Year: 2023

Comparison of physiological and psychobiological acute responses between high intensity functional training and high intensity continuous training

Santos, Douglas A T ; Morais, Naiane S ; Viana, Ricardo B ; Costa, Gustavo C T ; Andrade, Marilia S ; Vancini, Rodrigo L ; Weiss, Katja ; Knechtle, Beat ; de Lira, Claudio A B

Abstract: Little is known about the physiological and psychobiological responses that occur during and after high intensity functional training (HIFT). We compared physiological and psychobiological responses during and after a HIFT session with a high intensity continuous training (HICT) session. Twenty-one trained and healthy men were submitted to 20-min session of HIFT and HICT on separate days. The heart rate, blood lactate concentration [Lac], levels of state anxiety, rates of perceived exertion (RPE) and perceived discomfort (RPE-D), and affective valence were measured. Exercise intensity of the HICT was adjusted to the mean heart rate obtained in the HIFT session. The highest heart rate in the training sessions was significantly higher in HIFT (mean ± standard deviation [SD]: [187 ± 9] bpm) than in HICT (mean ± SD: [178 ± 8] bpm, $p < 0.001$). The [Lac] was significantly higher immediately after the HIFT (median [interquartile range (IQR)]: 6.8 [4.4] mmol/L) than the HICT (median [IQR]: 3.2 [1.9], $p = 0.021$) and 10 min after (median [IQR]: HIFT = 6.8 [4.9] mmol/L, HICT = 2.9 [2.4] mmol/L, $p = 0.003$). The RPE was also significantly higher in the HIFT (median [IQR]: HIFT = 20 [2], HICT = 15 [5], $p = 0.009$). The physiological and psychobiological responses compared between HIFT and HICT sessions are similar, except for the higher heart rate obtained during the sessions, [Lac] and RPE. Probably, the results found for the higher heart rate obtained during the sessions, [Lac] and RPE may be explained by the higher participation of the anaerobic glycolytic metabolism during the HIFT session.

DOI: https://doi.org/10.1016/j.smhs.2023.10.006

Originally published at:
Santos, Douglas A T; Morais, Naiane S; Viana, Ricardo B; Costa, Gustavo C T; Andrade, Marilia S; Vancini, Rodrigo L; Weiss, Katja; Knechtle, Beat; de Lira, Claudio A B (2023). Comparison of physiological and psychobiological acute responses between high intensity functional training and high intensity continuous training. Sports Medicine and Health Science:Epub ahead of print.
DOI: https://doi.org/10.1016/j.smhs.2023.10.006

Sports Medicine and Health Science xxx (xxxx) xxx

Contents lists available at ScienceDirect

Sports Medicine and Health Science

journal homepage: www.keaipublishing.com/smhs

Comparison of physiological and psychobiological acute responses between high intensity functional training and high intensity continuous training

Douglas A.T. Santos [a,b], Naiane S. Morais [b], Ricardo B. Viana [c], Gustavo C.T. Costa [d], Marilia S. Andrade [e], Rodrigo L. Vancini [f], Katja Weiss [g], Beat Knechtle [g,h,**], Claudio A.B. de Lira [b,*]

[a] *Colegiado de Educação Física, Universidade do Estado da Bahia, Teixeira de Freitas, Brazil*
[b] *Setor de Fisiologia Humana e do Exercício, Laboratório de Avaliação do Movimento Humano, Faculdade de Educação Física e Dança, Universidade Federal de Goiás, Goiânia, Brazil*
[c] *Instituto de Educação Física e Esportes, Universidade Federal do Ceará, Fortaleza, Brazil*
[d] *Núcleo de Estudo e Pesquisa Avançada em Esporte, Faculdade de Educação Física e Dança, Universidade Federal de Goiás, Goiânia, Brazil*
[e] *Departamento de Fisiologia, Universidade Federal de São Paulo, São Paulo, Brazil*
[f] *Centro de Educação Física e Desportos, Universidade Federal do Espírito Santo, Vitória, Brazil*
[g] *Institute of Primary Care, University of Zurich, 8006, Zurich, Switzerland*
[h] *Medbase St. Gallen Am Vadianplatz, 9000, St. Gallen, Switzerland*

A R T I C L E I N F O

Keywords:
Crossfit®
Heart rate
Lactate
Borg scale

A B S T R A C T

Little is known about the physiological and psychobiological responses that occur during and after high intensity functional training (HIFT). We compared physiological and psychobiological responses during and after a HIFT session with a high intensity continuous training (HICT) session. Twenty-one trained and healthy men were submitted to 20-min session of HIFT and HICT on separate days. The heart rate, blood lactate concentration [Lac], levels of state anxiety, rates of perceived exertion (RPE) and perceived discomfort (RPE-D), and affective valence were measured. Exercise intensity of the HICT was adjusted to the mean heart rate obtained in the HIFT session. The highest heart rate in the training sessions was significantly higher in HIFT (mean ± standard deviation [*SD*]: [187 ± 9] bpm) than in HICT (mean ± *SD*: [178 ± 8] bpm, $p < 0.001$). The [Lac] was significantly higher immediately after the HIFT (median [interquartile range (*IQR*)]: 6.8 [4.4] mmol/L) than the HICT (median [*IQR*]: 3.2 [1.9], $p = 0.021$) and 10 min after (median [*IQR*]: HIFT = 6.8 [4.9] mmol/L, HICT = 2.9 [2.4] mmol/L, $p = 0.003$). The RPE was also significantly higher in the HIFT (median [*IQR*]: HIFT = 20 [2], HICT = 15 [5], $p = 0.009$). The physiological and psychobiological responses compared between HIFT and HICT sessions are similar, except for the higher heart rate obtained during the sessions, [Lac] and RPE. Probably, the results found for the higher heart rate obtained during the sessions, [Lac] and RPE may be explained by the higher participation of the anaerobic glycolytic metabolism during the HIFT session.

1. Introduction

Although CrossFit® has more than 15 000 affiliated gyms in over 150 countries[1] and more than 415 000 athletes participating in Open CrossFit® 2018,[2] there are few reports in the literature about the physiological and psychobiological responses resulting from CrossFit® training session.[3] CrossFit® can be classified as a high intensity functional training (HIFT). Generically, HIFT sessions include a wide range of functional movements involving the whole body, including some activities that can be extrapolated to daily life. There are activities such as Olympic weight lifting (snatch, clean, and clean and jerk), powerlifting (squat, deadlift, push press, and bench press), gym movements/calisthenics (pull-ups, toes-to-bar, knees-to-elbows, lunges, muscle-ups, burpees, dips, push-ups, and rope climbs) and traditional aerobic exercises (running, rowing, and swimming), which can be performed at high intensity.[4] In the literature, there are studies that investigated the HIFT in a wide range of populations including healthy individuals, obese individuals, and athletes.[5–7] Therefore, HIFT can be used to improve different attributes of physical fitness (e.g., cardiorespiratory endurance, strength, body composition, flexibility, etc.) and performance in sports and activities of daily living in different populations.

