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Original Article

Acute effect of high-intensity functional training (HIFT) using a benchmark on cognition and physiological parameters according to the competitive level

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Abstract:
Analyze the acute effect of high-intensity functional training on cognition and physiological parameters according to performance. Thirty-two practitioners were divided into groups according to their performance: Elite (n=07; age: 28.9±4.7 years), Advanced (n=10; age: 33.4±4.6 years), and Beginner (n=15; age: 30.6±7.1 years). This research compares the groups and pre-HIFT and post-HIFT moments and correlations for physiological and cognition. Statistical analysis used ANOVA repeated measures and Pearson's correlation coefficient. Data are mean (M) ± standard deviation (SD). Applied the Five-digit test, evaluated the physiological parameters, and performed the WOD Fran. Showed a significant difference concerning the performance of the HIFT time (E:177.1±29.8s < A: 314.3±46.8s and B: 538.2±102.1s) and difference in cognition regarding the comparison between moments: reading (E:76.4±20.2 > A:75.5±28.9 and B:74.6±22.3 Pk), counting (E: 86.4±10.7 > A:77.5±20.6 and B:81.1±21.1Pk), choice (E:89.3±9.8 > A:89.0±9.7 and B:74.6±22.8Pk), shifting (A:91.0±8.4 > E:86.4±10.7 and B:76.4±21.7Pk), inhibition (A:76.5±12.5 > E:76.4±20.2 and B:68.6±18.3Pk), flexibility (A:93.0±6.3 > E:89.3±9.8 and B:86.1±11.1Pk), lactate (E:13.1±1.8 < A:15.1±3.2 and B:16.1±3.7mmol), heart rate (E:188.0±6.6 > A: 174.1±16.1 and B: 185.1±8.9bpm), systolic blood pressure (E:149.7±11.5< A:151.0±9.3 and B:152.5±8.1mmHg), and diastolic blood pressure (E:73.4±6.2 > A:72.8±9.6 and B:69.3±7.1mmHg). Our results confirm that high-intensity exercise improves cognitive functions.
Keywords: Sports Psychology, Sport Physiology, CrossFit, Cognitive skill, Crosstraining

Introduction

Sports psychology uses psychological knowledge and skills to address athletes' performance, well-being, and quality of life (Brown & Fletcher, 2017). With recent applications in sports, neuropsychology has emerged as an interface between psychology and neurology which researches the psychophysiological relationships between the brain, emotions, physiology, and human behavior within sports (Cooke & Ring, 2019). Some authors (Box et al., 2019) have indicated individual differences between high-intensity functional training (HIFT) participants in their respective primary modes of physical practice, determining psychologically predictive inferences for performance without assessing the physiological interaction associated with executive functions. During the last few years, research has shown that HIFT has improved emotional states(Corcoy et al., 2022; da Costa et al., 2022). However, studies on the effects of HIFT on practitioners' cognition have not yet been carried out, and whether this would be related to the competitive level of these practitioners.

HIFT is an exercise program that combines high-intensity workouts with functional movements to improve overall fitness and performance (Ferreira et al., 2020). HIFT is designed to incorporate a wide range of functional movements inspired by activities of daily life and sports, such as lifting, pushing, pulling, jumping, and running. Crosstraining is a type of HIFT, and workouts typically involve performing various exercises in a circuit or interval format(Castanheira et al., 2023; Tibana et al., 2022). These workouts often incorporate elements from different exercise disciplines, including weightlifting, cardiovascular conditioning, plyometrics, bodyweight exercises, and other functional movements(Durkalec-Michalski et al., 2022). The intensity of HIFT workouts is relatively high, with short rest periods or active recovery between exercises(Sousa Neto et al., 2022). The main goals of HIFT are to enhance cardiovascular endurance, improve strength and power, increase muscle mass, promote metabolic adaptations, and develop functional fitness that can be applied to various physical activities and real-life situations(Kapsis et al., 2022; Meier et al., 2023). HIFT has gained popularity recently due

