

Sensitivity of operational tests to training load in Crossfit®

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Abstract

Proper control of the training load and the state of fatigue-recovery of the CrossFit® practitioner may be a preventive strategy for unwanted events such as non-functional overreaching and injury. This study aimed to evaluate the sensitivity of motor tests and total quality recovery (TQR) to the training load of microcycles in CrossFit®. Seven female CrossFit® practitioners underwent two sets of three CrossFit® training microcycles: aerobic block (AB) and strength block (SB). On the first and sixth day of the last microcycle of each block, the volunteers performed a series of operative tests. In AB they performed TQR (subjective scale 6 – 20 points), Tapping Test, and KAREN (CrossFit® benchmark); while in SB they performed TQR, Countermovement Jump (CMJ), Bench Press Resistance, and Squat Resistance. The training load of the third microcycle of each block was measured from the RPE obtained 30 minutes after the end of the training session multiplied by the duration of the session. The Pearson correlation test was used for the association between the training load variables (mean and standard deviation) and performance of the operative tests. In SB, squat resistance was significantly correlated with the average training load ($r=0.76$; $p=0.04$), and there was a correlation trend between the CMJ test and the standard deviation of the training load ($r=0.73$; $p=0.06$). In AB, no operative test correlated with training load variables. In conclusion, the squat resistance test was shown to be sensitive to the average training load in a SF microcycle and can be considered a practical test for monitoring the fatigue-recovery status of CrossFit® practitioners.

Key words: Fatigue, Periodization, Sports Training, Bench Press.

Introduction

CrossFit® is a modality proposed to improve health, weight loss, and increased performance, which promotes different training sessions each day (Workout of a day [WOD]), using safe, effective, and efficient movements similar to those required in daily life (<https://www.crossfit.com/>). Butcher et al. (2015) showed that WODs comprising continuous circuits, as well as interval circuits, led to a rating of perceived exertion (RPE) with levels above 16 at the end of each session, while Maté-Muñoz et al. (2018) found blood lactate concentrations above 10mmol.L^{-1} after three different WODs, which reinforces the characterization of CrossFit® as a high-intensity mode.

The benefits of regular practice of CrossFit® include increase in maximum oxygen consumption and reduction in body fat percentage (Smith et al., 2013). Still, Crossfit® practitioners have a lower recovery heart rate than recreationally trained individuals with the same maximum oxygen consumption (Barbieri et al., 2019). However, greater exposure to training, whether in hours of training or training sessions per week, seems to be associated with a higher risk of injury (Montalvo et al., 2017), and can trigger rhabdomyolysis, as demonstrated by Meyer et al. (2021), Adhikari et al. (2021), and Lawrensia et al. (2021). Given the risks that the practice of high-intensity modalities may entail, adequate control of the training load applied, and the state of fatigue-recovery of the practitioner, it may be a preventive strategy for unwanted events such as non-functional overreaching and injury. In addition, it is challenging to establish adequate strategies to monitor fatigue-recovery. Indirect indicators of muscle injury, such as creatine kinase levels or muscle temperature (thermographic), are the most popular in high-performance sports. In the study by Freire et al. (2020), creatine kinase was significantly correlated with external load measurements obtained via GPS. However, both creatine kinase and muscle temperature are restricted to muscle damage and remain expensive for many physical activity practitioners. Total quality recovery (TQR) is a proposed global measure to assess recovery status (Kenttä; Hassmén, 2012). It is a subjective recovery assessment scale based on the rating of perceived exertion (RPE). Osiecki et al. (2015) found a negative correlation between TQR and blood creatine kinase levels in soccer players ($r = -0.75$, $p < 0.05$). Considering that higher values on the scale indicate a perception of greater recovery, the lower the amount of creatine kinase, the greater the perception of recovery, suggesting the possibility of using the TQR to determine the state of recovery in soccer players. However, in basketball athletes, the TQR was not influenced by the training load, but only by the individual characteristics of the athletes. Therefore, the suggestive functionality of TQR needs to be further studied in high-intensity sports.

