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Effects of different recovery times during high-intensity interval training using body weight on psychophysiological variables

Efectos de diferentes tiempos de recuperación durante el entrenamiento interválico de alta intensidad utilizando el peso corporal en variables psicofisiológicas

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Abstract. The present study aimed to analyze different recovery times on psychophysiological responses during HIIT sessions using body weight. All volunteers performed three sessions of HIIT using body weight with different recovery times of 60 s, 30 s, and 15 s. The recovery times were randomly assigned with an interval of 48 hours between sessions. The following variables were assessed: Heart rate (HR), perceived effort (SPE), perception of recovery (SPR), Total number of movements in the session (TAM), and lactate concentrations. There were no differences in absolute ($p = 0.057$) and relative ($p = 0.066$) HR between the 60 s and 30 s sessions, however the values of absolute ($p = 0.001$) and relative ($p = 0.002$) in the 15 s session were greater than 60 s. Considering the number of movements, the session using the 15 s recovery period ($p = 0.001$) presented lower values than sessions using 60 s and 30 s which did not differ from each other. The SPE values of the 60 s session were lower ($p = 0.028$; $p < 0.001$) than the 30 s and 15 s sessions, respectively, which differed in order ($p < 0.001$). The training load of the 60 s and 30 s sessions did not differ ($p = 0.649$) from each other, but both were lower ($p = 0.001$) than the 15 s session. The findings of the present study show that the variables SPE, SPR, and TAM for the 15 s recovery period had a significantly different response than the 60 s and 30s recovery, however, the lactate concentration between the different conditions (60 s, 30 s, and 15 s) after the training session did not produce a significantly different result.
Keywords: HIIT, whole body, interval training, time of recovery.

Resumen. El presente estudio tuvo como objetivo analizar diferentes tiempos de recuperación de las respuestas psicofisiológico durante sesiones de HIIT utilizando el peso corporal. Todos los voluntarios realizaron tres sesiones de HIIT usando el peso corporal con diferentes tiempos de recuperación de 60 s, 30 s y 15 s. Los tiempos de recuperación se asignaron aleatoriamente con un intervalo de 48 horas entre sesiones. Se evaluaron las siguientes variables: frecuencia cardíaca (FC), esfuerzo percibido (SPE), percepción de recuperación (SPR), número total de movimientos en la sesión (TAM) y concentración de lactato. No hubo diferencias en la FC absoluta ($p = 0{,}057$) y relativa ($p = 0{,}066$) entre las sesiones de 60 y 30 segundos, sin embargo, los valores de FC absoluta ($p = 0{,}001$) y relativa ($p = 0{,}002$) en la sesión de 15 segundos fueron mayores que años 60 Considerando el número de movimientos, la sesión que utilizó el período de recuperación de 15 s ($p = 0{,}001$) presentó valores más bajos que las sesiones de 60 s y 30 s que no difirieron entre sí. Los valores de SPE de la sesión de 60 s fueron menores ($p = 0{,}028$; p < 0,001) que los de las sesiones de 30 s y 15 s, respectivamente, que diferían en el orden ($p < 0{,}001$). La carga de entrenamiento de las sesiones de 60 s y 30 s no difirió ($p = 0{,}649$) entre sí, pero ambas fueron menores ($p = 0{,}001$) que la sesión de 15 s. Los hallazgos del presente estudio muestran que las variables SPE, SPR y TAM para el período de recuperación de 15 s tuvieron una respuesta significativamente diferente a la recuperación de 60 y 30 s, sin embargo, la concentración de lactato entre las diferentes condiciones (60 s, 30 s y 15 s) después de la recuperación sesión de entrenamiento no produjo un resultado significativamente diferente.
Palabras clave: HIIT, cuerpo entero, entrenamiento interválico, tiempo de recuperación.

