

# Physiological responses after two different CrossFit workouts

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**ABSTRACT:** The present study aimed to investigate the physiological response to CrossFit “workouts of the day” (WODs) based on two different structures of training session: 1) the “as many repetitions as possible” (AMRAP) “Cindy” and 2) the “round for time” (RFT) “Open 18.4” session. CrossFit athletes (11 men and 12 women) were divided into two groups: 1) one performing the WOD “Cindy” (GC) and 2) one performing the WOD “Open 18.4” (GO). Before, immediately after and 30 min after WODs, blood lactate (LAC), heart rate (HR) and systolic and diastolic blood pressures (SBP and DBP) were measured. A two-way ANOVA indicated differences in physiological responses between GC and GO. Both WODs increased HR to similar levels. Only GO significantly increased SBP immediately after exercise compared to the rest period ( $p < 0.01$ ), with no difference to GC. GO presented higher levels of LAC immediately after exercise compared to GC ( $15.8 \pm 4.9$  mM [GO] vs  $9.3 \pm 2.3$  mM [GC];  $p < 0.01$ ). LAC remained different between the groups 30 min after exercise ( $7.0 \pm 3.9$  mM [GO] vs  $3.9 \pm 0.9$  mM [GC];  $p < 0.01$ ). The results suggest that the studied WODs do not differ in acute cardiovascular responses, but depend on different metabolic demands, with RFT structure relying more on glycolytic metabolism (indicated by greater LAC levels after exercise in GO). Such results are in agreement independent of gender.

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## INTRODUCTION

CrossFit is a new sport modality, based on high-intensity circuit training which has gained great attention around the world for promoting significant adaptations to body composition and physical fitness for both men and women [1, 2]. Due to its increasing popularity, recent studies have aimed to investigate the physiological adaptations to CrossFit training in cardiovascular, respiratory and muscle systems [3–5]. The training sessions (also known as “Workout of the Day”, or WOD) consist of circuit training based on three types of exercises: 1) Gymnastics (exercises with one’s own body [pull-ups, push-ups, burpees, etc.]); 2) Metabolic (cardiovascular exercises [running, jumping, rowing, etc.]); and 3) Weightlifting (Olympic lifts, squats, deadlifts, etc.) [6]. Thus, CrossFit sessions can vary widely by mixing different types of exercises with distinct movement patterns.

In addition to the great variety of exercises that compose the WODs, manipulation of effort/rest ratio can significantly alter the “structure” of the training session, and thus affect differently the metabolic behaviour and physiological responses to exercise [5, 7]. Two structures of training are commonly used during CrossFit WODs: 1) the maximum repetition of series (or rounds) within a fixed time, also known as “as many repetitions as possible” (AMRAP); and 2) an “all-out” session with a fixed number of rounds performed in the shortest time possible within a time cap, also known as “round for time” (RFT) [8].

Both AMRAP and RFT may be considered highly metabolically demanding. However, it is possible that efforts with a fixed duration (AMRAP) induce involuntary intensity control so the athlete endures the effort demand until its completion. Thus, it is plausible that metabolic profile of AMRAP and RFT differ and, consequently, promotes distinct acute physiological responses to exercise, with greater anaerobic demand during efforts with higher intensity and lower volume.

Despite the required high-energy demands on both AMRAP and RFT structures, little is known about their specific impacts on metabolic and cardiovascular responses. Only a few studies have investigated the effect of different CrossFit WODs over physiological variables such as  $\dot{V}O_2$ , blood lactate concentration, rate of perceived exertion, and heart rate [4, 5, 7, 9, 10]. Additionally, information on blood pressure responses to WODs is scarce [11], and further investigation is necessary in this regard. Understanding the physiological responses to different structures of CrossFit WODs can help sports practitioners to improve training prescription and, therefore, its outcomes. A better comprehension of the impact of CrossFit training load is lacking in current literature and may reduce injury risk and optimize athletic performance [1]. Furthermore, considering the increasing popularity of CrossFit for both male and female practitioners, it is important to investigate whether physiological responses

to CrossFit WODs are influenced by gender differences, which could help to improve the sports comprehension and training prescription.

Thus, the present study aimed to investigate the effect of WODs with different structures (AMRAP vs RFT) on physiological responses of blood lactate concentration (LAC), heart rate (HR) and systolic and diastolic blood pressure (SBP and DBP, respectively) in young adult CrossFit practitioners.