Motor test performance has also been explored as an alternative to identify the state of fatigue-recovery in athletes from different modalities. Kennedy et al. (2017) demonstrated that the concentric, eccentric, and total duration of the jumps increased after 48 hours of the training session in rugby players, showing that this motor action was sensitive in identifying that the athletes were yet to fully recover from the previous session. Gathercole et al. (2015) analyzed different motor tests and identified that the countermovement jump (CMJ) was the most sensitive test in relation to the jump squat, drop jump, and 20 mt sprint tests to identify neuromuscular fatigue in endurance sports practitioners' equipment at 24 and 72 hours after the training session. Additionally, the CMJ appears to be sensitive to neuromuscular fatigue imposed by soccer training or matches (Beattie et al., 2021; De Hoyo et al., 2016). Based on these studies, the CMJ seems to be a useful tool to identify the state of fatigue-recovery of athletes in collective modalities, which may be related to the specificity of the motor demands of these sports and countermovement jumps. In modalities such as CrossFit®, which involves multiple demands, including lower limb power, it remains to be explored whether CMJ or other motor tests can be used as a useful tool to monitor fatigue-recovery status. Maté-Muñoz et al. (2017) studied CMJ performance to assess muscle fatigue after different WODs (Gymnastics WOD, Metabolic Conditioning WOD and Weightlifting WOD) in CrossFit® practitioners. The authors found that three minutes after Gymnastic and Weightlifting WODs performance in CMJ was lower compared to pre-training values, while in Metabolic Conditioning WOD performance decreased during training, but at the end it had already recovered. Similar results were found by García-Fernandez et al. (2021), who showed reduced performance in the CMJ immediately after the functional fitness training session. However, it is still necessary to understand the residual effects of different training loads, especially after a microcycle, when an accumulated fatigue effect is expected. Also, based on the study by Maté-Muñoz et al. (2017), different tests should be necessary, since their results indicate that the different training loads that are usual in the CrossFit® modality lead to different acute fatigue responses. Despite the need for practical methods to control the state of fatigue-recovery in CrossFit® practitioners, the literature is still scarce regarding the investigation of motor or subjective variables that may be associated with training load. Thus, the present study aimed to evaluate the sensitivity of motor tests and TQR to microcycle training load in CrossFit®. The hypothesis is that tests with a motor pattern similar to the modality may be associated with the applied training loads.

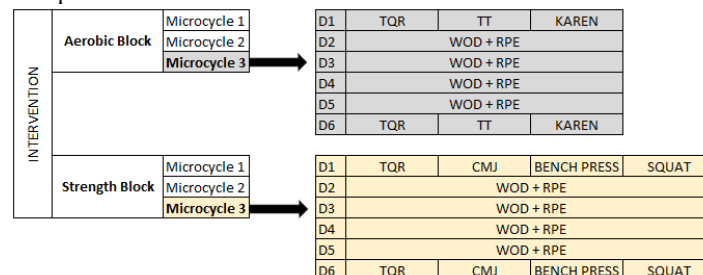
Material and Methods

Sample and Ethical Care

The participants comprised seven physically active female CrossFit® practitioners, with a body weight of 72.85 ± 9 kg, height 171.14 ± 4.33 cm, body mass index (BMI) 24.82 ± 2.46 and 23.85 ± 14.83 months of practical experience in sports. As an inclusion criterion, the participants had to be physically active women, aged between 18 and 40 years and with at least 10 months of CrossFit® practice. As an exclusion criterion, a training frequency of less than 75% during the data collection period was considered. Prior to data collection, the participants were duly informed about the study, its objectives, procedures, and possible risks, and signed an informed consent form. This study was approved by the Research Ethics Committee of the Federal University of Mato Grosso (CAAE number:33312220.2.0000.8124).

Procedures The subjects underwent six weeks of conventional CrossFit® training, with each week representing one microcycle. The microcycles were divided into two blocks: aerobic (AB) and strength (SB). From the first to the third microcycle, conventional CrossFit® training aimed at aerobic capacity (AB) was applied; whereas from the fourth to the sixth microcycle, conventional CrossFit® training aimed at strength capacity (SB) was applied (Fig.1). In AB, running activities and strength exercises with a higher number of repetitions, lower intensity, and organized in a circuit format were prioritized. Furthermore, the training mainly composed of gymnastic strength exercises (bar, handstand, single-leg squat, etc.) and strength training with short, high-intensity recovery periods in SB. During AB and SB, training sessions were performed five times per week for a total duration of approximately 60 minutes. Before and after the last microcycle of each block, the volunteers performed a series of exercises to verify whether the variation in performance between the tests was associated with the training load performed in the specific microcycle of each block.

Figure 1. Design of the experiment.



