

Article

Comparison of physiological responses and training load between different CrossFit® workouts with equalized volume in men and women

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Abstract: The purpose of the present study was to compare heart rate (HR), blood lactate and training load between different CrossFit® workouts, with equalized total volume in men and women. The study included 23 individuals (13 men and 10 women) experienced in CrossFit® training, who performed two workouts with different training types (as many reps as possible - AMRAP and for time) but equalized volume. Measurements of lactate, HR and rating of perceived exertion (RPE) were performed. The results showed that there was no HR interaction between workout time and sex ($p = 0.822$; $\eta^2 = 0.006$) and between workout type and sex ($p = 0.064$, $\eta^2 = 0.803$). HR significantly differed during each workout type ($p < 0.001$, $\eta^2 = 0.621$), but not between the two workout types ($p = 0.552$, $\eta^2 = 0.017$). Lactate showed no difference between the workout types ($p = 0.474$, $\eta^2 = 0.768$), although the training load was higher ($p = 0.033$, $\eta^2 = 0.199$) in women when they performed AMRAP. Altogether, HR was not significantly different between training types or sex, while RPE, lactate and training load showed small differences depending on the group (women or men) or workout type (AMRAP or 'for time').

Keywords: conditioning; high-intensity functional training; methods; performance; physical fitness

1. Introduction

CrossFit® is a constantly varied and high intensity functional training program that consists of a combination of different elements: cardiovascular, gymnastics and weight lifting [1,2]. A CrossFit® training session is structured around joint mobility, warm-up, technical drills and a workout of the day (WOD). The execution of the WOD is typically performed with short or no intervals between exercises and repetitions and rounds [3]. Previous studies have identified several hormonal and immune responses [4,5], metabolic responses [1,6], and cardiovascular and perceptual responses [6,7] after CrossFit® workouts.

Typically, the WODs are prescribed using training types to perform as many repetitions as possible (AMRAP) in a given period of time or as a set of tasks to be completed in

the shortest possible time ('for time'). These training types present positive stimuli for adaptations of aerobic and anaerobic capacity, especially AMRAP [8]. However, they seem to have the largest effect on increasing work capacity, even beyond changes in fitness [9].

A study by Kliszczewicz et al. [7] examined the cardiovascular and perceptual responses in the 'Cindy' benchmark WOD in CrossFit® beginners. The authors found that heart rate (HR) during training was > 93% of maximum HR, equivalent to vigorous exercise according to the American College of Sports Medicine [10]. Thus, several researchers have studied different ways of assessing the training load during CrossFit® training [11,12]. In addition to HR, the use of the effort perception scale (rating of perceived exertion; RPE) has been utilized by these studies to assess and quantify the intensity of training. The session RPE (s-RPE) has been considered a potential tool for these assessments [13], and has shown promise among CrossFit® beginners [14].

Generally, studies on the physiological and perceptual responses during CrossFit® benchmarks include workouts that have different training load characteristics, such as total time, intensity and volume [12,15–17]. Some WODs which are more often tested include 'Nancy' [18], 'Fran' [6,16], 'Cindy' [17,19], 'Fight Gone Bad' [6,16], 'Filthy 50,' 'Helen,' and 'Grace' [16]. In addition, other researchers have developed and tested their own unique CrossFit® style WODs [1,8]. To date, Bellar et al. [8] and Timón et al. [20] compared the AMRAP and 'for time' training type, but the exercises and the volume of repetitions and times differed between the workouts compared.

Some studies have reported results separately for women and men involved in CrossFit® training [21], but only one study [16] has examined differences between the responses of women and men. By design, CrossFit® training sessions vary widely in volume and intensity. However, for direct comparison between two workout styles (i.e., AMRAP and 'for time,' no one has yet compared WODs with the total work volume (TWV) equalized between them, as well as included comparison of responses between women and men. Thus, the aim of this study was to compare HR, blood lactate and training load between different CrossFit® workouts, with equal total volume. Our hypotheses were that (1) the 'for time' training would have higher lactate values but not HR nor training load, and (2) men would have higher lactate values than women after both training sessions.

