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Original Article

Perceptual and performance responses after a body-weight high-intensity interval exercise session in adult men

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Abstract:
High-intensity interval exercise (HIIE) has become increasingly popular, emerging a leading trend in the fitness industry worldwide, often performed using either traditional equipment or only body weight as resistance. While HIIE protocols can induce muscle fatigue for hours or days after exercise, however this, previous research has predominantly focused on treadmill or cycle ergometer-based HIIE. Despite its time efficiency and short duration, literature suggests that high-intensity exercises may lead to negative affective responses, potentially reducing adherence. Thus, this study aimed to analyze perceptual and performance responses following a bodyweight HIIE session in adult men. This cross-sectional quantitative analysis, was approved by the UPE Ethics and Research Committee (CAAE: 52201821.4.0000.5191). Ten physically active men, aged 18 to 40 years (mean age 24.80±1.21 years; mean BMI 24.61±0.77 kg/m²), participated. The experimental session consisted of the following exercise sequence: jumping jacks, burpees, mountain climbers, and squat jumps. A maximum of 20 sets of 30 seconds at all-out intensity were performed, with passive recovery of 30 seconds between sets. Before the session and immediately after, the Rating Perceived Exertion scale (RPE – Borg CR10) and Affective Valence by Feeling scale (FS) were measured, the average height of three countermovement vertical jumps (cm) and the average strength of three handgrip measurements (kg/f). Furthermore, the Pain Numeric Rating scale (PNR) and the Perceived Recovery Status scale (PRS) were monitored at the following moments: pre-session, 5 minutes later and 24 hours (h) after. A descriptive statistical analysis was performed (mean ± standard deviation), the Shapiro-Wilk normality test was applied, a Student's T-Test and a one-way ANOVA for dependent samples, considering an alpha of 5%. The results did not demonstrate significant differences in upper limb strength through handgrip (47.60±7.63 kg/f vs. 49.50±5.95 kg/f; $p>0.05$) and average vertical jump height (36.69 ± 4.46 cm vs. 33.91±7.02 cm; $p>0.05$), compared before and immediately after the session. There was an increase in RPE (0±0 au vs. 8±2 au, $p<0.01$) and a decrease in FS (2±2 au vs. -3±2 au; $p<0.01$) pre and post session. Furthermore, there was an increase in PNR 24h after the session, compared to the state before and immediately after (0±0 au pre; 1±1 au post; 4±2 au 24h after; $p<0.05$). and a decrease in PRS, immediately after and 24h, compared to the moment before (10±1 au pre; 5±2 au post; 6±3 au 24h; $p<0.05$). It is concluded that an HIIE session, with body weight, did not demonstrate a decrease in the average performance of upper limb strength (handgrip) and vertical jump height (lower limbs). showing a decrease in affective valence immediately after the session. Furthermore, 24 hours after the session, PRS is not completely restored to baseline levels, concurrently with an increase in delayed onset muscle pain.
Key Words: Physical exercise, Muscle pain, Affect, Fatigue, High-intensity interval training.

Introduction

Recently, the high-intensity interval training (HIIT) method has been gaining popularity, emerging among the main trends in global fitness (Thompson, 2023) with its practice being able to be performed in traditional models, with the use of treadmills and cycle ergometers (Evangelista et al., 2021) or even using only body weight as resistance (Machado et al., 2019; Scoubeau et al., 2022).

These Bodyweight HIIT sessions combine functional exercises, performed at high intensity, without the use of specific equipment, with a short recovery time between sets, and can induce simultaneous adaptations in several motor function markers, improvement of cardiorespiratory fitness, muscle fitness and body composition in different age groups (Scoubeau et al., 2022; Guo et al., 2023).

It is common for different protocols and types of exercises can induce fatigue or muscle damage, characterized by a temporary reduction in strength or power along with metabolic changes that last a few hours or days after training sessions (Carrol et al., 2017; Cross et al., 2022; Leite et al., 2023). To accurately prescribe HIIT programs is necessary to understand the acute responses evaluating the time and status of muscle recovery and delayed onset muscle soreness after high-intensity sessions (Leite et al., 2023; Tolusso et al., 2022)

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since this variable directly implies the prescription of the weekly frequency of activity, determine the point at which HIIT may negatively affect the performance of practitioners.