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Introduction

High-intensity interval training (HIIT) has been used by several professionals due to similar responses to continuous training at moderate intensity, but with a shorter training session duration (Kul et al., 2022; Zhang et al., 2017) in different populations (Teixeira et al., 2023; Monteiro et al., 2017, Allen et al., 2017, Buchheit et al., 2009) due to its time-efficient nature. Differently from traditional methods using ergometers, HIIT using body weight (HIIT-BW) can be considered a facilitative exercise method due to its easy application and low cost (Gray et al., 2016). In this way, the method may be useful to encourage more people to participate in regular physical exercises (McRae et al., 2012). For example, the use of bodyweight training increased significantly during the COVID-19 pandemic lockdown (Steele et al., 2021) due to the closure of gyms and physical training centers (Pitanga et al., 2020) be considered an interesting strategy for maintaining physical activity.

In a review study Buchheit e Laursen (2013) indicate at least nine parameters that can be used in the prescription of HIIT, these include the intensity, stimulus duration, modality/type of exercise, duration of recovery intervals, and the types of pauses. Among these parameters, information about how the type of pause can influence adaptive processes has been investigated. In this perspective it is suggested that, better resynthesis of resting phosphocreatine, reduction of intramuscular pH, lactate removal, oxidative phosphorylation provides greater potential to achieve high percentages and spend greater time in high percentages of VO_{2max} (Thevenet et al., 2007, Spencer et al., 2008, Tokmakidis et al., 2011). Its responses, may influence the energy demand, muscle fatigue and voluntary time to exhaustion (Zafeiridis et al., 2010), these together are considered important mechanisms that are influenced by the type of pause.

However, the recovery time around the set is still unclear (Flores et al., 2023). It suggests that different recovery times may alter biochemical aspects such as lactate concentration (Germano et al., 2019), and alterations in neuromuscular (Machado et al., 2018) responses indicating fatigue and muscle exhaustion. Together, these responses promote a reduction in muscle strength in response to intense activity resulting in multifactorial effects (Kent-Braun et al., 2012), such as changes in heart rate (HR), increased subjective perception of exertion (SPE) and decreased subjective perception of recovery (SPR). Considering that exercise intensity may induce influences on HR recovery in high-intensity training (Villelabeitia-Jaureguizar et al., 2017) information about SPE and SPR responses in HIIT-BW are important and easier parameters for monitoring exercise sessions in the real world (Machado et al, 2022).

In this way, to our knowledge, there are no reports in the literature about the influence of the interval time in HIIT-BW exercise sessions. Therefore, the purpose of the study was to evaluate the effects of the time of recovery following the training parameters during HIIT sessions using body weight in training parameters.

Methods

Study design

This crossover trial was designed to investigate the effects of different recovery times on psychophysiological responses following HIIT sessions in adult males and females. All participants underwent three sessions of HIIT session with different recovery times (60 s, 30 s, 15 s), randomly, with an interval of 48 hours between sessions. All participants were instructed to abstain from physical exercise for 48 hours before procedures and from caffeine consumption and alcohol for 24 hours before the session. In addition, the subjects were instructed to maintain their usual meals for 24 hours prior to the interventions and to arrive at the laboratory well-fed in the afternoon. The study was approved by the Human Research Ethics Committee of Federal University of Espírito Santo (CAAE: 25822119.2.0000.5542, nº 3.733.252/2019).

Participants

A total of 16 healthy adults (8 men and 8 women) participated voluntarily in the study. The study included subjects who were 27.37 $\pm$ 4.65 years old; body mass (kg) of 72.72 $\pm$ 17.55; height (m) of 1.69 $\pm$ 0.10, body mass index (kg/m^2) of 25.15 $\pm$ 3.71 and 2.00 $\pm$ 1.37 years of cross fit practice. All subjects were practitioners of CrossFit for at least 6 months and over 75 minutes of high-intensity physical activity per week. The following exclusion criteria was applied; individuals with joint and/or musculoskeletal disorder in the dominant lower limb that prevents performance exercise protocols; smokers; individuals with cardiovascular and metabolic alterations; individuals who have been using buffer substances or creatine as supplements, as well as those who did not agree with the consent term. All subjects completed informed consent forms before data collection.