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to its effectiveness in improving overall fitness, body composition, and athletic performance (Kapsis et al., 2022). It is often used in individual and group training settings and can be modified to suit different fitness levels and goals (Sousa Neto et al., 2022). However, little is known about the psychological parameters associated with the physiological effects of HIFT, specifically with Crosstraining (Banja et al., 2023; Aravena et al., 2022).
Psychological factors are one reason different sports agents cite to justify obtaining specific results (Blum-Menezes et al., 2019; de Brito et al., 2022; Soto et al., 2020). This process includes cognition, allowing us to control and regulate our thoughts, emotions, and actions in adversity. In all these situations, the mind is often more important than any tactic, technique, or skill (Diamond & Ling, 2016). cognition enables establishing, maintaining, supervising, correcting, and carrying out an action plan. In this context, it is essential to understand how the practice of a HIFT could impact cognition parameters (Tomporowski & Pesce, 2019). Regular participation in HIFT has been shown to increase maximal oxygen consumption (VO^2 max) and improve cardiovascular endurance (Ferreira et al., 2020; Moscatelli et al., 2023). HIFT incorporates functional movements targeting multiple muscle groups, improving strength and power. It can increase muscle mass, enhance neuromuscular coordination, and improve force production(Serafim et al., 2023). HIFT can elicit metabolic adaptations, including improved metabolic rate, energy expenditure, and insulin sensitivity(Schlegel & Křehký, 2022). High-intensity workouts enhance fat oxidation and support weight management goals (Kapsis et al., 2022).

Given the particularities of the modality and characteristics of HIFT (Claudino et al., 2018), it is not yet known how this practice can affect cognition associated with physiological parameters and what benefit this can have in the lives of practitioners of this modality. Therefore, it is relevant to understand cognition's role in achieving complex and unpredictable activities (de Brito et al., 2022; Soto et al., 2020). Thus, this study proposes to investigate the effect of a HIFT benchmark on cognition and physiological parameters and the interdependence of these factors according to the time performance of the Workout of the Day - WOD Fran. We hypothesized that the Fran benchmark does not alter the cognition of HIFT practitioners when compared between groups.

Material & methods

Study design

This research is pre-experimental, interdisciplinary, and transversal. The research started from the need for studies with greater control over evaluating and manipulating the intervention to make it possible to use the same HIFT in three different classifications of performance level. We proceeded with an acute intervention in which the participants were subjected to cognition and physiological parameters evaluations in two moments: pre and post-benchmark practice - WOD Fran. Then, they were divided according to their performance in the benchmark run time. The research was based on the guidelines of the HIFT guide and official website and selected the benchmark - WOD Fran, which is used as a performance evaluation parameter (Ferreira et al., 2020). The pre-intervention values were used as a control for the post-intervention values, then compared and paired between the moments.

Sample

The sample consisted of 32 HIFT practitioners: Elite group (E=07; gender: 28.6% female and 71.4% male; age: 28.9±4.7 years; body mass: 80.0±10.9 kg; height: 1.72±0.1 m; practice time: 50.0±13.3 months; training volume: 13:34±3:54 week hours and WOD execution time: 177.1±29.9 seconds), Advanced group (A=10; gender: 50% female and 50% male; age: 33.4±4.6 years; body mass: 71.7±15.5 kg; height: 1.70±0.1 m; practice time: 27.6±13.8 months; training volume: 8:34±3:05 week hours and WOD execution time: 314.3±46.8 seconds) and Beginner group (B=15; gender: 33,3% female and 66.7% male; age: 30.6±7.1 years; body mass: 72.3±11.0 kg; height: 1.70±0.1 m; practice time: 22.9±9.2 months; training volume: 4:42±1:07 week hours and WOD execution time: 538.2±102.8 seconds). All affiliated boxes were located in Governador Valadares (Minas Gerais, BRA). For the sample calculation, the post-hoc statistical power (1-β) was applied using the analysis of variance (ANOVA: Repeated measures, within-between interaction), Effect size f = 0.25, significance level = 0.05, α err prob = 0.05. Thus, the conferred statistical power present in the sample was 0.83%. G * Power software© version 3.1 was used (Krakatau Metrics, 2020).

Following Resolution No. 466/12 of the National Health Council, the Ethics Committee for Research with Human Beings submitted and approved the project at the Federal University of Juiz de Fora - CAAE: 13846919.8.0000.5257. All participants signed the Informed Consent Form.

Procedures

The first group was formed by athletes who performed A HIFT session in up to 225 seconds (n = 7), being classified as the Elite group; the second group consisted of athletes who performed the HIFT session between 240 to 393 seconds (n = 10), and was considered the Advanced group; lastly, the third group was formed by athletes who performed the HIFT session over 394 seconds (n = 15), being considered the Beginner group.

