Load and psychophysiological responses in high-intensity interval training with fixed and self-selected recovery

Respuestas de carga y psicofisiológicas en el entrenamiento por intervalos de alta intensidad con recuperación fija y autoseleccionada

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Abstract

Introduction and Objective. The study analyzed the training load in high-intensity interval training sessions with different conditions of recovery time between stimuli: fixed (1min.) and self-selected.

Methods. Nineteen individuals participated in the study: 13 men and 6 women (19±1.0 years; 64.0±9.2 kg; 169±8.5 cm; 22.0±2 BMI). For the training load analysis, heart rate variability (LnRMSSD), perceived effort (PE), and mood scale BRUMS (MS) were used. LnRMSSD and MS were evaluated before and after the sessions. The PE was evaluated during each session immediately after each stimulus. The protocol was 10 x 30s (95% Vpeak) with active recovery (40% Vpeak) in fixed or self-selected time. ANOVA-RM (2 [interventions] x 2 [time points]) for LnRMSSD and MS and (2 [interventions] x 10 [time points]) for PE was used.

Results. Between condition and time*condition, no differences were observed for LnRMSSD (p=.626; p=.879, respectively), PE (p=.191; p=.792, respectively), and MS (tension: p=.673; p=.463; depression: p=.867; p=.359; anger: p=.867; p=.359; vigor: p=.811; p=.778; fatigue: p=.144; p=.998; mental confusion: p=.828; p=.752, respectively). In terms of time, significant differences were observed in LnRMSSD (p<.001) and PE (1≠3-10; 2≠4-10; 3≠5-10; 4≠5-10; 5≠7-10; 6≠7-10; 7≠ 9,10; 8≠10, p<.001). In MS, there was a difference in domains of tension (p<.001), depression (p<.015), anger (p<.033), and mental confusion (p<.001). But not for vigor (p=.339) nor fatigue (p=.419), which are associated with the training load.

Conclusions. However, both recovery conditions showed similar acute internal load responses. Additionally, it is suggested that recovery with self-selected time (46.70±1.6.58s) may be a recovery option in HIIT prescription.

Keywords

High-intensity interval training; training load; heart rate variability; perceived effort; mood; physiological adaptations.

Resumen

Introducción y Objetivo. El estudio analizó la carga de entrenamiento en sesiones de entrenamiento interválico de alta intensidad con diferentes condiciones de tiempo de recuperación entre estímulos fijos (1min.) y autoseleccionados.

Métodos. Diecinueve individuos participaron en el estudio: 13 hombres y 6 mujeres (19±1,0 años; 64,0±9,2 kg; 169±8,5 cm; 22,0±2 IMC). Para el análisis de la carga de entrenamiento se utilizaron la variabilidad de la frecuencia cardiaca (LnRMSSD), el esfuerzo percibido (PE) y la escala de estados de ánimo (MS). LnRMSSD y MS se evaluaron antes y después de las sesiones. La PE se evaluó durante cada sesión inmediatamente después de cada estímulo. El protocolo fue de 10 x 30s (95% Vpico) con recuperación activa (40% Vpico) en tiempo fijo o auto-seleccionado. Se utilizó ANOVA-RM (2 [intervenciones] x 2 [puntos temporales]) para LnRMSSD y MS y (2 [intervenciones] x 10 [puntos temporales]) para PE.

Resultados. Entre condición y tiempo*condición, no se observaron diferencias para LnRMSSD (p=.626; p=.879, respectivamente), PE (p=.191; p=.792, respectivamente), y MS (tensión: p=.673; p=.463; depresión: p=.867; p=.359; ira: p=.867; p=.359; vigor: p=.811; p=.778; fatiga: p=.144; p=.998; confusión mental: p=.828; p=.752, respectivamente). En cuanto al tiempo, se observaron diferencias significativas en LnRMSSD (p<.001) y PE (1≠3-10; 2≠4-10; 3≠5-10; 4≠5-10; 5≠7-10; 6≠7-10; 7≠ 9,10; 8≠10, p<.001). En la MS, hubo diferencias en los dominios de tensión (p<.001), depresión (p<.015), ira (p<.033) y confusión mental (p<.001). Pero no para vigor (p=.339) ni fatiga (p=.419), que están asociados con la carga de entrenamiento.

Conclusiones. Sin embargo, ambas condiciones de recuperación mostraron respuestas de carga interna aguda similares. Además, se sugiere que la recuperación con tiempo autoseleccionado (46,70±1,6,58s) puede ser una opción de recuperación en la prescripción de HIIT.

Palabras clave

Entrenamiento interválico de alta intensidad; carga de entrenamiento; variabilidad de la frecuencia cardiaca; esfuerzo percibido; estado de ánimo; adaptaciones fisiológicas.

Introduction

High-Intensity Interval Training (HIIT) is increasingly used in interventions for different types of research (Atakan et al., 2021). Conceptually, HIIT is applied using stimuli based on physiological or mechanical thresholds (Buchheit & Laursen, 2013a, 2013b), respecting the balance between stimulus and recovery, thus promoting better use of the training (Thibault, 2003). In terms of protocols, HIIT can be applied in different types of protocols, characterized by the stimulus time, being short (<60s) and long (≥60s) (Buchheit & Laursen, 2013a). HIIT with short stimuli is usually conducted in a sprint format, referred to as Repeated Sprint Training (RST) or Sprint Interval Training (SIT). Even more categorically, in HIIT, stimuli shorter than or equal to 10 seconds (RST) and 10-30 seconds (SIT) were considered as short, the 30s to 2 minutes as a medium, and greater than or equal to 2 minutes as long (Wen et al., 2019).

