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Original Article

A comparison of cardiorespiratory responses between CrossFit® practitioners and recreationally trained individual

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Abstract:
The aim of this study was to compare the neuromuscular and cardiorespiratory capacities among CrossFit® (CF) practitioners and recreationally trained (RT) individuals. Sixteen participants between 18 and 30 years old of both sexes participated in this study. They were divided into CF Practitioners group (CF: sex= 4 men and 4 women; age= 28.6±4.3 yr; height= 170.7±6.5 cm; BMI= 23.1±1.9 Kg/m^2) and RT individuals group (RT: sex= 4 men and 4 women; age= 26.5±3.9 yr; height= 165.7±8.9 cm; BMI= 21.8±2.6 Kg/m^2). After familiarization with procedures, and a body composition evaluation by skinfolds, a duration of 72 h, all participants did a maximum cardiorespiratory test by an incremental cycle ergometer. Data were analyzed for normality, using the Shapiro-Wilks test, and then a student t-test was used to compare both of the groups. The CF group presented a significantly higher lean mass than the RT group (p= 0.003). The CF group had significant smaller second ventilatory threshold (p= 0.04), power of first ventilatory threshold (p= 0.01), and power of second ventilatory threshold (p= 0.04), than the RT group ($p < 0.05$). Also, the heart rate Recovery (HRR) was significantly smaller for the CF group than the RT group (p= 0.02). It could be concluded that although CF practitioners did not present higher VO_{2max} and maximum power than RT individuals, while the CF practitioners presented significant differences in more lean mass and better HRR, which shows cardiorespiratory and neuromuscular adaptations.
Key words: CrossFit®, neuromuscular, cardiorespiratory

Introduction

The CrossFit® (CF) modality was introduced by Greg Glassman in the United States in 1995, which becoming a highly popular competitive sport (CrossFit.com, 2016). Among the benefits of CF training among favorable motivational climate within training centers, suggested a positive effect on adherence to physical activity programs (Partridge, Knapp & Massengale, 2014), such as improvement of neuromuscular physical capacities and cardiorespiratory capacities (Bellar, Hatchett, Judge, Breaux & Marcus, 2015). The CF involves quickly multi-joint movements and varying numbers of repetitions. The objective of CF training would be to develop broad adaptations such as speed, strength, coordination, flexibility, power, and resistance (Murawska-Cialowicz, Wojna, & Zuwala-Jagiello, 2015). In general, the CF presents a resource series of exercises that stimulate the aforementioned capacities among other sports such as cycling, running, swimming, weightlifting, powerlifting, jumping, handstand, swing kettlebell (Glassman, 2003).

Similar to the interval training, the CF offers short and unstructured rest periods, which allows participants to be susceptible to elevate stress levels of exercise-induced. Thus, it presents changes in the body that could be beneficial or harmful, depending on the magnitude, duration and frequency of the stimulus (Powers & Jackson, 2008; Wasfy & Baggish, 2016). The adaptations to intense training with short rest periods are well described in the high intensity interval training (HIIT) modalities, and the CF presents similar characteristics of HIIT (Ahmadi et al., 2018; Claudino et al., 2008). The HIIT training is related to neuromuscular adaptations such as a greater amount of glycolytic fibers (type II or white fibers), greater power and muscular strength (Gibala & McGee, 2008; Gollnick, Armstrong, Saubert, Piehl, & Saltin, 1972); improving the removal of hydrogen protons and muscle lactate into the bloodstream, as well as increasing numbers and activities of enzymes in the glycolytic system (Perry, Heigenhauser, Bonen, & Spriet, 2008). These adaptations are attributed to the type of energy which involved in this training, and also the anaerobic system is highly requested during CF training (Naimo et al., 2015).