The minimum sample size was estimated at 14 participants for the condition when considering the analysis of G Power software (v. 3.1.9.4), for a power of (1 - beta) of 0.80 and alpha = 0.05, effect size = 0.25 with two measurements under three conditions, however considering possible dropouts, we decided to work with 16 individuals per experimental condition. All eligible individuals underwent three randomized HIIT-B sessions with a 48 hours interval between each session: 60 s (HIIT-B session with 60 seconds of recovery time), 30 s (HIIT-B session with 30 seconds of recovery time), and 15 s (HIIT-B session with 15 seconds of recovery time).

Procedures

The HIIT-B protocol consisted of a warm-up for 5 minutes without interruption with one minute of stationary running, followed by 30 seconds using the following exercises: jumping jacks, burpee, climber, and squat with jump, ending with another minute of skipping and one minute of walking at an intensity between 4 and 5 recorded on the Borg scale (score 0-10). The session started after warming up, consisting of 20 sets (five sets for each exercise) of 30 seconds of stimulus and 30 seconds of passive recovery between sets, which were performed using "all-out" intensity and monitored using the Borg scale adapted from (0-10). The following exercises were used: jumping jacks, burpees, mountain climbers and squat with jump, as previously published (Machado et al., 2019; Machado et al., 2018b). The experimental conditions 60 s, 30 s, or 15 s were randomly chosen by drawing lots on the day of the session.

Evaluated parameters

Lactate concentration

The blood lactate concentration assessment was performed before and immediately after the HIIT sessions. Blood samples were taken from the tip of a sterilized finger using a sterile lancet. The first drop of blood was discarded, and free-flowing blood was collected in glass capillary tubes. All blood samples for lactate analysis were evaluated using the Accutrend® equipment (Roche - Basel, Switzerland) previously calibrated according to previous publications (Machado et al., 2018c; Rica et al., 2018).

Heart rate

Heart rate (HR) was continuously assessed at rest for 10 minutes, immediately after each series (total of 20 measurements) and at the end of the session using a Polar frequency meter (Model H10). All subjects were instructed to check the equipment already positioned on the chest for 10 minutes to avoid any complications during collections. Absolute (HRmax) and relative (%HRmax) maximum heart rate were estimated using equations by Tanaka (Tanaka et al., 2001).

Perceptions of effort and recovery

Subjective perception of exertion (SPE) was assessed using the BORG scale as previously described (Evangelista et al., 2017; Machado et al., 2018c; Rica et al., 2018; Machado et al., 2019). The instrument consisted of a graduated scale, ranging from 0 to 10 with verbal anchors considering 0 little intense and 10 very intense. The subjective perception of recovery (SPR) was assessed using the quality of recovery scale (Machado et al., 2018c). The SPR scale is graduated from 0 to 10 and has verbal anchors related to the perception of recovery, in which 0 means not recovered and 10 means completely recovered, thus, the closer to 10 value, the greater the individual's perception of recovery. The SPE was evaluated immediately after the series performance, whereas the SPR was evaluated with 10s at the end of the recovery period.

Training load

The procedures used by Foster et al. (2001) were employed to assess training load. Briefly, the training load was evaluated by multiplying the total session time by the value of the exercise intensity of the session given from the SPE scale graduated from 0 to 10 points. To ensure that the information obtained from the SPE referred to the exercise as a whole body, the participant was requested to answer the question, "How was your training session?" 10 minutes after the end of the session.

Performance on session

The total amount of movements in each series was monitored and quantified for each series following previous publications (Machado et al., 2018d; Rica et al., 2018) and used as a performance parameter. A higher total number of moves performed reflects a higher performance in the HIIT-B session.

Statistical analysis

The Shapiro-Wilk test was used for data normality analysis.