However, when using HIIT protocols, consistency in the application is of paramount importance, and for this, controlling the intensity distribution (Seiler & Kjerland, 2006) and balance between stimulus and recovery (Thibault, 2003) will be determinant in the physiological responses, facing the mechanisms of evolution of physical conditioning as a whole. HIIT has a high potential in building central and peripheral physiological adaptations (MacInnis & Gibala, 2017), positively altering metabolic components (Kabasakalis et al., 2022), cardiovascular (Batacan et al., 2017), autonomic (Alansare et al., 2018), cardiorespiratory (Milanović et al., 2015) and neuromuscular (Buchheit & Laursen, 2013c). However, HIIT proves to be efficient and deserves attention in the prescription of different protocols in different populations, and in this sense, intensity control becomes primordial (Taylor et al., 2019). Thus, when faced with different strategies for controlling intensity, one of the main ones may be the way in which recovery between stimuli is conducted, through the type (e.g., active and passive) and the recovery time, taking into account the relationship between stimulus and recovery (e.g., 1:2) (Buchheit & Laursen, 2013a, 2013b)

Training with poor intensity control can cause physiological disorders and negatively affect obtaining the desired responses in the prescription and training planning (Sant'Ana et al., 2021). For this, training load control has been well used to avoid physiological stresses (Pind & Mäestu, 2017). Currently, different indicators (physiological and perceptual) for assessing training load are being used to control training, or training or both responses, such as heart rate (HR) (Borresen & Lambert, 2008), heart rate variability (HRV) (Plews et al., 2013), perceived effort (PE) (Foster et al., 2001) and mood (Morgan et al., 1987). Besides these, which are perhaps the most accessible, the behavior of lactate, creatine kinase, salivary cortisol, and oxygen consumption are also indicators for assessing the training load (Armstrong & VanHeest, 2002; Vanrenterghem et al., 2017). Although studies have focused their investigations of training load on performance (Borges et al., 2020; Impellizzeri et al., 2004; Nakamura et al., 2015), training load monitoring, too, is of great importance to health care in general (Borresen & Lambert, 2008; Meeusen et al., 2013).

Interventions with HIIT deserve attention in the control of the training load because the stimuli are always conducted at high intensity, and regardless of how this variation of training is prescribed, the evaluation of the responses has relevant importance (Kabasakalis et al., 2022). Studies investigating high-intensity exercise with internal load assessment have reinforced the importance of this type of analysis and demonstrated responses that deserve attention to be monitored, such as lactate, HR, and PE at high-intensity exercise using one's body weight (Machado et al., 2018), and an athlete follow-up through PE and HRV in the course of some sessions (38 weeks) of high-intensity training (Tibana et al., 2019).

Present Study

Despite the importance of assessing the training load to avoid possible physiological stresses (Impellizzeri et al., 2019), studies using this type of analysis with high-intensity training are scarce (Tibana et al., 2018, 2019), especially when it comes to HIIT (Kabasakalis et al., 2022). Moreover, research on this topic (internal load) is related to sports (Mclaren et al., 2017), becoming even scarcer with the general population, which would be necessary for health reasons (Sant'Ana et al., 2021). Concerning HIIT, regarding recovery between stimuli, it is common to use the active and passive pause (Sánchez-Otero et al., 2022) with a determined time and/or intensity. But, another recovery strategy between stimuli in HIIT is self-selected (McEwan et al., 2018), where the individual chooses how they will recover in terms of time and/or intensity and/or type of recovery (active or passive). However, this type of recovery requires optimal familiarization to be efficient in its application (Glaister et al., 2010). Recovery between stimuli at high intensity has great importance in the prescription of this type of training (Toubekis et al., 2006; Toubekis & Douda, 2005), and because of this, the evaluation of the training load becomes indispensable to control the responses and thus obtain positive results. Thus, this study aimed to investigate the training load through HRV, PE, and MS in HIIT sessions (10 x 30s) with fixed (60s) and self-selected active recovery. We hypothesized that both recovery strategies offer similar responses, reinforcing self-selected variation as another option in HIIT prescriptions (Gibson et al., 2017; Glaister et al., 2010; McEwan et al., 2018).

Method

Participants

Sample size and power calculations were developed using G*Power (v.3.1.9.7) (Faul et al., 2009). Considering the analysis to be performed on the primary outcomes, a between-within ANOVA-RM (2 [interventions] x 2 [time points]), anticipating a "large" effect size (f = 0.4), with an $\alpha = .05$, a statistical power of $(1 - \beta) = .95$, the correlated dependent variables with an r = .50, and a violation of sphericity (ε) = .80, will require a total sample size of 18 individuals. The suggested effect size and remaining parameters were defined according to similar studies evaluating changes in HRV and perceptive variables during exercise protocols (McEwan et al., 2018; Perkins et al., 2017).

The sample was composed of 19 participants: 13 were men, and 6 were women (table 1), all healthy and active. Inclusion criteria were as follows: Active exercisers with at least ≥ 6 months experience and a minimum weekly frequency of 3 times a week. As exclusion criteria, we considered using any pharmacological medication or ergogenic or both resources that could somehow influence the investigation (e.g., those that could influence the emotional state); the presentation of musculoskeletal disorders that could compromise the training protocol. All participants signed an informed consent form before the study intervention. This study was approved by the Ethics and Research Committee of the Catholic University of Petrópolis (CAEE: 59449822.2.0000.5281).