2. Materials and Methods

2.1. Participants

Twenty-three individuals participated in the study (26.5 ± 4.3 years, 70.1 ± 12.2 kg, 1.68 ± 0.11 m, 24.6 ± 2.2 kg/m²); 13 men and 10 women involved in CrossFit® Training for at least one year (24 ± 7.3 months) with a minimum weekly frequency of three days a week. All were enrolled in an affiliated training center of CrossFit, Inc. Participants could not have muscle and/or joint injuries or limitations that would have prevented them from performing the exercises in this study and could have not answered positively to any question from Physical Activity Readiness Questionnaire - PAR-Q [22]. All participants signed an informed consent form prior to their participation according to CONEP resolution 466/2012 of the Ministry of Health in line with the Declaration of Helsinki (2000). The procedures were approved by a Local Ethics Committee (CAAE: 23511419.7.0000.5147).

2.2. Procedures

Participants were instructed to maintain their normal eating and social habits in the 24 hours prior to the tests. Initially, an anthropometric evaluation (Welmy® anthropometric scale) was performed. In the following days which were separated by at least 48 hours, two training protocols developed for the study were carried out according to Table 1.

Each participant performed the workout on their own at a self-selected pace, and the movement patterns were judged according to crossfit.com movement standard (<https://www.crossfit.com/essentials/movements>). The TWV was calculated using the following formula: number of rounds x repetitions x load (expressed in kg). All individuals

started with WOD 1, in which the maximum number of rounds was obtained, enabling a calculation of the TWV. To calculate the number of rounds for WOD 2 the inverse calculation of the TWV of the WOD 1 was performed. Recovery time between the two WODs was 72 h and both workouts were completed at the same time of day.

Before each WOD, a specific warm-up was performed with the training movements: three sets of 10 deadlifts (only with the weight of the bar = 20 kg for men and 15 kg for women), 10 burpees and 10 kettlebell swings (with load of 12 kg for men and 8 kg for women).

Table 1. CrossFit® workouts tested in the study.

Characteristic	WOD ¹ 1	WOD 2
Type	AMRAP ² in 20 min	"X" ³ Rounds For Time
Exercise 1	13 σ /11 ρ Calorie row on a Concept2® ergometer	Con- 21 σ /18 ρ Calorie row on a Concept2® ergometer
Exercise 2	12 Deadlifts at 62 σ /44 ρ kg	18 Deadlifts at 62 σ /44 ρ kg
Exercise 3	10 Burpees over the bar	15 Burpees over the bar
Exercise 4	8 Kettlebell swings at 24 σ /16 ρ kg	12 Kettlebell swings at 24 σ /16 ρ kg

¹ WOD: Workout of the day

² AMRAP: As many rounds as possible

³ "X": number of rounds calculated to balance workout volume

2.3. Measures

2.3.1. Heart rate

Continuous monitoring of HR was performed using a heart monitor (Polar®, RCX3, Finland) and HR was averaged every 15 seconds. The maximum HR used was obtained after a maximum test of 2 km of rowing, which was also used to estimate the maximum oxygen consumption of the participants [23]. The maximum HR observed during the test was used once it exceeded 90% of the maximum HR predicted by the formula $208 - [0.7 \times \text{age}]$ [24].

2.3.2. Blood lactate

After, the first drop of blood was discarded through a transcutaneous puncture, capillary blood samples were collected on the medial side of the tip of the middle finger, using a disposable hypodermic lancet (Accu-Chek Safe-T-Pro Uno, Roche®, Hawthorne, USA). Blood lactate was measured by photometric reflectance on a validated portable lactate analyzer (Accusport, Boehringer Mannheim - Roche®, Hawthorne, USA). Before each WOD, the lactate analyzer was calibrated with a standard solution of known concentrations (4 mmol.l⁻¹). Blood lactate ([La⁻]) was measured two minutes after each WOD.

2.3.3. Training load

The training load was estimated using the s-RPE product with the total training time [13]. To estimate the RPE, a modified version of the Borg CR-10 perceived effort scale was used 30 minutes after each WOD. Participants answered the following question: "From 0 to 10, how was your training session?" The product of the calculation was expressed in arbitrary units (AU).