Considering these implications a recent systematic review aimed at describing the effects of a single session of High-Intensity Interval Training on exercise-induced muscle damage, in which HIIT protocols promoted changes such as increases in creatine kinase, myoglobin and lactate dehydrogenase immediately after the session, with delayed onset muscle soreness lasting over 24 hours (Leite et al., 2023). However, most of the studies analyzed involve traditional HIIT protocols on a treadmill and cycle ergometer, with greater cardiovascular demand and less peripheral muscle fatigue. Few investigated about recovery time in HIIT sessions with body-weight characterized by simultaneously cardiovascular and muscular demand.

Another factor that can influence during exercise adherence is the affective condition, or the feelings of pleasure and displeasure (Ekkekakis, 2017; Stevens et al., 2020). Short sessions can be efficient in terms of time utilization, however, high-intensity exercises, such as HIIT protocols, can be associated with negative affective responses (Hammer et al., 2022; Hu et al., 2022), which directly interferes in future actions since unpleasant affective experiences may result in less adherence.

Therefore, it becomes important to evaluate acute responses of pleasure, performance and recovery after HIIT sessions with body weight, to direct a better prescription of its practitioners. However, the goal of this study was to analyze the perceptual responses (affective condition, subjective perception of recovery and delayed muscle soreness) and performance (strength and power of upper and lower limbs) after a bodyweight HIIT session in adult men.

Material & methods

Research Design

This is an experimental study, with quantitative analysis of acute responses (PORTNEY, 2020). The research was submitted and approved by the Research Ethics Committee of the UPE (CAAE: 52201821.4.0000.5191). The participants were recruited in the cities of Petrolina – PE and Juazeiro – BA through the distribution of posters and on social media and signed a Free and Informed Consent Form (FICF) in accordance with resolution 466/12 of the National Health Council.

The participants went to the Biomechanics Laboratory to perform the research procedures, which took place in three visits. In the 1st and 2nd visits: the participants answered to a questionnaire of readiness to perform physical exercise PAR-Q, (Andreazz et al., 2016), and the physical activity level questionnaire, IPAQ short version (Matsudo et al., 2001). They also performed an evaluation of their anthropometric measurements to characterize the sample, in addition to two familiarization sessions with the proposed exercises (jumping jacks, burpees, mountain climbs, and squat jumps), the tests performed (countermovement vertical jump, maximal voluntary contraction - handgrip) and the anchoring of the perceptual scales.

On the 3rd visit: the experimental session was performed, with the bodyweight HIIT protocol, respecting the following order of exercises: jumping jack, burpee, mountain climb and squat jump (Figure 1), with a passive recovery of 30 seconds. The session included the execution of a maximum of 20 sets of 30 seconds at all-out intensity, as recommended by the literature (Machado et al., 2017; Machado et al., 2019).

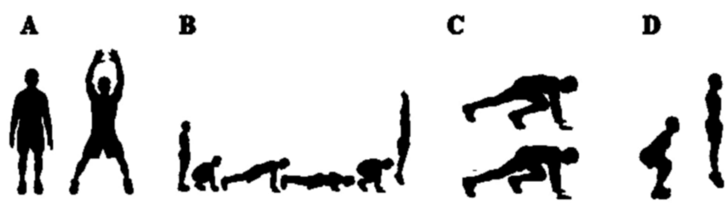

Figure 1. Exercises order. A: jumping jacks; B: burpees; C: mountain climbs; D: squat jumps.

Pre-session and immediately after, the Rating Perceived Exertion scale (RPE) and Feeling scale (FS) were measured, as well as the mean height of three countermovement vertical jumps (cm) for indirect measurement of lower limb power and the mean strength of three handgrip measurements (kg/f) for upper limb strength analysis. In addition, pre-session, immediately after, and 24 hours later, 48 and 72 hours, the Perceived Recovery Status scale (PRS) and Pain Numeric Rating scale (PNR) were monitored.