Note: D1-6 = Day 1 to 6; WOD = Workout of a day; TQR = Total quality recovery; TT = Tapping Test; CMJ = Countermovement jump; BENCH PRESS = Flat bench chest press.

Prior to the intervention, in a separate session, familiarization with the applied tests, tapping test (TT), and CMJ was carried out, and the TQR and RPE were also presented. The other tests applied were bench press resistance, squat resistance, and Karen, usually occurring in CrossFit® practice, regardless of familiarization due to the previous experience of the sample.

The series of exercises was specific for each block; in AB, they were applied to TQR, TT, and Karen; in SB, they were applied to TQR, CMJ, straight bench press resistance, and squat resistance. The tests were performed on the first and sixth days of the third microcycle of each block, before the daily training session. During each training session of the third microcycle of each block, RPE was collected to measure the training load of the specific test week. The participants were free from intense exercise for at least 48 hours before collection on the first day of the third and sixth microcycles.

Description of operational tests

TQR: The TQR scale (6 to 20 points), proposed by Kenttä and Hassmén (1998), was applied before the first and after the last training of the third microcycle of each block. The participants were instructed to report the number on the scale that corresponded to their perception of recovery at that time.

Karen: CrossFit® standardized training, which is characterized by throwing, after a squat, a 14-pound medicine ball 150 times at a standardized height of three meters in the shortest possible time.

Bench Press/Squat Resistance: Greater number of repetitions, without pause, until exhaustion, of the bench press and/or free squat, following the usual load of the sample, 25 kg, and 45 kg, respectively. In the bench press, repetitions were validated where the individual supported the bar against the body with his back on the bench, subsequently presenting full extension of the elbows. In the squat, the repetitions were validated when, with the bar on the back, the participants flexed their knees at an angle $\leq 90^\circ$ and returned to the initial standing position.

Countermovement Jump (CMJ): Vertical jump was performed on a reliable contact mat MultiSprint® - Hidrofit (Ferreira et al., 2008), which was performed with the hands on the waist, immediately after a semiflexion of the knees. The participants were instructed to jump as high as possible. During the flight phase, there was no knee flexion until the first contact was made to return to the ground. Three attempts were made with an interval of approximately 30 seconds between attempts. The best mark was adopted as the final result.

Tapping Test (TT): For 10 seconds, the participants were to complete the maximum number of alternating taps between the feet on the contact mat (MultiSprint® - Hidrofit). The participants were in a standing position, with one foot on each mat, knees semi-flexed, and were instructed to keep both hands in front of the body so as not to coordinate movements between the lower and upper segments. Two attempts were repeated with an interval of one minute between them. The best mark was adopted as the final result.

On the days of application of the operative tests, the session began with a standardized warm-up, which consisted of 100 meters of jogging, 10 squats, 10 jumping jacks, and 10 push-ups. The sequence of exercises was repeated for 10 minutes.

Training Load Log

The training load of the sessions was measured from the RPE obtained 30 minutes after the end of the training session multiplied by the duration of the session. The mean and standard deviation were calculated from these measurements according to Foster et al. (2001). The RPE was collected under the question, "How was your training today?." A scale of 0 to 10 was used, as described by Foster et al. (2001).

Data analysis

Parametric statistical tests were used for data analysis. The Pearson correlation test was used for the association between the training load variables (mean and standard deviation) and performance of the operative tests. The percentage change in test performance ((performance after – performance before) $\times$ 100/performance after) was used for these correlations. Pre- and post-microcycle test performances were compared using a paired t-test. The results of the tests applied as well as the variables of the training load are presented as mean $\pm$ standard deviation. SigmaStat version 3.5 was used.

Results

The last AB microcycle had a mean training load of 300 ± 74.42 a.u. and standard deviation of the training load of 109.5 ± 42.2 a.u. In the SB, the mean training load was 300 ± 73.86 a.u. and the standard deviation of the training load was 91.6 ± 34.9 a.u. The results of the operative tests of the evaluated microcycles are presented as mean $\pm$ standard deviation in Table 1, as well as the absolute (post-pre-microcycle) and relative (%) variations and the result of the paired t-test. When $p < 0.05$, there was an increase in the number of squat repetitions at the end of the microcycle in SB. Additionally, in AB, there was a reduction in the perception of recovery (TQR) and a reduction in performance in KAREN at the end of the microcycle but an increase in TT performance, considering a significance level of $p < 0.10$.

Table 1. Mean $\pm$ Standard Deviation of the operational tests and TQR in the two test microcycles.

