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Neuromuscular and autonomic responses during a CrossFit® competition: a case study

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Abstract
Introduction. The number of sports practitioners engaged on extreme physical conditioning programs has been growing exponentially in the last decades. However, the information about participating in competitions on their physiological systems is scarce. Aim of Study. This study aimed to evaluate the neuromuscular and autonomic responses of CrossFit® practitioners in a competition. Material and Methods. Three subjects (with 17 months of experience) were monitored during a two consecutive days competition. Participants performed five events (three on the first day and two on the second one) composed of body weight exercises, Olympic weightlifting and aerobic activities. Neuromuscular performance and autonomic response were assessed through countermovement jump and heart rate variability (respectively). Results. Subject A has decreased in 8% his countermovement jump and heart rate variability values from pre-day 1 to the end of the competition. Subject C have showed a decreasing of the –4.0% on the vertical impulse of countermovement jump height at the end of the competition. Therefore, two CrossFit® competition consecutive days negatively influenced neuromuscular and autonomic function of the male practitioner. Conclusions. By characterizing the behavior of internal and external load variables of CrossFit® practitioners during a competition, it was evidenced that monitoring strategies provide data that favor a better decision making on the need recovery strategies during and after a CrossFit® competition.

KEYWORDS: extreme conditioning program, muscle power, performance, heart rate variability.

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Introduction

Currently, extreme conditioning programs are pointed out as the fastest growing exercise modes concerning the number of practitioners and training centres [1, 11], arousing the interest of the scientific community to its risks and benefits [1]. Among them, CrossFit® stands out as one of the most popular, using workout of the day routines incorporating body weight exercises (e.g. pull up, handstand and muscle up), Olympic weightlifting (e.g. squats, press and clean) and aerobic activities (e.g. running, rowing and air bike) [24]. CrossFit® training routines involve exercises using large groups of muscles, high number of repetitions, fast execution speed and short recovery periods. Given the plurality of the stimulated physical capacities, its practitioners seek benefits related to health [14, 24] and sport performance [3, 17].
Complementarily, monitoring the internal and external load plays a decisive role in promoting positive

adaptations of the athlete [3, 8, 24], allowing adjustments in his/her physical stress (e.g. number of sessions or bouts per day) and eventually avoiding injuries. Therefore, monitoring the training load became accessible, reliable and reproducible both for exercise and sport scientists, as well as for coaches [8, 9]. From a number of variables, heart rate variability and neuromuscular function are easily incorporated into the training routine and provide reliable information regarding practitioners readiness level [4, 27].

Despite the above referred, there is a gap in the scientific literature regarding the monitoring of the CrossFit® specific load. Some studies have assessed the training phase using rating of perceived effort, blood pressure and blood lactate [6, 22]. Another study showed that two workout of the day consecutive days caused an increase in the inflammatory condition although the lower limbs muscle power remained similar [23], evidencing that the neuromuscular function was not suppressed whereas the immune system of practitioners was attenuated in response to stressful exercise.

Meanwhile, it is possible to speculate that changes in neuromuscular function and other responses during a CrossFit® competition might be more pronounced and complex due to the unpredictability of the routines and to the different possible environments (e.g. at the beach and/or with elevated room temperature) that the competitor is not familiar with [10, 12]. In fact, these factors may lead to serious clinical events such as upper respiratory tract infections and injuries [12]. Therefore, the acute alterations of the different energy systems that occur in competition should be well monitored to mitigate the probability of infections and/or injuries. CrossFit® related literature is very scarce regarding the effects of a competition on internal and external load parameters.

Aim of Study

To evaluate the effect of a CrossFit® competition on participants heart rate variability and neuromuscular function. Obtained data will enable researchers and coaches to better understand what happens to the autonomic nervous and neuromuscular systems during a competition and, if necessary, to implement strategies that favor a faster recovery between exercise blocks. A more efficient management of these variables will reduce the injury risk and optimize performance.