* Corresponding author. Avenida Esperança s/n, Câmpus Samambaia CEP 74690-900, Goiânia, Goiás, Brazil.
** Corresponding author. Institute of Primary Care, University of Zurich, 8006 Zurich, Switzerland.
E-mail addresses: beat.knechtle@hispeed.ch (B. Knechtle), claudioandre@ufg.br (C.A.B. de Lira).

https://doi.org/10.1016/j.smhs.2023.10.006
Received 6 July 2023; Received in revised form 23 October 2023; Accepted 30 October 2023
Available online xxxx

List of abbreviations

[Lac]	blood lactate concentration
AMRAP	as many rounds/repetitions as possible
BMI	body mass index
bpm	beats per minute
cm	centimeters
CI	confidence interval
HICT	high intensity continuous training
HIFT	high intensity functional training
HR	heart rate
HRmax	maximal heart rate
HRmean	average heart rate
kg	kilogram
km	kilometers
L	liters
m	meters
μL	microliters
mL	milliliters
mmol	millimoles
PAR-Q	Physical Activity Readiness Questionnaire
RPE	rate of perceived exertion
RPE-D	rate perceived discomfort
STAI	State-Trait Anxiety Inventory
VO_2	oxygen consumption
VO_2max	maximal oxygen uptake
VT1	first ventilatory threshold
VT2	second ventilatory threshold
WOD	workout of the day

In recent years, interest in acute[8–10] and chronic[8,11–13] responses promoted by HIFT has increased; however, the scarcity of research in the literature describing the physiological strains during a HIFT session is worrying. Therefore, more studies are needed to elucidate the physiological demands of HIFT as already verified in other modalities such as boxing,[14] Olympic weightlifting,[15] and exergames.[16–18] The understanding of the physiological responses to exercise is important, because physiological variables provide reference points for the prescription and monitoring of an exercise program effects, and to allow the identification of the practitioner's potential and limitations.[14] In this context, one of the most widely used measurements for determining/monitoring exercise intensity is heart rate (HR) response during the exercise session.[19] Another important marker of exercise intensity is lactate blood concentration. Lactate is a product of glycolysis under anaerobic conditions, which indicates high-intensity energy demands.[20]

According to the American College of Sport Medicine,[21] an annual survey of fitness trends around the world showed that high-intensity training (including HIFT) has been one of the main trends for the past 10 years, reaching the top spot in 2018. A possible explanation for the increasing popularity of this type of training may be related to the exercise programs and social[9] and psychobiological aspects[22] that are exclusive to HIFT. Indeed, there is evidence on the psychological and motivational factors[9] and competitive performance[22] related to HIFT. For example, Heinrich et al.[6] examined the effects of HIFT compared to moderate-intensity aerobic and resistance training on exercise initiation, pleasure, adherence, and intentions. The results suggest that HIFT participants spent significantly less time exercising per week yet were able to maintain exercise enjoyment and were more likely to intend to continue. However, studies comparing the acute physiological and psychobiological responses between HIFT and high intensity continuous training (HICT), performed at the same mean HR were not found. Therefore, further studies should be conducted regarding these aspects, especially to investigate the acute and chronic effects of HIFT on state anxiety.

Several studies have investigated the acute and chronic effects of exercise on anxiety in other exercise modalities. Ensari et al.[23] conducted a meta-analysis including randomized clinical trials published over 25 years that aimed to analyze the effects of acute exercise on anxiety. Among the 383 studies analyzed, 36 were included in the meta-analysis. Of these, 27 had an exercise session between 20 and 30 min at intensities ranging from mild to intense. The authors concluded that acute exercise sessions promote a small reduction in state anxiety. However, less is known about acute effects of high-intensity training on state anxiety.

Evidence suggests that vigorous exercise elicits a more positive affective response immediately after the session.[24] Hallgren et al.,[24] with the aim of examining the effects of a single bout of vigorous exercise on mood and anxiety among individuals with and without a history of participation in regular exercise, showed significant post-exercise improvements in mood and reductions in state anxiety. On the other hand, non-regular exercisers reported an initial decline in post-exercise mood and increased anxiety, suggesting that prior exercise participation mediates affective responses to acute bouts of vigorous exercise. Furthermore, other studies used perceived discomfort rating scale[25,26] and affective valence[27] scale to assess perception of discomfort related to physical activity and affective responses, respectively. However, less is known about these variables during a HIFT session.

Mangine et al.[28] evaluated subjective anxiety, HR variability, and catecholamines (baseline, before, immediately after, and 30 and 60 min after the session) in 10 competitors for two different workouts of the day (WODs) (7-min as many rounds/repetitions as possible [AMRAP] × 13-min AMRAP). There was a significant difference for all variables measured between times and WODs, and interactions observed for anxiety and catecholamines had higher values on the 13-min WOD. Wilke, Pfarr, and Möller[22] examined the fear of competition and relevant coping skills, as well as potential correlates of individuals participating in HIFT competitions, and found substantial levels of anxiety, particularly regarding the somatic dimension of the competition fear index. The main conclusion of the study was that competitive athletes seem to exhibit substantial fears related to competition.

Regarding motivational factors, participants of group-based HIFT had greater pleasure about the modality and were more likely to continue in the modality than participants who combined aerobic training and resistance training at moderate intensity.[29] Fisher et al.[29] compared the motivational factors of HIFT practitioners versus resistance training. The findings suggest that those for engaging in HIFT may be similar to those seen in sport participation, and therefore may have an influence on facilitating the long-term adherence in comparison with other resistance exercise modalities.

Considering that most studies that investigated exercise responses on anxiety level were conducted on moderate-intensity continuous exercise protocols,[23] that HIFT is one of the fastest-growing extreme conditioning programs in the world, in terms of the number of adherents[2]; and that lactate, a product resulting from the activation of anaerobic metabolism, alters psychobiological responses,[30,31] studies that investigate the characteristics and responses associated with HIFT are needed. The aims of current study were to investigate the physiological and psychobiological responses during and after HIFT sessions. In addition, we compared the physiological and psychobiological responses of a HIFT session with those evoked by a continuous traditional exercise (running) performed at the same exercise intensity as the HIFT session. We hypothesized that HIFT would promote higher physiological (blood lactate concentration [Lac]) due to vigorous exercise and intermittence that characterized the modality and positive psychobiological (anxiety and affective valence) responses compared to HICT, when performed at the same average HR.

2. Materials and methods

2.1. Ethics statement

Informed consent was obtained from all participants before starting the study. All experimental procedures were approved by the Research University Ethics Committee (approval number: 04996818.6.0000.5083) and conformed to the principles outlined in the Declaration of Helsinki.

2.2. Participants

Twenty-one trained and healthy men were recruited through advertisements on social media and through direct contact (a convenience sample). We did not recruit women because female hormonal fluctuations affect physiological[32] and psychobiological[33] variables. The inclusion criteria were as follows: (i) men, (ii) aged $\geq$ 18 years, and (iii) have over six months experience in HIFT. The exclusion criteria were as follows: (i) contraindication for physical activity as assessed by the Physical Activity Readiness Questionnaire (PAR-Q)[34]; (ii) consuming anxiolytic drugs, antidepressants, anabolic-androgenic steroids, or stimulants; and (iii) having some type of bone, muscle, or joint injury at the time of the selection. Additional participant information is shown in the Table 1.

2.3. Study design

The study was carried out over three visits with a 24- to 72-h interval between visits. The first visit was at the laboratory where the participants answered the PAR-Q[34] to track possible contraindications for physical activity. Those considered fit for participation in the study answered the State-Trait Anxiety Inventory (STAI) trait form and were submitted to an anthropometric assessment followed by a cardiorespiratory exercise test on a treadmill. On the second and third visits, the participants were submitted to 20 min HIFT session and 20 min HICT session, respectively. HIFT session was performed at the same exercise facility (HIFT gym) that the participant routinely trained at and HICT session was performed at exercise physiology laboratory. For both sessions, resting HR and [Lac] were evaluated, and participants answered the STAI state form. HR was measured during the entire session up to 120 min after exercise sessions. Rating of perceived exertion (RPE) was measured at 5, 10, 15, and 20 min of the exercise sessions. Immediately after the exercise session, the affective valence, [Lac], and state anxiety were evaluated. [Lac] was also evaluated 5 and 10 min after exercise session, while state anxiety was assessed 10, 30, 60, and 120 min, and 24 h (through phone call) after the session. Perceived discomfort (RPE-D) was evaluated 30 min after exercise sessions.