Regarding cardiorespiratory adaptations, HIIT shows improvements in maximal oxygen consumption (VO_{2max}) for various age groups and conditioning levels (Milanovic, Sporis, & Weston, 2015), lower values of maximum heart rate (HR) in performance tests (Etxebarria, Anson, Pyne, & Ferguson, 2014), as well as better HR recovery (Ostojic et al., 2010), which demonstrates favorable cardiorespiratory adaptations for performance

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and health. The cardiothoracic improvements related to HIIT are attributed to the great demand of the oxidative system. This stimulus induces the increase of mitochondrial content and the kinetics of enzymes related to oxidative metabolism (Gibala, Little, Macdonald, & Hawley, 2012; Gibala & McGee, 2008). It is widespread that the CF training can maximize both cardiorespiratory and neuromuscular adaptations (CrossFit.com, 2016). The adaptations of hypertrophy and power (neuromuscular) occur in different proportions depending on characteristics of the training, similar to that occurring in the adaptations of VO_{2max}, Maximum HR (HRmax) and HR of Recovery (HRR).

A few studies have been conducted to understand the impacts of the CF training, or skills and abilities that developed by it. Therefore, the present study aimed to compare the cardiorespiratory capacities among CF practitioners and recreationally trained (RT) individuals. It was hypothesized that the CF practitioners will have better results for the neuromuscular and cardiorespiratory variables than RT individuals.

Methodology

Participants

The study sample consisted of 16 participants between 18 and 30 years old of both sexes which composed of two groups, a group of the CF Practitioners (n= 8: 4 men and 4 women) and a group of RT individuals (n= 8: 4 men and 4 women). The choice of groups composed of both men and women was made to increase the ecological validity of the sample, since the cross-fit training sessions are mixed. A dissemination of the project information was done through electronic media, leaflet and social networks. All volunteers completed a demographic questionnaire containing the following information: training mode, weekly training frequency, practice time in years, and duration of training sessions. The volunteers were balanced in the both groups regarding the number of men and women in each group and for the following variables: Age, Height, and BMI. The matched participants were invited to participate in an explanatory meeting, where the exercise protocols, calendar of activities, possible risks and benefits that could occur throughout the intervention were presented. All participants stated in an anamnesis to perform their physical activity 3 to 6 times a week. Ischemic myocardial disease, chronic obstructive diseases, arrhythmias, osteomioarticular problems, using hormones and obesity (BMI> 30 kg/m^2) were applied as exclusion criteria. In addition, all participants presented a medical certificate to allow them for doing physical activity. The characteristics of the participants are summarized in Table 1.

Experimental Design

This study was designed as an experimental, cross-sectional study, where all participants performed a familiarization session and a maximal incremental test session on cycle ergometer. The participants performed the sessions at the same time of day, to avoid of the circadian cycle variations (Drust, Waterhouse, Atkinson, Edwards, & Reilly, 2005). Also they instructed not to engage in vigorous physical activity and drink alcohol or any drugs during 48 hours before the tests. In addition, the participants were instructed not to consume stimulant beverages for at least 6 hours prior to the sessions and abstain from meals two hours prior to testing. The women participants performed the tests outside of the menstrual period, to avoid possible oscillations of performance (Masterson, 1999). In the first session, the body composition evaluation by skinfolds was performed (Jackson & Pollock, 1978), then the participants performed a familiarization session with the incremental cycle ergometer test. After 72 hours of familiarization (first session), all the participants returned to the laboratory for the maximum cardiorespiratory test. This test was used to evaluate the maximum cardiorespiratory capacity, characterized by the maximum oxygen intake (VO_{2max}) recorded at the time of exhaustion during the incremental protocol. The cycle ergometer test also represented, information about the neuromuscular capacity of the participants by the maximum power reached in the test (Power max). Figure 1, presents experimental design with the steps that made it up which each stage represents a visit to the laboratory and the participants had 72 hours between the two sessions.