Material and Methods

Participants

Sample comprised three CrossFit® training practitioners: one male (subject A: 30 years old, 93 kg and 188 cm) and two females (subject B: 21 years old, 68 kg and 169 cm; subject C: 28 years old, 59 kg and 164 cm) all with 17 month experience. Participants were duly informed on the research objectives and procedures, and provided a free written informed consent. Data collection was part of the routines in which competitors and coach had been assessed in the previous two weeks. Therefore, the normal ethics committee clearance was not required [28]. Nevertheless, to ensure confidentiality, all personal identifying information was removed before data analysis.

Procedures

Experimental design was divided into pre- and post-competition on days 1 and 2. Variables collected were heart rate variability, countermovement jump, rating of perceived effort and internal competition load (these two latter were not collected in pre-competition moments). Data were obtained along a two days competition

Table 1. CrossFit® competition details and time duration

Day 1			Day 2	
Event 1	Event 2	Event 3	Event 4	Event 5
32 m sprint + 20 box jumps + 20 kettlebells (best time on 10 min)	50 wall ball + 15 burpees + 40 kettlebells + 15 burpees + 30 dumbbells snatch + 15 burpees + 20 overhead squat dumbbells + 15 burpees + 10 rope climbs (as many repetitions as possible on 12 min)	(3 min) 15 clean and jerk with two kettlebells + 10 handstands push up + iso position hack with two kettlebells + 1 min rest + 15 clean and jerk with two kettlebells + 10 push up (as many repetitions as possible on 12 min)	16 m front hack lunge kettlebell + overhead lunge kettlebell + 16 deadlift + 30 air squat and iso overhead (best time on 10 min)	21, 15 and 9 pull ups + 15, 12 and 9 iso thruster repetitions (best time on 8 min)

performed on the beach comprising four qualifying events and one final dispute. Mean duration of each event was 9.4 min and included multiarticular exercises executed with body weight, squat, burpees, pushups, handstand push up and using dumbbells/kettlebells (Table 1).

Before the start and immediately after each competition day, practitioners rested 5 min to begin heart rate variability assessment. Data was collected for 1 min [15], using their Ithlete Finger sensor connected to a smartphone with the IthleteTM software (Heart Rate Variability Fit Ltd, USA), with participants keeping a spontaneous breathing [20]. The indices obtained were converted into a natural logarithm of the root mean square differences between adjacent R-R intervals (lnRMSSD) that is considered the most sensitive measure of fatigue level in a short time period [16]. After heart rate variability evaluation, subjects answered to wellbeing perception scales, sleep quality, stress, mood, muscle pain and fatigue that were listed in a 9-point scale (using the IthleteTM).

Lower limbs neuromuscular function was assessed immediately before and after each competition day by performing three repetitions a countermovement jump (with 1 min rest interval) on a platform DIN-A2 (Chronojump, Boscosystem, Spain). Using the Chronojump software to evaluate jump height it was selected the highest jump for posterior analysis. Complementarily, subjects answered to a rating of perceived effort scale varying between 0 (rest) and 10 (maximal exertion). The internal load of each event was quantified by multiplying rating of perceived effort score by the corresponding event duration, with the internal load of each day being obtained by the summing the rate of perceived effort of each event [24].

Statistical analysis

Descriptive statistics (mean ± standard deviation) was used to characterize each studied variable. Delta percentage (Δ%) between pre- and post-competition moments (T0 = pre-day 1 vs T1 = post-day 1, T2 = pre-day 2 and T3 = post-day 2) of lnRMSSD and countermovement jump were calculated as follows: Δ% = ([post – pre] / pre) × 100.

