durations, energy expenditure, and enjoyment responses were tested by t-tests for paired samples, with statistical significance set at $p \leq 0.001$. Cohen's d effect sizes (ES) were calculated considering 0.2, 0.5, and 0.8 as thresholds for small, medium, and large effects, respectively (7). All statistical calculations were performed using the SPSS 20.0 (IBM™, New York, United States).

RESULTS

Table 1 describes the sample characteristics. There was no difference between HR (p = 0.37) and VO_2 (p = 0.29) at rest *vs*. pre-exercise sessions, with a high intraclass correlation (ICC = 0.82 and 0.79, respectively).

Table 1. Age, anthropometric characteristics and cardiorespiratory data before HIRT sessions and at the end of the CPET.

Variables	Mean ± SD
Age (years)	27.1 ± 3.9
Height (cm)	179.7 ± 6.6
Body mass (kg)	84.6 ± 9.0
VO_{2peak} ($ml.kg.^{-1}min^{-1}$)	56.6 ± 7.5
R ($ml.kg^{1}.min^{-1}$)	1.1 ± 0.09
HR_{peak} ($bat{\cdot}min^{-1}$)	189.6 ± 7.1
HR_{30} rest ($bat{\cdot}min^{-1}$)	64.1 ± 9.2
HR_{SS} rest ($bat{\cdot}min^{-1}$)	62.7 ± 12.1
$VO_{2\,30}$ rest ($ml.kg.^{-1}min^{-1}$)	3.83 ± 1.23
$VO_{2\,SS}$ rest ($ml.kg.^{-1}min^{-1}$)	4.28 ± 1.09

Age, anthropometric characteristics and cardiorespiratory data before HIRT sessions and at the end of the CPET. VO_{2peak}: peak oxygen consumption; R: respiratory quotient; Peak HR: peak heart rate; HR_{30}: resting heart rate of the HIIT session with a 30-second interval; HR_{SS}: resting heart rate of the HIRT session with self-selected interval; $VO_{2\,30}$: oxygen consumption at rest in the HIRT session with a 30-second interval; $VO_{2\,SS}$: oxygen consumption at rest of the HIRT session with self-selected interval.

Figure 2 illustrates the relative HRR and VO_2R in HIRT performed with different rest intervals. Relative HRR was higher in self-selected *vs.* fixed intervals in the first round [Panel 2A; F(2.12, 31.88) = 2.76; p = 0.04; ES = 0.50]. %HRR was greater in the 1st and 2nd rounds *vs.* 3rd and 4th rounds of the session performed with fixed intervals [F(1.370, 20.552) = 102.835; p < 0.01; ES = 0.63], while the session performed with self-selected intervals produced greater %HRR in the 1st round *vs.* others [F(1.370, 20.552) = 102.835; p < 0.01; ES = 0.87]. Overall, the average HRR was similar across conditions (Panel 2B; p = 0.14). The relative VO_2R was higher in self-selected *vs.* fixed intervals in the 1st [F(34.02, 184.74) = 2.762; p = 0.05; ES = 0.53] and 2nd [F(34.02, 184.74) = 2.762; p = 0.03; ES = 0.56] rounds (Panel 2C). In both HIRT conditions, %VO_2R was greater in the 1st *vs.* other rounds (F(34.02, 184.74) = 2.762; p < 0.05; ES = 0.68). No difference between conditions was found for the average %VO_2R (Panel 2D; p = 0.10).