## MATERIALS AND METHODS

### Subjects

Twenty-three volunteers participated in the present study (11 men and 12 women;  $25.9 \pm 3.6$  years). All participants had at least six months of experience in CrossFit. The participants were informed of the risks and benefits of participating in the research, and the study was performed in accordance with the Declaration of Helsinki and approved by the Institutional Research Ethics Committee of Human Research of the Federal University of Paraíba (protocol number: 2.580.619). Each participant signed an informed consent form prior to the tests.

### Experimental Design

During the study, volunteers were instructed to avoid high-intensity exercise, caffeine or alcohol ingestion during the 24 h preceding the experimental procedures. All procedures were performed at a CrossFit training centre. After anthropometric measures, subjects remained seated for ten minutes so their resting heart rate (HR), diastolic and systolic blood pressures (DBP and SBP) and blood lactate concentration (LAC) were measured. Thereafter, volunteers were randomly divided into two groups: one performed the AMRAP "Cindy" CrossFit session (GC;  $N = 11$ ) and the other the RFT competitive session "Open 18.4" (GO;  $N = 12$ ). Measures of HR, DBP, SBP and LAC were taken immediately after and 30 minutes after each exercise session. Table 1 shows the anthropometric measures between groups.

### Workout of the Day (WOD)

The Cindy session consisted of an AMRAP (as many repetitions as possible) sequence of 5 pull-ups, 10 push-ups and 15 air squats, which were continuously repeated for 20 minutes [7].

The Open 18.4 consisted of two parts: the first part was a WOD called "Diane": with a running clock, as fast as possible perform 21 deadlifts (102 kg for men, 70 kg for women) and 21 handstand push-ups, then 15 deadlifts (102 kg for men, 70 kg for women) and 15 handstand push-ups, then 9 deadlifts (102 kg for men, 70 kg for women) and 9 handstand push-ups. The second part was composed of 21 deadlifts (142 kg for men, 93 kg for women) and 15.24 m handstand walk, then 15 deadlifts (142 kg for men, 93 kg for women) and 15.24 m handstand walk and then ending with 9 deadlifts (142 kg for men, 93 kg for women) and 15.24 m handstand walk. The total number of repetitions should be completed within the 9-minute time cap.

Total number of repetitions achieved during Cindy and Open 18.4 was recorded for further comparison.

### Heart Rate and Blood Pressure

Diastolic and systolic blood pressure were measured by the auscultatory method with a previously calibrated sphygmomanometer and according to the American Heart Association guidelines [12]. Heart rate was measured using a chest strap electrical sensor connected to a digital watch (Polar Electro, S810, Kempele, Finland).

### Blood Lactate Determination

After local asepsis, a 25  $\mu$ L blood sample was collected from the ear lobe with a previously calibrated and heparinized capillary tube. The blood was transferred to a 1.5 mL capacity microtube containing 400  $\mu$ L of trichloroacetic acid (4%) and immediately stored at a temperature between 2°C and 8°C. After centrifugation at 3000 rpm for 3 min, 100  $\mu$ L of supernatant was homogenized with 500  $\mu$ L of reagent based on hydrazine hydrate (88%; pH 8.85), ethylenediaminetetraacetic acid (EDTA), glycine,  $\beta$ -nicotinamide adenine dinucleotide (NAD), and lactate dehydrogenase (LDH). Analysis was carried out on a spectrophotometer at 340 nm against a calibration curve [13].

### Analysis

Data are presented as mean  $\pm$  standard deviation. After confirming normality and homogeneity of data respectively by Shapiro-Wilk and Levene tests, a parametric approach was used. For mean comparison of total repetition performed by men and women from GC or GO, an independent sample Student t-test was performed. A factorial ANOVA was used to indicate mean differences of the dependent variables (HR, DBP, SBP and LAC) for the different independent variables (groups: GO vs GC; and time: rest vs immediately after and 30 min after exercise). When necessary, the differences among variables were indicated by the Newman-Keuls post hoc test. Effect size was measured using partial eta squared ( $\eta^2$ ). The significance level was set to 5% ( $p < 0.05$ ).

