

Six-months CrossFit training improves metabolic efficiency in young trained men

Seis meses de CrossFit mejora la eficiencia metabólica en jóvenes entrenados

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Abstract

The objective was to analyse the effects of 6 months' CrossFit on physical performance, metabolic efficiency, body composition, and biochemical parameters. Ten trained CrossFit practitioners were assessed before and after CrossFit training. Anthropometric measurements, biochemical parameters and physical performance parameters were assessed with functional and incremental tests. After 6 months of CrossFit, fat oxidation rate and energy percentage obtained from fat significantly increased (+221.43%; $p=.043$ and +222.39%; $p=.043$ respectively) with a concomitant decrease in carbohydrate oxidation rate and use of carbohydrates in maximal values (-47.35%; $p=.043$ and -34.41%; $p=.043$, respectively). In the maximal fat oxidation zone, maximal oxygen uptake increased (+20.3%; $p=.043$). Fat oxidation rate significantly increased with a concomitant decrease in carbohydrate oxidation rate (+62.75% vs -27.67%; $p=.043$). Lactate dehydrogenase values increased significantly (+27.13%; $p=.043$). In conclusion, 6 months of CrossFit improves the metabolic efficiency of the fat oxidation zone, without muscle damage.

Key words: CrossFit, high-intensity, body composition, physical performance, muscle damage.

Resumen

El objetivo del estudio fue examinar los efectos de un período de entrenamiento de 6 meses de CrossFit sobre el rendimiento físico, eficiencia metabólica, composición corporal y parámetros bioquímicos. Diez practicantes habituales de CrossFit fueron evaluados antes y después de 6 meses de entrenamiento. Medidas antropométricas, sanguíneas y parámetros de rendimientos fueron medidos a través de test funcionales y un test incremental. Tras seis meses de CrossFit, el ratio de oxidación y porcentaje de energía de grasa obtenido se incrementó significativamente (+221.43%; $p=.043$ and +222.39%; $p=.043$ respectivamente) en detrimento de los valores de hidratos de carbono en valores máximos (-47.35%; $p=.043$ and -34.41%; $p=.043$ respectivamente). En la zona de máxima oxidación de grasa, el volumen de oxígeno máximo incrementó (+20.3%; $p=.043$). El ratio de oxidación de grasa aumentó significativamente en detrimento del ratio de carbohidratos (+62.75% vs -27.67%; $p=.043$). Los valores de lactato deshidrogenasa incrementaron significativamente (+27.13%; $p=.043$). En conclusión, seis meses de CrossFit mejora la eficiencia metabólica en cuanto al ratio de oxidación de grasa, sin conllevar daños musculares.

Palabras clave: CrossFit, alta intensidad, composición corporal, condición física, daño muscular.

Introduction

In recent years, CrossFit has become recognized as one of the fastest growing training methods. CrossFit could be defined as a training method based on high-intensity functional movements used to optimize physical competence in cardiovascular endurance, strength, flexibility, power, velocity, coordination, agility, balance and accuracy (Claudino et al., 2018). Different studies have examined the effect of short-term interventions on body composition parameters and/or physical performance parameters (Meyer, Morrison, & Zuniga, 2017; Smith, Sommer, Starkoff, & Devor, 2013). In relation to body composition, this training method may be efficient in decreasing fat mass percentage and increasing muscle mass and bone tissue in active participants after 10 to 12 weeks of exercise (Eather, Morgan, & Lubans, 2016; Murawska-Cialowicz, Wojna, & Zuwala-Jagiello, 2015; Smith et al., 2013). However, in terms of exercise performance, results are less conclusive. While improvements in aerobic capacity have been shown after 8 to 12 weeks of training (Eather et al., 2016; Goins, 2014; Heinrich, Patel, O'Neal, & Heinrich, 2014; Murawska-Cialowicz et al., 2015; Smith et al., 2013), only Goins, (2014) obtained significant improvements in anaerobic capacity after 6 weeks of the CrossFit programme.

CrossFit requires a high technical level of maximum effort and incomplete recovery between bouts and sessions. Therefore, it can lead to high levels of fatigue, perceived exertion and overtraining (Bergeron, 2011). However, some studies have demonstrated that functional programmes of high intensity, such as CrossFit, generate a similar or even lower fatigue than other traditional training methods (Poston et al., 2016).

Despite its great popularity and the possible beneficial effects obtained from CrossFit, only a few studies with low methodological quality and short-term interventions have been conducted (Claudino et al., 2018). Thus, the purpose of the present study was to analyse the effects of 6 months' CrossFit training on physical performance, metabolic efficiency, body composition and biochemical parameters in trained men.