The following inclusion criteria were considered for participants: Age between 20 and 40 years; regular training routine (minimum three times a week) and minimum experience of 12 continuous months of activity; belonging to boxes affiliated to the HIFT Program; any women doing hormonal control. The following exclusion criteria were applied: People who reported the use of drugs that may alter psychophysiological characteristics in the last three months according to the list of substances considered doping by the World Anti-Doping Agency (Heuberger & Cohen, 2019); not completing one of the proposed tests, and participating in two or more physical activity programs simultaneously.

Participants were familiar with the WOD Fran. The pre-test was before the execution of the WOD Fran, and the post-tests were immediately after the completion of the HIFT. The evaluations were performed at night. During the intervention, the athletes were instructed to reach the condition of exhaustion, with continuous heart rate monitoring and voice encouragement as behavior modulation to motivate the participant to execute a clean WOD without quitting and finishing at the appropriate time. A single evaluator was used per parameter, training, and alignment, with a pilot model to make the adjustments. All subjects were instructed to maintain their usual lifestyle and regular diet before and during the study so that there was no interference from uncontrolled variables during the WOD. Women were instructed to maintain hormonal control.

Measurements pre and post-WOD

Cognitive variables

Executive Function Evaluation – Five Digit Test -The Five Digit Test (Campos et al., 2016) is an instrument used to evaluate the effect of attentional interference using conflicting information about numbers and quantities, the task of assessing executive capacity, mainly inhibitory control, and cognitive flexibility (Campos et al., 2016).

The four main variables of the test were used as measures (reading, counting, choosing, and Shifting times), in addition to two executive indices (inhibition and flexibility). In the four test situations, these last two indices provide information about some mental processes such as processing speed (reading and counting times); inhibitory control/selective attention (choice and inhibition times); cognitive flexibility/alternating attention (shifting times and flexibility) (Campos et al., 2016). Scores are generated from the execution times in different stages: inhibition, calculated by the time difference of the choice/reading step; flexibility, calculated by the time difference of the alternation/counting step. The cut scoring guidelines are provided with the recommendation that the scores be adjusted based on the characteristics of the sample and the purpose of use (Campos et al., 2016; de Paula et al., 2017). This test is private to the psychologist.

Physiological parameters

Heart rate - Measured with a chest monitor and wristwatch receiver (Polar ProTrainer 5, USA) used during and after the intervention for monitoring.

Blood pressure - Systolic and diastolic blood pressure were recorded before and shortly after the intervention using an aneroid sphygmomanometer and a stethoscope (Premium, Duque de Caxias – Brasil) calibrated and with the appropriate cuff size.

Blood lactate - Blood lactate concentrations were measured with the Accutrend® analyzer (GC/GCT, USA) before and after HIFT in a blood sample taken from the finger.

Benchmark Intervention – WOD Fran

The acute intervention was performed using a benchmark - WOD Fran, which is a three-round workout with a repetition scheme (Perform the 21 Thrusters and 21 Pull-Ups, then 15 Thrusters and 15 Pull-Ups, then 9 Thrusters and 9 Pull-Ups). This type of HIFT aims to complete the prescribed exercises and repetitions as quickly as possible. This benchmark was chosen because it is a classic reference training, a performance marker in HIFT and stimulates the three energy systems (Glassman, 2015). The total load used in the Thruster exercise was 95lb for men and 65lb for women (Glassman, 2015). A standardized 5-minute warm-up consisted of running around the box and simulating movements at low intensities (~ 60% of the maximum heart rate). The execution of the HIFT session started after 5 minutes of rest.

Statistical Analysis

The Kolmogorov-Smirnov and Levene tests were applied to verify the data's normality and homogeneity of variance, respectively. The data are described as mean (M) and standard deviation (SD), with the calculation of the 95% confidence interval for the difference (CI), with $p \leq 0.05$ as the significance criterion. ANOVA with independent factors was performed to compare groups and repeated measures. ANOVA was applied to compare between and intra-conditions to compare the dimensions of the executive function and the physiological parameters in the pre and post-HIFT moments. The Mauchly test verified the sphericity hypothesis, and the degrees of freedom were corrected by the Greenhouse-Geisser estimates when violated. The size of the variance effect was calculated by the eta squared ($\eta p2$). The magnitude of the difference was considered small (0.02), medium (0.1), or large (0.25). As the executive function test is expressed in seconds, we inverted the values of each value to the percentile in the time necessary to complete each task step, according to the table suggested by the test, thereby providing a better interpretation. Pearson's correlation was used for interdependence between executive function and physiological variables. The classification from r = 0.10 to 0.30 (weak) was used; r = 0.40 to 0.60 (moderate); r = 0.70 to 1.0 (strong) to interpret the correlations.