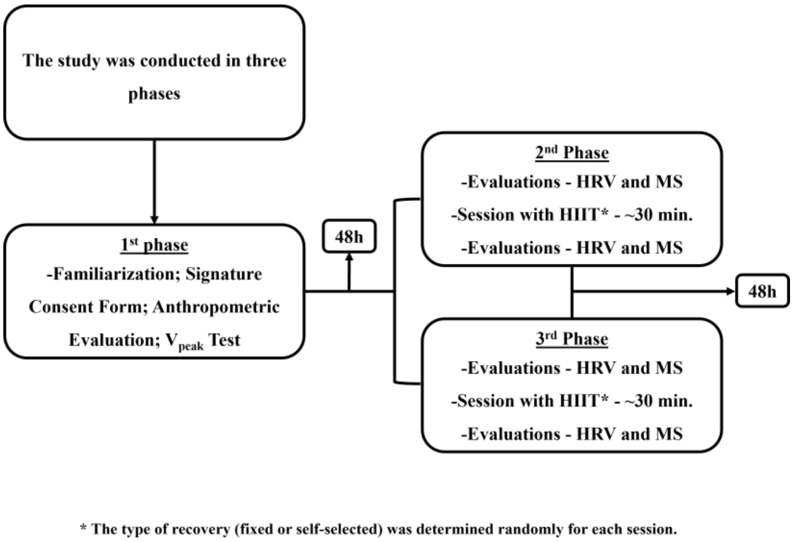
Table 1. Characteristics of the sample in general

Anthropometric variables	Sample	
	Mean	SD
Age (years)	19.0	1.0
Weight (kg)	64.0	9.2
Height (cm)	169.1	8.5
BMI (kg/m^2)	22.0	2.0

Experimental Design

The present study was conducted in three laboratory sessions for approximately 30 minutes (see Figure 1). The analyses were subdivided in each session, following the phases: the first phase: going to the laboratory to become familiar with the whole study, signing the informed consent form, anthropometric evaluations (weight, height, and BMI), and performance of the maximum aerobic speed test (Vpeak) to determine the second and third phases training intensities. Then, going to the lab for the first and second intervention sessions. The intervention sessions were randomized to determine which protocol the subject would perform at each visit: HIITRec-A (fixed recovery) or HIITRec-B (self-selected recovery). Before and after the HIIT sessions, subjects completed a questionnaire for mood assessment and had heart rate variability (HRV) collected for 10 minutes. The post-effort evaluation was started five minutes after the session's end to eliminate the effort's immediate influence on the responses, thus reducing bias on the autonomic (HRV) perceptual (PE and mood) results. PE was collected during the training protocol immediately after each stimulus of the HIIT session. From the first to the second phase, the interval was 24 hours between sessions. From the second to the third phase, the participants were separated by 48 hours. All data were collected by a single researcher so that it was possible to have uniform assessments across all participants.

Figure 1. Experimental Design



Heart rate variability assessment

HRV was measured at rest and after the training session for 10 minutes with the subject sitting down (Holmes et al., 2020), considering the 5 minutes post-stabilization (Draghici & Taylor, 2016). At the post-session, we waited 5 minutes for the recording to start, thus avoiding a sympathetic load and thus allowing an overestimated HRV reading (Botsva et al., 2017). For the HRV collection, a Polar® watch was used (RS800CX Multisport™) (Quintana et al., 2012). After HRV collection, the data were corrected in Polar Pro Trainer 5 software and then transferred to Kubios HRV Standard 7.0 software to be processed. The data were visually inspected to identify artifacts (≤ 2%), considering the time of highest stabilization and the lowest level of artifacts (Johnston et al., 2020). To analyze the internal load, the RMSSD index was used, which is related to the time domain and is very well accepted for this type of analysis (Schmitt et al., 2015). After being calculated, all values of the selected indexes were transformed into logarithms (LnRMSSD) (Alkahtani et al., 2020).

Assessment of perceived effort

The assessment of PE was OMNI scale (0-10) (Utter et al., 2004). Each stimulus (10 x 30 seconds) was performed immediately for both conditions.

Mood state assessment

For mood evaluation, the Brunel scale (Brums) will be used. This instrument is for emotional evaluation and early detection of overtraining syndrome (Rohlfs et al., 2008). This questionnaire has 24 items subdivided into 6 domains on a scale of 0 to 4, being: tension (items 1, 13, 14, and 18), depression (items 5, 6, 12, and 16), anger (items 7, 11, 19 and 22), vigor (items 2, 15, 20 and 23), fatigue (items 4, 8, 10 and 21), and mental confusion (items 3, 9, 17 and 24). After summing up the responses for each item, the values for tension, depression, anger, fatigue, and confusion are expected to be decreased. And that the domain values of vigor are maintained or increased. For this evaluation, it is possible through a line graph to plot to identify the "iceberg" profile related to physiological stress (Morgan et al., 1987). All domains are analyzed, but vigor and fatigue are emphasized for training load evaluation. Where "vigor" values are expected to be maintained or increased and, on the other hand, "fatigue" values are expected to be maintained or reduced (Morgan et al., 1987).

Anthropometric assessment

An anthropometric evaluation was performed using the variables of weight (kg), height (m), and body mass index (BMI, kg/m^2). A brand scale, TANITA®, and a brand stadiometer SECA® (AS 217), were used to identify weight and height. Both were duly tested and calibrated. As for the BMI, it was obtained using the formula: $BMI=weight/height^2$.

Peak speed test (Vpeak)

The test to identify peak velocity (Vpeak) was performed on a NORDIC TRACK® (T 22.0) professional treadmill. The protocol was composed of the Initial phase (warm-up): 5 minutes at a speed of 8.0 km/h and a sequence of static stretches with a resistance of 20 seconds for each exercise. Main phase (test): start at 8.0 km/h with an increment of 1.0 km/h every minute until voluntary exhaustion. The final phase (deceleration): 5 minutes at 5.0 km/h. An incremental test was performed based on the Conconi (Conconi et al., 1982, 1996) and in studies that have demonstrated the fidelity of Vpeak for the identification of intensity (da Silva et al., 2015; Machado et al., 2013; Noakes et al., 1990). The maximum speed achieved was considered to be the one maintained for at least 50% of the determined time (1 min) for each increment.