The second and third visits were not randomized, as the HICT was performed at the same HR average as the HIFT; for this reason, the HIFT needed to be performed before the HICT. All participants were instructed to refrain from eating 2 h prior to the sessions and to abstain from caffeine, alcohol, and strenuous physical activity on the day of the experiment. The experiments were conducted in the mornings, afternoons, or nights. However, for each participant, the visits were conducted at the same time of the day to respect their circadian rhythm.[35]

Table 1
- Characteristics of participants ($n = 21$).

Variables	Mean (standard deviation)
Age (years)	26.4 (4.1)
Body mass (kg)	79.9 (8.4)
Height (m)	1.77 (0.06)
Body mass index (kg/m^2)	25.5 (1.9)
VO_2max (mL·kg^{-1}·min^{-1})	67.3 (6.8)
Training experience (years)	2.1 (1.1)
Training frequency (days/week)	4.7 (0.9)
Session duration (h)	1.3 (0.5)

VO_2max: maximum oxygen consumption. kg: kilogram. min: minutes. m: meters. ml: milliliters. h: hour.

2.4. PAR-Q and anthropometric assessment

The PAR-Q aims to assess the general health status. Briefly, this questionnaire consists of seven questions, aims to identify individuals who need medical clearance to perform a maximal effort test or to join an exercise program.[34] Body mass was measured using an electronic scale with a resolution of 50 g (body mass range 5 –150 kg) (Omron, HN-289, USA). Height was measured using a wall-mounted stadiometer with a measuring field up to 200 cm (Caumaq, Brazil). With the values of these two variables, the participants' body mass index (BMI) was calculated using the equation: BMI = body mass (kg)/height (m) squared.[36]

2.5. Cardiorespiratory exercise test

All participants completed a cardiorespiratory exercise test to evaluate their maximal oxygen uptake (VO_2max), maximal HR (HRmax), and first (VT1) and second (VT2) ventilatory thresholds. The test was performed as an incremental maximal exercise test on a motorized treadmill (model ATL, Inbramed, Brazil) with 0% slope. Respiratory gas samples were analyzed using a gas analyzer (VO2000, MedGraphics, USA) and HR was monitored with an HR monitor (V800, Polar, Finland). The test consisted of a 5 min warm-up period at 7 km/h and then the speed was increased at a rate of 1 km/h per minute until the participant's exhaustion.[14] During the test, participants were verbally stimulated to proceed with the exercise for as long possible. Before each test, gas analyzer was calibrated according to manufacturer guidelines. The tests had an average duration of (9.5 ± 1.5) min.

Two experienced investigators independently identified the VT1 and VT2 by averaging the data every 10 s. The VT1 and VT2 were determined by the method of ventilatory equivalents.[37,38] The VT1 was the intensity of the exertion above which the first increase in pulmonary ventilation/oxygen uptake was observed, that is, a non-linear increase in pulmonary ventilation/VO_2 with a concomitant increase in end-expiratory oxygen pressure and without an increase in pulmonary ventilation/carbon dioxide production. The VT2 was the intensity of exertion above which an increase in ventilation/carbon dioxide production was observed with a concomitant decrease in end-expiratory carbon dioxide pressure.

The VO_2 max was identified by the point at which the increase in workload (speed) did not determine an additional increase in oxygen uptake, reaching a plateau.[39] When this plateau was not reached, VO_2 max was identified by the point at which the participant reached the HRmax predicted for their age, respiratory exchange ratio $\geq$ 1.1, and an RPE of 20 on the Borg scale.[39]

2.6. High intensity functional training (HIFT)

The training started with 5 min of mobility, dynamic stretching exercises, and a warm-up consisting of 5 min of low intensity running at a self-selected pace in the exercise facility. The HIFT performed was the WOD "Cindy" (AMRAP)[40] which involves the execution of the largest number of sets of five pull-ups, 10 push-ups, and 15 air squats, in this order, during 20 min. Each exercise was properly performed according to pre-established minimum standards.[40] During the entire HIFT session, the participants were submitted to the usual music of HIFT training. This strategy aimed to guarantee the ecological validity of the experiment, considering that usual HIFT sessions are performed in the presence of music. The entire HIFT session was conducted and controlled by an exercise science professional with experience in exercise prescription and who had at least a Level One HIFT certification.

2.7. High intensity continuous training (HICT)

The HICT started with 5 min of mobility, dynamic stretching exercises, and a warm-up consisting of 5 min of running on a treadmill at a self-selected pace. The HICT was only started when the participant's HR reached the average HR obtained in the HIFT session, which occurred during the warm-up on the treadmill. The HICT consisted of continuous running on a treadmill (model ATL, Inbramed, Brazil) with duration equal to the total time of the HIFT (20 min). The intensity was equivalent to the participant's mean HR during HIFT. During the entire performance of the HICT, participants were submitted to the usual music from HIFT training to reduce music-related bias.[41]

2.8. Heart rate assessment

HR was evaluated using an HR monitor (model V800, Polar, Finland) attached to the participants' xiphoid process throughout each session. The data were downloaded to a personal computer. HR was used to characterize exercise intensity. Highest HR obtained during exercise sessions was the mean of two values.

2.9. Lactate assessment

The plasma [Lac] was determined using a portable lactimeter (Accutrend® GC/GCT, Roche, Germany). Samples of blood (25 µL) were collected from the ear lobe directly on the tape of the lactimeter and the reading was performed on the device itself.[42] The [Lac] was evaluated before the session, immediately after the session, and 5 and 10 min after both exercise sessions. The [Lac] was used to characterize anaerobic glycolytic metabolism contribution in the HIFT and HICT sessions.

2.10. Trait and state anxiety assessment

Trait and state anxiety was assessed by the STAI,[43] translated and validated for the Brazilian Portuguese population by Gorenstein and Andrade.[44] Participants were instructed to answer each of the questions according to how they felt "right now; that is, at this moment" for the state form and "how you generally feel" for the trait form. STAI scores can vary with a range of 20–80. Scores of ≤ 30, between 31 and 49, and ≥ 50 indicate low, intermediate, and high levels of anxiety, respectively.[43] The STAI was chosen because of its easy application and low cost and because it has been used in many different disciplines and translated into 30 languages.[45] At the first day of the study, participants answered the trait form of STAI. On days of training sessions, the participants responded to the state form of STAI, before and after (immediately after, 10, 30, 60, and 120 min after, and 24 h after) the sessions. Data collection was done with participants sitting and listening to the usual HIFT training music. The flow of people in laboratory was restricted to only personnel involved with data collection. The internal consistency of the trait and state domains is good, with Cronbach's α of 0.93 and 0.87, respectively.[46]

2.11. Rating of perceived exertion

RPE was assessed using the Borg scale[47] during the HIFT and HICT sessions at 5-min intervals. Due to the strong positive associations with physiological variables, such as VO_2, HR, and [Lac], RPE is a widely accepted mean of estimating the intensity of exercise in adults. Moreover, RPE has been used to provide a safe and effective training intensity for aerobic exercises[48] and present a good reliability (intra-rater absolute standard error of measurement ranging from 0.25 to 0.66).[25]

