COMPARISON BETWEEN STRENGTH, POWER AND MUSCULAR ENDURANCE IN STRENGTH TRAINING AND CROSSFIT® TRAINED SUBJECTS

Comparação entre força, potência e resistência muscular em praticantes de crossfit e praticantes de musculação

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Abstract: Functional training has gained considerable attention and popularity in recent years, mainly due to the rise of standardized training models such as CrossFit®. This modality advocates that high-intensity, constantly varied functional exercises are effective for the comprehensive development of physical capacities. In contrast, traditional resistance training, such as weightlifting, remains widely used in sports and high-performance contexts. Given the limited comparative research between these approaches, the present study aimed to evaluate and compare them. This is a descriptive, cross-sectional and comparative study with a quantitative approach that assessed anaerobic capacity, strength, muscular endurance, and power. Eight trained individuals (23.5 ± 4.4 years) participated and were divided into two groups: CrossFit (n=4) and Strength Training (n=4), each with a minimum of two years of experience in their respective modality. Results showed significantly faster heart rate recovery in the CrossFit group during the anaerobic cycling test (p=0.002). The Strength Training group demonstrated superior upper limb endurance in the 1-minute push-up test (p=0.01). No significant differences were found between groups in lower limb strength, lower limb power, pull-ups, or maximum heart rate during the cycling test. In conclusion, although specific differences were observed—such as better heart rate recovery in the CrossFit group and greater upper limb endurance in the strength training group—the overall results do not indicate a broad performance superiority of one modality over the other.

Keywords: CrossFit; Weight Training; Resistance Training; Heart Rate; Functional Training

Resumo: O treinamento funcional tem ganhado atenção e popularidade nos últimos anos, principalmente devido ao surgimento de modelos padronizados como o CrossFit®. Essa modalidade defende que exercícios funcionais de alta intensidade e constantemente variados são eficazes para o desenvolvimento global das capacidades físicas. Em contraste, o treinamento resistido tradicional, como a musculação, continua amplamente utilizado em contextos esportivos e de alto rendimento. Diante da escassez de estudos comparativos entre essas abordagens, o presente estudo teve como objetivo avaliá-las e compará-las. Trata-se de um estudo descritivo, transversal e comparativo, com abordagem quantitativa, que avaliou a capacidade anaeróbica, força, resistência muscular e potência. Participaram oito indivíduos treinados (23,5 ± 4,4 anos), divididos em dois grupos: CrossFit (n=4) e Treinamento de Força (n=4), todos com no mínimo dois anos de prática na respectiva modalidade. Os resultados demonstraram recuperação significativamente mais rápida da frequência cardíaca no grupo CrossFit durante o teste anaeróbico em bicicleta (p=0,002). O grupo de Treinamento de Força apresentou maior resistência de membros superiores no teste de flexões de 1 minuto (p=0,01). Não foram encontradas diferenças significativas entre os grupos quanto à força de membros inferiores, potência de membros inferiores, número de repetições em barra fixa ou frequência cardíaca máxima no teste. Conclui-se que, embora tenham sido observadas diferenças específicas — como melhor recuperação da frequência cardíaca no grupo CrossFit e maior resistência de membros superiores no grupo de força —, os resultados gerais não indicam superioridade ampla de uma modalidade sobre a outra.

Palavras-chaves: CrossFit; Treinamento com Pesos; Treinamento Resistido; Frequência Cardíaca; Treinamento Funcional

INTRODUCTION

CrossFit® is a training method characterized by performing varied exercises in constantly increased intensity. This type of training uses olympic lifting exercises, body weight exercises and calisthenics exercises, powerlifting, aerobic exercises and gymnastic movements (TIBANA, et al., 2015). This training model was created by Greg Glassman in 1995, aims to develop broad general conditioning, preparing individuals for any physical contingency needed. The objective of Crossfit® is to develop as much as possible the metabolic pathways and the 10 domains of physical fitness: cardiorespiratory endurance, strength, vigor, power, speed, coordination, flexibility, agility, balance and precision (TRAINING GUIDE LEVEL 1, 2016). It is widespread that this training modality can enhance cardiorespiratory and neuromuscular adaptations (SABINO, 2016). Classically, we have that high intensity modalities and short rest intervals favor the adaptations of power, strength and speed (GARBER, et al., 2011).

CrossFit® practitioners aspire to improve their bodies, mainly benefits include physical conditioning, muscle hypertrophy and body composition (TIBANA, et al., 2016).

