DOI 10.26773/smj.230702

SportMont

ORIGINAL SCIENTIFIC PAPER

Acute Effect of a Cross-Training Benchmark on Psychophysiological Factors of Cross-Training According to Performance

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Abstract

The study aims to analyze the acute effect of a Cross-Training benchmark on executive functions and physiological parameters according to performance. Thirty-two practitioners were divided according to their performance, Elite group (n=7; age: 28.9±4.7 years; practice: 50.0±13.3 months), Advanced group (n=10; age: 33.4±4.6 years; practice: 27.6±13.8 months) and Beginner group (n=15; age: 30.6±7.1 years; practice: 22.9±9.2 months). This research compares the groups and the pre-WOD and post-WOD moments for physiological (heart rate, lactate concentration, diastolic and systolic blood pressure) and neuropsychological variables (executive function); correlations between the physiological and neuropsychological effects of the benchmark. The results showed a significant difference concerning the performance of the WOD time (Elite: 177.1'±29.8' s and the difference in executive functions regarding the comparison between moments: reading (Elite:76.4±20.2 percentiles), counting (Elite: 86.4±10.7 percentiles), choice (Elite: 89.3±9.8 percentiles), shifting (Advanced: 91.0±8.4 percentiles), inhibition (Advanced:76.5±12.5 percentiles), flexibility (Advanced: 93.0±6.3 percentiles), lactate (Elite:13.1±1.8 mmol/L), heart rate (Elite: 188.0±6.6 bpm), systolic blood pressure (Elite: 149.7±11.5 mmHg), and diastolic blood pressure (Elite: 73.4±6.2 mmHg). Our findings confirm that high-intensity exercise could influence the physiological mechanisms responsible for the intervention in cognitive performance, improving executive functions.

Keywords: *sport psychology, cognition, anxiety, physiology of exercise, neuroscience, sport performance*

Introduction

Neurophysiological factors are why different sports agents are cited to justify obtaining specific results (Vealey, 1992; Brown & Fletcher, 2017; Slimani et al., 2017; Znazen et al., 2017; Brandt et al., 2019). The mind is often more important than any tactic, technique, or skill (Browne et al., 2016; Diamond & Ling, 2016). Understanding the cognitive aspects that improve a Cross-Training benchmark practice (Griffin et al., 2011; Wang et al., 2013; Murawska-Cialowicz et al., 2015; Tomporowski & Pesce, 2019; Brandt et al., 2021). Conceptually, Cross-Training is a strength training and general conditioning program that enables a broad physiological adaptation for any person (Glassman, 2015). The Program is based on three exercise bases: functional movements, high intensity, and constant variation (Claudino et al., 2018). Some studies (Bellar et al., 2015; Haddock et al., 2016; Box et al., 2019) have recently indicated individual differences between Cross-Training participants in their respective primary modes

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of physical practice, determining psychologically predictive inferences for performance without assessing the physiological interaction associated with executive functions.

Several investigations (Mangine et al.; 2018; Beatty & Janelle, 2019; Heinrich et al., 2020) have demonstrated that engaging in Cross-Training programs, which involve the simultaneous practice of multiple physical activities, can lead to positive changes in psychophysiological outcomes. These outcomes include cognitive function, mood regulation, stress reduction, and overall mental well-being (Coco et al., 2019; Heinrich et al., 2020). Moreover, the diverse nature of Cross-Training activities appears to promote improved mood states and stress resilience, potentially attributed to the combination of aerobic exercise, strength training, and flexibility components (Reppa et al., 2023). However, despite these promising findings, there remain notable gaps in the literature concerning the impact of Cross-Training benchmarks on psychophysiological factors.

Given the particularities of the modality and characteristics of Cross-Training (Claudino et al., 2018), it has yet to be discovered how this practice can affect executive functions associated with physiological parameters and what benefit this can have in the lives of practitioners of this modality. Therefore, it is relevant to understand the executive functions' role in achieving complex and unpredictable activities (Diamond, 2013). Thus, the present study proposes to investigate the effect of a Cross-Training benchmark on executive functions and physiological parameters and the interdependence of these factors according to the time performance of the Workout of the Day - WOD Fran.