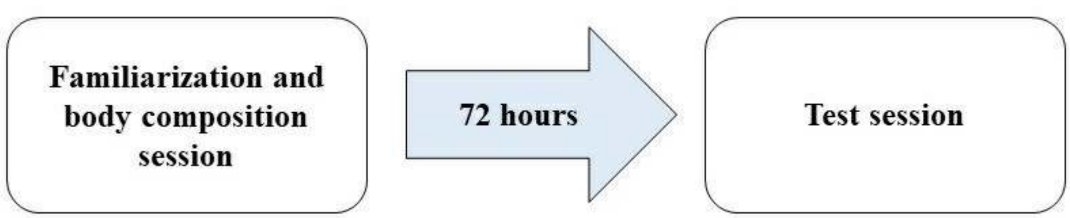

Figure 1. Experimental design

Neuromuscular and Cardiorespiratory Evaluation

The test was performed by a simulator cycle ergometer (RacerMate®, ComputrainerTM, Seattle, USA) with using continuous gas collection equipment (CPX Ultima, Medgraphics, USA). Temperature at the test place was steady all over the test, ranging among 21-23 ºC. Only three people were allowed in the evaluation room, two researchers and one participant. The cycle ergometer was adjustment according to the manufacturer's recommendations. The distances measures of the handlebars and seat were kept as same as the familiarization session for each participant. The participants performed a progressive protocol until exhaustion level, which consisted of a preliminary phase of 5 minutes' rest, 6 minutes' warm-up at the lowest load of the equipment (50 W) then followed by increments of 25 W every minute until Participants' physical exhaustion or impossibility to maintain a constant speed of 70-75 revolution per minute (RPM). Finally followed by five minutes' recovery period at 50 W (three minutes' active recovery under 60 rpm and then two minutes' passive recovery). During the entire progressive test, a cardio-frequency meter Polar® (S810i, Polar ElectoOy, Kempele, Finland) was used to record the HR. Also The Borg Scale (0-20) was applied every minute during the test to obtain information about the rate perceived exertion (RPE). The RPE was used as one of the criteria to consider the test level (Borg reported> 18) (Borg, 1982). Also it was other criteria to consider the test as maximum: HR greater than 90% of predicted (220 - participant' age) and respiratory quotient greater than 1.3 (Howley, Bassett, & Welch, 1995; Silva, Silva, Ahmadi & Teixeira, 2019). The cardiorespiratory capacity was determined by the values of maximum oxygen intake (VO_{2max}), minute ventilation (VE) and HR, as well as values related to the first ventilatory threshold (VT_1), detected as the first inflection point of the curve analyzed (V.CO2) and VE curves (Binder et al., 2008). The second ventilatory threshold (VT_2), was identified in duplicate by visual verification of the decrease in PCO2/watts variables and ventilation by carbon dioxide production (VE/V.CO2), considering the abrupt increase of V.CO2 as a confirmation of VT_2 according to the criteria which proposed by Meyer et al. (2005). The ventilatory thresholds were verified and confirmed by two experienced assessors.

Evaluation of Body Composition

The body composition was measured by the method of seven sites skinfolds (chest, scapula, axilla, triceps, waist, hip and thigh folds) of Jackson & Pollock equation (1978). The Siri equation (Siri, 1956). used for the conversion of the values in percentage of fat and lean mass. For skin folds, a scientific adipometer (Sanny®, São Paulo, Brazil) with a precision of 0.2 mm was used.

Statistical analysis

A descriptive statistic was applied for selection and tabulation of the results. A ShapiroWilk's test ($p< 0.05$) showed that the data were approximately normally distributed (Heirani & Ahmadi, 2012; Shapiro & Wilk, 1965). The student t test was used to compare the variables between both of the groups including the variables that were used to balance the groups. All statistical analysis was carried out with Statistica ® 6.0 software package.

Results

All data are presented as mean ± standard deviation. It was observed that the CF group had a weekly training frequency of 5.8 times a week and the RT group had an average of 3.7 times a week ($p= 0.01$). Regarding the time of practice (years), it was observed that recreational group had more experience in their modalities (6.5 years) than CF group (1.6 years) and this difference was significant ($p= 0.01$). Also duration of the training sessions was verified that, CF group exercised about 63.7 minutes per session and the RT group about 61.4 minutes per session, there was not significant difference between groups ($p= 0.84$). The characteristics of the participants are summarized in Table 1.