The differences between the 60 s, 30 s, and 15 s conditions were analyzed by analysis of variance with repeated measures followed by Tukey's post-hoc test. Analysis of variance with repeated measures with two factors: time (before and after) and condition (time*condition) with the Bonferroni post hoc test used to verify the effects on the studied variables over time. The mean of the difference and the 95% confidence interval (CI) were calculated to confirm the differences. The Analysis were performed using GraphPad Prism software (v. 6.01; GraphPad software, USA) with a significance level of $p < 0.05$ with data presented as mean ± standard deviation.

Results

A main time effect (F = 167.9; $p < 0.0001$) without significant interaction (F = 0.18; $p = 0.8334$) was found for blood lactate concentrations. An increment in lactate concentration was found for 60 s (After: 1.31 ± 0.12 mmol.L^{-1}, Before: 15.10 ± 4.89 mmol.L^{-1}, MD [95% CI]: -13,78 [-15.08 to -12.48]; $p < 0.0001$); 30s (After: 1.61 ± 0.22 mmol.L^{-1}, Before: 15.15 ± 4.80 mmol.L^{-1}, MD [95% CI]: -13,53 [-14.83 to -12.23; p < 0.0001) and 15s (After: 1.66 ± 0.27 mmol.L^{-1}, Before: 15.00 ± 3.72 mmol.L^{-1}, MD [95% CI]: -13,34 [-14.64 to -12.04; p < 0.0001).

Table 1 shows the training parameters for HIIT on different experimental conditions. No differences were found in absolute ($p = 0.057$) and relative ($p = 0.066$) heart rate between the 60 s and 30 s sessions, however the values of absolute ($p = 0.001$) and relative ($p = 0.002$) heart rate of 15 s session were higher than the 60 s condition. No differences were found between the 30 s and 15 s session conditions. Considering the number of movements, differences were found between experimental conditions as shown in table 1. The values of SPE in the session using 60 s was smaller ($p = 0.028$; $p < 0.001$) than 30 s and 15 s sessions, respectively, which differed in order ($p < 0.001$). The training load of the 60s and 30 s sessions did not differ ($p = 0.649$) from each other, however both were smaller ($p = 0.001$) than the 15s session.

Table 1.
Training parameters of HIIT on different experimental conditions.

Parameters	60s	30s	15s	F	P
HR (bpm)	164.50 ± 7.86*	168.40 ± 7.19	169.40 ± 5.86	9.923	= 0.004
HR_{max} (%)	87.23 ± 4.31*	89.32 ± 3.50	89.86 ± 3.12	9.439	= 0.005
TAM (reps)	648.70 ± 70.66*†	624.20 ± 60.01*	600.30 ± 63.66	16.68	< 0.001
SPE (0-10)	6.43 ± 1.20*†	7.31 ± 0.70*	8.50 ± 0.63	22.32	< 0.001
Training load (ua)	136 ± 25*	140 ± 22*	169 ± 12	14.95	< 0.001

Values expressed in mean ± standard deviation of 60 s, 30 s and 15 s recovery time conditions. HR: heart rate (HR). TAM: total amount of movements. SPE: subjective perception effort. *$p < 0.05$ vs 15s; †$p < 0.05$ vs 30 s.

In figure 1, it is possible to observe the data related to HR, SPE, and SPR along the sets and their respective areas under the curve. Significant differences were found regardless of the experimental condition from the second set to 60 s (F = 24.31, $p < 0.001$), the fifth set to 30 s (F = 17.97, $p < 0.001$), and the fourth set to 15 s (F = 8.67, $p < 0.001$) condition compared to the first set. In relation to SPE and SPR, significant differences were found to fourth 60 s (F = 6.80, $p = 0.004$), fourth set to 30 s (F = 5.66, $p = 0.012$) and first set to 15 s (F = 8.85, $p < 0.001$) condition compared to the first set, to SPR 60 s (F = 64.94, $p < 0.001$), third set to 30 s (F = 57.52, $p < 0.001$) and third set to 15 s (F = 26.68, $p < 0.001$) condition compared to first set to SPR. Differences (F = 8.98; $p = 0.006$) was found between

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the values of the area under the curve for HR (Panel B) to 60 s (3223 ± 110) compared to 15 s (3132 ± 147) without differ to 30 s (3204 ± 138).