**TABLE 1.** Anthropometric measures (mean  $\pm$  DP) of individuals separated by group.

Anthropometry	GC	GO
Age (years)	$27.2 \pm 3.6$	$25.4 \pm 2.9$
Weight (kg)	$71.1 \pm 16.3$	$79.0 \pm 17.4$
Height (cm)	$167 \pm 8.0$	$170.9 \pm 7.4$
BMI (kg/m <sup>2</sup> )	$25.2 \pm 3.9$	$26.9 \pm 4.7$

## RESULTS

There were no differences in the number of repetitions achieved during GO (GO: men =  $62.2 \pm 35.8$  and women =  $71.2 \pm 57.7$ ;  $p = 0.32$ ) or GC between men and women (GC: men =  $497.5 \pm 133.4$

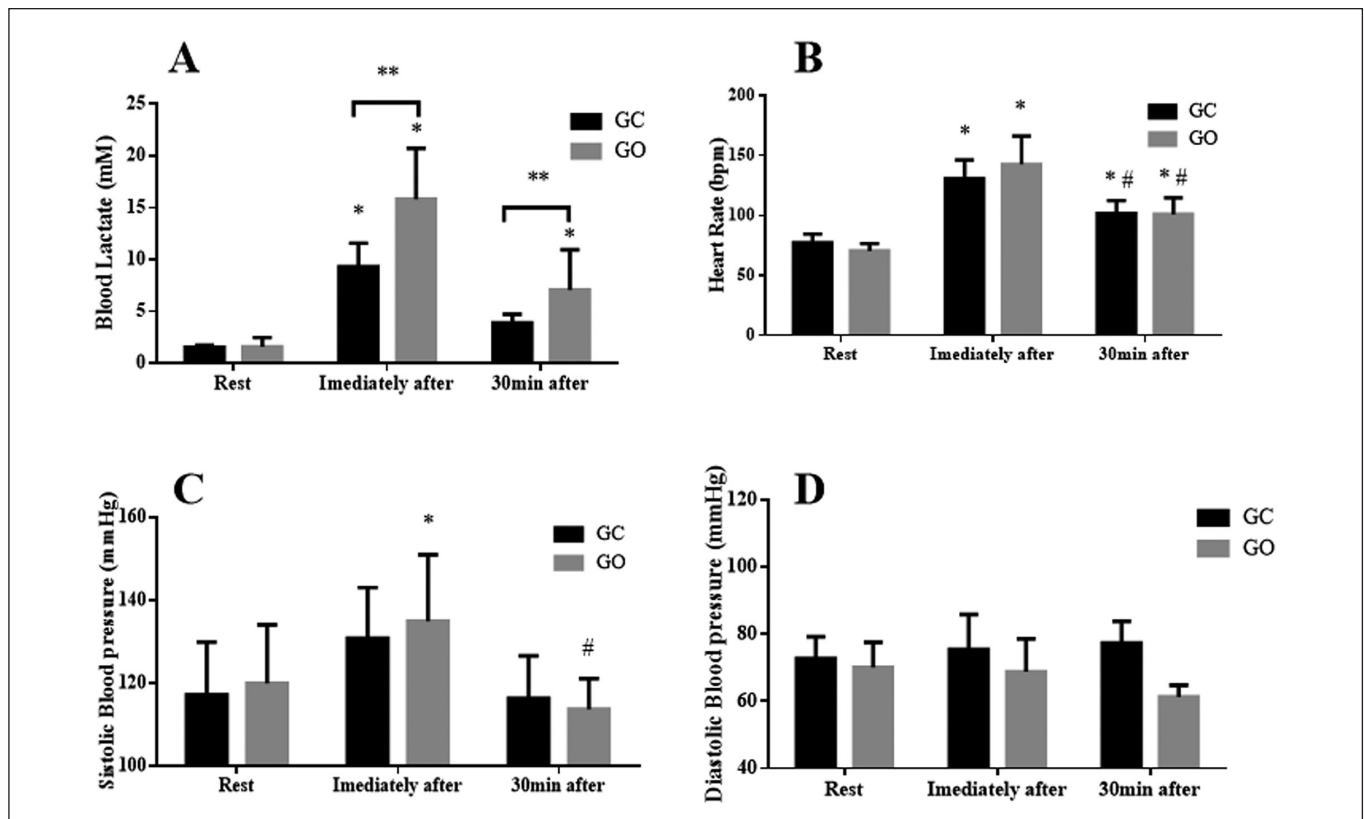
and women =  $472.3 \pm 51.3$ ;  $p = 0.06$ ). Physiological responses of HR, SBP, DBP and LAC for individuals of both genders are illustrated in Figure 1. In summary, a significant increase of SBP was observed immediately after WOD for GO ( $p = 0.00$ ;  $\eta^2 = 0.30$ ) but not for GC, with no significant changes in DBP for both groups. A significant increase in HR for both groups was observed immediately after WOD compared to the rest period, and despite a significant decrease 30 minutes after WOD, HR was still significantly higher than the rest period for both groups ( $p = 0.00$ ;  $\eta^2 = 0.80$ ). Blood lactate increased immediately after WOD for both groups ( $p = 0.00$ ;  $\eta^2 = 0.74$ ), with significantly greater values for GO ( $0.00$ ;  $\eta^2 = 0.27$ ). Thirty minutes after WOD, GO LAC remained greater than the rest period and GC.