Training protocols

For the intervention, we will use a HIIT protocol performed on a treadmill based on studies on the method (Billat, 2001; Buchheit & Laursen, 2013a; Thibault, 2003). The HIIT was conducted as follows: Initial phase (warm-up): 10 min (50% Vpeak). Main phase (stimulus/recovery): 10 x 30 sec (95% Vpeak) to 1 min active recovery (40% Vpeak) (HIITRecA) or self-selected recovery (HIITRecB). In the fixed recovery protocol, we assumed a 1:2 stimulus-recovery ratio, following recommendations (Buchheit & Laursen, 2013a, 2013b) and considering the optimal responsiveness of all participants throughout the series. The self-selected recovery will be the convenient time (self-evaluation) determinate for each participant to return to the next stimulus, the final phase (cool down): 5 min (50% Vpeak).

Statistical Analysis

Normality and homoscedasticity were checked with the Shapiro-Wilk (n < 50) and Levene. ANOVA-RM (2 [interventions] x 2 [time points]) for LnRMSSD and MS and (2 [interventions] x 10 [time points]) for PE were used to examine the differences between the dependent variables. For all tests, the significance level to reject the null hypothesis was set at 5% (p<.05). The sphericity assumptions were examined using Mauchly's test. When this assumption was not met, the Greenhouse-Geisser fitted values and degrees of freedom were reported (Ho, 2014) and indicated by decimal degrees of freedom. Bonferroni adjusted post-hoc tests followed repeated measures analyses to analyze pairwise comparisons. The effect size η2p was calculated, and the assumed reference values were as follows: "small" effect = .01, "medium" effect = .06, and "large" effect = .14 (Cohen, 1988). Statistical analyses were conducted in IBM SPSS Statistics version 27.

Results

The recovery time (seconds) performed by the participants between stimuli in the HIITRecB condition was 46.70±16.58 seconds. In Table 2, no differences were observed for LnRMSSD (HRV) for condition and time*condition. However, a significant difference was observed for LnRMSSD (HRV) in terms of time (p<.001), and the observed effects are medium (>.06).

Table 2. Global sample repeated measures ANOVA for LnRMSSD (HRV).

	Mean Square	F	df1	df2	p	η^2p	Pairwise comparisons
LnRMSSD (HRV)							
Time	4.50	128.82	1	18	<.001	.88	1 ≠ 2
Condition	0.30	.246	1	18	.626	.01	nd
Time*Condition	.005	.024	1	18	.879	.001	nd

F = test results; df1 = degrees of freedom of the six conditions; df2 = error degrees of freedom; p = significance; η2p = partial eta-squared; nd = no difference detected.

In PE (Table 3), no differences were observed according to condition and time*condition. However, a significant difference in the perceived effort was observed in time (all p<.001), and the observed effect size is medium.

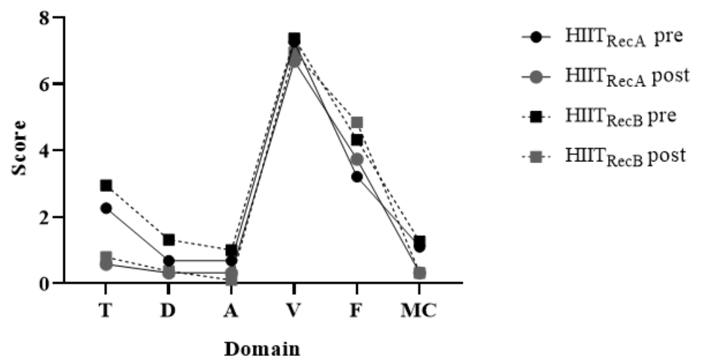
Table 3. Global sample repeated measures ANOVA for perceived effort.

	Mean Square	F	df1	df2	p	η^2p	Pairwise comparisons
Perceived effort							
Time	229.26	112.232	1	18	<.001	.863	1 ≠ 3-10;2 ≠ 4-10; 3≠5-10; 4≠5-10; 5≠7-10; 6≠7-10; 7≠9,10; 8≠10.
Condition	6.25	1.83	1	18	.191	.091	nd
Time*Condition	.474	.058	1	18	.792	.004	nd

F = test results; df1 = degrees of freedom of the six conditions; df2 = error degrees of freedom; p = significance; η2p = partial eta-squared; nd = no difference detected.

Regarding mood, between condition and time*condition, no differences were observed in Brums scale domains (tension: p=.673; p=.463; depression: p=.867; p=.359; anger: p=.867; p=.359; vigor: p=.811; p=.778; fatigue: p=.144; p=.998; mental confusion: p=.828; p=.752, respectively). In terms of time, there was a difference in the domains of tension (p<.001), depression (p<.015), anger (p<.033), and mental confusion (p<.001). But not for vigor (p=.339) nor fatigue (p=.419), which are associated with the internal load, represented by the ''iceberg'' profile. Figure 2 represents the mood scale with its domains in both conditions (HIITRec-A and HIITRec-B), demonstrating the ''iceberg'' profile proposed by Morgan et al. (1987) to assess training load and thus monitor physiological stress. There was a reduction in the "vigor" domain and an increase in the "fatigue" domain later for both conditions without statistical differences. These findings are acceptable and expected after the effort is submitted in the conditions.

Figure 2. The mood-scale domains represent the "iceberg" profile proposed by Morgan et al. (1987).