Results

Table 2 shows lnRMSSD, countermovement jump and competition internal load results and Figure 1 presents lnRMSSD and countermovement jump percentage difference between T0 vs T1, T2 and T3, and T0 vs T3

Table 2. Practitioners absolute values of the studied variables on the four monitoring moments

	Day 1					Day 2				
	T0 (Pre)		T1 (Post)		ICL (AU)	T2 (Pre)		T3 (Post)		ICL (AU)
	lnRMSSD (ms)	CMJ (cm)	lnRMSSD (ms)	CMJ (cm)		lnRMSSD (ms)	CMJ (cm)	lnRMSSD (ms)	CMJ (cm)	
Subject A	8.25	44.9	7.43	43.1	140.9	8.05	38.5	7.61	41.1	88.0
Subject B	7.94	34.5	8.25	34.9	97.6	8.53	31.3	8.19	36.6	64.0
Subject C	8.29	27.5	8.27	29.8	98.2	8.22	25.5	8.23	26.5	48.1

Note: T0 = pre-day 1 (baseline); T1 = post-day 1; T2 = pre-day 2; T3 = post-day 2; lnRMSSD – logarithm of square root of intervals R-R successive; CMJ – countermovement jump; ICL – internal competition load; AU – arbitrary units

Table 3. Pre-days 1 and 2 psychometric variables

	Practitioners					
	A		B		C	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Sleep	5	8	9	8	9	9
Stress	1	2	3	1	3	1
Mood	8	8	9	9	8	9
Muscle pain	2	2	3	2	2	2
Fatigue	1	5	2	5	2	3

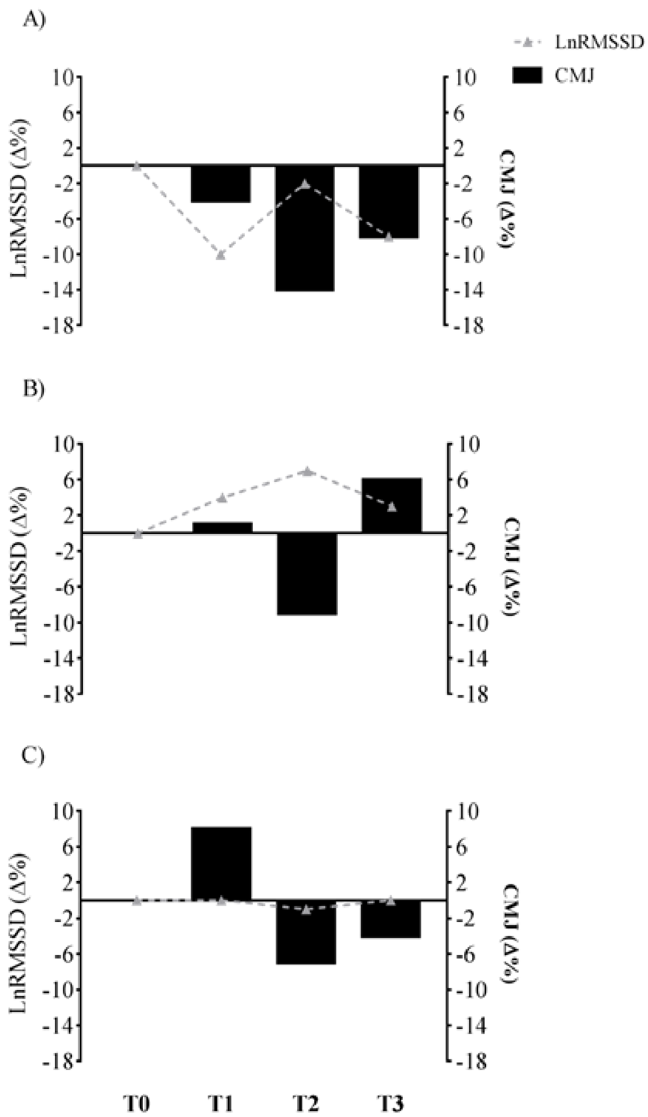

Figure 1. Delta differences percentages between T0 (pre-day 1, baseline) vs T1 (post-day 1), T2 (pre-day 2) and T3 (post-day 2) for LnRMSSD and CMJ