On the other hand, strength training appears to be the most used training methods by sport and conditioning professionals. This traditional and practical method consists of performing exercises against external resistance, with free weights and specific exercises for each muscle groups. Strength training serves people interested in obtaining an aesthetic improvement (FRONTERA et al., 1988) and health indicators benefits (POLLOCK et al., 2000). Today, most sports make use of strength training for physical abilities improvement and/or injury prevention/rehabilitation (PINNO & GONZÁLEZ, 2005). According to Leite (2012), strength training is a modality that provides improvement in maximum strength, endurance strength and explosive strength. In fact, strength training has a great history and is highly known and practiced all around the world, in addition to being famous for its results, being a modality extremely studied by science and applied at a professional level in sports training. Sabino, et al., (2016) comments that CrossFit® and strength training promote improvements in similar capabilities such as physical conditioning, hypertrophy, muscle strength and endurance. However, CrossFit® stands out in relation to other physical capacities. According to the author, physical capacities is a set of physiological characteristics that the individual possesses, or achieves, that allow performance of various physical activities. In other words, the two modalities develop some similar benefits, but they differ in their training method. Therefore, the study comparing individuals trained in each modality is interesting.

In this sense the present study aims to compare the neuromuscular and cardiorespiratory capacities between trained individuals in Crossfit® and trained individuals in strength training. We believe that Crossfit® practitioners will present better performance in the investigated variables, since the modality covers a wide spectrum of abilities in their training routines.

MATERIALS AND METHODS

This is a descriptive, cross-sectional and comparative study with a quantitative approach. Eight participants between the 18 and 30 years old were recruited for this project. Participants were recruited through electronic media and visits to institutions and training centers. The volunteers were allocated in one of two groups, CrossFit® (CF n=4), and Resistente Training (RES n=4). The participants included 4 males and 4 females, with ages ranging from 18 to 30 years. All participants were recreationally trained, not involved in competitive events, and had no history of cardiovascular, musculoskeletal, or metabolic diseases. Although body composition measures (e.g., body fat percentage or BMI) were not assessed, all individuals maintained regular training routines in their respective modalities.

Exclusion criteria included: (1) use of anabolic steroids or other ergogenic substances in the past 6 months; (2) recent musculoskeletal injuries; (3) participation in another structured physical training program beyond CrossFit® or Strength Training; and (4) known clinical conditions that could impair physical performance or exercise safety.

As an inclusion criteria, all participants were required to be engaged in physical activity 3 to 6 times a week for at least 2 years in one of the modalities, CF or ST. All participants signed an informed consent. This project followed the ethical principles of the Helsinki Declaration, being approved by the local ethics committee under number 3.709.499.

Volunteers received videos and descriptive texts of how each test would be performed, as well as the rules for executing and validating the exercises. They performed the sessions in the same period of the day to avoid variations in the circadian cycle (DRUST, et al., 2005) and were also instructed not to perform vigorous physical activities and ingest alcoholic beverages or any other drug 48 hours before the tests. They were also instructed not to consume stimulant drinks for at least 6 hours before the sessions and to abstain from meals two hours before the tests.

After warm-up, the evaluation tests were performed in the following order: Air Bike (30seconds), Push-Up, Horizontal jump, Pull-Up and 1 repetition maximum (1RM) squat. Between tests, a 3-minute rest was performed.

All tests were performed using standardized equipment. The anaerobic power test was conducted using a Schwinn® Airdyne AD6 Air Bike, calibrated before each use according to manufacturer instructions. The heart rate was monitored using a Polar® H10 heart rate sensor, synchronized with a mobile application for real-time data collection.

For the strength assessment, the 1RM squat was performed using a free- weight Olympic barbell (20 kg) and calibrated weight plates on a standard squat rack.

Push-up and pull-up tests were executed using a rubberized floor mat and adjustable pull-up bar, respectively. The horizontal jump was measured using a standard metric tape, placed on a flat, non-slip gym floor, with measurements recorded from the starting line to the nearest point of heel contact.

The anaerobic power test was performed in Airbike through a maximum sprint of 30 seconds (30s), where heart rate was collected every 10 seconds during the 30 seconds of test and another 60 seconds of recovery. The amount of calories spent during the test was also recorded. The maximum strength, lower limb power and endurance strength capacities were evaluated, respectively, by the 1 RM squat. Push- Up and Pull-Up (evaluated by the highest number of repetitions without pause) and horizontal jump (evaluated by the maximum distance reached in three attempts).