The experimental sessions and evaluations were standardized in the morning. Participants were instructed not to use/consume tobacco, caffeine, alcoholic beverages, supplements and/or stimulants that alter their performance, as well as not to perform vigorous physical activity in the 24 hours before and after the experimental session.

Participants

Based on a previous sample calculation using the GPower v. 3.0 software, considering a T-test for repeated measures, $\alpha = 0.05$, a Power of 0.80 and an effect size (d) = 0.90 according to the analysis of previous studies (Alloca Filho et al., 2022; Espirito-Santo; Daniel, 2017). The required sample size was of 10 participants.

Inclusion Criteria: Male participants aged 18 to 40 years, physically active (75 minutes of vigorous intensity or 150 minutes of moderate intensity per week) (Ritti Dias et al., 2021), with a body mass index between 18.5 and 29.9 kg/m2, living in the cities of Petrolina – PE or Juazeiro – BA were included.

Exclusion Criteria: Participants with cardiometabolic diseases or health history dysfunctions (such as musculoskeletal limitations that prevent the completion of the proposed exercises, or the use of medications and/or stimulants that alter physical performance) were excluded.

Measurement Instruments

Anthropometric Assessment

For the purpose of characterizing the sample, the height and body mass of the participants were measured to calculate the Body Mass Index - BMI (body mass/height^2) with the use of a digital scale with a variation of 0.1kg (Líder LD1050) with an attached vertical bar stadiometer, graduated every 0.5cm. Waist circumference will also be gauged using an anthropometric tape measure of the Cescorf brand (Porto Alegre/RS, Brazil) made of flexible steel, with a sequential scale (graduated in millimeters), 2m in length and 6mm in width (Alvarez; Pavan, 2011). To evaluate the fat percentage, a scientific body fat caliper (1mm scale) of the Lange brand was used, following the protocol proposed by Jackson and Pollock (1978) to measure the skinfolds of the male sex in the pectoral, abdomen and thighs areas.

Perceptual Evaluations

The intensity of the exercise session was measured using the Subjective Perception of Exertion (RPE – CR10) with an 11-point Likert scale, in which the number "0" indicates the lowest effort - rest and the number "10" indicates the maximum effort. (Borg, 1982; Foster et al., 2001; Tibana et al., 2019). Demonstrating a concurrent validity with blood lactate after a functional exercise session ($r = 0.66$).

Affective condition (pleasure and displeasure) was measured by the Felling Scale, an 11-point single-item scale ranging from +5 (very good) to -5 (very poor) duly translated to the Portuguese with a reliability of 0.644 (0.425 to 0.779 - 95%IC) (Alves et al., 2019; Hardy; Rejeski, 1989).

To analyze perceived recovery, the Perceived Recovery Status was recorded, which consists of a scale from 0 to 10 arbitrary units ranging from "0" (very poorly recovered), "5" (moderately recovered) and "10" (fully recovered) with concurrent validity for performance measures such as speed ($r = -0.63$) and vertical jump height ($r = 0.84$) (Laurent et al, 2011; Tolusso 2022).

The pain levels were assessed using Pain Numeric Rating scale in which the quadriceps and hamstring muscles were palpated and stretched from a knee extension and flexion, for approximately 3 seconds, while the participant remained in the standing position, immediately after, the participant was instructed to report pain perception, after palpation and stretching (Lodo et al., 2013). The 11-point NRS measures the subjective intensity of pain, ranging from "0" (no pain) to "10" (worst possible pain). It has good inter- and intra-rater reliability, excellent internal consistency (Cronbach's alpha: 0.88) in healthy adults (Bodessa et al., 2021; Herr et al., 2004; Lodo et al., 2013).

The FS and RPE were applied in two moments: pre-session and immediately after. While the PRS and PNR were applied in three moments: pre-session, immediately after, and 24 hours later.