2.12. Rating of perceived exertion-discomfort

The subjective perception of discomfort (RPE-D) was assessed using the Perceived Discomfort Rating Scale.[25,26] The scale begins at zero which is described as no perceived discomfort. This can be linked to a perception of discomfort at a time where you feel no noticeable sensations relating to physical activity. The scale ends at 10 which is described as the maximum perceivable discomfort. This can be linked to a perception of discomfort where you could not imagine the sensations relating to physical activity being any more intense.[25] The RPE-D was applied 30 min after the end of the HIFT and HICT sessions according to protocol proposed by a previous published study.[25] RPE-D is a recent option[26] based on the differentiation of concepts between perceived effort and discomfort.[25] Moreover, RPE-D presents an acceptable reliability (intra-rater absolute standard error of measurement ranging from 0.60 to 1.01).[25]

2.13. Affective valence

Affective responses were assessed using the affective valence scale, proposed by Hardy and Rejeski.[27] The scale is quantified from +5 to −5, corresponding to the antagonistic descriptors of feeling during physical activity: 5 = very bad, −3 = bad, −1 = fairly bad, 0 = neutral, 1 = fairly good, 3 = good, and 5 = very good. This scale was suggested by other studies to measure the affective response after exercise and present high reproducibility (intraclass coefficient correlation = 0.644 [95%*CI*: 0.425 to 0.779]).[49] The scale was presented right after the following question: "How do you currently feel?" and was performed immediately after the HIFT and HICT sessions.

2.14. Statistical analysis

The normality of the data was tested by the Shapiro-Wilk test. The comparison between two measures was made using the paired Student *t*-test for data that followed a normal distribution (mean HR obtained during sessions, highest HR obtained during sessions, and RPE-D) or the Wilcoxon signed rank test for data that did not follow a normal distribution (affective valence).

The HR comparison between sessions was performed using the Friedman test (2 × 7, session [HIFT and HICT] × time [before, immediately after, and 5, 10, 30, 60, and 120 min after]). The comparison of [Lac] between sessions was performed using the Friedman test (2 × 4, session [HIFT and HICT] × time [before, immediately after, and 5 and 10 min after]). The comparison of state anxiety between sessions was performed using the Friedman test (2 × 7, session [HIFT and HICT] × time [before, immediately after, 10, 30, 60, and 120 min after, and 24 h after]). The comparison of RPE during the sessions was performed using the Friedman test (2 × 4, session [HIFT and HICT] × time [5, 10, 15, and 20 min]). When a statistical difference between the data was revealed by the Friedman test, Bonferroni post hoc multiple comparisons were applied to determine the paired difference. We used Friedman test for comparison between sessions (HIFT and HICT) × time because HR, [Lac], state anxiety, RPE did not follow a normal distribution.

Statistical analyzes were performed using the program Statistical Package for the Social Sciences (SPSS, version 26.0, IBM, USA). The level of significance was set at $p < 0.05$. Changes were calculated through the mean difference or median difference and its respective 95 % confidence interval (95%*CI*). Data are expressed as the mean ± standard deviation (for data that followed a normal distribution) and as the median [interquartile range] (for data that did not follow a normal distribution), unless otherwise stated.

3. Results

There were no medical complications during the experimental procedures. In the HIFT, participants performed (87.3 ± 22.2) pull-ups, (168 ± 46.6) push-ups, and (246 ± 68.7) air squats. The total number of cumulative repetitions from the three exercises was 501.7 ± 137.1.

3.1. Heart rate

As expected, there was no significant difference in the mean HR between the HIFT ([173 ± 8] bpm) and HICT (173 ± 8) bpm (mean difference = 0.3 bpm [95%*CI*: 0.6 to 1.2], $p = 0.450$). Both sessions were performed at an exercise intensity corresponding to VT2 ([174 ± 10] bpm) obtained during the cardiorespiratory exercise test. On average, the participants remained 0.7 min (3.3%) below VT1, 8.5 min (42.5%) between VT1 and VT2, and 10.8 min (54.2%) above VT2 in the HIFT. In the HICT session, the participants remained 17.9 min (89.3%) between VT1 and VT2, and 2.1 min (10.7%) above VT2. Regarding the highest HR obtained during the training sessions, there was a significant difference between the HIFT ([187 ± 9] bpm) and HICT ([178 ± 9] bpm) (mean difference = 9.2 bpm [95%*CI*: 7.2 to 11.2], $p < 0.001$). Fig. 1 shows HR response throughout the HIFT and HICT sessions.

As expected, HR was significantly higher immediately after the session than before for both sessions. The HR returned to values from before the session at 10 and 30 min after the HICT and HIFT sessions, respectively (Fig. 2). No significant difference was found in HR between the sessions for any time evaluated after exercise session (5, 10, 30, 60, and 120 min).

3.2. Lactate

The Friedman test showed a significant difference ($\chi^2 = 84.989$, $p < 0.001$) and the Bonferroni post hoc of multiple comparisons demonstrated that there was a significant difference between the before and after session time points (median difference = 4.5 mmol/L, $p < 0.001$), 5 min (median difference = 3.3 mmol/L, $p < 0.001$), and 10 min (median difference = 5.1 mmol/L, $p < 0.001$) in the HIFT session. Also, there was a significant difference in the [Lac] immediately after the sessions (median difference = 3.6 mmol/L, $p = 0.021$) and 10 min after the sessions (median difference = 3.9 mmol/L, $p = 0.003$) (Fig. 3) between HIFT and HICT sessions.

3.3. Trait and state anxiety

The level of trait anxiety was 31.8 ± 5.2, classifying the participants' levels of trait anxiety as intermediate. In the HIFT session, state anxiety was significantly lower in 10, 30, 60, and 120 min after, and 24 h after HIFT than immediately after the HIFT session. In the HICT session, the state anxiety was significantly lower in 60 and 120 min and 24 h than immediately after the HICT session (Fig. 4). No significant difference was found in state anxiety between sessions for any time evaluated.

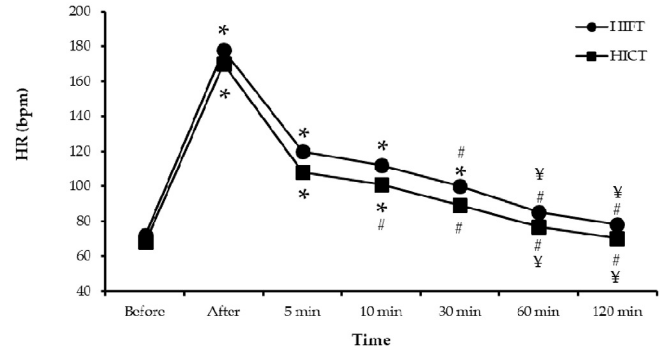

Fig. 2. Comparison of HR before and after the HIFT and HICT sessions. HR (bpm): heart rate in beats per minute. HIFT: high-intensity functional training. HICT: high intensity continuous treadmill training. Data are expressed as the median values. *Significant difference from values before the respective training session ($p < 0.05$). #Significant difference from immediately after values in the respective training session ($p < 0.05$). ¥Significant difference from 5 min values in the respective training session ($p < 0.05$).

3.4. Rating of perceived exertion

The RPE significantly increased 10 min after the start of training in both sessions. However, only the HIFT session elicited a significant progressive increase after 10 min of training (Fig. 4). Furthermore, a significant difference was found in the RPE between the HIFT and HICT sessions, evaluated at the end of the sessions (20 min) (Fig. 5).

3.5. Rating of perceived exertion-discomfort

There was no significant difference in RPE-D (mean difference = 0.8 [95%*CI*: 0.9 to 2.5], $p = 0.334$) between the HIFT (5.9 ± 2.5) and HICT (5.1 ± 2.2) sessions. In both sessions, the discomfort was assessed as moderate discomfort.