Discussion

Although some studies show the relevance of monitoring the training load in front of sports or other activities (Pind & Mäestu, 2017), there are still few studies regarding this type of monitoring in the HIIT intervention (Machado et al., 2018). It is known that self-selected recovery, as a prescription option inserted into HIIT training (Gibson et al., 2017), but as the individual who chooses how to recover (in this study, the time), it could influence the training load and perhaps have differences compared to the fixed time condition. Thus, in addition to analyzing the training load responses in HIIT, we also aimed to verify the repercussion of this situation in different recovery strategies between stimuli (10 x 30s; 95% Vpeak), being the recovery by fixed time (60s) and self-selected, both active (HIITRecA and HIITRecB, respectively).

However, to evaluate the training load in HIIT sessions with different recovery strategies, the present study used the HRV through the LnRMSSD index, which is reliable for this type of evaluation (Schmitt et al., 2015), PE (Nakamura et al., 2010) and Brums mood scale, by plotting the "iceberg" profile (Morgan et al., 1987). Between conditions (HIITRecA and HIITRecB), results were similar for HRV, PE, and mood scale (i.e., no statistical differences, p>.05). We observed differences for these internal load analysis instruments in terms of time (pre and post) for HRV, mood scale (p<.05), during effort for PE (p<.05) and both conditions. Even in the HIITRecB condition, the subjects recovered with a shorter time (46.70±16.58 seconds) than in the HIITRecA condition, which performed the pause at a fixed time (60 seconds).

Studies evaluating training load in HIIT sessions have shown significant responses in lactate, HR, and PE after a protocol of 20 x 30s of stimulus (all-out) for 30s of passive recovery (Machado et al., 2018). In these findings, only the PE corroborates the present study's findings, where an increase in perceived exertion was also observed since we did not evaluate lactate or HR but HRV. Unlike ours, the study mentioned above used its protocol exercises with body work (HIIT Body Work), which was performed on a treadmill with running at 95% of Vpeak. But the stimulus and recovery time were equal (the 30s). However, this study conducted an intervention with 10 more series than in our research (Machado et al., 2018). However, the intensity level of the interventions was intense, which interfered significantly with the physiological responses and the training load (Borresen & Lambert, 2009). Other high-intensity interventions have also shown similar results to ours on PE responses but using high-intensity functional training (HIFT), and concluded that PE is an excellent tool for assessing internal load in high-intensity work (Tibana et al., 2018).

Regarding the use of HRV for assessing the magnitude of the training response, studies reinforce its reliability (Nuuttila et al., 2022; Plews et al., 2013). And in sessions using high-intensity exercise, this monitoring becomes even more relevant (Tibana et al., 2019) to avoid injury and maintain performance gain (Sant'Ana et al., 2021). Tibana et al. (2019) conducted a case study with a HIFT athlete using some instruments, including the HRV, PE, and mood state, which were used in the present study. However, the study by Tibana et al. (2019) conducted a 38-week follow-up. But it reinforces the importance of these variables as essential parameters for evaluating training load in work with high intensities (Lundstrom et al., 2023) , as well as in endurance sports, such as running, which was our intervention (Sanchez et al., 2025).

The submission of the individual at extreme intensity causes significant metabolic reactions (Kabasakalis et al., 2022), and these responses need constant monitoring so as not to cause imbalances and thus increase the risk of injuries (Pollock et al., 2019), loss of performance (Borresen & Lambert, 2009) and even the affliction of the well-known overtraining syndrome (Armstrong & VanHeest, 2002). Studies enrich the importance of training load monitoring using physiological variables such as lactate and HRV, (Bara-filho et al., 2013; Vanrenterghem et al., 2017) and perceptual (e.g. PE and mood) (Mclaren et al., 2017; Tibana et al., 2019), especially in interventions where high intensities are used, such as the one used in our research , even if with different protocols (Machado et al., 2018; Tibana et al., 2018). In sports, these extremely important evaluations and the variables we use are also advocated in evaluations with athletes from different modalities (Borges et al., 2020; Nakamura et al., 2015).

Regarding the intervention used in our study, no study was found to confront our findings. HIIT significantly alters physiological and perceptual variables during the session (Farias-Junior et al., 2019; Fennell & Hopker, 2021). However, controlling these alterations, even if acute, is indispensable. Regarding the type of recovery between stimuli we use, we know that the fixed time or intensity is, in the vast majority, plausible to approach the demand that the body needs to reestablish itself after the stimulus (Thibault, 2003). But in the case of self-selected recovery, because the individual drives it, different physiological responses can be affected (Bonen & Belcastro, 1976), and in this case, an optimal familiarization with this type of recovery strategy can be important, especially in work using HIIT (Glaister et al., 2010). Both recovery strategies (active with fixed time and self-selected) demonstrated similar results on training load assessments using HRV, PE, and mood scales. Thus, our findings demonstrated positive parameters in both interventions. However, considering these for the age group studied (19.0±1.0).

The present study has some limitations; one is the restriction of studies that evaluated the training load under HIIT intervention and studies that used different recovery strategies (mainly self-selected). Another limitation is that we cannot extrapolate our conclusions chronically because we performed an acute analysis, and evaluations on training load offer more information when performed chronically (Foster et al., 2001). The type of recovery, active or passive, is important and relevant in the prescription of HIIT (Madueno et al., 2019). We used active recovery for both conditions (HIITRecA and HIITRecB), and perhaps if we used the passive variation, we would have different responses. Thus, we limit ourselves to showing the results only with the active recovery mode, we suggest that other studies using this theme be led to evaluating the conditions used here and others such as passive recovery and with the recovery intensity also self-selected, since here, in the HIITRecA condition, the intensity was also fixed (40% Vpeak). However, to establish complementary information for this study, we suggest future research following this theme. In particular, with homogeneous groups and different protocols, such as a 1:1 stimulus-recovery ratio.