Vertical Jumps

Three countermovement vertical jumps in (CMJ) were performed in the bipedal position, with a standardization of 60 seconds between jumps as the recovery period (Goulart et al., 2021). The two-legged jump was performed with the participant standing on a contact mat (Jump System Pro®, CEFISE, Nova Odessa, Brazil) with the knees extended and hands on the hips, then the knees will first be flexed to 90º (eccentric action) and then explosively extended in a coordinated manner (concentric action) in order to reach the maximum height (cm). During the flight phase, the knees were extended and the contact with the ground was made first with the tip of the feet, avoiding lateral displacements. (Rodrigues; Marins, 2011). Three attempts at the countermovement vertical jump (CMJ) were performed, considering the arithmetic mean for fatigue analysis (Claudino et al., 2017). The following variables were analyzed: flight time (ms) and jump height (cm) (Maté-Muñoz et al., 2018). The jumps were performed in two moments: pre-session and immediately after.

Handgrip Test

The subjects were seated in a chair with both feet flat on the floor, with the elbow of the dominant limb at a flexion of approximately 90°, with slight abduction of the shoulder, and wrist in a neutral position. Each subject performed three maximal voluntary contractions (MVC) lasting 5 seconds, with 1 minute interval between each attempt. The arithmetic mean of the three MVC attempts (kgf) was used for the analysis (Cronin et al. 2017). The handgrip test was performed in two moments: pre-session and immediately after.

Data Analysis

Descriptive statistics were adopted, with analysis of mean and standard deviation. The Shapiro-Wilk test was used to verify the normality of the data. A Student's t-test for dependent sample (pre- and immediately after) and a one-way ANOVA were applied to verify the effects of time throughout the session (Pre, immediately after, and 24 hours), with Bonferroni's Post hoc used for comparison between pairs. The alpha was set at 5%, and the effect sizes were reported by eta-square ($\eta 2$) and Cohen's D (d) using SPSS software version 22.0 for Windows.

Results

Table 1 describes the general characteristics of the sample, composed of 10 physically active male participants.

Table 1. Descriptive characterization of the sample (n=10).

Age (years)	24.80 ± 3.82
Height (cm)	174 ± 4.00
Body mass (kg)	74.14 ± 8.03
Body Mass Index (kg/m²)	24.62 ± 2.44
Body fat percentage (%)	12.25 ± 6.15
Waist Circumference (cm)	80.45 ± 4.80

Figure 2 analyzes the results, before and immediately after the bodyweight HIIT session, regarding the isometric strength of the upper limb, measured through handgrip (Figure 2A), showing no significant differences (47.60±7.63 kg/f vs. 49.50±5.95 kg/f; p>0.05; d=0.278). There were also no significant differences for the mean height of the countermovement vertical jump (36.69 ± 4.46 cm vs. 33.91±7.02 cm; p>0.05; d=0.473), compared before and immediately after the session (Figure 2B)

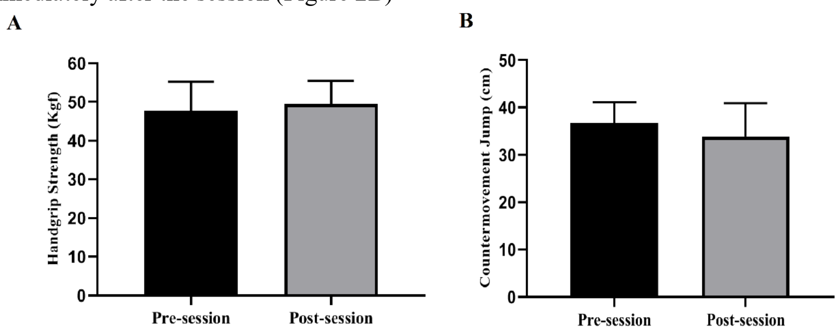

Figure 2. Average and standard deviation of isometric handgrip strength (2A) and vertical jump height in countermovement (2B) in the moments before and immediately after the session.

The RPE (Figure 3) was used to measure session intensity, showing an increase when comparing the moments before and immediately after the session's last set of exercises (0±0 AU vs. 8±2 AU, p<0.01; d= 5.657). Throughout the session, there was a decrease in the response of the FS, comparing the moments before and immediately after (2±2 u.a vs. -3±2 u.a; p<0.01; d=2.500), indicating displeasure at the end of the last set of exercises (Figure 4).