Methods

Sample

The sample consisted of 32 Cross-training practitioners randomly chosen and, after that, stratified by level: Elite group (E=7; 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). The CrossFit-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 =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).

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

The following inclusion criteria were considered for participants: participants should have ≥18 years old; regular training routine (minimum three times a week) and minimum experience of 12 continuous months of activity; belonging to boxes affiliated with the CrossFit Program; any women doing hormonal control.

The following exclusion criteria were applied: Athletes 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. Before the study, athletes attended a briefing meeting. They signed an informed consent document to ensure they understood the testing procedures and the risks and benefits associated with the research. No interferences were made in athletes' training, nutritional, or hydration status. Following the WMA's Declaration of Helsinki, the local Ethics and Research Committee previously approved this research (nº13846919.8.0000.5257).

Procedures

Participants were familiar with WOD. The pre-test was before the execution of the WOD Fran, and the post-tests were immediately after completing the WOD Fran. All collected data occurred in air-conditioned boxes between 18:30 and 21:30 at a range temperature between 24.5o-26.5oC. 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. This protocol reproduced the actual Cross-training activity, and coaches controlled the data collection to guarantee that all athletes realized validated techniques.

Measures and Instruments

Executive Function Evaluation – Five Digit Test pre and post-WOD

The Five Digit Test (Sedó et al., 2015) 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) and 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) (Sedó et al., 2015; 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 participants and the purpose of use (Sedó et al., 2015; Campos et al., 2016; de Paula et al., 2017). This test is private to the psychologist.

Assessments of Physiological Parameters pre and post-WOD Fran

Heart rate: Measured with a chest monitor and wristwatch receiver (Polar ProTrainer 5, USA) used during and after the intervention for monitoring (Maté-Muñoz et al., 2018).

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 – Brazil) calibrated and with the appropriate cuff size (Shaw et al., 2015; Malachias et al., 2016).

Blood lactate: Blood lactate concentrations were measured with the Accutrend® analyzer (GC/GCT, USA) before and after WOD in a blood sample taken from the finger (Zebrowska et al., 2019).

Benchmark Intervention – WOD Fran

The acute intervention was performed using a benchmark - WOD Fran, 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 WOD 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 Cross-Training, and stimulates the three energy systems (Glassman, 2015; McArdle et al., 2016). The total load in the Thruster exercise was 95lb for men and 65lb for women (Glassman, 2015). There was a standardized 5-minute warm-up which consisted of running around the box and simulating movements at low intensities (~60% of the maximum heart rate). The execution of WOD Fran started after 5 minutes of rest.

Statistical Analysis

The data are described as mean (M) and standard deviation (SD), with a calculation of the 95% confidence interval for the difference (CI), with $p \leq 0.05$ as the significance criterion. ANOVA with independent factor was performed to compare groups, and repeated measures ANOVA was applied to compare intra-conditions to compare the dimensions of the executive function and the physiological parameters in the pre and post-WOD moments. The size of the variance effect was calculated by the eta squared ($\eta p2$) (Cohen, 1992). Pearson's correlation was used for interdependence between executive function and physiological variables (Schober et al., 2018). All analyses were applied using the Statistical Package for Social Sciences (SPSS 22.0) for Windows.

Results

The performance of participants in the executive function testing stages and the assessment of physiological parameters are described in Table 1 as mean and standard deviation.

Table 1. Evaluation of cognition and physiological parameters pre and post intervention with WOD Fran.

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*
			Physiological Parameters			
HR (bpm)	100.14±17.69	188.00±6.63*	87.90±13.31	174.10±16.06*	92.07±9.13	185.13±8.93*
SBP (mmHg)	127.14±7.65	149.71±11.46*	127.00±7.96	151.00±9.25*	129.60±8.66	152.53±8.05*
DBP (mmHg)	81.43±2.51	73.43±6.19*	83.00±4.45	72.80±9.58*	80.93±6.13	69.33±7.08*
LAC (mmoL)	3.57±0.97	13.07±1.81*	3.10±0.99	15.14±3.21*	3.61±0.61	16.05±3.69*

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

The statistical analysis for executive functions showed a significant difference between pre and post-WOD Fran in all of them, with a total of five digits ($F1.29=8.04$; $p=0.008$; $\eta p2=0.217$), reading factor ($F1.29=7.25$; $p=0.012$; $\eta p2=0.200$), counting factor ($F1.29=4.87$; $p=0.035$; $\eta p2=0.144$), choice factor ($F1.29=21.18$; $p=0.001$; $\eta p2=0.422$), shifting factor ($F1.29=74.71$; $p=0.001$; $\eta p2=0.720$), inhibition factor ($F1.29=13.82$; $p=0.001$; $\eta p2=0.323$), and flexibility factor ($F1.29=50.73$; $p=0.001$; $\eta p2=0.636$).