Table 1. Characteristics of the Participants

Variables	CF	RT	*P*
Age (years)	28.6 ± 4.3	26.5 ± 3.9	0.39
Height (cm)	170.7 ± 6.5	165.7 ± 8.9	0.21
BMI (Kg/m^2)	23.1 ± 1.9	21.8 ± 2.6	0.09
Fat (%)	11.8 ± 4.9	14.1 ± 5.3	0.37
Lean mass (Kg)	59.8 ± 10.7	49.6 ± 8.1	0.003*
Weekly training (days)	5.8 ± 0.5	3.7 ±1.1	0.01*
Years of training (years)	1.6 ± 0.7	6.5 ± 4.8	0.01*
Duration of a training session (min)	63.7 ± 10.6	61.4 ± 33.4	0.84

P<0.01

BMI: Body Mass Index.

The age, height, BMI, %fat variables did not present significant differences between both of the groups. The CF group presented significant higher lean mass than the RT group ($p < 0.01$). For the variables related to the incremental test we found that VO_{2max}, VT_1, HRmax, test time, maximum power, HR in VT_1, and HR in VT_2 did not present significant differences between groups (all $p > 0.05$). The CF group had significant smaller VT_2, power of VT_1 and power of VT_2 than the RT group ($p < 0.05$). Also the HRR was significant smaller for the CF group than RT group ($p = 0.02$). Table 2, shows the comparisons between groups.

Table 2. **Mean and standard deviation of performance variables in the incremental test**

Variables	**CF**	**RT**	***p***
Time test (s)	531.1 ± 217.1	514.5 ± 209	0.64
Power max (w)	243.7 ± 56.3	231.2 ± 45.8	0.35
Power of VT_1 (w)	96.4 ± 17.2	128.5 ± 24.7	0.01*
Power of VT_2 (w)	214.2 ± 28.3	217.9 ± 29	0.04*
VO_{2max} (ml.kg/min)	42.5 ± 5.3	44.38 ± 5.5	0.41
VT_1 (ml.kg/min)	19 ± 6.8	23.58 ± 4.4	0.14
VT_2 (ml.kg/min)	30.5 ± 3.5	36.5 ± 7	0.04*
HRmax (bpm)	179.8 ± 9.6	186 ± 8.3	0.29
HR in VT_1 (bpm)	133.7 ± 32.4	141.3 ± 22.2	0.53
HR in VT_2 (bpm)	163.6 ± 13.6	173.7 ± 13.7	0.25
HRR (bpm)	137.2 ± 10.4	151.1 ± 10.6	0.02*

*** p< 0.05**

BMI: Body mass index; **VO_{2max}**: peak oxygen uptake; **VT_1**: first ventilatory threshold; **VT_2**: second ventilatory threshold; **HR**: Heart rate; **HRmax**: maximum heart rate; **HRR**: heart rate recovery.

Discussion

The greatest finding of this study was to have found similar results for VO_{2max} and maximum power in incremental test between the CF and RT groups. However, significant differences were found in VT_2, as well as in the power of VT_1 and power of VT_2, which the CF group presented lower values in these three variables. The literature is scarce in studies that have proposed to investigate the differences between the cardiorespiratory capacities of CF practitioners and other modalities. Although studies which investigated HIIT protocols, have demonstrated that their adaptations for VO_{2max}, VT_1 and VT_2 are similar or even superior when compared with conventional training methodologies (Helgerud et al., 2007; Poole & Gaesser, 1985).