Data were presented as mean, standard deviation (SD) and confidence interval (95% CI). The data between the CF and RES groups were directly compared using the Student's T test (significance adopted was $p<0.05$), in addition, the Cohen's D - Effect-Size (ES) test (Beker, 2000) was applied. ES was considered small (0.2- 0.5), medium (0.5-0.8) and large (>0.8).

RESULTS

No significant differences were found between age and practice time between the groups (Age p=0.9; Practice time p=0.2). However, the effect size reveals longer training time for RES (ES=1.5).

The analysis of heart rate variation during the anaerobic power test (air bike) and recovery time are shown in Figure 1. No significant differences were found for heart rate in the first 30 seconds of the test for both groups (T test p>0, 76; ES <0.2). For recovery time observed in 60 seconds, we also did not observe any significant difference (T test for all recovery times p>0.05). However, the recovery time of the CF group was faster than ST, when we used ES analysis, for all recovery time points (0.8- 1.1) (Figure 1). In addition, an analysis between heart rate at the end of exercise (30 seconds) and heart rate at the end of recovery (90s) revealed that the CF group showed significant recovery (T test p=0.002), while the RES group did not show significant recovery (T test p=0.54) (Figure 2).

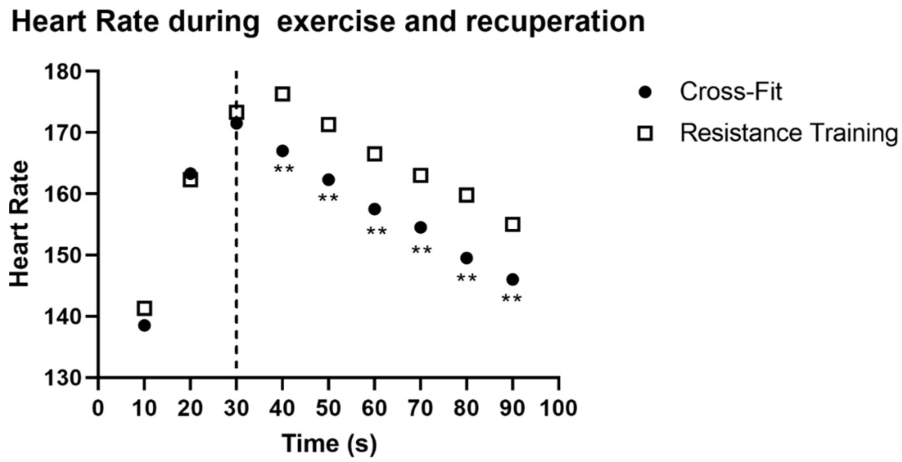

Figure 1. Heart rate during the anaerobic power test evaluated in Airbike. ** Represents a large EF (>0.8) observed between the groups CF and ST. No significant difference was observed between the groups using de T test (p<0,05) for any point.

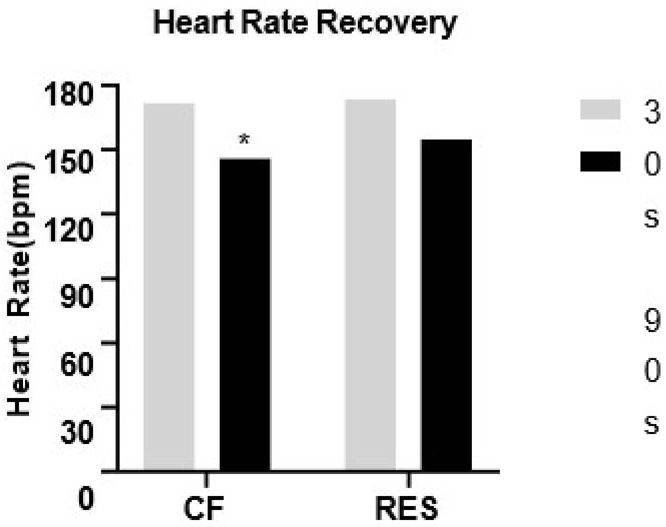

Figure 2. Heart rate recovery between moments 30s (end of anaerobic power test) and 90s (end of recovery time). * Represents a significant difference (T test p<0.05) identified in the Student's T test.

The amount of calories expended in the airbike test did not show a significant difference between the groups (T test p=0.1), but showed a large ES (ES=1.4) showing that the participants in the CF group had higher expenditure energy during the 30- second test.

The pull up strength endurance test did not show a significant difference between the groups (T test p=0.4), however, a large difference effect was found (ES=0.8) demonstrating better performance for the RES group.