2.4. Statistical analysis

The continuous quantitative variables were subjected to a Shapiro-Wilk normality test and a Levene's homogeneity test. Furthermore, the coefficient of variation was calculated to verify the distribution of data in each group. HR was taken before (pre) and during each WOD, which was stratified in quartiles of 25%, 50%, 75%, and 100% and compared using a two-way ANOVA for repeated measures 4 (quartiles) vs. 2 (WOD), followed by Tukey's Post-hoc for multiple comparisons. The sphericity was confirmed

through the Mauchly test and the effect size by *eta* squared. Considering the total sample size ($n = 23$) a Post-Hoc analysis with the Gpower 3.0 software [25] indicated a 98% statistical power requiring a minimum effect size of 0.35. The comparison of individual characteristics between women and men was performed using independent samples t-tests. A two-way ANOVA for independent samples (sex) and dependent measures (WOD) was performed, using Tukey's Post-Hoc to identify significant differences. For this test, a statistical power of 96% was indicated, requiring a minimum effect size of 0.4. A Pearson correlation was performed to verify the relationship between the final time of the 'for time' and the number of repetitions of the AMRAP with the responses of each dependent variable. A t-test was used to compare the area under the curve (AUC) between the two WODs. The level of statistical significance was $p < 0.05$. Analyses were performed using the SPSS software for Mac v.23 (SPSS Inc., Chicago, IL, USA).

3. Results

The assumptions of normality and homogeneity were confirmed with the Shapiro-Wilk and Levene's tests, respectively. For individual data, the independent samples t-tests showed significant differences between women and men for body masses, height, BMI, weekly frequency and training experience, but not for age (Table 2).

Table 2. Individual data between women and men who practice CrossFit® training.

Characteristic	Women (n = 10)	Men (n = 13)	p-value
Age (years)	25.6 ± 4.8 (18.8) ¹	27.3 ± 3.9 (14.4)	0.359
Body mass (kg)	59.8 ± 8.6 (14.4)	78.0 ± 7.9 (10.2)	< 0.001
Height (m)	1.59 ± 0.07 (4.4)	1.75 ± 0.07 (4.0)	< 0.001
Body Mass Index (kg/m ²)	23.4 ± 2.1 (8.8)	25.6 ± 1.9 (7.5)	0.016
Weekly frequency (days)	5.5 ± 0.7 (12.9)	4.6 ± 0.9 (20.8)	0.024
Training experience (months)	24.0 ± 7.4 (17.8)	31.3 ± 10.7 (34.2)	0.016

¹ Values presented in average ± standard deviation (coefficient of variation, %)

The Mauchly test found a violation of sphericity for workout time ($p < 0.001$) and the interaction of time with WOD ($p < 0.001$). There was no interaction between time and sex [$F_{\text{Greenhouse-Geisser}}(1.567, 32.902) = 0.137, p = 0.822, \eta^2 = 0.006$] or between WOD and sex [$F_{\text{Greenhouse-Geisser}}(1, 21) = 2.256, p = 0.064, \eta^2 = 0.803$]. HR was significantly different during the WODs [$F_{\text{Greenhouse-Geisser}}(1.567, 32.902) = 34.425, p < 0.001, \eta^2 = 0.621$], but not between each WOD [$F_{\text{Greenhouse-Geisser}}(1, 21) = 0.366, p = 0.552, \eta^2 = 0.017$] (Figures 1A and 1B, respectively). The paired t-test did not find differences between each WOD in HR-AUC ($t(22) = -0.360; p = 0.722$).

The two-way ANOVA showed that there were significant differences between sexes for resting HR [$F(1,21) = 5.266, p = 0.032, \eta^2 = 0.200$], repetitions completed [$F(1,21) = 5.131, p = 0.034, \eta^2 = 0.196$] and TWV [$F(1,21) = 44.074, p < 0.001, \eta^2 = 0.677$]. For within-sex comparisons of responses to each WOD, significant differences were found for RPE [$F(1,21) = 16.059, p = 0.001, \eta^2 = 0.433$], training load [$F(1,21) = 9.078, p = 0.007, \eta^2 = 0.302$] and repetitions [$F(1,21) = 14.662, p = 0.001, \eta^2 = 0.411$] in women, and lactate [$F(1,21) = 17.402, p = 0.001, \eta^2 = 0.405$] and workout time [$F(1,21) = 14.279, p = 0.001, \eta^2 = 0.405$] in men.