Results
The participants' score performance in the executive function testing stages is described in Table 1 as mean and standard deviation.

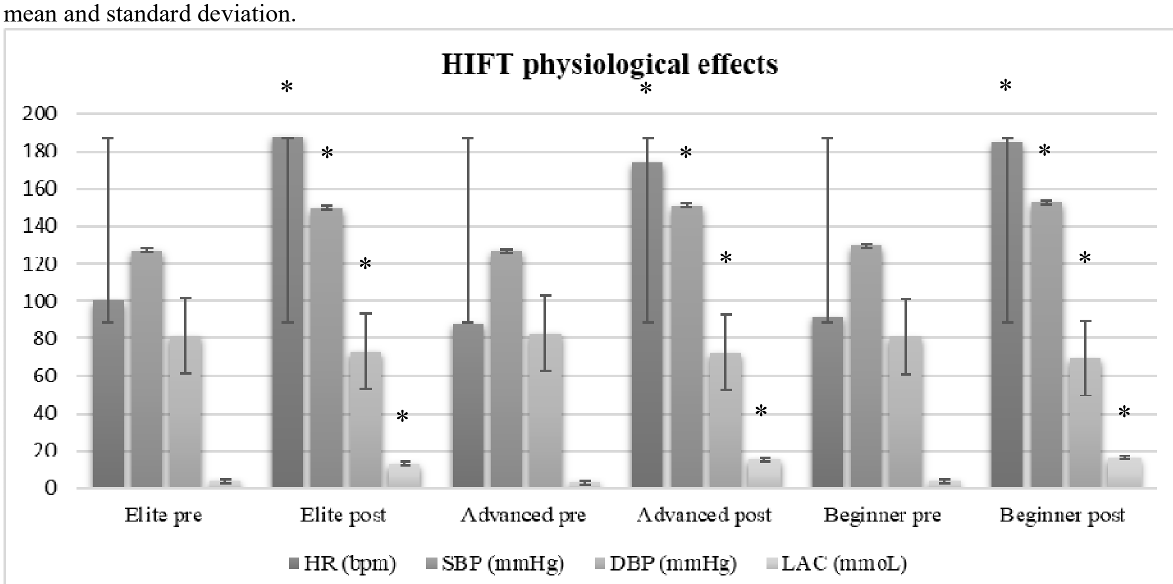
Table 1. Evaluation of cognition parameters pre and post-intervention with HIFT.

Variables	M±SD					
	Elite (n=7)		Advanced (n=10)		Beginner (n=15)	
	pre	post	pre	post	pre	post
	Cognition					
Total Five Digits	17.29±4.11	17.43±3.61*	17.70±2.54	19.20±3.12*	16.43±3.52	18.86±3.59*
Reading (P_k)	92.14±7.56	76.43±20.15*	88.50±14.91	75.50±28.91*	85.71±16.74	74.64±22.32*
Counting (P_k)	77.86±7.56	86.43±10.69*	79.00±8.43	77.50±20.58*	67.50±24.86	81.07±21.14*
Choice (P_k)	77.14±15.24	89.29±9.76*	71.00±23.07	89.00±9.66*	55.00±27.46	74.64±22.83*
Shifting (P_k)	60.00±23.09	86.43±10.69*	49.50±22.42	91.00±8.43*	49.64±23.24	76.43±21.70*
Inhibitory (P_k)	55.71±29.07	76.43±20.15*	59.00±27.87	76.50±12.48*	46.43±26.12	68.57±18.34*
Flexibility (P_k)	60.00±23.09	89.29±9.76*	49.50±22.42	93.00±6.32*	53.57±24.21	86.07±11.14*

Note: M – Mean; SD – Standard Deviation; *Difference between pre and post of the three groups is significant $p \leq 0.05$.