Comparisons of the physiological responses of HR, SBP, DBP and LAC separated by gender are illustrated in Figure 2 (men) and 3 (women). Blood lactate response to exercise followed similar behaviour when separated by gender, with a significant increase in LAC immediately after exercise, and a significant decrease 30 min after exercise for both groups ( $p = 0.00$ ;  $\eta^2 = 0.84$ ). Significantly greater levels of LAC for GO compared to GC immediately after exercise were observed ( $p = 0.01$ ;  $\eta^2 = 0.243$  for men and  $p = 0.000$ ;  $\eta^2 = 0.31$  for women) (Fig. 2A and 3A) and remained higher in

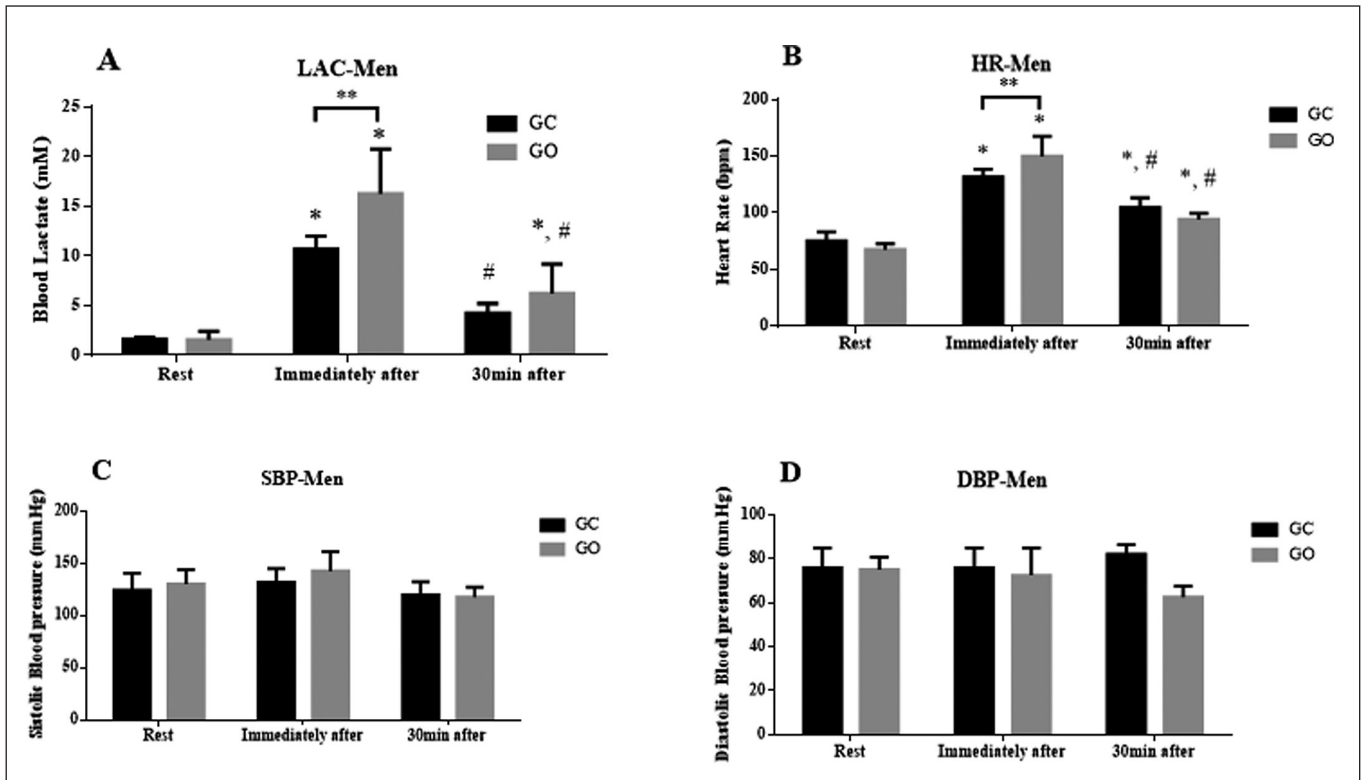
women 30 minutes after exercise ( $p = 0.03$ ;  $\eta^2 = 0.31$ ). Heart rate also presented similar behaviour in both genders, with an increase immediately after exercise compared to the rest period and 30 min after exercise ( $p = 0.00$ ;  $\eta^2 = 0.99$  for men and  $p = 0.00$ ;  $\eta^2 = 0.67$  for women) (Fig. 2B and 3B). However, men's HR of GO presented higher values compared to GC immediately after exercise ( $p = 0.01$ ;  $\eta^2 = 0.00$ ) (Fig. 2B). When divided by genders, only women showed a significant increase in SBP in both WODs immediately after exercise compared to the rest period and 30 min after exercise ( $p = 0.00$ ;  $\eta^2 = 0.57$ ) (Fig. 3C).