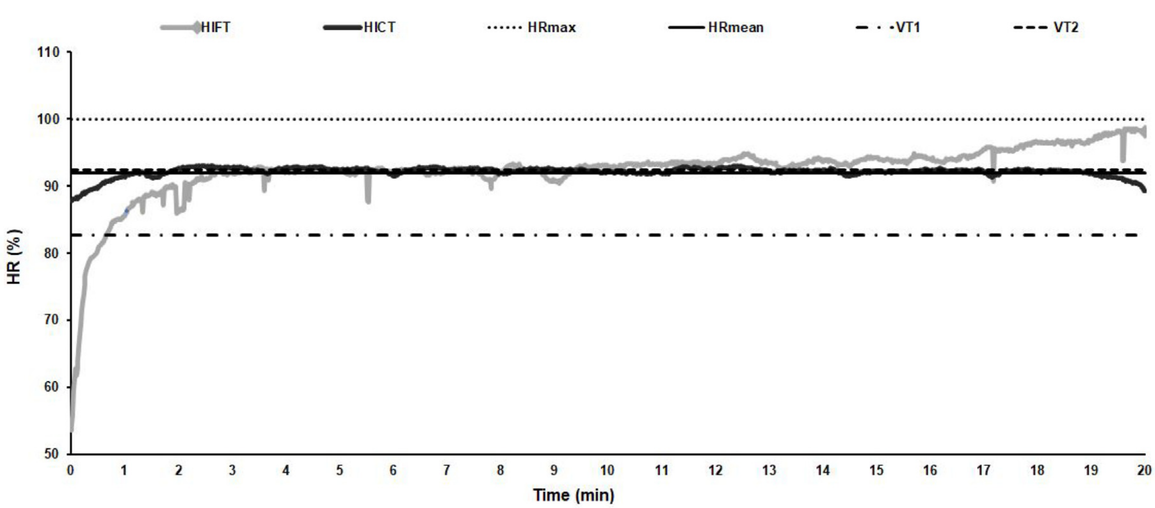

Fig. 1. Heart rate behavior during HIFT and HICT training sessions. HR (%): percentage of the maximal heart rate obtained in the cardiorespiratory exercise test. HIFT: participants mean heart rate behavior during the high intensity functional training session. HICT: participants mean heart rate behavior during the high intensity continuous training session. HRmax: maximal heart rate obtained in the cardiorespiratory exercise test. HRmean: average heart rate of the HIFT and HICT sessions. VT1: first ventilatory threshold. VT2: second ventilatory threshold.

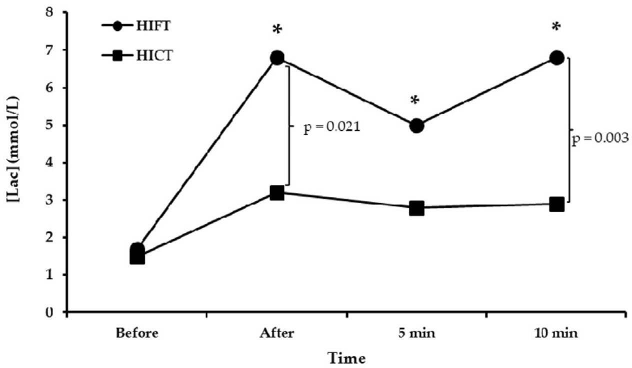

Fig. 3. Comparison of [Lac] before and after the HIFT and HICT sessions. [Lac]: blood lactate concentration in millimoles per liter. HIFT: high-intensity functional training. HICT: high intensity continuous treadmill training. min: minutes. Data are expressed as the median values. *Significant difference from values before the respective training session ($p < 0.05$). **Note:** $p = 0.021$ and $p = 0.003$ represents a significant difference in immediately after values and 10 min values, respectively, between HIFT and HICT sessions.

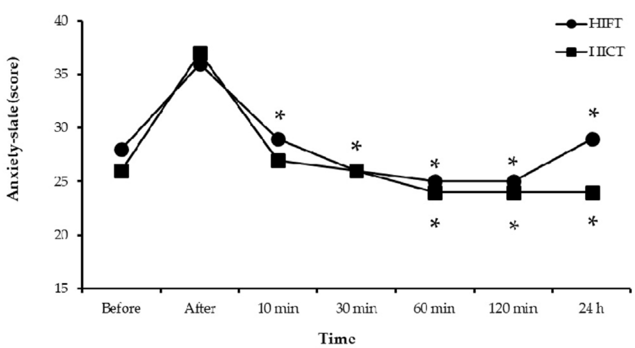

Fig. 4. Comparison of anxiety-state before and after the HIFT and HICT sessions. Data are expressed as the median values. HIFT: high-intensity functional training. HICT: high intensity continuous treadmill training. min: minutes. *Significant difference from immediately after values in the respective training session ($p < 0.05$).

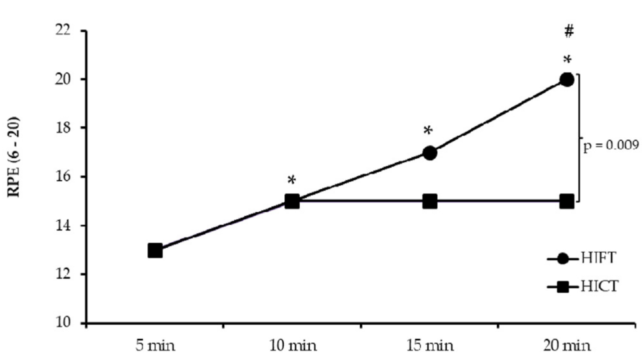

Fig. 5. RPE behavior during the HIFT and HICT training sessions. RPE: rating of perceived exertion. HIFT: high-intensity functional training. HICT: high intensity continuous treadmill training. min: minutes. Data are expressed as the median values. *Significant difference from 5 min values in the HIFT session ($p < 0.05$). #Significant difference from 10 min values in the HIFT session ($p < 0.05$). **Note:** $p = 0.009$ represents a significant difference in 20 min values between HIFT and HICT sessions.

3.6. Affective valence

There was no significant difference between affective valence between the HIFT (3 [*IQR*: 3]) and HICT (3 [*IQR*: 4]) training sessions (median difference = 0 [95%*CI*: 1.0 to 2.5], $p = 0.417$). The scores for both sessions were classified as "good".

4. Discussion

This study compared the physiological and psychobiological responses of a HIFT session with those evoked by a traditional exercise modality (running) performed at the same HR average. Some of initial hypotheses were confirmed and other not. State anxiety, RPE-D, and affective valence were similar in both interventions. Conversely, we found that: (i) the highest HR measured in training sessions was significantly higher in the HIFT than in the HICT; (ii) the [Lac] was significantly higher immediately after the HIFT session than the HICT session and between sessions in the time immediately after and 10 min after; (iii) RPE was significantly higher in the HIFT than HICT; and (iv) the RPE was gradually increased in HIFT and there was a difference between the sessions in the time of 20 min. Altogether, these results suggest that there is not a linear direct relationship between psychobiological and physiological responses.