	Operational Test	Pre-Microcycle	Post-Microcycle	Δ	$\Delta\%$	Test t
AB	TQR (a.u.)	16,14 $\pm$ 2,97	13,86 $\pm$ 1,57	-2,29 $\pm$ 2,75	-12,38 $\pm$ 13,74	0,07*
	TT (rp)	37,57 $\pm$ 4,89	40,14 $\pm$ 5,58	2,57 $\pm$ 3,31	7,05 $\pm$ 9,05	0,09*
	KAREN (s)	918,71 $\pm$ 192,61	797,00 $\pm$ 156,27	121,71 $\pm$ 160,13	-12,01 $\pm$ 15,12	0,09*
SB	TQR (a.u.)	16,86 $\pm$ 2,67	15,43 $\pm$ 2,15	-1,43 $\pm$ 2,29	-7,34 $\pm$ 13,41	0,15
	CMJ (cm)	19,43 $\pm$ 5,75	19,37 $\pm$ 3,25	-0,06 $\pm$ 4,11	5,17 $\pm$ 27,53	0,97
	Bench Press (rp)	19,57 $\pm$ 10,58	21,14 $\pm$ 8,93	1,57 $\pm$ 2,88	11,42 $\pm$ 12,20	0,19
	Squat (rp)	29,14 $\pm$ 7,65	32,71 $\pm$ 7,41	3,57 $\pm$ 3,82	14,01 $\pm$ 13,45	0,04**

Note: AB = Aerobic Block; SB = Strength Block; TQR = Full Recovery Quality; TT = Tapping Test; CMJ = Countermovement Jump; a.u. = arbitrary units; rp = repeats; Δ = Variation (post-pre); $\Delta\%$ = Percentage variation relative to pre performance; *p<0.10; ** p<0.05.

The correlation analysis between the performance variation in the last AB microcycle and training load variables did not show a significant correlation with any of the applied operative tests. The only significant correlation observed was between operative tests, in which TT performance was negatively associated with perceived recovery (Table 2). In SB, there was a positive and high correlation between the variation in squat performance and the average microcycle training load. Furthermore, when p<0.10, there was a positive and high correlation between the performance variation in CMJ and the standard deviation of the training load. Among the operative tests, there was a high negative correlation between the perception of recovery and the variation of performance in the bench press (Table 3).

Table 2. Correlation between performance variation in the Aerobic Block microcycle and microcycle training load variables.

	SD OF TL	TT	KAREN	TQR
MEAN OF TL	0,14 (0,76)	-0,53 (0,22)	-0,21 (0,65)	0,49 (0,26)
SD OF TL		0,16 (0,73)	0,25 (0,59)	-0,37 (0,41)
TT			-0,12 (0,79)	-0,88 (0,01)*
KAREN				0,33 (0,47)

Note: MEAN OF TL = Mean Training Load; SD OF TL = Standard deviation of training load; TT = Tapping Test; TQR = Total quality recovery; * indicates significant correlation (p<0.05).

Table 3. Correlation between performance variation in the Aerobic Block microcycle and microcycle training load variables.

	SD OF TL	TQR	SQUAT	CMJ	BENCH PRESS
MEAN OF TL	0,27 (0,55)	-0,43 (0,34)	0,76 (0,04)*	0,25 (0,59)	0,43 (0,33)
SD OF TL		0,04 (0,92)	0,05 (0,90)	0,73 (0,06)**	0,32 (0,49)
TQR			-0,07 (0,87)	0,03 (0,95)	-0,92 (0,01)*
SQUAT				0,05 (0,91)	0,04 (0,92)
CMJ					0,22 (0,63)

Note: MEAN OF TL = Mean Training Load; SD OF TL = Standard deviation of training load; TQR = Total quality recovery; CMJ = Countermovement Jump; *indicates significant correlation (p<0.05); **indicates significant correlation (p<0.10).

Discussion

This study aimed to evaluate the sensitivity of operative tests to training load variables in microcycles belonging to two specific training blocks in CrossFit®: an aerobic block (AB) and a strength block (SB). The main findings demonstrate a significant correlation between performance variation in squat resistance and average training load in the SB microcycle, suggesting that greater performance variation tends to occur with higher values of average training load. The t-test results reinforce the group's higher performance in squat resistance at the end of the microcycle. Even so, in the same block, with a confidence level of 90%, it was observed that the performance variation in the SCM was correlated with the standard deviation of the training

load, suggesting a positive variation in the performance of the CMJ when the standard deviation of the training load is greater. In AB, no operative test correlated with training load variables.