Methods

Participants

Ten trained men were recruited from a CrossFit training centre and participated voluntarily in the study. Characteristics of the participants are shown in

Table 1. Characteristics and body composition of participants.

Variable	Mean \pm SD
Age (years)	30.4 \pm 5.37
Body mass (kg)	75.62 \pm 7.58
Height (m)	1.73 \pm 0.06
Body Mass Index-BMI (kg/m ²)	25.22 \pm 2.28
Σ Skinfolds (mm)	50.8 \pm 14.34
Muscle mass (%)	53.21 \pm 1
Bone mass (%)	14.12 \pm 0.85
Fat mass (%)	8.57 \pm 1.39
Fat body mass (kg)	6.54 \pm 1.67
Residual weight (kg)	18.23 \pm 1.83
Lean body mass (kg)	40.21 \pm 3.77
Free-fat weight (kg)	69.08 \pm 6.13
Bone weight (kg)	10.64 \pm 0.72

Table 1. All of them fulfilled the following inclusion criteria: not having any cardiovascular, metabolic or neurological diseases; not having suffered an injury in the last 3 months; having at least 1 year of experience in CrossFit training; and training at least 2 days per week. It was also required that participants did not perform any type of strenuous physical exercise, did not ingest any type of stimulating substance or alcohol in the 48 hours prior to the session, and maintained their habitual lifestyle and normal dietary intake during the study. Before the study, all participants were informed about the protocol and potential risks, and they signed a written informed consent. This study was developed following the amendments of the Declaration of Helsinki and was conducted following approval from the Committee of Biomedical Ethics of the University of Extremadura.

Exercise sessions

All participants performed 26 weeks of CrossFit training, which included 10 weeks of general training (aerobic endurance and strength based on general weightlifting exercise and long circuits), 10 weeks of specific training (strength based on specific weightlifting exercise and short circuits), and 6 weeks of competitive training in which the objective was to achieve transfer through combined exercise. Training sessions of 90 to 120 minutes were performed on Monday, Tuesday, Wednesday, Thursday and Saturday.

Measurements

The measurements were always made by the same researcher at the same time of the day and in similar

conditions of temperature and humidity (20–23 °C and 40–45%, respectively). Anthropometric measurements, biochemical parameters and physical performance parameters were assessed with functional and incremental tests.

Anthropometric measurements

Body mass and height were measured using a portable stadiometer (Seca 213, Germany), and body mass index (BMI) was calculated from the ratio of weight/height² (kg/m²). Subcutaneous fat skinfolds (triceps, subscapular, abdomen, suprailiac, thigh and leg) were measured on the right side of the body using a skinfold caliper (Harpندن, West Sussex, UK) following the recommendations of the International Society for Advancement in Kinanthropometry (ISAK).

Physical performance parameters

Countermovement jump (CMJ) and plank test were performed pre- and post-exercise after training. Firstly, the CMJ was performed on a portable contact platform (Chronojump; Boscosystem, Spain), on which jump height data were instantaneously recorded by the free software distributed by the manufacturer (Chronojump V1.8.0, Boscosystem, Spain). Participants performed two maximal CMJs with 30 seconds of rest in between, and the average jump height was recorded. Participants began in a stationary and upright position. On command, the participant flexed their knees and jumped as high as possible while maintaining the hands on the waist, and landed with both feet. Secondly, the plank test was performed to evaluate the endurance of the core stabilizing muscles. Participants started with the upper body supported off the ground by the elbows and forearms, and the legs were straight with the weight taken by the toes. The hip was lifted off the floor creating a straight line from head to toe. The test was over when the individual was not able to hold the back straight and the hip was lowered. The score was the total time completed.

After a 5-min warm-up at 50 watts (w) and 1 min of rest, the maximal ramp incremental test with a gas analyser (Metalyzer® EB Cortex, Leipzig, Germany) and data collection were initiated. Participants started cycling at 75 w, and the work rate was increased by 25 w every 2 min until exhaustion in a cyclo ergometer (Ergoselect 100, Ergoline, Baden-Württemberg, Germany). Heart rate (HR) was recorded continuously during the test using a heart rate monitor (Polar H7 HR, Polar Electro Oy, Kempele, Finland). VO₂ was considered maximal when at least three of the following

four criteria were met: 1) a plateauing of VO₂ (defined as an increase of no more than 2 mL·kg⁻¹·min⁻¹ with an increase in workload) during the later stages of the exercise test; 2) a HR < 90% of the predicted maximum for their age (220 – age); 3) a RER > 1.1; and 4) an inability to maintain the minimal required pedalling frequency (i.e. 60 rpm) despite maximum effort and verbal encouragement. The figures for VO₂max, peak power and maximal heart rate (HRmax) were obtained. VO₂max was calculated as the average oxygen uptake over the last 60 s of the test. Peak power was defined as the maximal power achieved in the last 3 min step completed during the incremental test. Aside from carbohydrates (CHs), oxidation rate CH through (4.55*VCO₂) – (3.21*VO₂), and fat oxidation rate through (1.67*VO₂) – (1.67*VCO₂) were measured. The highest fat oxidation rate value was determined as maximal oxidation fat zone (FATmax). The percentage of hydrocarbons (HC) and fat were calculated.