The knowledge of physiological characteristics of a particular type of exercise is useful for the purpose of prescribing exercise.[50] In the present study, we found that HR average of the investigated sessions correspondents to 91.4% of the HR_{max} determined in the cardiorespiratory exercise test, corresponding to a vigorous intensity.[48] However, due to the intermittent characteristic of HIFT,[51] the highest HR obtained in this session corresponded to 99.5% of the HR_{max}, being classified as near-maximal to maximal intensity.[48] Thus, HR monitoring during HIFT becomes relevant to mitigate possible overload or underestimation of workloads, potentiating physiological responses, increasing performance,[8] and decreasing risk of overtraining syndrome.[52]

Higher [Lac] after the HIFT than the HICT sessions confirms a greater anaerobic glycolytic metabolism contribution. Given their greater contraction velocity,[53] type II motor units may have been preferentially recruited in HIFT over HICT. These units are more susceptible to fatigue than type I motor units and depend on glycolytic metabolism.[54] Previous studies demonstrated the influence of HIFT bouts in [Lac][55] and most of them used Cindy or a different AMRAP WOD. Although AMRAP requires the athlete to complete the maximum repetitions during the WOD, the fixed time (i.e., 20 min in "Cindy") may induce an auto-regulatory cadence of exercise in the athlete. Forte et al.[56] speculated that in a HIFT WOD, the [Lac] is dependent on the duration of effort and the structure of WOD, with all-out efforts producing greater levels of [Lac], indicating higher dependence on glycolytic metabolism. Fernandez et al.[57] highlighted the high glycolytic profile of this WOD, alerting that participants of HIFT should strive to maintain a good understanding of their limitations during exercise to cope with high intensity and repetitive exercise bouts.

Although the HICT was performed at the same HR mean as the HIFT, the physiological strain of the training sessions was different, as observed by the highest HR obtained in the sessions, by the [Lac] and by RPE. Additionally, we observed different behavior of the RPE between sessions. In HICT, RPE remained constant throughout the training session, a predictable result because it is a continuous aerobic training program.[58] However, in HIFT, RPE gradually increased throughout the training session, presenting a significant difference at the end of the session compared to the HICT, proving the intermittent characteristic of the HIFT.[40]

Whilst other acute studies have found significant differences in the state anxiety[23] while performing high-intensity exercises, our results did not reproduce previous studies. There are few studies about HIFT that investigated anxiety responses.[22,28] Methodological differences, such as study design (e.g., acute or chronic), participants, conditions (e.g., laboratory or competition), and the instrument for determining anxiety, make it difficult to compare our results. A possible hypothesis that there is no anxiolytic effect may be the HIFT training experience, as our participants had a mean experience of 2.1 years; thus, the probable anxiolytic effects of this modality could have already been experienced.[59] Indeed, a plethora of studies have found a positive acute and chronic effect on anxiety.[23,60–62] In addition, the participants presented a high cardiorespiratory fitness and previous studies showed that high cardiorespiratory fitness is associated with lower mood disorder symptoms.[63]

The discomfort scale was used to make participants separate their perceptions of exertion from the associated physical discomfort, as it is common for people to anchor themselves to each other with traditionally perceived exertion rating scales.[25,26] Steele et al.[26] suggested that similar discomfort between the two conditions may result from similar stimulation of muscle fibers, providing afferent feedback on exercise-induced metabolic and mechanical conditions. However, in our study we found differences in HR and [Lac] responses obtained in the training sessions, suggesting a greater recruitment of type II muscle fibers in HIFT than in HICT, and surprisingly, we did not find significant differences in RPE-D. Certainly, RPE-D in HIFT practitioners needs to be further explored. Unfortunately to date, we have not found many studies with this specific population. For example, Steele et al.[26] performed a study with recreationally active participants that had not been involved in any structured exercise interventions for the previous six months, which makes comparisons difficult.

The relationship of affective valence with physical exercise was investigated[64] and with contradictory results between continuous aerobic exercises of moderate-intensity[64] and high-intensity interval exercises.[51] Hypotheses were formulated for affective responses to be dependent on exercise intensity and duration.[65] Specifically, for HIFT, we did not find studies that could give us theoretical support; however, our results are in line with studies that indicate that exercises performed close to or above VT2 can also present “good” affective assessments[66] regardless of whether they are performed intermittently, on HIFT, or continuous, on a treadmill.

Our study had several limitations. First, the measurement of catecholamines and HR variability could enhance the discussion of the study. Second, there was a lack of a control condition without exercise. Third, the training sessions took place in different environments (gym for HIFT and laboratory for HICT). Fourth, we did not evaluate recovery between training sessions. On the other hand, as strengths, the results can be used by HIFT practitioners and trainers in their training routine of this modality. For example, as HIFT is characterized by high intensity, the physiological values herein presented can be used as reference values for the purpose of exercise. Furthermore, this study may be one of the first to have investigated RPE-D and affective valence in HIFT practitioners.

5. Conclusion

A HIFT session presented higher HR, [Lac], and RPE, demonstrating the higher physiological strains imposed by this kind of training protocol. Conversely, there were no difference between exercise sessions regards to state anxiety and RPE-D. These results can be explained by higher participation of glycolytic metabolism during HIFT. As in HIFT, there is a large glycolytic demand, and future studies investigating the glycolytic capacity in HIFT practitioners are needed. We recommend that HIFT practitioners with similar characteristics to those investigated in the present study can perform both HICT and HIFT, as long as they can tolerate higher intensity peaks. Finally, the results presented herein can be used as reference values for exercise prescription purposes.

Funding

This research was partially funded by Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior (CAPES, Brazil), grant number finance code 001. RLV is a productivity fellowship at the Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (FAPES) agency (Edital Nº 18/2018-Bolsa Pesquisador Capixaba). CABL and MSA are productivity fellowships at the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

Submission statement

The work described has not been published previously, it is not under consideration for publication elsewhere, that its publication is approved by all authors, and, if accepted, it will not be published elsewhere including electronically in the same form.

Ethical approval statement

All experimental procedures were approved by the Research University Ethics Committee (approval number: 04996818.6.0000.5083) and conformed to the principles outlined in the Declaration of Helsinki. Informed consent was obtained from each participant before starting the study.

CRediT authorship contribution statement

Douglas A.T. Santos: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Naiane S. Morais:** Writing – review & editing, Writing – original draft, Formal analysis. **Ricardo B. Viana:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Gustavo C.T. Costa:** Writing – review & editing, Writing – original draft, Formal analysis. **Marilia S. Andrade:** Writing – review & editing, Writing – original draft, Formal analysis. **Rodrigo L. Vancini:** Writing – review & editing, Writing – original draft, Formal analysis. **Katja Weiss:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Beat Knechtle:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Claudio A.B. de Lira:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Conflict of interest

Beat Knechtle is an editorial board member for Sports Medicine and Health Science and was not involved in the editorial review or the decision to publish this article. All authors declare that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Acknowledgements

We would like to thank the participants for their effort and commitment to the research project.

References

1. Official CrossFit. CrossFit affiliate map. CrossFit. https://www.crossfit.com/map. Accessed September 12, 2023.
2. CrossFit. The 2021 season schedule, beginning with the open march 11. CrossFit. https://games.crossfit.com/article/2021-season-schedule-beginning-open-march-11. Accessed September 12, 2023.