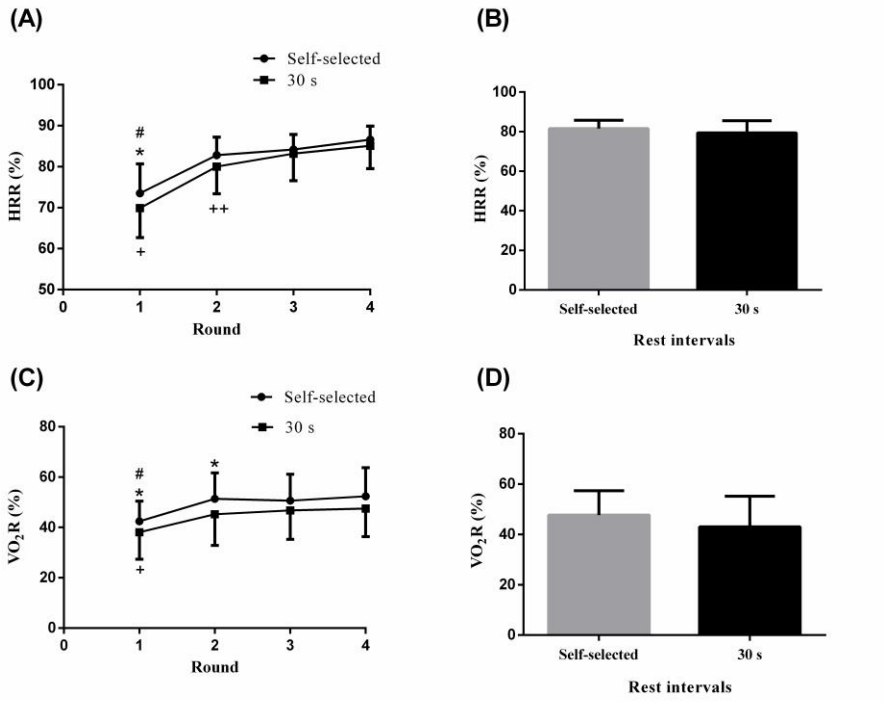

Figure 2. Relative HRR (Panels A and B) and VO_2R (Panels C and D) in each round and overall HIRT sessions performed with 30-s and self-selected intervals. *: difference between conditions in a given round (p < 0.05; ES = 0.50); #: difference between the 1st round *vs.* others in HIRT performed with self-selected intervals (p < 0.05; ES = 0.87); +: difference between the 1st round *vs.* others in HIRT performed with 30-s intervals (p < 0.05; ES = 0.63]; ++: difference between the 2nd round *vs.* others in HIRT performed with 30-s intervals (p < 0.01; ES = 0.63).

Figure 3 depicts the number of repetitions in the two HIRT conditions. In all rounds, the number of repetitions was greater in fixed *vs.* self-selected intervals (p < 0.05; ES = 0.75). Comparisons within conditions revealed a systematic decrease along successive rounds in both interval strategies (Panel 4; p < 0.01; ES = 0.68). In consequence, the overall number of repetitions was 12.4% greater in sessions performed with fixed compared to self-selected intervals (p < 0.01; ES = 1.3).

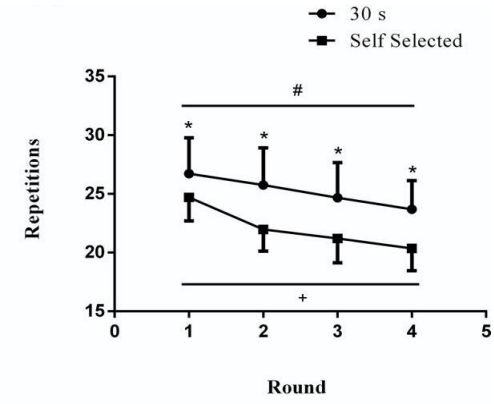

Figure 3. Number of repetitions throughout the rounds of HIRT performed with fixed and self-selected intervals. *: difference between conditions in each round [F(1.83, 20.22) = 9.519; $p < 0.05$; ES = 0,75]; #: difference between rounds within HIRT performed with 30-s intervals [F(1.90, 20.95) = 48.24; $p < 0.01$; ES = 0.68]; +: difference between rounds within HIRT performed with self-selected intervals [F(1.90, 20.95) = 48.24; $p < 0.01$; ES = 0.68].

Figure 4 presents the overall duration (Panel A), duration of rest intervals (Panel B), energy expenditure (Panel C), and enjoyment perception (Panel D) elicited by HIRT conditions. Given the shorter resting intervals in self-selected condition, the total exercise duration was longer in sessions performed with fixed intervals ($p < 0.001$; ES = 0.83). The energy expenditure was also greater in fixed *vs.* self-selected intervals ($p < 0.0001$; ES = 0.13), while the enjoyment perception ($p = 0.65$) was similar across conditions.

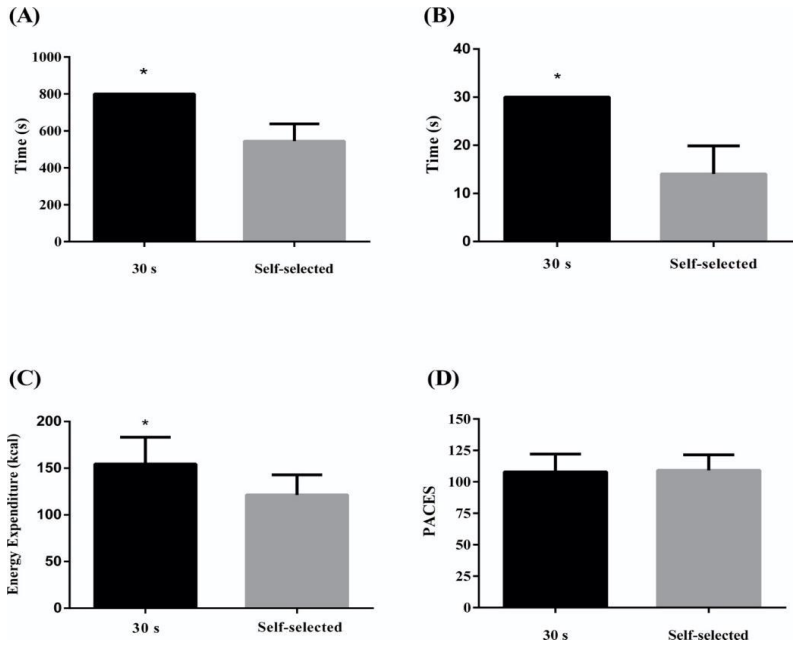

Figure 4. Total duration of HIRT sessions performed with 30-s and self-selected intervals (Panel A); Total interval time (Panel B); Energy expenditure (Panel C); Physical Activity Enjoyment Scale score (Panel D). *: significant difference between conditions – Panel A ($p < 0.001$; ES = 0.8); Panel B ($p < 0.0001$; ES = 3.2); Panel C ($p < 0.001$; ES = 0.13).