The statistical analysis for cognition showed a significant difference between pre and post-HIFT session, with a total of five digits (F1.29=8.04; p=0.008; ηp2=0.217), reading factor (F1.29=7.25; p=0.012; ηp2=0.200), counting factor (F1.29=4.87; p=0.035; ηp2=0.144), choice factor (F1.29=21.18; p=0.001; ηp2=0.422), shifting factor (F1.29=74.71; p=0.001; ηp2=0.720), inhibition factor (F1.29=13.82; p=0.001; ηp2=0.323), and flexibility factor (F1.29=50.73; p=0.001; ηp2=0.636).

The physiological effects of HIFT in assessing physiological parameters are described in Figure 1 as mean and standard deviation.



Note: M – Mean; SD – Standard Deviation; HR - Heart Rate; SBP - Systolic Blood Pressure; DBP - Diastolic Blood Pressure; Lac - Blood Lactate; *Difference between pre and post of the three groups is significant $p \leq 0.05$.

Figure 1. Evaluation of cognition and physiological parameters pre and post-intervention with HIFT.

The statistical analysis for the physiological parameters identified a difference in the comparison between the pre and post-measurements in all groups for heart rate (F1.29=1091.07; p=0.001; ηp2=0.97), systolic blood pressure (F1.29=138.47; p=0.001; ηp2=0.83), diastolic blood pressure (F1.29=31.35; p=0.001; ηp2=0.52) and blood lactate (F1.29=318.19; p=0.001; ηp2=0.92).

The correlations of the physiological parameters and cognition of the Elite, Advanced, and Intermediate group participants are presented in Table 2.

Table 2. Pearson's correlation for physiological parameters and cognition.

Variables		TIME HIFT	HR		SBP		DBP		LAC	
			pre	post	pre	post	pre	post	pre	post
Elite Group										
Total Five Digits	pre	-0.022	-0.292	0.287	-0.108	-0.748	-0.661	0.125	0.834*	-0.417
	Post	0.154	0.339	0.209	0.112	-0.304	-0.19	0.642	0.756*	-0.569
Reading	pre	-0.471	0.153	0.133	0.297	0.451	0.603	0.387	-0.217	0.253
	Post	0.316	0.020	0.168	0.236	0.385	0.052	-0.5	-0.672	0.294
Counting	pre	0.027	0.769*	-0.332	-0.066	0.396	0.452	0.326	-0.258	-0.156
	Post	0.569	-0.063	-0.188	-0.186	0.412	0.036	-0.49	-0.729	0.571
Choice	pre	-0.476	-0.151	0.067	-0.548	-0.689	-0.52	0.107	0.553	-0.091
	Post	0.472	0.372	-0.824*	-0.881**	-0.256	-0.156	0.379	0.399	-0.191
Shifting	pre	0.322	0.141	0.310	0.038	-0.17	-0.403	-0.152	0.054	-0.151
	Post	0.516	0.149	-0.329	-0.839*	-0.296	-0.462	0.115	0.211	0.177
Inhibitory	pre	0.398	0.233	-0.315	-0.469	-0.089	-0.268	-0.248	-0.165	0.004
	Post	0.239	0.156	-0.723	-0.824*	-0.576	-0.377	0.222	0.628	-0.419
Flexibility	pre	0.322	0.141	0.31	0.038	-0.17	-0.403	-0.152	0.054	-0.151
	Post	0.072	-0.805*	0.721	0.013	-0.375	-0.701	-0.505	0.032	0.505
Advanced Group										
Total Five Digits	pre	-0.524	0.689*	0.692*	-0.181	0.648*	-0.403	-0.437	0.524	0.178
	Post	-0.517	0.429	-0.071	0.17	0.724*	-0.432	-0.527	0.669*	0.462
Reading	pre	0.282	-0.037	0.527	-0.407	-0.109	-0.427	0.196	0.291	-0.631
	Post	-0.142	0.497	0.873**	-0.254	0.272	0.065	-0.266	0.049	0.051
Counting	pre	-0.217	0.123	0.374	0.132	0.456	-0.237	-0.154	0.21	-0.018
	Post	-0.178	0.577	0.214	-0.071	0.493	-0.212	-0.344	0.553	0.118
Choice	pre	0.018	0.386	0.817**	-0.478	0.26	-0.401	-0.235	0.283	-0.023
	Post	0.009	0.219	0.319	-0.029	0.323	-0.466	-0.134	0.619	-0.186
Shifting	pre	-0.323	0.396	0.410	-0.103	0.512	-0.362	-0.153	0.231	0.403
	Post	-0.498	0.491	-0.144	-0.132	0.342	-0.593	-0.011	0.329	0.624
Inhibitory	pre	-0.308	0.686*	0.547	-0.225	0.526	-0.511	-0.425	0.471	0.424
	Post	0.085	-0.404	-0.386	0.576	-0.101	0.47	0.147	-0.356	0.089
Flexibility	pre	-0.323	0.396	0.410	-0.103	0.512	-0.362	-0.153	0.231	0.403
	Post	-0.073	-0.029	-0.26	-0.486	-0.342	-0.395	0.616	-0.32	0.333
Beginner Group										
Total Five Digits	pre	-0.255	0.042	-0.108	-0.045	-0.125	0.043	-0.096	0.28	-0.277
	Post	0.011	-0.414	-0.171	0.191	-0.031	-0.128	0.076	0.336	0.169
Reading	pre	-0.008	0.174	0.303	-0.041	-0.109	-0.006	-0.363	-0.018	0.154
	Post	-0.557*	0.076	-0.024	-0.169	0.064	0.152	-0.361	0.242	0.034
Counting	pre	-0.375	0.259	-0.419	-0.078	-0.124	0.301	-0.433	-0.184	-0.293
	Post	-0.473	0.137	-0.236	-0.207	-0.123	0.187	-0.249	0.081	-0.083
Choice	pre	-0.064	-0.137	-0.315	-0.047	-0.247	0.32	0.095	0.578*	0.074
	Post	-0.136	-0.066	-0.225	0.039	-0.293	0.276	-0.089	0.229	0.082
Shifting	pre	-0.144	0.152	-0.228	0.077	-0.233	0.491	-0.006	0.476	-0.098
	Post	-0.218	-0.045	-0.296	-0.174	-0.102	0.196	-0.254	0.159	0.221
Inhibitory	pre	-0.191	-0.126	-0.443	0.013	-0.174	0.285	0.299	0.422	-0.111
	Post	0.12	0.159	-0.022	0.276	-0.401	0.14	0.347	-0.072	-0.024
Flexibility	pre	0.176	-0.132	0.157	-0.011	0.024	0.311	0.256	0.731**	0.142
	Post	0.298	-0.343	-0.079	0.345	0.050	0.302	0.283	0.176	0.641**