**DISCUSSION**

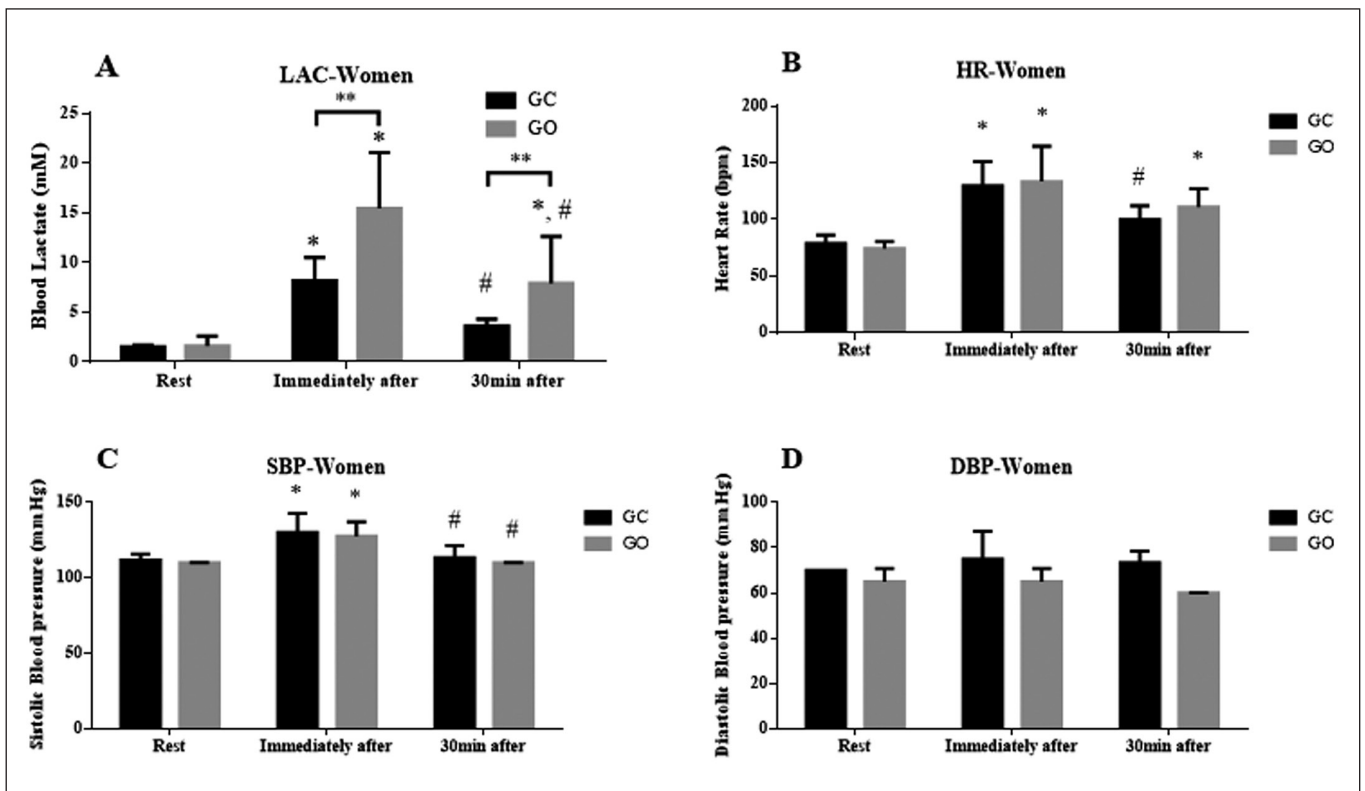
The present study aimed to evaluate physiological response in two different CrossFit WODs: one based on a 20 min max repetition series of three exercises ("Cindy") and the other consisting of an "all-out" session of 12 series within a 9 min cap. Despite significant alterations in HR and a few variations in SBP at different moments, the results suggest that the studied models of WOD do not differ in cardiovascular responses but promote different metabolic demands. These statements are supported by the responses in HR, blood pressure and LAC after the exercise session.