No differences were found in the area under the curve for SPE (60 s: 184 ± 7; 30 s: 184 ± 7; 15 s: 183 ± 10; F = 0.05; p = 0.871) as shown in Panel D. The values of the area under the curve for SPR (Panel E) of 60 s (67 ± 16) and 30 s (66 ± 16) do not differ between then, however, were higher (F = 25.45; $p < 0.0001$) than 15 s (43 ± 18) conditions.

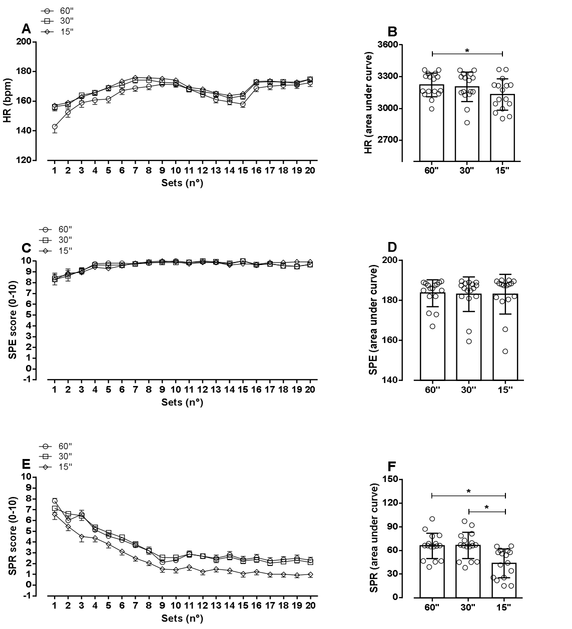

Figure 1. Values expressed in mean ± standard deviation of 60 s, 30 s and 15 s recovery time conditions. Panel A: heart rate (HR). Panel B: area under curve of HR. Panel C: subjective perceived effort (SPE). Panel D: area under curve of SPE. Panel E: subjective perceived recovery (SPR). Panel F: area under curve of SPR. *$p < 0.05$"

Discussion

The present study analyzed the effects of different recovery intervals during High Intensity Interval Training (HIIT) using body weight on SPE, SPR, HR and lactate responses. The main finding of this study was that the responses between the protocols using 30 and 60 seconds of passive recovery did not differ significantly, and there were no differences between the different conditions analyzed for lactate concentrations. This partly rejects the initial hypothesis that we would have different responses for the analyzed variables for different intervals.

The blood lactate concentrations of the protocols in the present study using different recovery times did not present statistical differences, which leads us to conclude that the differences between the recovery times proposed in this study was not sufficient to promote an acute change in the concentration of blood lactate, and corroborate other studies (Toubekis et al., 2005; Toubekis et al., 2006; Kostoulas et al., 2017). In the study by Germano et al. (2019), the researchers observed that the different recovery times (2 and 8 min) and different types (active and passive) in the HIIT session also did not promote significant differences when comparing the group that recovered 2 min actively and passively and the group that recovered 8 minutes actively.

Machado et al. (2021) analyzed the HR, latacte, and TAM responses using two different types of HIIT sessions (block and circuit) using body weight and observed that the lactate concentration was significantly lower in the circuit session when compared to the block session. This evidence suggest that the circuit HIIT session structure has a lower metabolic impact, even with a 1:1 load ratio when compared to a block HIIT session with body weight and with a ratio load ratio of 1:2, which may be due to alternations between movements and time spent performing the same movement in the session, as proposed in this study.