Note: HR – Heart Rate; SBP - Systolic Blood Pressure; DBP – Diastolic Blood Pressure; LAC – Lactate Blood; **The correlation is significant at $p \leq 0.01$. *The correlation is significant at the level of $p \leq 0.05$.

The analysis in the Elite group showed that there is a strong positive correlation between the counting factor and heart rate (r=0.769) and a negative and strong correlation between the choice factor and heart rate (r=-0.824), choice factor and systolic blood pressure (r=-0.881), shifting factor and systolic blood pressure (r=-0.839), inhibition factor and systolic blood pressure (r=-0.824), flexibility factor and heart rate (r=-0.805).

The Advanced group demonstrated a strong and positive correlation between the reading factor and heart rate (r=0.873), choices factor and heart rate (r=0.817), total five digits and systolic blood pressure (r=0.724), as well as a moderate and positive correlation for inhibition and heart rate (r=0.686), total five digits and heart rate (r=0.689), total five digits and systolic blood pressure (r=0.648), total five digits and lactate (r=0.669). The Beginner group identified a strong correlation between flexibility factor and blood lactate (r=0.731); a moderate and positive correlation between flexibility factor and blood lactate (r=0.641), choice factor and lactate (r=0.578); and a moderate and negative correlation between the reading factor and HIFT execution time (r=-0.557).