Our interventions showed great potential in practical applicability, and our protocols were conducted with easily accessible parameters. We used reliable intensity (Vpeak) parameters (da Silva et al., 2015), and in our evaluations of the internal load, we used the variables that are widely accepted in the scientific community, these being HRV (Schmitt et al., 2015), PE (Nakamura et al., 2010) and mood scale (Morgan et al., 1987). Furthermore, these physiological and perceptual parameters are essential in monitoring interventions with HIIT.

Conclusions

The present study used HIIT interventions using two active recovery conditions between stimuli, the one with a fixed time (60 seconds) and the self-selected one. We analyzed the training load responses using heart rate variability (HRV), perceived effort (PE), and the mood scale (MS). We can conclude that the recovery strategies between stimuli of the HIIT used here do not cause different responses in training load in the way we evaluated here. Thus, we can suggest that in addition to the traditional way of active retrieval, in terms of time, this being fixed, self-select may also be an option. But we reinforce the importance of familiarization with this strategy before application.

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References

Alansare, A., Alford, K., Lee, S., Church, T., & Jung, H. (2018). The effects of high-intensity interval training vs. moderate-intensity continuous training on heart rate variability in physically inactive adults. Int J Env Res and Public Health, 15(7), 1508. https://doi.org/10.3390/ijerph15071508

Alkahtani, S., Flatt, A. A., Kanas, J., Aldyel, A., & Habib, S. S. (2020). Role of type and volume of recreational physical activity on heart rate variability in men. Int J Env Res and Public Health, 17(8). https://doi.org/10.3390/ijerph17082719

Armstrong, L. E., & VanHeest, J. L. (2002). The Unknown mechanism of the overtraining syndrome. Sports Med, 32(3), 185–209. https://doi.org/10.2165/00007256-200232030-00003

Atakan, M. M., Li, Y. C., Kosar, S. N., Turnagol, H. H., & Yan, X. (2021). Evidence-based effects of high-intensity interval training on exercise capacity and health: A review with historical perspective. Int J Env Res and Public Health, 18(13). https://doi.org/10.3390/ijerph18137201 WE - Science Citation Index Expanded (SCI-EXPANDED) WE - Social Science Citation Index (SSCI)

Bara-filho, M. G., Freitas, D. S., Moreira, D., Matta, M. O., Lima, J. R. P., & Nakamura, F. Y. (2013). Heart rate variability and soccer training : a case study. Motriz, 19(1), 171–177.

Batacan, R. B., Duncan, M. J., Dalbo, V. J., Tucker, P. S., & Fenning, A. S. (2017). Effects of high-intensity interval training on cardiometabolic health: A systematic review and meta-analysis of

intervention studies. Br J Sports Med, 51(6), 494–503. https://doi.org/10.1136/bjsports-2015-095841
Billat, V. L. (2001). Interval training for performance: A scientific and empirical practice. Special recommendations for middle- and long-distance running. Part I: Aerobic interval training. Sports Med, 31(1), 13–31. https://doi.org/10.2165/00007256-200131010-00002
Bonen, A., & Belcastro, A. N. (1976). Comparison of self-selected recovery methods on lactic acid removal rates. Med Sci Sports, 8(3), 176–178.
Borges, N. R., Scanlan, A. T., Reaburn, P. R., & Doering, T. M. (2020). A comparison of heart rate training load and perceptual effort between masters and young cyclists. Int J Sports Physiol and Perform, 15(5), 759–762. https://doi.org/10.1123/ijspp.2019-0413
Borresen, J., & Lambert, M. I. (2008). Autonomic control of heart rate during and after exercise: Measurements and Implications for monitoring training status. Sport Med, 38(8), 633–646. https://doi.org/10.1103/PhysRevD.41.2634
Borresen, J., & Lambert, M. I. (2009). The quantification of training load, the training response and the effect on performance. Sports Med, 39(9), 779–795. https://doi.org/10.2165/11317780-000000000-00000
Botsva, N., Naishtetik, I., Khimion, L., & Chernetchenko, D. (2017). Predictors of aging based on the analysis of heart rate variability. Pacing Clin Electrophysiol, June, 1–10. https://doi.org/10.1111/pace.13180
Buchheit, M., & Laursen, P. B. (2013a). High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. Sport Med, 43(5), 313–338. https://doi.org/10.1007/s40279-013-0029-x
Buchheit, M., & Laursen, P. B. (2013b). High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. Sport Med, 43(5), 313–338. https://doi.org/10.1007/s40279-013-0029-x
Buchheit, M., & Laursen, P. B. (2013c). High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. Sports Med, 43(10), 927–954. https://doi.org/10.1007/s40279-013-0066-5
Buchheit, M., & Laursen, P. B. (2013d). High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. Sports Med, 43(10), 927–954. https://doi.org/10.1007/s40279-013-0066-5
Cohen, J. (1988). Statistical power analysis for the behavioral sciences. New York, NY: Routledge Academic.
da Silva, D. F., Simões, H. G., & Machado, F. A. (2015). vVO2max versus Vpeak, what is the best predictor of running performances in middle-aged recreationally-trained runners? Sci Sports, 30(4), e85–e92. https://doi.org/10.1016/j.scispo.2014.10.006
Draghici, A. E., & Taylor, J. A. (2016). The physiological basis and measurement of heart rate variability in humans. J Physiol Anthropol, 35(1), 1–8. https://doi.org/10.1186/s40101-016-0113-7
Farias-Junior, L. F., Macêdo, G. A. D., Browne, R. A. V., Freire, Y. A., Oliveira-Dantas, F. F., Schwade, D., Mortatti, A. L., Santos, T. M., & Costa, E. C. (2019). Physiological and psychological responses during low-volume high-intensity interval training sessions with different work-recovery durations. J Sports Sci Med, 18(1), 181–190.
Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behav Res Methods, 41(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149
Fennell, C. R. J., & Hopker, J. G. (2021). The acute physiological and perceptual effects of recovery interval intensity during cycling-based high-intensity interval training. Eur J Appl Physiol, 121(2), 425–434. https://doi.org/10.1007/s00421-020-04535-x
Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Suzanne, P., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. J Strength Cond Res, 15(1), 109–115.
Gibson, N., Brownstein, C., Ball, D., & Twist, C. (2017). Physiological, perceptual and performance responses associated with self-selected versus standardized recovery periods during a repeated sprint protocol in elite youth football players: A preliminary study. Ped Exerc Sci, 29(2), 186–193. https://doi.org/10.1123/pes.2016-0130