Biochemical parameters

Blood samples were taken pre- and post-exercise training programme. Participants attended the research laboratory after a minimum of 8 hours overnight fasting for measurements. Participants could have breakfast after the blood draw, at least 2 hours before the beginning of the other tests. Blood samples were taken from the antecubital vein (5 ml) by one experienced nurse and included the determination of blood urea nitrogen (BUN), total bilirubin (TBIL), glutamic-oxaloacetic transaminase (GOT), glutamic-pyruvic transaminase (GPT), lactate dehydrogenase (LDH), creatine phosphokinase (CPK), glucose (GLU), triglycerides (TG), and total cholesterol (COL). One hundred uL of whole blood was collected in heparinised microwells and centrifuged for 5 min at 6,000 rpm (MC6 Centrifuge, Sarstedt, Nümbrecht, Germany). The analysis of samples was performed with an automatic dry-chemistry analyser system (Spotchem EZ SP-4430; Arkray, Inc. Kyoto, Japan). The calibration was checked daily, according to the manufacturer's recommendation, through indicated reagent cards.

In the same testing sessions, 2.5 mL were taken for an immediate haematocrit (Hct) and haemoglobin concentration ([Hb]) assessment. To assess Hct, 100 uL of whole blood was collected in a heparinised glass capillary tube (Brand GMBH + CO KG, Wertheim, Germany) and centrifuged during 5 min at 13,000 rpm (ZipoCrit, Lw Scientific, Gerogia, USA). Upon completion, the sample was removed and assessed using a Hawksley haematocrit reader for the determination

Table 2. Effects of Crossfit training programme on body composition.

	Pre	Post	Δ (%)	p value	d Cohen
Body mass (kg)	75.62 ± 7.58	75.68 ± 7.69	+ 0.08	.892	.01
BMI (kg/m ²)	25.22 ± 2.28	25.25 ± 2.43	+ 0.12	.893	.01
Skinfolds					
Abdominal (mm)	10 ± 4.65	9.8 ± 4.34	- 2	.786	.04
Suprailiac (mm)	6.3 ± 2.11	5.8 ± 1.89	- 7.94	.357	.25
Subscapular (mm)	8.5 ± 1.41	8 ± 1.73	- 5.88	.131	.32
Triceps (mm)	6.9 ± 2.27	7.4 ± 2.58	+ 7.25	.414	.21
Thigh (mm)	10.7 ± 3.51	11.6 ± 3.8	+ 8.41	.223	.25
Leg (mm)	8.4 ± 2.68	9 ± 3.67	+ 7.14	.581	.19
Σ Skinfolds (mm)	50.8 ± 14.34	51.6 ± 16.72	+ 1.57	1.000	.05

BMI: body mass index.

of cellular volume and plasma volume. Data were expressed as a percentage of cells to total volume. Hb was assessed with a photometry device (Hemocue 201, Angholm, Sweden). This photometry device is factory-calibrated and should not be recalibrated. The calibration was checked daily according to the manufacturer's recommendation. The calibration was stable during our study period. The reproducibility was evaluated by measuring the Hb level 10 times from a single blood sample and determining the coefficient of variation (CV = 0.73%).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 23 (IBM Corp., Armonk, New York, USA). The Kolmogorov–Smirnov test was applied to verify a normal distribution of the data, and Levene's test was used to assess the homogeneity of variance. An ANOVA with repeated measures was conducted to analyse differences over time. The significance level was set at $p \leq .05$ with a confidence level of 95%. Means and standard deviations (SD) were used as descriptive statistics. The effect size (ES) was calculated for all variables between pre- and post-testing (Cohen, 1988). The magnitude of the difference was considered small (0.2), moderate (0.5), or large (0.8) ES.

Results

The effects of the training programme on body compositions are shown in Table 2. No differences were found in any of the evaluated variables.