Discussion

Currently, no studies address the acute effect on cognition related to physiological parameters in HIFT (Claudino et al., 2018). However, there are studies separately analyzing the processes of attention and lactate (Perciavalle et al., 2016), cognitive functions and lactate (Coco et al., 2019), and memory and lactate (Perciavalle et al., 2015) in HIFT practitioners. We assume that the psychological aspects are multifactorial and fundamental in the athlete's performance and encompass a series of combined factors that can explain different effects on performance according to the competitive level (Basso & Suzuki, 2017). The main results indicated significant differences between moments in cognition, with a considerable impact of HIFT session in the five digits' test, including reading, counting, choice, shifting, inhibition, and cognitive flexibility. In addition, strong and positive correlations were observed between these cognitive factors and physiological parameters, as present research identified a difference in the comparison between the pre and post-measurements in heart rate, systolic blood pressure, diastolic blood pressure, and blood lactate. This physiological result aligns with past studies (Aravena et al., 2022; Ferreira et al., 2020; Mangine et al., 2018; Vestberg et al., 2017).

Regarding the grouping of participants, this sample was randomized and stratified according to the level of performance in the benchmark execution time - WOD Fran, to form the subgroups. In contrast to our study, we found a study by Mangine et al. (2018), who developed normative values for five benchmark exercises (Fran, Grace, Helen, Filthy-50, and Fight-Gone-Bad) using the performance data of 133,857 male and female profiles, located on a publicly available website, and classified by gender and competitive age. However, they did not control essential variables to verify the physiological and psychological effects on the practitioner. They did not consider the reliability of the evaluators since such secondary data presents descriptive elements associated with competitive events.

Elite group participants completed the Benchmark in 53% less time than the Advanced group, and this percentage increases to 84% of the participants when compared to the Beginner group. Furthermore, 61% of the participants in the Advanced group completed the Benchmark in less time than the Beginner group. These differences can be explained by the technical skill and specific physical aptitude acquired by the practice time of the modality and the training time, which facilitates performing movements and consequently improves the final time (Glassman, 2015). Regarding the practice time in the modality, 60% of the Elite group had a longer time than the other groups considering the weekly training volume, which was almost twice as voluminous as the other groups. This information helps create normative data for HIFT considering the execution time of the Benchmark - WOD Fran, according to the classification by competitive levels.

This research showed a positive effect on the executive function considering pre- and post-HIFT moments, emphasizing the Elite group. The findings suggest that a HIFT session improves the performance of executive functions, especially concerning cognitive flexibility and inhibitory control. These results can be of great importance in elucidating the influence of exercise on the efficiency of cognition and therefore contribute to improving athletic performance (Li et al., 2014). Athletes with better-developed cognitive processes achieve higher performance levels (Vestberg et al., 2017). Cognitive performance after acute exercise seems linked to exercise intensity, as demonstrated in a meta-analysis (Chang et al., 2012). The exercise intensity had a significant influence when < 50% of HRMax was prescribed, showing a result that had a significant negative effect with magnitude (Cohen's d=−0.113) on the cognitive performance; furthermore, the results were positive when prescribed above 60% of HRMax, with an effect and magnitude of (d=−0.202) and (d=−0.268).

The experimental study by Lambrick et al. (2016) suggests that an acute exercise of just 15 minutes in duration, whether of an intermittent or continuous nature, is sufficient to cause significant improvements in executive functions. These effects can be maintained for up to 30 minutes after the end of the activity. Most studies use the Stroop test and point out that the higher the intensity, the better the cognitive performance (Li et al., 2014; Vazan et al., 2017). This study obtained a similar result to the abovementioned studies in performing an acute intervention with high intensity and short duration exercise (WOD Fran), varying between athletes from 145 seconds to 763 seconds. It was observed that a single exercise session could promote cognition performance using the five-digit test (Campos et al., 2016). Thus, the ability to inhibit dominant responses or actions in progress is essential for successful performance, as well as greater control of behavior, attention, thought, and emotion, enabling the inhibition of behaviors or automatic routines and the execution of controlled or conscious routines in favor of what is most appropriate or precise (Huijgen et al., 2015).

There is still a discussion about the physiological mechanisms which guide acute brain adaptations about cognition (Chang et al., 2012; Li et al., 2014; Perciavalle et al., 2016; Coco et al., 2019). The existing literature tends to highlight a positive relationship if the exercise is of submaximal intensity, while the effects of exhaustive exercises seem negative (Perciavalle et al., 2015, 2017; Strömmer et al., 2020). Possible hypotheses to explain improved post-exercise executive function include the acute effect of exercise intensity on cognitive response or increased cerebral blood flow generated by exercise effort, which can be noted in post-exercise cognitive performance.