DISCUSSION

The present study investigated the effect of fixed and self-selected intervals between exercises in HIRT sessions on cardiorespiratory responses, number of repetitions and enjoyment in trained young men. The main findings revealed that the intensity of effort, expressed by relative HRR and VO_2R did not differ between sessions performed with different rest intervals between exercises. The 30-s rest interval between exercises allowed for greater number of repetitions and energy expenditure, but resulted in a longer session duration. The enjoyment perception was similar in both conditions.

To the best of our knowledge, our study was the first to evaluate how the manipulation of rest intervals between exercises impacts on cardiorespiratory responses, number of repetitions, and subjective enjoyment during HIRT. Prior studies compared cardiorespiratory responses in HIRT *vs.* Sprint Interval Cycling (37) or assessed the physiological responses to different types of activity (4, 11, 12, 38), but did not address the potential influence of resting intervals. This is a relevant question, since the recovery between exercises may affect both physiological (27, 28, 29) and perceptual (26, 27) responses.

Although the fixed 30-s interval had been almost twice the average self-selected intervals (14 s), the intensity of effort sessions was similar in both conditions. However, based on the ACSM classification (1), the relative intensity reflected by HRR (Figure 2) indicated that subjects sustained high intensities for longer periods when the rest interval was longer (e.g., 30-s fixed interval). Interestingly, VO_2R responses were similar between conditions [43% VO_2R (30 s) *vs.* 47.7% VO_2R (self-selected)], and effort intensities would be classified as *moderate* (1).

In HIRT circuits, the exercises are performed in a short period of time and at high intensity. Due to its large anaerobic component (30), the relationship between HR and VO_2 is affected. Therefore, the interaction of aerobic and anaerobic systems may influence the effort intensity, albeit the VO_2 had been moderate (3). The amount of work sustained at high intensity is fundamental for improving the cardiorespiratory fitness (14), since exercises performed at higher intensities will result in greater gains in VO_{2max} compared to moderate or low intensity (20, 23). In addition, high-intensity exercise sessions eliciting greater HR responses for a prolonged period seem to favor cardiorespiratory gains (16). In comparison to self-selected intervals, our results indicate that HIRT sessions performed with 30-s intervals can be more efficient to improve cardiorespiratory fitness, since higher intensities were sustained for a longer time (13.50 min *vs.* 9.16 min, respectively).

Concerning the relationship between number of repetitions *vs.* physiological and perceptual responses in HIRT, we could locate a single trial investigating the effects of exercise muscle mass in young men (19). Unfortunately, there is a lack of studies focusing on resting intervals, which limits the comparison of prior research with our results. In the present study, HIRT performed with 30-s intervals resulted in a higher number of repetitions *vs.* self-selected intervals in all circuit rounds. The slightly greater HRR and VO_2R sustained for longer periods in sessions

performed with fixed over self-selected intervals also resulted in greater overall energy expenditure (154.4 kcal *vs.* 121.4 kcal, respectively).

The subjective enjoyment perception may influence the adherence to exercise training (15, 34), but this issue has not been yet investigated in HIRT. Furthermore, it is still unclear whether participants with different levels of training experience could exhibit distinct enjoyment responses in HIRT circuits conducted with fixed vs self-selected rest intervals. In our study, the enjoyment responses assessed by the PACES questionnaire were similar in HIRT performed with both intervals. These findings call attention to the fact that trained men can experience positive feelings of enjoyment when practicing this modality of circuits, regardless of the resting interval strategy. In short, the overall number of repetitions and relative intensity in HIRT were greater in circuits performed with 30-s *vs.* self-selected intervals, for a similar level of enjoyment perception.

The present study has limitations. Participants should perform the exercises in an "all-out" intensity, but we cannot ensure that this has effectively happened. However, all-out HIRT sessions are inherent conducted in maximal effort, therefore exercise intensity is not likely to be overestimated. Even though participants in self-selected have been explicitly instructed to rest enough time for optimal performance of the consecutive all-out exercises, they probably underestimated the rest interval once the number of repetitions were greater in the HIRT session with a 30-second interval.

In conclusion, HIRT performed at all-out intensity with fixed (30 s) or self-selected (~14s) intervals elicited similar moderate- to high relative intensity (%HRR and %VO_2), and enjoyment perception in trained men. However, the total number of repetitions (~12%) and overall energy expenditure (~21%) were greater in circuits performed with fixed over self-selected intervals. This original information may have implications for the design of HIRT interventions.

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