Note: LnRMSSD – logarithm of square root of R-R consecutive intervals; CMJ – countermovement jump

per subject. Subject A presented 9.9% decrease of lnRMSSD in the first day and was the only one showing a reduction of this variable at the end of two competition days (–8.0%). Subjects A and C presented a decrease (–8.0 and –4.0, respectively) on the vertical impulse of the countermovement jump height at the end of the competition (T3). The studied psychometric variables values are displayed at Table 3, with subject A attributing a low value to sleep quality in the first day and all subjects reporting high fatigue levels in the second day.

Discussion

The current study monitored the effects of a CrossFit® competition using internal and external load, heart rate variability and countermovement jump of three practitioners. Data have shown different responses, with male subject A presenting lower recovery of neuromuscular and nervous autonomic systems during competition and subject C decreasing countermovement jump performance from the beginning of the first competition day (T0) to the final of the second day (T3). Interestingly, female subjects B and C have not decreased their values of heart rate variability when responding to two CrossFit® consecutive days.

Heart rate variability might provide data on the homeostasis disturbances induced by physical exercise [2]. Therefore, the lnRMSSD reduction is related to fatigue accumulation and short recovery time caused by high external load stimuli in training and competition [2, 16]. This is probably due to the predominance of the sympathetic nervous system (that reduces the autonomic response), which is associated with subjects readiness and recovery when facing an aggressive stimulus (as physical exercise) [2]. In our study, female subjects B and C have not presented a heart rate variability decrease for two consecutive competition days. Conversely, male subject A showed a diminution of this variable suggesting that the competition induced suppressive effects on his autonomic nervous system (in accordance with the reported high load perception). This is in accordance with the males sympathetic nervous system predominance compared to females [21].

In addition, subject A reported a low quality of sleep (that contributes to a delay in recovery [19]) and presented a higher internal competition load on competition days. This corroborates the fact that males and females exhibit different competition approaches [3, 18], with the former emphasizing performance (they want to obtain better results than their peers) and the latter tending be more effective than in their last competition [3]. This difference might favour male subjects to execute exercises with a higher relative intensity than females contributing to a higher autonomic nervous system marker reduction [13].

Subjects A and C presented a vertical impulse decrement in countermovement jump after two competitive days, being more evident for the male subject (–8.0%). Since this variable evidence the neuromuscular system recovery status [4], it is possible that subject A might be under residual fatigue effect due to competition demands. In a previous study on the effect of the workout of the day performed in two consecutive days,

neuromuscular responses were assessed and observed no muscle power decrease [23]. Nonetheless this information is not in agreement with our findings, it should be interpreted with caution since a decrement of the immune system was also reported. The context where subjects have been evaluated might provide a possible explanation for these differences. Tibana et al. [23] evaluated muscle power in training conditions whereas the current study was conducted during a competition, probably eliciting a higher demand of the physiological systems compared to training and non-competitive context [25]. This organismic adjustment to an official competition promotes higher cortisol production [25] and a decreasing of neuromuscular function until 120 h after competition [26].
Since CrossFit® competition related research is very scarce to further understanding its demands [3] our findings should be cautiously interpreted. In fact, they are based on case reports, which might not reproduce a trustworthy behaviour of the assessed population. Furthermore, some confounding variables (e.g. nutritional status and hydration levels) might have played an important role on the results obtained before, during and after the competition. Also, our sample encompassed recreational practitioners, meaning that future studies comprising higher level practitioners are required to test if responses differ according to training level.

Conclusions

This study characterized the behaviour of internal and external load variables of CrossFit® practitioners during a competition showing a probable predominance of male subjects sympathetic nervous system after an exhaustive effort lasting two days. Complementarily, this participant presented a neuromuscular function decrease at the end of competition. This type of monitoring strategies provide data that favour a better decision making on the need of recovery strategies during and after a CrossFit® competition.

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