The results of the physiological parameters showed differences in the pre and post-WOD comparisons between the three groups. There was a difference in the heart rate variable before and after HIFT, with an increase of approximately 95% of HRmax; blood lactate increased above 100%, an expressive increase in systolic blood pressure, and a decrease in diastolic blood pressure. These results corroborate the findings in the study by (Fernández et al., 2015), which compared the Fran and Cindy post-WOD routine in healthy adults aged 30 ± 4.2 years. The results revealed that both HIFTs could be characterized as high-intensity exercises, reaching acute physiological responses and representing 90-95% HRmax.

They also concluded that the acute physiological demands of the analyzed HIFTs met the ACSM guidelines for energy expenditure and exercise intensity in healthy adults. However, safety does not exist due to the high intensity of the analyzed exercises and the lack of research on this topic.

Our study noticed hypotension right after the intervention; after a training session, the body produces physiological responses classified into immediate treble pre and post-intervention (Materko et al., 2020). Several studies (Meier et al., 2023) report that the DBP decreased 15 and 30 minutes after the exercise session, justifying hypotension. Most findings indicate an increase in SBP after effort, meaning they corroborate the results obtained in this study (Tibana et al., 2017; Fonseca et al., 2018; Materko et al., 2020).

In comparing the pre and post-HIFT measurements for blood lactate, there was a difference in post-HIFT lactate above 100% mmoL for both groups. These findings are similar to those found in the study by Perciavalle et al. (2016), which report an increase in blood lactate during an exhaustive exercise, which is an expression of performance intensity instead of muscle fatigue.

The Elite group showed a strong and positive correlation between a low heart rate with an improvement in the counting factor. However, the group showed strong and inverse correlations between low heart rate and the best choice analysis and cognitive flexibility, low systolic blood pressure, and best choice analysis, alternation, and inhibition. Overall, we see an improvement in some cognition after the intervention.

The effects of cognition associated with physiological parameters in the Advanced group showed a strong correlation between high heart rate about the improvement in the reading factor, moderate correlations between low heart rate and weak inhibitory control, and low or high heart rate did not change the result of the total of five digits, suggesting that exercises which optimize physical fitness may be engaging to improve executive function. Low lactate improves five digits, indicating improvement in cognitive performance.

The Beginner group showed a strong correlation between flexibility factor and blood lactate; a moderate and positive correlation between flexibility factor and blood lactate, choice factor and lactate; and a moderate and negative correlation between reading factor and HIFT session execution time.

We agree with a hypothesis raised by Coco (2019) that high levels of lactate in the blood induced by exercise can affect some factors of executive functions; however, our study shows significant improvement in cognitive flexibility and processing speed, in contrast to some studies which note the relation to the functions supported by the prefrontal cortex, such as processing speed (Strömmer et al., 2020), cognitive flexibility (Coco et al., 2019) and resistance to interference (Laurent et al., 2020) which seem to be more affected, while the functions supported by more posterior cortical areas such as visual attention and task changes are not affected (Uehara et al., 2019).

This is the first study to analyze the effect of the practice of a HIFT WOD Fran on the physiological variables and cognition according to the performance of the HIFT. However, limitations must be pointed out for a better analysis of these findings: i) Absence of collection time after the recovery period, which would enable inferences about the periods necessary for the return to base values; ii) Equivalent distribution of both genders for each group; iii) Interval application of the test right after the exercise without minimum rest time; iv) Lack of standardization of interventions. This compromises these functions' physical activity performance level measurement (Conde et al., 2022). We suggest that future studies explore randomized experiments with effects after one hour, eight hours, 12 hours, 24 hours, and chronic effects.

Conclusion

The present study is vital for physical training by scientifically investigating the psychophysiological effects of an acute HIFT intervention. Professionals working in this area can use this information to improve the quality of performance of their athletes.

The main findings indicated an acute effect of HIFT on cognition and physiological parameters. There has a progressive effect according to the competitive level in the Fran benchmark. HIFT impacted the physiological parameters and executive brain function, including reading, counting, choice, shifting inhibition, and cognitive flexibility.

In addition, strong and positive associations were observed between these cognitive factors and physiological parameters, considering competitive levels. Our findings confirm that high-intensity exercise presented a strategy capable of sharply influencing the physiological mechanisms responsible for intervening in cognitive performance, efficiently improving executive functions.

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