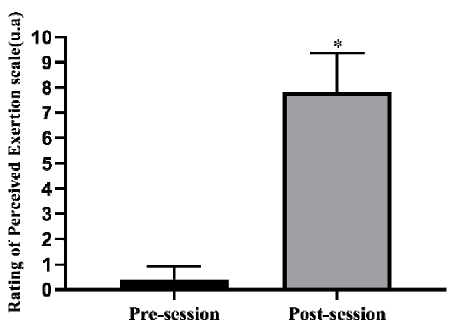

Figure 3. Mean and standard deviation rating of perceived exertion in the moments before and immediately after the session; *p<0.05

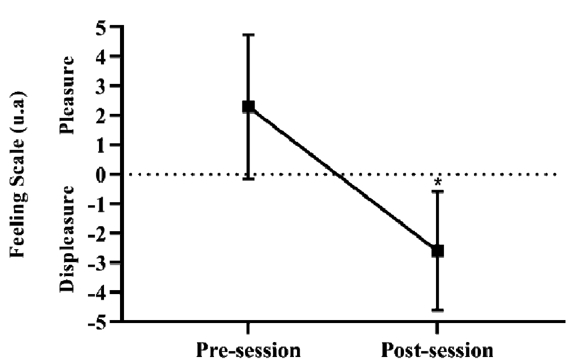

Figure 4. Mean and standard deviation rating of feeling scale in the moments before and immediately after the session; *p<0.05

Delayed onset muscle soreness (Figure 5A) and recovery status (Figure 5B) responses were analyzed in the moments before, immediately after, and 24 hours after the session. The results showed an increase in the PNR 24h after the session compared to the moments before and immediately after (0±0 AU pre; 1±1 AU post; 4±2 AU 24h after; $p<0.05$; η2=0.409) and a decrease in PRS immediately after and 24h after, compared to pre session (10±1 AU pre; 5±2 AU post; 6±3 AU 24h; $p<0.05$; η2=0.446)

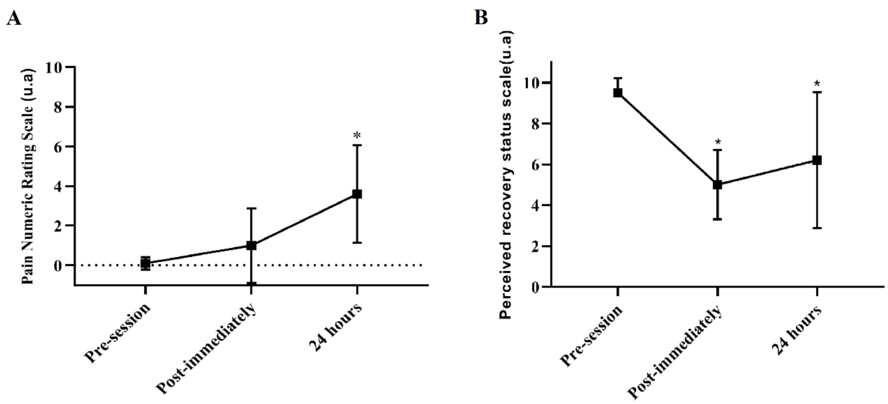

Figure 5. Mean and standard deviation numeric pain scale (5A) and perceived recovery scale (5B) before, immediately after and 24 hours the session. *p<0.05

Discussion

The present study aimed at analyzing the perceptual and performance responses after a bodyweight HIIT session in adult men. The main findings demonstrated a maintenance of performance, the average, in handgrip strength and lower limb power measured by the height of the vertical jump immediately after the BW-HIIT session (Figure 2). However, there was a decrease in FS, associated with negative values that indicate a status of displeasure immediately after the session (Figure 4). In addition, 24 hours after the session, the perception of recovery was not completely reestablished compared to baseline levels, and there was an increase in delayed muscle soreness compared to the moments before and immediately after the session (Figure 5).