3. Butcher S, Neyedly T, Horvey K, Benko C. Do physiological measures predict selected CrossFit® benchmark performance? *Open Access J Sports Med*. 2015;6:241. https://doi.org/10.2147/OAJSM.S88265.
4. Partridge JA, Knapp BA, Massengale BD. An investigation of motivational variables in CrossFit facilities. *J Strength Condit Res*. 2014;28(6):1714–1721. https://doi.org/10.1519/JSC.0000000000000288.
5. Feito Y, Patel P, Sal Redondo A, Heinrich K. Effects of eight weeks of high intensity functional training on glucose control and body composition among overweight and obese adults. *Sports*. 2019;7(2):51. https://doi.org/10.3390/sports7020051.
6. Heinrich KM, Patel PM, O'Neal JL, Heinrich BS. High-intensity compared to moderate-intensity training for exercise initiation, enjoyment, adherence, and intentions: an intervention study. *BMC Publ Health*. 2014;14(1):789. https://doi.org/10.1186/1471-2458-14-789.
7. Avetisyan AV, Chatinyan AA, Streetman AE, Heinrich KM. The effectiveness of a crossfit training program for improving physical fitness of young judokas: a pilot study. *J Funct Morphol Kinesiol*. 2022;7(4):83. https://doi.org/10.3390/jfmk7040083.
8. Tibana RA, Sousa NMF de, Prestes J, Feito Y, Ferreira CE, Voltarelli FA. Monitoring training load, well-being, heart rate variability, and competitive performance of a functional-fitness female athlete: a case study. *Sports*. 2019;7(2):35. https://doi.org/10.3390/sports7020035.
9. Box AG, Feito Y, Brown C, Petruzzello SJ. Individual differences influence exercise behavior: how personality, motivation, and behavioral regulation vary among exercise mode preferences. *Heliyon*. 2019;5(4):e01459. https://doi.org/10.1016/j.heliyon.2019.e01459.
10. Tibana RA, Prestes J, DE Sousa NMF, et al. Time-course of changes in physiological, psychological, and performance markers following a functional-fitness competition. *Int J Exerc Sci*. 2019;12(3):904–918.
11. Mangine GT, Stratton MT, Almeda CG, et al. Physiological differences between advanced CrossFit athletes, recreational CrossFit participants, and physically-active adults. *PLoS One*. 2020;15(4):e0223548. https://doi.org/10.1371/journal.pone.0223548.
12. Menz V, Marterer N, Amin SB, Faulhaber M, Hansen AB, Lawley JS. Functional vs. running low-volume high-intensity interval training: effects on VO_2max and muscular endurance. *J Sports Sci Med*. 2019;18(3):497–504.
13. Lu Y, Wiltshire HD, Baker JS, Wang Q. The effects of running compared with functional high-intensity interval training on body composition and aerobic fitness in female university students. *Int J Environ Res Publ Health*. 2021;18(21):11312. https://doi.org/10.3390/ijerph182111312.
14. de Lira CAB, Peixinho-Pena, Vancini RL, et al. Heart rate response during a simulated Olympic boxing match is predominantly above ventilatory threshold 2: a cross sectional study. *Open Access J Sports Med*. 2013;4:175. https://doi.org/10.2147/OAJSM.S44807.
15. Storey A, Smith HK. Unique aspects of competitive weightlifting. *Sports Med*. 2012; 42(9):769–790. https://doi.org/10.2165/11633000-000000000-00000.
16. Viana RB, Alves CL, Vieira CA, et al. Anxiolytic effects of a single session of the exergame Zumba® fitness on healthy young women. *Games Health J*. 2017;6(6): 365–370. https://doi.org/10.1089/g4h.2017.0085.
17. Morais NS, Viana RB, Silva WF, et al. Effect of both dance exergame and a traditional exercise on state anxiety and enjoyment in women. *J Sports Med Phys Fitness*. 2022; 62(4):560–567. https://doi.org/10.23736/S0022-4707.21.12237-6.
18. da Silva WF, Viana RB, Morais NS, et al. Acute effects of exergame-based calisthenics versus traditional calisthenics on state-anxiety levels in young adult men: a randomized trial. *Sport Sci Health*. 2022;18(3):715–723. https://doi.org/10.1007/s11332-021-00841-9.
19. Fletcher GF, Balady GJ, Amsterdam EA, et al. Exercise standards for testing and training. A statement for healthcare professionals from the American Heart Association. Circulation. 200;104(14):1694-1740. https://doi.org/10.1161/hc3901.095960.
20. Ferguson BS, Rogatzki MJ, Goodwin ML, Kane DA, Rightmire Z, Gladden LB. Lactate metabolism: historical context, prior misinterpretations, and current understanding. *Eur J Appl Physiol*. 2018;118(4):691–728. https://doi.org/10.1007/s00421-017-3795-6.
21. Thompson WR. Worldwide survey of fitness trends for 2018. *ACSM's Health & Fit J*. 2017;21(6):10–19. https://doi.org/10.1249/FIT.0000000000000341.
22. Wilke J, Pfarr T, Möller MD. Even warriors can be scared: a survey assessing anxiety and coping skills in competitive crossfit athletes. *Int J Environ Res Publ Health*. 2020; 17(6):1874. https://doi.org/10.3390/ijerph17061874.
23. Ensari I, Greenlee TA, Motl RW, Petruzzello SJ. Meta-analysis of acute exercise effects on state anxiety: an update of randomized controlled trials over the past 25 years. *Depress Anxiety*. 2015;32(8):624–634. https://doi.org/10.1002/da.22370.
24. Hallgren MÅ, Moss ND, Gastin P. Regular exercise participation mediates the affective response to acute bouts of vigorous exercise. *J Sports Sci Med*. 2010;9(4): 629–637.
25. Steele J, Fisher J, McKinnon S, McKinnon P. Differentiation between perceived effort and discomfort during resistance training in older adults: reliability of trainee ratings of effort and discomfort, and reliability and validity of trainer ratings of trainee effort. *J Trainology*. 2016;6(1):1–8. https://doi.org/10.17338/trainology.6.1_1.
26. Steele J, Butler A, Comerford Z, et al. Similar acute physiological responses from effort and duration matched leg press and recumbent cycling tasks. *PeerJ*. 2018;6: e4403. https://doi.org/10.7717/peerj.4403.
27. Hardy CJ, Rejeski WJ. Not what, but how one feels: the measurement of affect during exercise. *J Sport Exerc Psychol*. 1989;11(3):304–317. https://doi.org/10.1123/jsep.11.3.304.
28. Mangine GT, Kliszczewicz BM, Boone JB, Williamson-Reisdorph CM, Bechke EE. Pre-anticipatory anxiety and autonomic nervous system response to two unique fitness competition workouts. *Sports*. 2019;7(9):199. https://doi.org/10.3390/sports7090199.
29. Fisher J, Sales A, Carlson L, Steele J. A comparison of the motivational factors between CrossFit participants and other resistance exercise modalities: a pilot study. *J Sports Med Phys Fit*. 2017;57(9):1227–1234. https://doi.org/10.23736/S0022-4707.16.06434-3.
30. Karnib N, El-Ghandour R, El Hayek L, et al. Lactate is an antidepressant that mediates resilience to stress by modulating the hippocampal levels and activity of histone deacetylases. *Neuropsychopharmacology*. 2019;44(6):1152–1162. https://doi.org/10.1038/s41386-019-0313-z.
31. Carrard A, Elsayed M, Margineanu M, et al. Peripheral administration of lactate produces antidepressant-like effects. *Mol Psychiatr*. 2018;23(2):392–399. https://doi.org/10.1038/mp.2016.179.
32. Dos Santos Andrade M, Mascarin NC, Foster R, De Jarmy DI Bella ZI, Vancini RL, De Lira CA. Is muscular strength balance influenced by menstrual cycle in female soccer players? *J Sports Med Phys Fit*. 2016;57(6):859–864. https://doi.org/10.23736/S0022-4707.16.06290-3.
33. Kundakovic M, Rocks D. Sex hormone fluctuation and increased female risk for depression and anxiety disorders: from clinical evidence to molecular mechanisms. *Front Neuroendocrinol*. 2022;66:101010. https://doi.org/10.1016/j.yfrne.2022.101010.
34. Canadian Society for Exercise Physiology. Physical activity readiness questionnaire - PAR-Q. http://www.csep.ca/CMFiles/publications/parq/par-q.pdf; 2002. Accessed September 12, 2023.
35. Hower IM, Harper SA, Buford TW. Circadian rhythms, exercise, and cardiovascular health. *J Circadian Rhythms*. 2018;16:7. https://doi.org/10.5334/JCR.164.
36. WHO. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep*. 2000;894(i-xii):1–253.
37. Wasserman K, Whipp BJ, Koyl SN, Beaver WL. Anaerobic threshold and respiratory gas exchange during exercise. *J Appl Physiol*. 1973;35(2):236–243. https://doi.org/10.1152/jappl.1973.35.2.236.
38. Wasserman J, Sue D, Stringer W, Whipp B. *Principles of Exercise Testing and Interpretation*. third ed. Lippincott Williams & Wilkins; 1999.
39. Milani RV, Lavie CJ, Mehra MR, Ventura HO. Understanding the basics of cardiopulmonary exercise testing. *Mayo Clin Proc*. 2006;81(12):1603–1611. https://doi.org/10.4065/81.12.1603.
40. Maté-Muñoz JL, Lougedo JH, Barba M, García-Fernández P, Garnacho-Castaño MV, Domínguez R. Muscular fatigue in response to different modalities of CrossFit sessions. *PLoS One*. 2017;12(7):e0181855. https://doi.org/10.1371/journal.pone.0181855.
41. Egenti NT, Ede MO, Nwokenna EN, et al. Randomized controlled evaluation of the effect of music therapy with cognitive-behavioral therapy on social anxiety symptoms. *Méd*. 2019;98(32):e16495. https://doi.org/10.1097/MD.0000000000016495.
42. Buckley JD, Bourdon PC, Woolford SM. Effect of measuring blood lactate concentrations using different automated lactate analysers on blood lactate transition thresholds. *J Sci Med Sport*. 2003;6(4):408–421. https://doi.org/10.1016/S1440-2440(03)80267-0.
43. Spielberger C. *State-Trait Anxiety Inventory: Bibliography*. 2nd ed. Consulting Psychologists Press; 1989.
44. Gorenstein C, Andrade L. Validation of Portuguese version of the Beck depression inventory and the state-trait anxiety inventory in Brazilian subjects. *Braz J Med Biol Res*. 1996;29(4):453–457.
45. Spielberger C. *State-trait Anxiety Inventory: A Comprehensive Bibliography*. Consulting Psychologists Press; 1989.
46. Knight RG, Waal-Manning HJ, Spears GF. Some norms and reliability data for the state-trait anxiety inventory and the Zung self-rating depression scale. *Br J Clin Psychol*. 1983;22(4):245–249. https://doi.org/10.1111/j.2044-8260.1983.tb00610.x.
47. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med*. 1970;2(2):92–98.
48. Garber CE, Blissmer B, Deschenes MR, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. *Med Sci Sports Exerc*. 2011;43(7):1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefb.
49. Alves ED, Panissa VLG, Barros BJ, Franchini E, Takito MY. Translation, adaptation, and reproducibility of the physical activity enjoyment scale (PACES) and feeling scale to Brazilian Portuguese. *Sport Sci Health*. 2019;15(2):329–336. https://doi.org/10.1007/s11332-018-0516-4.
50. Liguori G. *American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription*. eleventh ed. Wolters Kluwer; 2021.
51. Haines M, Broom D, Gillibrand W, Stephenson J. Effects of three low-volume, high-intensity exercise conditions on affective valence. *J Sports Sci*. 2020;38(2):121–129. https://doi.org/10.1080/02640414.2019.1684779.
52. Cadegiani FA, Kater CE, Gazola M. Clinical and biochemical characteristics of high-intensity functional training (HIFT) and overtraining syndrome: findings from the EROS study (The EROS-HIFT). *J Sports Sci*. 2019;37(11):1296–1307. https://doi.org/10.1080/02640414.2018.1555912.
53. Korhonen MT, Cristea A, Alén M, et al. Aging, muscle fiber type, and contractile function in sprint-trained athletes. *J Appl Physiol*. 2006;101(3):906–917. https://doi.org/10.1152/japplphysiol.00299.2006.
54. Pérez M, Lucia A, Santalla A, Chicharro JL. Effects of electrical stimulation on VO_2 kinetics and delta efficiency in healthy young men. *Br J Sports Med*. 2003;37: 140–143. https://doi.org/10.1007/s10409-020-01026-2.
55. Timón AR, Olcina G, Camacho-cardeñosa M. Camacho- A. 48-hour recovery of biochemical parameters and physical performance after two modalities of CrossFit