Table 3 shows the results obtained in physical performance and metabolic efficiency. After 6 months of CrossFit, the fat oxidation rate increased significantly (+221.43%; $p < .043$) with a concomitant decrease of

CH oxidation rate (-47.35%) with a large ES. Percentage of energy obtained from fat increased with a concomitant decrease of HC ($p < .043$) with a large ES, contributing HC in $56.8 \pm 12.89\%$ vs. $43.2 \pm 12.89\%$ from fat after training. Related to FATmax, the percentage of VO_2max increased to $48.6 \pm 12.1\%$ with a large ES (20.3% compared with baseline; $p < .043$). Also, the fat oxidation rate increased significantly (+88%; $p < .034$) with a concomitant decrease of HC oxidation rate (-12%) with a large ES. The percentage of energy from both substrates was equivalent, contributing HC in $50.2 \pm 8.22\%$ vs $49.8 \pm 8.22\%$ from fat after training ($p < .043$). Regarding HR and power, we did not find a significant difference.

Table 4 shows the effect of training on biochemical parameters. LDH values (+27.13%; $p = 0.043$) increased significantly with a large ES after 6 months of training.

Discussion

The purpose of the present study was to analyse the effects of a 6-month CrossFit training on physical performance, metabolic efficiency, body composition and biochemical parameters in trained men. The results of the present study show that this training method could be effective in improving the metabolic efficiency in the FATmax zone without additional effects on body composition or functional performance in trained adults. Also, 6 months of training affected muscle damage markers without kidney or hepatic damage.

After 6 months of CrossFit training, the participants showed more efficiency in producing energy. Traditionally, high-intensity training has been shown to have fewer effective methods for improving muscle oxidative capacity than endurance training (Kubukeli, Noakes, & Dennis, 2002). However, in the present

Table 3. Effects of Crossfit training programme on physical performance.

	Pre	Post	Δ (%)	p value	d Cohen
Physical performance					
CMJ (cm)	41.36 ± 7.78	41.34 ± 7.24	- 0.05	.960	.003
Plank (s)	162.4 ± 52.8	163.6 ± 50.03	0.74	.738	.002
Incremental test- maximal values					
HR maximal (rpm)	191.4 ± 3.58	191.6 ± 3.36	+ 0.10	.828	.006
Power maximal (watts)	255 ± 48.09	235 ± 33.54	- 7.84	.102	.49
VO2 maximal (ml/kg/min)	47.8 ± 3.63	47.6 ± 4.83	- 0.42	.866	.05
HC oxidation rate (g/min)	2.26 ± 0.72	1.19 ± 0.61	-47.35	.043	1.61
Fat oxidation rate (g/min)	0.14 ± 0.17	0.45 ± 0.11	+221.43	.043	2.21
% energy from HC	86.6 ± 15.55	56.8 ± 12.89	- 34.41	.043	2.09
% energy from Fat	13.4 ± 15.54	43.2 ± 12.89	+222.39	.043	2.09
Incremental test- FATmax					
HR maximal (rpm)	100 ± 9.88	114 ± 22.48	+ 13.89	.068	0.86
Power maximal (watts)	85 ± 22.36	110 ± 41.83	+ 29.41	.102	0.78
VO2 maximal (ml/kg/min)	40.4 ± 6.73	48.6 ± 12.1	+ 20.3	.043	0.87
HC oxidation rate (g/min)	1.26 ± 0.30	1.11 ± 0.47	-11.9	.345	0.39
Fat oxidation rate (g/min)	0.25 ± 0.13	0.47 ± 0.10	+88	.043	1.91
% energy from HC	69.4 ± 13.35	50.2 ± 8.22	-27.67	.043	1.78
% energy from Fat	30.6 ± 13.35	49.8 ± 8.22	+62.75	.043	1.78

HR: heart rate; VO2 maximal: maximal oxygen uptake; HC: hydrocarbons.

Table 4. Effects of Crossfit training programme on biochemical parameters.

	Pre	Post	Δ (%)	p value	d Cohen
BUN (mg/dl)	21.8 ± 4.97	18 ± 4.47	- 17.43	.080	.80
TBIL (mg/dl)	0.56 ± 0.17	0.64 ± 0.17	+ 14.29	.285	.47
GOT (IU/L)	31.8 ± 6.72	35.2 ± 16.05	+ 10.69	.715	.30
GPT (IU/L)	31.2 ± 9.04	37.2 ± 20.36	+ 19.23	.686	.41
LDH (IU/L)	262.4 ± 27.54	333.6 ± 47.69	+ 27.13	.043	1.89
CPK (IU/L)	478 ± 180.87	574.8 ± 555.74	+ 20.25	.893	0.26
GLU (mg/dl)	95.4 ± 12.05	108 ± 11.47	+ 13.21	.080	1.07
TG (mg/dl)	54.6 ± 19.88	76.4 ± 39.13	+ 39.93	.136	.74
COL (mg/dl)	174.6 ± 39.64	188.6 ± 33.32	+ 8.02	.100	.38
HB (g/dl)	14.9 ± 1.54	15.2 ± 0.58	+ 2.01	.500	.28
HTC (%)	44.7 ± 4.63	45.06 ± 1.58	+ 0.81	.500	.12