Table 3 showed that greatest responses were during the 'for time' WOD when compared with AMRAP for RPE, training load and maximum number of repetitions (in women) and lactate (in men). Men performed the 'for time' WOD in less time than the AMRAP. TWV was not different between the two WODs, but men showed higher values than women for each WOD. The only statistically significant Pearson correlation coefficient was a moderate relationship for women between the maximum number of repetitions and ($[\text{La}^-]_b$) following the AMRAP ($r = 0.654; p = 0.040$).

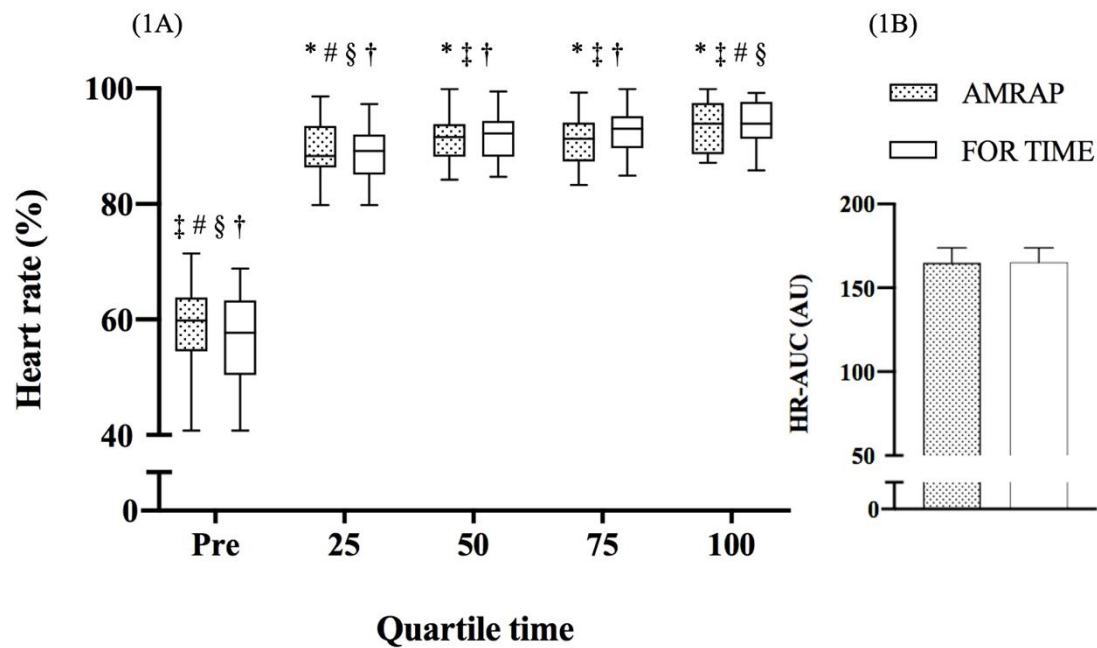


Figure 1. Quartiles of heart rate (HR) during the workout of the day (WOD) and area under the HR curve.

Values presented in median and interquartile range (1A) and average and standard deviation (1B). HR-AUC: Area under curve of heart rate. * Significant difference in relation to the pre ($p < 0.001$); †Significant difference in relation to the 25th quartile ($p < 0.01$); ‡Significant difference in relation to the 50th quartile ($p < 0.01$); §Significant difference in relation to the 75th quartile ($p < 0.01$); ¶Significant difference in relation to the 100th quartile ($p < 0.001$).

Table 3. Comparison of dependent variables between the two workouts of the day in women and men.