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 ($F1.29=1091.07$; $p=0.001$; $\eta p2=0.97$), systolic blood pressure ($F1.29=138.47$; $p=0.001$; $\eta p2=0.83$), diastolic blood pressure ($F1.29=31.35$; $p=0.001$; $\eta p2=0.52$) and blood lactate ($F1.29=318.19$; $p=0.001$; $\eta p2=0.92$).

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

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

Variables		TEMPO WOD	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**

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

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 reading factor and WOD execution time (r=-0.557).

Discussion

There are currently no studies addressing the acute effect on executive functions related to physiological parameters in Cross-Training (Claudino et al., 2018; Brander Löf & Lindblom, 2019). 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 Cross-Training 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 (Crust, 2007; Crust & Azadi, 2010; Basso & Suzuki, 2017).

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. This sample was randomized and stratified according to the level of performance in the benchmark execution time - WOD Fran, to form the subgroups. 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 increased to 84% of the participants 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 (Bellar et al., 2015; 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 Cross-Training considering the execution time of the Benchmark - WOD Fran, according to the competitive-level classification.

The findings suggest that a WOD Fran 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 executive functions and therefore contribute to improving athletic performance (Yanagisawa et al., 2010; Li et al., 2014). Athletes with better-developed cognitive processes tend to achieve higher performance levels (Vestberg et al., 2017). We found that cognitive performance after acute exercise seems to be 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 FCMax, 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 (Yanagisawa et al., 2010; 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 the performance of executive functions using the five-digit test (Campos et al., 2016). Thus, the ability to inhibit dominant responses or actions in progress is important 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 that guide executive functions' acute brain adaptations (Chang et al., 2012; Li et al., 2014; Perciavalle et al., 2016; Coco et al., 2019). The existing literature highlights 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, noted in post-exercise cognitive performance.

The present results of the physiological parameters corroborate the findings in the study by previous authors, as Perciavalle et al. (2016), Hall et al. (2016), and 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 WODs could be characterized as high-intensity exercises, reaching acute physiological responses and representing 90-95% HRmax. We noticed in our study that there was 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, such as that by Rezk et al. (2006) and Ferrari et al. (2014), report that the DBP decreased at 15 and 30 minutes after the exercise session, justifying hypotension. Most findings indicate an increase in SBP after effort, which corroborates the results obtained in this study (Tibana et al., 2017; Fonseca et al., 2018; Materko et al., 2020). 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 study is the first to analyze the effect of a Cross-Training WOD Fran on the physiological variables and executive functions according to the performance of the WOD. However, limitations must be pointed out for a better analysis of these findings: Absence of collection time after the recovery period, which would enable inferences about the periods necessary for the return to base values; equivalent distribution of both genders for each group. All of this compromises the physical activity performance level measurement on these functions. 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 essential for physical training by scientifically investigating the psychophysiological effects of an acute Cross-training intervention. Our research demonstrated a positive effect on the executive function associated with a WOD Fran session. The outcomes suggest that a WOD Fran session improves the performance of executive functions, especially concerning cognitive flexibility and inhibitory control. Professionals working in this area can use this information to improve the quality of performance of their athletes. Our findings confirm that high-intensity exercise presented a strategy that sharply influenced the physiological mechanisms responsible for intervening in cognitive performance, efficiently improving executive functions.

Conflict of Interest
The authors declare that they have no competing interests.

Authors' contributions
MAB, JRF, PHBC and BM participated in the study design, collection and data analysis, manuscript preparation, funding acquisition; CJB, EAM, DASS participated in the data analysis and manuscript preparation.

Funding
This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. MAB received a PDSE/CAPES Scholarship.

Received: 01 February 2023 | **Accepted:** 09 May 2023 | **Published:** 01 June 2023

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