**FIG. 1.** Physiological responses of blood lactate (A), heart rate (B), systolic blood pressure (C) and diastolic blood pressure (D) at rest, immediately after and 30 min after exercise for all participants of both groups. \*  $p < 0.05$  vs rest of the same group; \*\*  $p < 0.05$  between groups at the same time; #  $p < 0.05$  vs immediately after exercise for the same group.



**FIG. 2.** Physiological responses of blood lactate (A), heart rate (B), systolic blood pressure (C) and diastolic blood pressure (D) at rest, immediately after and 30 min after exercise for men of both groups. \*  $p < 0.05$  vs rest of the same group; \*\*  $p < 0.05$  between groups at the same time; #  $p < 0.05$  vs immediately after exercise for the same group.



**FIG. 3.** Physiological responses of blood lactate (A), heart rate (B), systolic blood pressure (C) and diastolic blood pressure (D) at rest, immediately after and 30 min after exercise for women of both groups. \*  $p < 0.05$  vs rest of the same group; \*\*  $p < 0.05$  between groups at the same time; #  $p < 0.05$  vs immediately after exercise for the same group.

### Cardiovascular Responses

Despite the differences of structure in WODs of GC and GO, we observed similar HR responses in both WOD models for all participants (Figure 1B). Previous studies compared the WOD “Cindy” to other training models such as high-intensity interval training (HIIT) [5, 9], treadmill [14], power cleans [5] and the WOD “Fran” (similar to the Open 18.4) [15]. When compared to treadmill, HIIT and power cleans, “Cindy” promotes greater increase in HR [5, 9, 14]. However, when compared to WOD “Fran” (which has similar structure and duration to Open 18.4), HR elevates at similar levels [10, 15]. Increase in HR is associated with reduction of parasympathetic and increase of sympathetic autonomic stimulus, which during exercise is caused by proprioceptors (movement), baroreceptor reflex (carotid dilatation) and chemoreceptors (low  $pO_2$ , high  $pCO_2$  and  $H^+$  in bloodstream) [16]. Thus, HR increase during exercise depends on the time expended in movement, the muscle mass involved in exercise and the intensity of effort. In the present study, GC performed an effort for more than twice the time of GO (20 min vs maximum 9 min); however, the all-out session performed during GO may have induced higher intensity efforts, leading to greater anaerobic metabolism utilization and increased blood acidosis, which compensated the differences in duration and led to similar increases in HR. This hypothesis is supported by the greater increase in LAC for GO compared to GC.