Participants also had their strength resistance of the upper limbs analyzed through push-up in which a significant difference was identified between the groups (T test p<0.01). Also demonstrating better performance for the RES group.

The power test for lower limbs was evaluated using a horizontal jump. No significant differences were found between groups (T test p=0.4), with a small ES between them (ES=0.3).

The maximum strength of the lower limb was analyzed through the 1RM test in the free squat exercise. No significant differences were identified between groups (T test p=0.1), however, a large ES was identified between groups (ES=1.2) demonstrating that participants in the CF group performed better in this test.

The results and their percentage differences can be seen in Table 1:

Table 1 – Comparison between the evaluated variables

	CF (Mean±SD) [95% CI]	RES (Mean±SD) [95% CI]	Change %	ES	P Value
Age	24,3 ± 5,3 [15,87 – 32,73]	22,8 ± 3,9 [16,59 – 29,01]	6.2	0.3	0.9
Practice time	2,0 ± 0,0 [2,00 – 2,00]	3,5 ± 1,7 [0,79 – 6,21]	75	1.7	0.2
Airbike Calories (cal)	32,7 ± 9,7[17,27 – 48,13]	22,7 ± 4,3 [15,86 – 29,54]	30.5	1.4	0.1
Pull Up (Repetitions)	11,0 ± 1,2 [9,09 – 12,91]	12,3 ± 2,1 [8,96 – 15,64]	11.4	0.8	0.3
Horizontal Jump (m)	1,91 ± 0,14 [1,69 – 2,13]	1,86 ± 0,11 [1,68 – 2,04]	2.7	0.4	0.3
Push-ups (Repetitions)	30,0 ± 2,4 [22,36 – 37,64]	45,5 ± 3,1 [35,15 – 55,85]	51.7	5.6	0.0002
1RM Free Squat (kg)	65,0 ± 30,0 [96,10 – 233,90]	131,3 ± 27,2 [68,94-193,66]	20.5	1.2	0.7

DISCUSSION

Different from the initial hypothesis, no better results were found for the investigated variables in the CF group. Our main finding in this study is the result of the comparison between the highest heart rate during anaerobic power test (found in a 30sec) and the lowest heart rate during rest (90sec), which revealed significant recovery capacity in the CF group. Recovery heart rate is the rate at which heart rate (HR) decreases, or the time required for HR recovery after exercise, and is dependent on the relationship between the parasympathetic and sympathetic nervous systems (Borresen and Lambert 2008; Ostojic et al. . 2011). The literature has shown that right after the end of a physical exercise, the HR drops quickly and monoexponentially (Pierpont et al, 2000). Thus, the post-exercise HR response depends on the integrated action of several cardiovascular control mechanisms, called the autonomic nervous system, through the integrated sum of reactivation of vagal tone and removal of sympathetic tone (Imai et al., 1994; Perini et al., 1989). Post-exercise heart rate recovery is a widely used tool in clinical and sports practical application (Lima et al., 2011). Even because, a better heart rate recovery between training sessions and sports events predisposes a better sports performance (Borresen & Lambert, 2008; Kiviniemi et al, 2007). The most interesting is the difference in the ability to recover between the two groups, and we can attribute this to the model and training environment between CF and ST.

Ostojic and Calleja-Gonzalez, (2010) and Ostojic et al. (2011) evaluated high performance athletes, dividing them into two groups, according to their aerobic fitness. Thirty female athletes, aged between 20 and 22 years who performed consistent training in the last two years, underwent a maximal exercise on a treadmill with heart rate recording one minute after exercise. The authors observed that athletes with greater aerobic fitness have better HR recovery after maximal exertion. Corroborating this, Smith et al. (2013) and Reis (2014) in their studies, found results that point to a significant difference showing a better cardiorespiratory capacity in individuals practicing CF. In another study, Yamamoto et al., (2001) submitted twelve healthy male students to a cycle ergometer training for 6 weeks (4 days/w) at 80% of VO2max, with the intensity being weekly adjusted according to the increase in VO2max. The authors found improvement in HR recovery after a high-intensity training program. Nagashima et al. (2011) also found better HR recovery in athletes who practice high-intensity sports modalities compared to those who practice less intense sports modalities.

High-intensity training provokes more powerful adaptations on the metabolite removal system associated with the performance of exercise, allowing a chronic improvement in the recovery capacity after physical exercise (LIMA et al., 2011). Also according to Lima et al (2011), the intermittent character of the CF modality, with alternating periods of high intensity and periods of low/medium intensity, or rest result in a better HR recovery.