Glaister, M., Witmer, C., Clarke, D. W., Guers, J. J., Heller, J. L., & Moir, G. L. (2010). Familiarization, reliability, and evaluation of a multiple sprint running test using self-selected recovery periods. J Strength Cond Res, 24(12), 3296–3301. https://doi.org/10.1519/JSC.0b013e3181bac33c

Ho, R. (2014). Handbook of univariate and multivariate data analysis with IBM SPSS (C. Press, Ed.; 2nd ed.).

Holmes, C. J., Fedewa, M. V., Dobbs, W. C., Liu, Y., Flatt, A. A., Nakamura, F. Y., & Esco, M. R. (2020). The effects of different body positions on the accuracy of ultra-short-term heart rate variability indexes. J High Tech Manag Res, 31(1), 100375. https://doi.org/10.1016/j.hitech.2020.100375

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load : 15 years on internal and external training load : 15 years on training load : Internal and external load theoretical framework : The training process. Int J Sports and Performance, Ahead of P. https://doi.org/10.1123/ijspp.2018-0935

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. Med Sci Sports Exerc, 36(6), 1042–1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Johnston, B. W., Barrett-Jolley, R., Krige, A., & Welters, I. D. (2020). Heart rate variability: Measurement and emerging use in critical care medicine. J Int Care Soc, 21(2), 148–157. https://doi.org/10.1177/1751143719853744

Kabasakalis, A., Nikolaidis, S., Tsalis, G., & Mougios, V. (2022). Low-volume sprint interval swimming is sufficient to increase blood metabolic biomarkers in master swimmers. Res Quart Exerc and Sport, 93(2), 318–324. https://doi.org/10.1080/02701367.2020.1832183

Lundstrom, C. J., Foreman, N. A., & Biltz, G. (2023). Practices and applications of heart rate variability monitoring in endurance athletes. Int J Sports Med, 44, 9–19. https://doi.org/10.1055/a-1864-9726

Machado, A. F., Evangelista, A. L., Miranda, J. M. Q., Teixeira, C. V. S., Rica, R. L., Lopes, C. R., Figueira-Júnior, A., Baker, J. S., & Bocalini, D. S. (2018). Description of training loads using whole-body exercise during high-intensity interval training. Clinics, 73(12), 1–6. https://doi.org/10.6061/CLINICS/2018/E516

MacInnis, M. J., & Gibala, M. J. (2017). Physiological adaptations to interval training and the role of exercise intensity. J Physiol, 595(9), 2915–2930. https://doi.org/10.1113/JP273196

Madueno, M. C., Guy, J. H., Dalbo, V. J., & Scanlan, A. T. (2019). A systematic review examining the physiological, perceptual, and performance effects of active and passive recovery modes applied between repeated-sprints. J Sports Med Phys Fit, 59(9), 1492–1502. https://doi.org/10.23736/S0022-4707.18.09188-0

McEwan, G., Arthur, R., Phillips, S. M., Gibson, N. V., & Easton, C. (2018). Interval running with self-selected recovery: Physiology, performance, and perception. Europ J Sport Sci, 18(8), 1058–1067. https://doi.org/10.1080/17461391.2018.1472811

Mclaren, S. J., Macpherson, T. W., Coutts, A. J., Hurst, C., Spears, I. R., & Weston, M. (2017). The relationships between internal and external measures of training load and intensity in team sports : A Meta-analysis. Sports Med. https://doi.org/10.1007/s40279-017-0830-z

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., Raglin, J., Rietjens, G., Steinacker, J., & Urhausen, A. (2013). Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the european college of sport science and the American College of Sports Medicine. Med Sci Sports Exerc, 45(1), 186–205. https://doi.org/10.1249/MSS.0b013e318279a10a

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO2max improvements: A systematic review and meta-analysis of controlled trials. Sports Med, 45(10), 1469–1481. https://doi.org/10.1007/s40279-015-0365-0

Morgan, W. P., Brown, D. R., Raglin, J. S., O'Connor, P. J., & Ellickson, K. A. (1987). Psychological monitoring of overtraining and staleness. Brit J Sports Med, 21(3), 107–114. https://doi.org/10.1136/bjsm.21.3.107

Nakamura, F. Y., Flatt, A. A., Pereira, L. A., Ramirez-Campillo, R., Loturco, I., & Esco, M. R. (2015). Ultra-short-term heart rate variability is sensitive to training effects in team sports players. J Sports Sci Med, 14(3), 602–605.