Sex and Variables	As Many Rounds As Possible	For time	p-value
Women			
HR rest (bpm)	63.7 ± 7.6 (16.8) ¹	65.8 ± 9.1 (14.7)	0.345
HR median (bpm)	170.7 ± 9.1 (5.3)	170.4 ± 6.7 (3.9)	0.546
HR peak (bpm)	187.7 ± 6.5 (4.7)	188.2 ± 7.7 (4.2)	0.701
Lactate (mMol.L ⁻¹)	16.8 ± 2.9 (32)	15.4 ± 2.6 (22.6)	0.393
RPE	7.9 ± 0.8 (16.3)	9.1 ± 0.5 (13.1)	0.001
Time (min)	20.0 ± 0.0 (-)	19.5 ± 1.0 (5.4)	0.202
Training Load (arbitrary units)	158.0 ± 17.5 (16.3)	177.9 ± 13.7 (13.9)	0.007
Repetitions	233.0 ± 38.4 (16.5)	269.8 ± 25.6 (9.4)	0.001
Total Work Volume (kg)	7281.1 ± 1363.2 (11.1)	7303.5 ± 1355 (10.1)	0.733
Men			
HR rest	57.3 ± 9.6 (12.0) ²	56.6 ± 8.3 (14.0) ²	0.720
HR median	177.0 ± 7.0 (4.0)	176.4 ± 8.6 (4.9)	0.647
HR peak	183.7 ± 8.5 (3.5)	189.0 ± 7.8 (4.1)	0.637
Lactate	14.1 ± 4.5 (17.3)	17.0 ± 3.8 (17.4)	0.048
RPE	7.6 ± 1.2 (11.1)	8.1 ± 1.0 (6.2) ²	0.093
Time (min)	20.0 ± 0.0 (-)	18.9 ± 1.0 (1.1)	0.001
Training Load (arbitrary units)	153.8 ± 25.0 (11.1)	154.0 ± 21.4 (7.7) ²	0.975
Repetitions	247.3 ± 43.6 (17.6) ²	273.1 ± 26.8 (9.8)	0.324
Total Work Volume (kg)	10759.9 ± 1189.6 (18.7) ³	10717.3 ± 1086.8 (18.6) ³	0.461

¹ Values presented in average ± standard deviation (coefficient of variation, %)

² Difference in relation to women ($p < 0.05$)

³ Difference in relation to women ($p < 0.001$)

4. Discussion

The aim of this study was to compare HR, blood lactate and training load between different CrossFit® workouts with equalized total volume in men and women. The main results herein partially support our a priori hypotheses. We predicted lactate values to be higher after the 'for time' WOD, but they were only significantly higher for men. As predicted, HR was not different between each WOD. Training load was also hypothesized to be similar between each WOD, but for women training load was significantly higher in the 'for time' WOD. Finally, we predicted men would have higher lactate after each WOD than women, but this hypothesis was not supported.

As CrossFit® training is characterized by constantly varying functional movements performed at high intensity, previous studies have investigated different types of workout [12,18,26]. Typically, the WODs presented in the literature cover different total volumes and that may hinder a comparison between the studies; for example: 'Fran' with 4 minutes and 'Fight Gone Bad' with 17 minutes duration [6], and 'Cindy' with 20 minutes [15,17,19] are difficult to compare with each other. The current study was the first to compare two WODs with equal volume and to compare them between women and men. The findings of this study help us to understand the physiological and perceptual responses among WOD type by standardizing the volume of work completed by each participant.

HR did not differ between the WODs nor between women and men. These similar responses can be explained by a similar nature of the exercises, in which the cardiac output seems to remain unchanged, likely due to the mechanical occlusion caused by muscle contractions [27]. Despite previous studies showing that HR may not show differences between intensities during functional fitness [12], the present study attributes the absence of these differences to equalization of TWV between the two WODs. The HR response reached 99.4% of HR_{max} during the AMRAP and 99% of HR_{max} during the 'for time' WOD, while the average HR over the entire workout was 91.4% and 91.7% of HR_{max} during the AMRAP and the 'for time' WODs, respectively. These values are in accordance with previous studies of CrossFit® training [12,15,26] and with treadmill running workouts [7]. When comparing two WODs with different times ('Cindy' and 'Fran'), Fernández et al. [15] did not find differences in the mean or peak HR, but they did find that in 'Cindy' participants spent the most time in the high intensity training zone (> 80% of maximum HR). High HR values can be understood by a combination of a high demand for O_2 as a function of muscle work, as well as to sustain breathing. A small difference was found in the resting HR in the WODs between women and men, which can be attributed to differences between the sexes and to intervening factors such as diet, stress and sleep quality, which quantitatively vary from 3 to 5 bpm [28,29] or up to 10 bpm [30].