After a physical exercise session, regardless of its aerobic or resistance characteristics, its intensity can lead to a decrease in the capacity to produce muscle strength or power that can last for a few hours or days, called muscle fatigue (Carroll et al., 2017; Cross et al., 2022; Thomas et al., 2018). In this study, there was no decrease in the average strength and power, respectively, of the upper and lower limbs after the BW-HIIT session. There was a high variability for lower limb results (−7.084cm to 0.484cm confidence interval 95%) countermovement jump. Since the subjects evaluated were physically active, speculated that the total volume of the session, order and complexity of the exercise, and the equalization between execution and rest time may influence these responses.

Machado et al. (2024) analyzed the acute effect of different recovery times on psychophysiological responses during bodyweight HIIT sessions in trained individuals, showing that a shorter interval between sets promotes a higher heart rate and a recovery perception lower throughout a session. Considering the same volume of execution.

Leite et al. (2023), in a review study, demonstrated that HIIT sessions induced mechanical and metabolic changes that ranged from moments immediately after the session up to seven days later, with changes in creatine kinase and lactate dehydrogenase markers and delayed onset muscle soreness. However, the main manifestations of muscle damage occurred in the first 24 hours after the session. The main studies cited investigated traditional HIIT sessions on a cycle ergometer or treadmill, the role of muscle damage in bodyweight protocols, with a focus on muscle endurance, still poorly founded.

Some factors can directly influence responses in the level of muscle damage induced by physical exercise, including HIIT sessions, such as type of contraction, the level of training of the subject and the volume of the session (Carroll et al., 2017; Leite et al. 2023). Severe muscle fatigue can cause a decline in muscle function and joint instability, affecting exercise performance and increasing the risks of injury (Alba-Jiménez, et al., 2022). In this sense, it is important to evaluate the neuromuscular recovery after the exercise to control the training load and improvements of the weekly frequency recommendation.

The health benefits of high-intensity interval training, with improvement in cardiovascular and metabolic responses, aerobic fitness, and body composition in diverse populations reported in the literature (Scoubeau et al., 2022; Guo et al., 2023; Wu et al., 2021). Although HIIT has been proposed as a viable solution to address the commonly reported barrier of lack of time for physical exercise, evidence suggests that the pleasure or displeasure experienced during high-intensity sessions directly interferes with future actions, since unpleasant affective experiences may imply in less adherence (Ekkekakis, 2017; Ekkekakis; Brand, 2019;

Tavares et al., 2021). These results corroborate the findings of the present study, which demonstrate a decrease in pleasure measured immediately after the session (Figure 4).

A recent study shows that the type of passive or active recovery in bodyweight HIIT protocol does not influence affective responses after the session, however, for both conditions they show a decrease in affective condition/pleasure after the exercise (Machado et al., 2023). Alloca Filho et al. (2022) also demonstrate that a bodyweight HIIT session consisting of twenty sets of thirty seconds, alternating execution and recovery decreases affective condition, can be mitigated with a preferred musical distraction. These results corroborate the findings of the present study.

However, although the present study contributes significantly to elucidate the perceptual and performance responses of BW-HIIT, worth mentioning some limitations, such as the lack of investigation of perceptual recovery responses and delayed muscle soreness beyond 24 hours, until baseline levels were reestablished, in addition, metabolic responses of creatine kinase throughout recovery would better elucidate the assessment of muscle damage. We highlight the importance of knowing the perceptual and fatigue responses after a BW-HIIT session for a better recommendation of this protocol, considering the weekly frequency of training in addition to modulating the variables that aim to improve the affective response and its association with adherence.

Conclusion

Concluded that a session of bodyweight high-intensity interval exercise does not demonstrate a decrease in performance in handgrip strength and vertical jump height for the lower limbs in physically active adult men, it does present a decrease in affective condition immediately after the session. In addition, 24 hours after the session, the recovery status not completely reestablished compared to baseline levels, with an increase in delayed onset muscle soreness. Despite the non-decrease in strength and power performance of the upper and lower limbs, related to fatigue, muscle pain remained for 24 hours, which requires attention to this variable for a complete recovery from muscle damage and improvement in the prescription of weekly frequencies. In order to optimize the performance and adherence of practitioners.

Conflicts of interest

The authors declare no conflicts of interests regarding this research, authorship, and/or publication of the present paper.

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