Nakamura, F. Y., Moreira, A., & Aoki, M. S. (2010). Monitoramento da carga de treinamento: A percepção subjetiva do esforço da sessão é um método confiável? Rev Educ Física/UEM, 21(1), 1–11. https://doi.org/10.4025/reveducfis.v21i1.6713

Nuuttila, O., Seipäjärvi, S., Kyröläinen, H., & Nummela, A. (2022). Reliability and sensitivity of nocturnal heart rate and heart-rate variability in monitoring individual responses to training load. Int J Sports Physiol Perform, Ahead of P, 1–8. https://doi.org/10.1123/ijspp.2022-0145

Perkins, S. E., Jelinek, H. F., Al-Aubaidy, H. A., & de Jong, B. (2017). Immediate and long term effects of endurance and high intensity interval exercise on linear and nonlinear heart rate variability. J Sci Med in Sport, 20(3), 312–316. https://doi.org/10.1016/j.jsams.2016.08.009

Pind, R., & Mäestu, J. (2017). Monitoring training load: necessity, methods and applications. Acta Kinesiol Univ Tart, 23, 7–18. https://doi.org/10.12697/akut.2017.23.01

Plews, D. J., Laursen, P. B., Stanley, J., Kilding, A. E., & Buchheit, M. (2013). Training adaptation and heart rate variability in elite endurance athletes : Opening the door to effective monitoring. Sports Med, 43, 773–781. https://doi.org/10.1007/s40279-013-0071-8

Pollock, S., Gaoua, N., Johnston, M. J. J., Cooke, K., Girard, O., & Katya, N. M. (2019). Training regimes and recovery monitoring practices of elite british swimmers. J Sports Sci Med, 18, 577–585.

Quintana, D. S., Heathers, J. A., & Kemp, A. H. (2012). On the validity of using the Polar RS800 heart rate monitor for heart rate variability research. Eur J Appl Physiol, 112(2), 4179–4180.

Rohlfs, I. C. P. M., Rotta, T. M., Luft, C. B., Andrade, A., Krebs, R. J., & De Carvalho, T. (2008). Brunel mood scale (BRUMS): An instrument for early detection of overtraining syndrome. Rev Bras Med Esp, 14(3), 176–181. https://doi.org/10.1590/S1517-86922008000300003

Sanchez, R., Nieto, C., Leppe, J., Gabbett, T., & Besomi, M. (2025). Associations between training load, heart rate variability, perceptual fatigue, sleep, and injury in endurance athletes during a 12-week training mesocycle. International Journal of Sports Science & Coaching. https://doi.org/10.1177/17479541251335613

Sánchez-Otero, T., Tuimil, J. L., Boullosa, D., Varela-Sanz, A., & Iglesias-Soler, E. (2022). Active vs. passive recovery during an aerobic interval training session in well-trained runners. Eur J Appl Physiol, 122, 1281–1291. https://doi.org/10.1007/s00421-022-04926-2

Sant'Ana, L. O., Bara-Filho, M. G., & Vianna, J. M. (2021). Monitoramento da carga de treinamento na corrida: Aspectos fisiológicos e metodológicos na aplicabilidade prática desta modalidade. Res Soc Develop, 10(9), 1–11. https://doi.org/10.33448/rsd-v10i9.16986

Schmitt, L., Regnard, J., & Millet, G. P. (2015). Monitoring fatigue status with HRV measures in elite athletes : An avenue beyond RMSSD ? Front Physiol, 6(343), 1–3. https://doi.org/10.3389/fphys.2015.00343

Seiler, K. S., & Kjerland, G. Ø. (2006). Quantifying training intensity distribution in elite endurance athletes: Is there evidence for an "optimal" distribution? Scand J Med Sci Sports, 16(1), 49–56. https://doi.org/10.1111/j.1600-0838.2004.00418.x

Taylor, J. L., Holland, D. J., Spathis, J. G., Beetham, K. S., Wisløff, U., Keating, S. E., & Coombes, J. S. (2019). Progress in Cardiovascular Diseases Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. Progress in Cardiovascular Diseases, 62(2), 140–146. https://doi.org/10.1016/j.pcad.2019.01.004

Thibault, G. (2003). A graphical model for interval training. New Stud Athlet, 18(3), 49–55.

Tibana, R. A., de Sousa, N. M. F., Prestes, J., Feito, Y., Ernesto, C., & Voltarelli, F. A. (2019). Monitoring training load, well-being, heart rate variability, and competitive performance of a functional-fitness female athlete: A case study. Sports, 7(35), 1–11. https://doi.org/10.3390/sports7020035

Tibana, R. A., Sousa, N. M. F., Cunha, G. V., Prestes, J., Fett, C., Gabbett, T. J., & Voltarelli, F. A. (2018). Validity of session rating perceived exertion method for quantifying internal training load during high-intensity functional training. Sports, 6(68), 1–8.

Toubekis, A. G., & Douda, H. T. (2005). Influence of different rest intervals during active or passive recovery on repeated sprint swimming performance. Eur J Appl Physiol, 93, 694–700. https://doi.org/10.1007/s00421-004-1244-9

Toubekis, A. G., Smilios, I., Bogdanis, G. C., Mavridis, G., & Tokmakidis, S. P. (2006). Effect of different intensities of active recovery on sprint swimming performance. Appl Physiol Nutr Metab, 31, 709–716. https://doi.org/10.1139/H06-075

Utter, A. C., Robertson, R. J., Green, J. M., Suminski, R. R., McAnulty, S. R., & Nieman, D. C. (2004). Validation of the adult OMNI Scale of Perceived Exertion for walking/running exercise. Med Sci Sports Exerc, 36(10), 1776–1780. https://doi.org/10.1249/01.MSS.0000142310.97274.94

Vanrenterghem, J., Nedergaard, N. J., Robinson, M. A., & Drust, B. (2017). Training load monitoring in team sports : A novel framework separating physiological and biomechanical load-adaptation pathways. Sports Med. https://doi.org/10.1007/s40279-017-0714-2

Wen, D. Z., Utesch, T., Wu, J., Robertson, S., Liu, J., Hu, G. P., & Chen, H. C. (2019). Effects of different protocols of high intensity interval training for VO2 max improvements in adults: A meta-analysis of randomised controlled trials. J Sci Med Sport, 22(8), 941–947. https://doi.org/10.1016/j.jsams.2019.01.013 WE - Science Citation Index Expanded (SCI-EXPANDED)

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