We also observed a large ES (ES=1.4) in calories expended during the test (CF 32.7±9.7 / RES 22.7±4.3). As the test consisted of pedaling at maximum intensity for 30s, This suggests that the calories expended and the total work production can be correlated with the result in Watts. As performance in Watts is dependent on phosphogenic, glycolytic and partially oxidative metabolism, these data indicate a better energy capacity of CF individuals (ZIEMANN et al, 2011).

According to some authors (Gibala et al. 2012; Nybo et al. 2010; Weston et al. 2014) High Intensity Interval Training (HIIT) results in physiological adaptations such as improvements in aerobic capacity, cardiorespiratory fitness, fatigue endurance, skeletal muscle oxidative capacity, glycogen content and utilization, and reductions in the rate of lactate production. In addition, HIIT sessions cause high levels of metabolic stress, and according to several evidences, result in benefits in aerobic and anaerobic capacity (ZIEMANN et al, 2011; COOK et al, 2010; FALK and KENNEDY, 2019; BELLAR et al. 2015; MURAWSKA-CIALOWICZ et al. 2015; SLOTH et al. 2013;
AGUIAR et al, 2016). Also, according to Ziemann et al (2011), during exercise lasting up to 30 seconds, a substantial amount of energy is derived from anaerobic metabolism. Thus, we attribute to the Air Bike power test a greater dependence on anaerobic energy systems, such capacity is highly improved by the Crossfit® modality, which could explain why this group has better results in this category. However, it is important to remember that the CF group is more familiar with Airbike as it is part of the modality's training. Furthermore, the calories provided on the ergometer do not take into account the weight, HR or any other individual parameter, and that it is obtained from the work performed on the Airbike only.

For the upper limb muscle strength endurance test, we found significant differences between the groups only in the Push-up test (CF 30±2.4 / RES 45.5±3.1) (T test $p<0.01$), although the ES analysis reveals a large difference (0.8) for the pull up (CF 11±1.2 / RES 12.3±2.1), which suggests that this difference may reach significance with a larger sample. CF is often characterized by performing exercises that integrate large muscle groups (LEVEL 1 TRAINING GUIDE, 2016). This work ability means maximizing work as much as you can over a time domain, which is, seeking to work in a submaximal or comfortable zone so that you are still able to continue after a quick recovery. On the other hand, Strength training is generally characterized by work up to concentric muscle failure, which, according to the literature, signals good effects on hypertrophy (LASEVICIUS, T., et al, 2019), we attribute to this fact the advantage of the RES group in terms of performing the maximum number of repetitions to failure.

Regarding the 1RM Squat test, the CF group showed large EF (1.2), but without significance difference compared to the RES group (T test $p = 0.1$). As a hypothesis for greater muscle strength in the lower limbs, we believe that the training structuring had influence, since the CF has its training based on a percentage of the results of 1RM and periodic maximum strength training and olympic weight lifting (TIBANA et al, 2016) and in strength training, the maximum strength test is not a strategy that is so present in training routines.

Contrary to our initial hypothesis, we did not find a significant result or a large EF for the lower limb power test ($p=0.4$ and ES=0.3). We choose the horizontal jump test to to avoid favoring the CF group, which make up vertical jump in their daily training. Perhaps, with a larger sample, the results may be more expressive since the CF includes plyometric and olympic weight lifting training, which has benefits on power performance of the lower limbs (LAMAS, et al, 2008 and DURIGAN et al, 2013).

Among the limitations of this study, we highlight the small sample size and the absence of formal test familiarization, which may have affected performance in tasks requiring motor coordination or technical execution. Additionally, differences in exposure to specific exercises—such as the AirBike in CrossFit® or Push-up in strength training—may have favored performance in familiar movements. Variations in weekly training volume, frequency, and intensity between individuals were not controlled and could also have influenced outcomes. Future studies should standardize familiarization protocols and monitor training loads to minimize these biases.

CONCLUSIONS

Corroborating the findings in the literature, we conclude that the CF, characterized by high intermittent training through extremely varied functional and sporting exercises (gymnastics, calisthenics, running, powerlifting, etc.) presents significantly better HR recovery, compared to the RES group. On the other hand, the RES group obtained significantly better results for muscle endurance tests, probably due the specificity of training and familiarization with concentric failure exercises. Future research should consider larger and more diverse samples, as well as standardized familiarization protocols and monitoring of training loads, to better isolate the specific contributions of each modality. Longitudinal designs may also help clarify the long-term adaptations associated with CrossFit® and traditional resistance training.

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