Ferreira and Szmuchrowski (2008) proposed three levels of training load control, one of which is operational control, which aims to identify the state of fatigue-recovery at the training microcycle level. In CrossFit®, the search for an operational control variable remains a challenging task, especially because it is a multitask modality that uses activities such as squats and jumps, as well as rapid snatch or throw movements, with the objective of developing the general physical conditioning of the practitioner (Da Costa et al., 2019). In the present study, we sought to explore practical tools that could be easily implemented in the training routine; however, in AB, none of the operational control variables were sensitive to training load. With so much variability in sports demand, it is difficult to identify a task that represents an athlete's overall state of fatigue-recovery.

In the SB, the squat resistance test showed a significant correlation ($r = 0.765$, $p = 0.045$) with the average training load, assuming that a greater positive variation in the number of repetitions in the squat was expected when the training load average was greater in that microcycle. This finding contrasts with the study by Balsalobre-Fernández et al. (2015), in which the authors found no significant correlation between the 1RM squat test and the two markers of training load. It is suggested that the low applicability of the squat test in the study by Balsalobre-Fernández et al. (2015) is due to the sports population studied, as the authors involved middle- and long-distance running athletes, a practice that does not present specificity with maximum effort in the squat. The results also showed a trend ($r = 0.727$; $p = 0.064$) in the correlation between the CMJ test and the standard deviation of the training load, in line with the findings of Zurutuza et al. (2017), who evaluated the relationship between external and internal training load indicators and objective and subjective fatigue experienced by 15 soccer players. In this study, neuromuscular fatigue measured with the CMJ was sensitive to different percentages of load borne by players during the training week. Similarly, Gathercole et al. (2015), in a study of elite rugby athletes, found significant correlations between different microcycles and CMJ, which was useful for estimating neuromuscular fatigue. Thus, despite the 90% level of significance, the results of this study and the findings of Zurutuza et al. (2017) and Gathercole et al. (2015) suggest that CMJ can be used as a tool to identify the state of fatigue-recovery.

The squat resistance test also showed a significant increase in performance ($p = 0.048$) after the third SB microcycle, which may be explained by the subacute neuromuscular adaptations resulting from resistance training. The only variable that correlated with the training load (with a significance level of 95%) was also the only variable that varied significantly pre and post microcycle. Therefore, the t-test results strengthen the correlation findings.

In AB, no operative test correlated with training load variables. While the KAREN is a CrossFit® training, which requires resistance strength, the TT is a test that has been applied to assess coordination but is still little explored in the sports field (Pivovarniček et al., 2015). The present study showed that the performance variation in these motor demands is not associated with the training load of the microcycle in which they were evaluated. Physiological variables are associated with training load in sports with a determining aerobic characteristic. In a study by González-Fimbre et al. (2020), for example, reduced heart rate variability was negatively associated with exercise intensity in triathletes. However, in the present study, there were no physiological measurements. The recovery perception assessment was the only common variable between the two types of microcycles evaluated because it was not indicative of specific fatigue, and neither did it correlate with the training load in any of the microcycles evaluated. Therefore, other practical means of operational control during the application of aerobic blocks need to be tested.

Owing to the scarcity of studies regarding the control of the state of fatigue-recovery in CrossFit®, direct associations with the data of the present study are not feasible. For the reproduction of this study, the use of a larger sample is suggested to increase the power of the statistical data generated. In addition, the time of application of the operational tests can be decisive in establishing a relationship with the training load variables. This study was limited to a single moment of post-intervention evaluation, and additional moments of application of operative tests are suggested in future studies.

Conclusions

The squat resistance test was shown to be sensitive to the average training load in a SF microcycle and can be considered a practical test for monitoring the fatigue-recovery status of CrossFit® practitioners. The CMJ showed a trend in correlation with the standard deviation of the training load; therefore, attention should be paid to this type of test, which needs to be explored in future studies. From a practical point of view, the results of this study suggest the use of the squat resistance test and CMJ to monitor the fatigue-recovery state after strength microcycles in CrossFit® practitioners. For AB, it is necessary to investigate the tools that are sensitive to the applied training load. The subjective perception of recovery assessed through TQR was not related to the training load variables investigated in either of the two types of microcycles evaluated.

Conflicting Interests: The author(s) declared no potential conflicts of interest.

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