In the present study, we found lower values of O_2 consumption in VT_2 for CF practitioners than RT individuals, however the test time was similar for the both groups ($p > 0.05$). This shows that the CF practitioners performed the incremental test with a longer time rate above VT_2, which possibly implies a higher efficiency of the glycolytic system for energy production and removal of residual substances. Perry et al. (2008) found that, HIIT training protocols lead to improvements in glycolytic energy production, as well as higher concentrations of proteins related to the removal of residual substances, such as lactate and hydrogen protons. In addition, Simoneau et al. (1985) investigated changes in muscle fiber type versus a high-intensity interval training protocol for 15 weeks with twenty-four volunteers who were divided into two groups, control and experimental. Biopsy analysis of the vastus lateralis muscle showed that training increased the proportion of type I fibers and decreased type IIb fibers. The proportion of type IIa fibers remained unchanged. It has also been shown a large increase in hypertrophy of type I and IIb fibers, which confers the modality of HIIT adaptations for both slow and fast contraction fibers. Our study did not directly evaluate the type of muscle fiber among the participants, also their body composition showed a significant difference in lean mass ($p = 0.003$), which the CF practitioners presented about 10 kg more lean mass.

It is also described in the literature that type II fibers present a greater hypertrophic capacity compared to the type I fibers, which being preferentially affected by intense training such as strength training (Darvishi, Ahmadi, Hierani & Jabari, 2013; Fry, 2004). We argued that possibly the CF practitioners in the present study had higher proportions of type II fibers, which demonstrated by the large difference in lean mass compared to the RT group. Another argument for this hypothesis is the evidence of the lower consumption of O_2 in VT_2 for the CF group, this would be caused by the fact that type II fibers present a lower oxidative capacity compared to type I fibers (Fry, 2004). On the other side, even with this possible of cellular metabolic balance in favor of glycolytic metabolism, we cannot ignore the fact that both groups presented similar VO_{2max} results, which shows positive adaptations of aerobic capacity as well. However, it was expected that the greater proportion of type II fibers reflected in significant improvements to the maximum power in the test, which it is a fact that was not observed in the present study (p= 0.35).

There was also a significant better HRR for the CF group after 1-minute recovery. Ostojic et al. (2010) have tested a hypothesis which athletes engaged in intermittent exercise modalities would present better HRR than athletes engaged in continuous exercise modalities. To this end, forty- six volunteers were recruited, which divided into two groups (Continuous and Intermittent Group), and balanced by age and aerobic capacity. After maximal treadmill testing, volunteers were placed in A supine position and then their HRR was analyzed. As a result, the authors confirmed that individuals engaged in intermittent exercise modalities had better HRR. The HRR is positively influenced by the best sympatho-vagal balance after exercise, and it is a good marker for assessing the level of athlete's endurance training (Lamberts, Swart, Capostagno, Noakes, & Lambert, 2010; Ostojic et al., 2010; Yektayar, Saham, Ahmadi & Khodamoradpoor, 2012). This finding demonstrates that although the CF practitioners, not presenting higher values of VO_{2max} when compared to the RT group, but they presented specific markers related to aerobic performance superior in comparison with RT individuals.
This project has the following limitations, which include:

- The methodology of analysis for the body composition does not allow accurate inference about the composition of muscle fiber types;
- Weekly training volume differences were not analyzed;
- There were no tests to evaluate specific CF training exercises.

Conclusion

Although it was predicted that the modality of the CF presents wide adaptations (ranging from improvements in aerobic capacity to pure manifestations of strength), but CF practitioners in the present study did not present higher values than the RT individuals for the VO_{2max} and maximum power in the incremental test. However, the CF group presented significant differences in more lean mass and better HRR, which does not rule out this training modality, in fact, offer ample cardiorespiratory and neuromuscular adaptations. We recommend that further studies attempt to evaluate the physiological and psychological (Ahmadi, Heirani & Jabari, 2013; Ahmadi, Heyrani & Yoosefy, 2018; Ahmadi, Jabari, Jamali, Moradi & Sadeghi, 2013) adaptations which caused by the CF trainings.

Informed Consent: All participants signed an informed consent form to participate in the study.
Ethical Approval: Current research study was approved by the Research Ethics Committee of the University of Campinas (1.376.230).
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Conflict of Interests: The authors have no conflict of interest to declare.

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