Systolic blood pressure of all participants significantly increased in GO immediately after WOD compared to the rest period, but no differences were found in GC at any time (Figure 1C). These results can be explained by the differences in duration and intensity between WODs, with GO performing exercises of weightlifting, which denotes higher external intensity, and similarly to resistance exercises, a higher level of SBP [17]. No changes were observed for DBP (Figure 1D). To date, only one study has investigated the effect of a CrossFit bout on blood pressure [11]. In this study, individuals performed a “Triplet” (3 burpees, four push-ups and five squats), and despite the increase in HR, SBP and DBP did not change significantly after the “Triplet”. In the present study, SBP presented similar values to the study with “Triplets” ( $135 \pm 16$  for GO,  $131 \pm 12$  for GC and  $129 \pm 27$  for “Triplets”), which could indicate that exercise was performed at “moderate intensity” [11]. However, blood lactate in the present study showed two or three times the values observed after “Triplets” ( $15.8 \pm 4.9$  for GO,  $9.3 \pm 2.3$  for GC and  $5.9 \pm 3.2$  for Triplets), indicating that GO and GC were submitted to high-intensity efforts.

### Blood Lactate

Both WODs increased LAC immediately after exercise, with higher levels observed for GO compared to GC (Figure 1A). Lactate is a product of anaerobic glycolysis, which indicates high-intensity energy demands and increase in metabolic acidosis [18, 19]. Previous studies demonstrated the influence of CrossFit bouts in blood lactate levels [5, 7, 8, 11, 15, 20], and most of them used Cindy or a different AMRAP WOD. In two different studies, “Cindy” increased LAC

to similar concentrations found in the present study, and these values were significantly higher than HIIT [5, 7]. Only two studies compared the AMRAP models to the all-out session performed for a best time (also referred to as ‘round for time’, or RFT) as in the present study [8, 15]. When AMRAP “Cindy” (20 min duration) was compared to RFT “Fran” (9 min duration), both promoted similar increases in LAC [15]. However, LAC after a 5 min duration AMRAP was significantly lower than a 9 min duration RFT [8]. Here, the RFT (Open 18.4) promoted a greater increase in LAC than AMRAP (“Cindy”).

Although AMRAP require the athlete to complete the maximum repetitions during the WOD, the fixed time (i.e. 20 min in “Cindy”) may induce an auto-regulatory cadence of exercise in the athlete. On the other hand, RFT (i.e. Open 18.4 or “Fran”) requires all-out efforts and a higher energy/time ratio (maximum 9 minutes duration), leading to a greater anaerobic dependence and lactate production. Considering the results of the present and previous studies, we may speculate that in a CrossFit WOD, the LAC response is dependent on duration of effort, but also the structure of WOD, with all-out efforts producing greater levels of LAC, indicating higher dependence on anaerobic metabolism.

### Gender

Various studies have investigated male and female CrossFit practitioners’ morphological, physiological and psychological characteristics [2, 3, 21, 22], but without separating gender influence on the variables of interest. It is well known that gender differences influence adaptation to acute and chronic exercise; however, knowledge on this subject still is very scarce regarding CrossFit training. For instance, the study of Poderoso et al. [23] observed an increase in testosterone and decrease in cortisol in men, while women did not present significant hormonal changes during the same period of CrossFit training. However, the study did not investigate whether the hormonal changes lead to changes in other physiological or performance adaptation.

In the present study, we observed similar behaviour of physiological variables in men and women when compared to the results of grouped genders. A few differences were observed when divided by gender, such as the statistical difference in HR of GC vs GO immediately after exercise for men. However, these differences were accompanied by a small effect size. Thus, our results suggest that the physiological response to acute CrossFit exercise is not deeply influenced by gender differences. These results are supported by the number of total repetitions in GO and GC, which did not significantly differ between genders. Consequently, it is plausible to infer that both genders performed the exercise sessions with a similar total external load of both WODs. Nevertheless, the total workload of WODs must be considered before making such an assumption. In “Open 18.4” WOD, females performed deadlifts with a lower absolute workload and although “Cindy” WOD was performed with only body weight, because women weigh less than men, they probably performed the exercise session with a similar total internal workload, but lower external workload [24].

## CONCLUSIONS

Our results suggests that the Open 18.4 training model, based on a fixed number of repetitions in a short time, does not differ from Cindy regarding cardiovascular responses for both genders. However, Open 18.4 produced high levels of blood lactate in both genders, which could reflect an increased glycolytic dependence or greater muscle mass involved during this WOD. Therefore, the structure of WODs can significantly alter metabolic behaviour, and should be considered during CrossFit training prescription.

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## Conflict of interests

The authors have declared that no competing interests exist regarding the present study.

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