Domínguez et al. (2018), observed that a HIIT session increased lactate concentration, and resulted in a greater overload in cardiorespiratory work leading to neuromuscular fatigue. These physiological changes corroborate to the present study, as different HIIT protocols, specifically with shorter recovery intervals, can result in increased lactate (Domínguez et al., 2018). However, HIIT using body weight uses different structures of sessions (Machado et al., 2021), exercises (Machado et al., 2020), and exercise distribution (Machado et al., 2022) that can all influence physiological adaptations including increases in HR, lactate concentration, SPE and SPR (Machado et al., 2018).

The results of this study did not show a significant response in HR and HRmax (%) of the group using recovery intervals of 60 seconds when compared to the groups using 30 and 15 seconds of recovery, which suggests that the group with the longest recovery time (60 seconds) had a less expressive HR response. These results corroborate the study by Arazi et al. (2013), which compared the response of two different recovery intervals in circuit training, and also the study by Hottenrott et al. (2021), who observed the responses of two different recovery intervals in trained men and women.

SPE and SPR variables analyzed in the present study did not present significant differences between the groups with recovery intervals of 30 and 60 seconds, as well as the TAM variable, which also did not present a significant difference in the groups with 30 and 60 seconds of recovery. These findings lead us to understand that even though the groups with a recovery time of 15, 30, and 60 seconds did not present significant differences for the lactate concentration variable, the group with a recovery time of 15 seconds presented significant differences for the SPE, SPR, and TAM which may represent an alternative and practical way of observing the stress of the HIIT session using body weight.

Any type of recovery interval, whether long or short, can generate changes in the cardiorespiratory system, corroborating the present study in which the different recovery intervals promoted increments in different physiological parameters, such as HR, SPE, and SPR (Germano et al., 2019), and physical, such as TAM (Machado et al., 2018). Recovery interval time is one of the factors that has a direct influence on the athlete's physical and physiological performance. This parameter must be considered when prescribing training (Nogueira et al., 2012).

In this sense, HIIT using body weight with different recovery times can be used as an alternative training method to improve physical and physiological performance, monitoring SPE, SPR, and HR to control results. According to Machado et al. (2019), in bodyweight training, the biological individuality of all participants must be considered to control HR, SPR and SPE, respecting the principles of exhaustion time, recovery and training session.

Despite the valuable insights gained from this study, it is important to acknowledge its limitations. First, the study employed a relatively small sample size, which may limit the generalizability of the findings to a broader population. Additionally, the study was conducted over a relatively short period, which restricts the ability to assess the long-term effects of different recovery times during bodyweight HIIT. Moreover, the study focused on crossfit practioners, potentially limiting the applicability of the results to other populations or settings. Additionally, the sample was composed by men and women, thus physiological response between subjects could promote some influence in our results obtained. Thus the evaluation by sex on physical physiological responses could clarify and help others to create exercise design programs and regimes. Future studies with larger and more diverse participant samples, conducted over longer durations, would help to strengthen the findings and provide a more comprehensive understanding of the effects of recovery times in body weight HIIT. These limitations should be considered when interpreting the results and highlight opportunities for further research.

In resume, the findings show that the different recovery times between the groups were not enough to generate a significantly different lactate concentration after the training session. However, even with the metabolic stress between the groups without a significant difference, the group that worked using 15 seconds of recovery obtained a greater SPE, a smaller SPR, and a smaller TAM compared to sessions using 30 and 60 seconds of recovery between the stimuli. The loss of ability to perform movements was affected even without a significantly different lactate concentration between groups, which leads us to believe that other factors independent of metabolic stress may affect the ability to perform movements during the session. Additionally, it suggests that the use of 15-second recovery intervals be applied using HIIT sessions with body weight in individuals with a better level of conditioning. As for beginners, the recommendation is to use the 30-second recovery time interval, a recommendation that contradicts a previous publication by our group, which suggests the use of different recovery intervals based on a literature review. The results allow us to understand that manipulation of the training variables of HIIT programs using body weight seem to be more efficient and safer by physical education professionals who use this modality as part of their training prescriptions.

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Conflict of interest

The author AFM declare conflict of interest for selling clinics and workshops associated with the topic of the manuscript. The other authors do not declared conflict of interest.

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