workouts. *Biol Sport*. 2019;36(3):283–289. https://doi.org/10.5114/biolsport.2019.85458.

56. Forte LDM, Freire YGC, Júnior JSDS, Melo DA, Meireles CLS. Physiological responses after two different Crossfit workouts. *Biol Sport*. 2022;39(2):231–236. https://doi.org/10.5114/biolsport.2021.102928.
57. Fernández Fernández J, Sabido Solana R, Moya D, Sarabia Marin J, Moya Ramon M. Acute physiological responses during Crossfit® workouts. *Eur J Hum Mov*. 2015;35(35):114–124.
58. Kliszczewicz B, John QC, Daniel BL, Gretchen OD, Michael ER, Kyle TJ. Acute exercise and oxidative stress: CrossFit^{TM} vs. treadmill bout. *J Hum Kinet*. 2015;47(1):81–90. https://doi.org/10.1515/hukin-2015-0064.
59. Schuch FB, Stubbs B, Meyer J, et al. Physical activity protects from incident anxiety: a meta-analysis of prospective cohort studies. *Depress Anxiety*. 2019;36(9):846–858. https://doi.org/10.1002/da.22915.
60. Wipfli BM, Rethorst CD, Landers DM. The anxiolytic effects of exercise: a meta-analysis of randomized trials and dose-response analysis. *J Sport Exerc Psychol*. 2008;30(4):392–410. https://doi.org/10.1123/jsep.30.4.392.
61. Viana RB, Alves CL, Vieira CA, et al. Anxiolytic effects of a single session of the exergame Zumba®Fitness on healthy young women. *Game Health J*. 2017;6(6):365–370. https://doi.org/10.1089/g4h.2017.0085.
62. Stubbs B, Vancampfort D, Rosenbaum S, et al. An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: a meta-analysis. *Psychiatr Res*. 2017;249:102–108. https://doi.org/10.1016/j.psychres.2016.12.020.
63. Kandola A, Ashdown-Franks G, Stubbs B, Osborn DPJ, Hayes JF. The association between cardiorespiratory fitness and the incidence of common mental health disorders: a systematic review and meta-analysis. *J Affect Disord*. 2019;257:748. https://doi.org/10.1016/J.JAD.2019.07.088.
64. Parfitt G, Blisset A, Rose EA, Eston R. Physiological and perceptual responses to affect-regulated exercise in healthy young women. *Psychophysiology*. 2012;49(1):104–110. https://doi.org/10.1111/j.1469-8986.2011.01287.x.
65. Ekkekakis P. The dual-mode theory of affective responses to exercise in metatheoretical context: II. Bodiless heads, ethereal cognitive schemata, and other improbable dualistic creatures, exercising. *Int Rev Sport Exerc Psychol*. 2009;2(2):139–160. https://doi.org/10.1080/17509840902829323.
66. Frazão DT, de Farias Junior LF, Dantas TCB, et al. Feeling of pleasure to high-intensity interval exercise is dependent of the number of work bouts and physical activity status. *PLoS One*. 2016;11(3):e0152752. https://doi.org/10.1371/journal.pone.0152752.