When lactate was evaluated, a concentration greater than 14 mmol.L^{-1} was found after both WODs for women and men, indicating a high anaerobic output similar to that in the study by Maté-Muñoz et al. [17]. The responses in the present study showed that only men had higher blood lactate values after the 'for time' WOD compared with those after the AMRAP. Perhaps the greater body mass and height of men and a fast start with increased exertion in the initial phase of the 'for time' exercise (which was observed during this study) may help to explain the higher lactate accumulation. Previous studies presented different results according to the training type. Fernández et al. [15] found no differences between 'Fran' WOD (14 mmol.L^{-1}) and 'Cindy' WOD (14.5 mmol.L^{-1}), while Tibana et al. [6] verified higher values in the 'for time' ('Fran' = 17.7 mmol.L^{-1}) compared with AMRAP ('Fight Gone Bad' = 16.2 mmol.L^{-1}). Maté-Muñoz et al. [17] attribute differences in blood lactate to the recovery intervals performed during training. High lactate levels are one physiological indicator for the key aspects of the anaerobic system (e.g., as the involvement of muscle fibers, the proportion of aerobic and anaerobic metabolism, and the ability of glycolysis) [31]. This information is extremely relevant to determine the best training for CrossFitters and enables coaches to understand an ideal training schedule (i.e., short versus long workouts).

Training intensity has been assessed through various physiological and perceptual parameters [11–13]. Many CrossFit® training sessions, both continuous and interval, are carried out with high exertion. The ability to sustain effort across the entire workout and sufficiently recover between strategized breaks would appear to be influenced by aerobic capacity [1]. In the study of Tibana et al. [12], subjects completed four rounds of a metabolic conditioning session designed to attain maximum RPE (10) throughout the session. However, a RPE of 10 was attained by all participants only from round 3. In the present study, HR increased rapidly in the first few minutes (quartile 25), remaining high during training (quartiles 50 and 75) and rising again at the end (quartile 100), which was similar for both training sessions. A progressive cardiovascular stress is typical in high-intensity exercise, either continuous or interval [20]. The results herein confirm this idea and also show that the training type (AMRAP vs 'for time') did not seem to influence HR response, since the area under the curve (AUC) did not differ between the two WOD types.

A combination of the use of external and internal loads have been suggested for the control of training performance [32], which is related to body stress and often with the need for recovery of more than 24 hours [15]. However, the different training types and variation of elements in the prescription of CrossFit® training make it difficult to quantify external load. Training load assessment helps coaches to choose the stress necessary for better performance and lowering injury risk. In the present study, the training load was assessed by s-RPE, 30-min after the WOD, which is a parameter found in the literature [11–13]. Other studies measured the RPE immediately after the session [14]. Higher RPE values were found for 'Cindy' than a treadmill run, but without differences in physiological stress [7]. However, when comparing 'Cindy' (AMRAP) with 'Fran' ('for time'), no differences were found in RPE; even with different exercise times [15]. Maté-Muñoz et al. [17] compared three WOD with different elements: cardiovascular (double unders), gymnastics ('Cindy'), and weightlifting (power cleans) and found elevated HR and RPE during all three WODs. Lactate, measured immediately after each workout, was higher in 'Cindy' than in double unders but not compared to power cleans. Perhaps the combination of different movements in 'Cindy' (pull-ups, push-ups and squats) is fundamental key factor for intensifying training.

In the present study, women had a higher internal load in 'for time' when compared with AMRAP. This difference was due to the higher s-RPE in the 'for time' attributed to the psychological influence of finishing the WOD in a shorter time. The TWV was balanced between the two WODs, but men showed higher values than women in both workouts, which is justified by the greater muscle mass, height, body mass index and the time of experience in CrossFit®. These responses agree with Billaut and Bishop [33] who demonstrated that the morphological, metabolic and neuromuscular properties produce different responses between women and men. As well, having a defined amount of work to complete 'for time' can result in participants pushing harder than when they have a set amount of time within which to complete as much work as possible [34].

It is necessary to take into account the limitations of the field testing where there is a risk of worsening or distortion of records due to the absolute load versus the relative load. However, based on the responses to each WOD, both workout types can be recommended to develop fitness or as a part of specific sport training. It is necessary to confirm the results from this study on a sample with different levels of conditioning and other workouts with different movement elements (cardiovascular, gymnastics and weightlifting).

5. Conclusions

This study demonstrated that when the workout total work volume was the same, few differences were found between the different CrossFit® workout types. Heart rate did not differ between training types, nor sexes, while RPE, lactate and training load showed small differences depending on the group (women or men) or training type (AMRAP or 'for time'). Our results indicate that coaches can use either AMRAP or 'for time' as strategies during CrossFit training.

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