BUN: blood urea nitrogen; TBIL: total bilirubin, GOT: glutamic-oxaloacetic transaminase; GTP: glutamic-pyruvic transaminase; LDG: lactate dehydrogenase; CPK: creatine phosphokinase; GLU: glucose; TG: triglycerides; COL: total-cholesterol.

study, the participants obtained more energy from fat than at the beginning of the programme. Also, it was produced with a high intensity of exercise, similar to the intensity found in a previous study (Van Loon, Greenhaff, Constantin-Teodosiu, Saris, & Wagenmakers, 2001). Thus, the high-intensity interval training could be a time-efficient method to achieve metabolic adaptations (Gibala et al., 2006; Rodas, Ventura, Cadefau, Cussó, & Parra, 2000). Despite increasing fat oxidation, 6 months' CrossFit training did not produce changes in body composition parameters. These

results confirm those obtained in previous studies (Murawska-Cialowicz et al., 2015), which did not produce significant changes in body composition of males. Conversely, other studies obtained significant improvements in body mass and BMI after a CrossFit programme of 6–10 weeks (Goins, 2014; Smith et al., 2013). It is claimed that the number and duration of training sessions per week have the biggest influence on body mass reduction and changes in body composition (Murawska-Cialowicz et al., 2015). In this sense, a frequency of 3 to 5 days per week may maintain body

mass and body composition parameters (Myers et al., 2002). On the other hand, even when the exercise is a useful tool for maintaining body mass, diet plays a key role in improving these parameters (Bouchard, Bray, & Hubbard, 1990). Finally, comparing our results with the results of previous studies, initial level can play a vital part in changes after the CrossFit programme. Due to the participants being trained participants, the capacity to improve these parameters could be lower than the capacity in untrained participants (Bouchard, Depres, & Tremblay, 1993). A previous study during two sessions of CrossFit with trained participants showed that the level of experience was a determining factor in achieving improvements (Bellar, Hatchett, Judge, Breaux, & Marcus, 2015).

Although this study did not result in a significant change in body composition as noted by other previous studies (Goins, 2014; Smith et al., 2013), all studies resulted in an increase in VO_2 max when assessed with direct measurement of oxygen uptake to assess aerobic capacity. Smith et al., (2013) reported an increase after a 10-week programme, and Goins, (2014) reported improvements after just 6 weeks, whereas results for this study were noted after 12 weeks. This is important because international sports associations encourage the participation in vigorous-intensity activity, and claim that the same benefits can be seen in a shorter amount of vigorous-intensity activity when compared to longer duration moderate-intensity activity (Garber et al., 2011).

LDH analysis has been established as a key indicator of muscle damage (Jastrzebski, 2006). In the present study, the global analysis of biochemical data before CrossFit training already showed muscle fatigue (LDH baseline: 262.4 ± 27.54 IU/L vs normal basal values of

160 IU/L; CPK baseline: 478 ± 180.87 IU/L vs normal basal values of 170 IU/L). On the other hand, LDH increased significantly after CrossFit training. Normally, LDH and CPK tend to increase after training in which changes in aerobic-anaerobic metabolic parameters were produced (Hubner-Wozniak et al., 1995; Lutowska, Sendeki, Wojcieszak, & Pośnik, 1988). During the training programme, the participants performed high-intensity sessions with a high frequency of training (5 days per week), and LDH and CPK values increased. These results were found in a previous study (Hak, Hodzovic, & Hickey, 2013) in which the most frequent injuries in CrossFit were evaluated. This study found only muscle injuries with a similar rate compared to other sports (Hak et al., 2013; Meyer et al., 2017).

Some limitations should be pointed out. Firstly, due to the study sample being small, it is difficult to generalize the obtained results. However, few studies have analysed the long-term effects of CrossFit training. Performance tests are not specific to CrossFit training, and this could influence the results. Finally, due to diet being a limiting factor in achieving changes in body composition, controlling for diet during the training protocol could improve the understanding of the results obtained in the present study.

Conclusion

In conclusion, 6 months of CrossFit training improved metabolic efficiency in the fat oxidation zone without effects on body composition or physical performance. This training method could generate muscle damage.

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