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Exercise-associated muscle cramps and creatine kinase responses after workload spikes in a professional soccer player: a case study

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ABSTRACT
Purpose. Exercise-associated muscle cramps (EAMC) are characterized by intense pain and involuntary contractions of a single muscle or muscle group. While EAMCs may occur during and after exercise, their precise aetiology remains unknown. However, there are some potential risk factors, as the workload of physical training previously performed. The purpose of this case report was to evaluate the acute:chronic workload ratio (ACWR) and creatine kinase (CK) concentrations in a professional soccer player to verify the potential influence of recent training history on an extreme EAMC episode and subsequent muscle damage.
Methods. A 21-year-old professional soccer player (body fat: 6.5%; body mass: 76 kg; height: 1.76 m) who experienced an extreme EAMC episode after the end of an official soccer match was monitored with session rating of perceived exertion before and after the EAMC episode and with post-match CK concentrations.
Results. ACWR revealed several spikes on the days before the match, with the highest one observed on the match day. The CK concentrations recorded 35 and 53 hours after the EAMC episode were 262% and 182% higher, respectively, than the maximal CK concentrations recorded during the season (703 U/l).
Conclusions. This case report illustrates, for the first time, how workload spikes, monitored with ACWR, preceded an extreme EAMC episode that was followed by an exacerbated muscle damage response. Some insights are provided in this case report for practitioners working in professional soccer to help them better manage similar cases.
Key words: load control, muscle damage, acute:chronic workload ratio, muscle cramps, training

Introduction

Exercise-associated muscle cramps (EAMC) are characterized by intense painful involuntary muscle contractions of a particular muscle or muscle group [1]. While EAMCs can occur during and after exercise, their precise aetiology still remains unknown [1, 2]. However, some risk factors have previously been suggested to be related to the occurrence of EAMCs, including the intensity and duration of the preceding

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physical conditioning, along with the previous occurrence of an EAMC episode, and family history [1, 3].

The occurrence of EAMC has been widely investigated in ultra-endurance sports as Ironman [4] and ultramarathon [3] races. Probably, the long duration of these competitive races is the major contributor to the higher incidence of EAMCs in endurance sports as compared with team sports [5]. It has been suggested that muscle fatigue may play a more important role than hydration status in EAMC aetiology in endurance sports [1], and that the electrolyte balance would be more important than hydration status [6]. Regarding soccer, only 2 studies have previously reported EAMC occurrence in players [7, 8]. Owing to the intense muscle contractions associated with EAMC episodes, soccer players are not able to continue the training session or the competition after an EAMC. EAMCs can result in increased skeletal muscle damage [9], which, in turn, raises the permeability of the plasmatic membrane, therefore releasing creatine kinase (CK) into the bloodstream [10]. The monitoring of CK concentrations in soccer players is a common practice because of its association with muscle damage and injury [11]. Some previous evidence suggested that EAMC could increase muscle damage [9], which has been largely associated with changes in CK concentrations after soccer activities [12]. Furthermore, increased muscle damage results in delayed onset of muscle soreness and a concomitant decrease of performance [13]. Thus, EAMC occurrence should be also taken into account for appropriately interpreting individual CK values.

Fatigue seems to be another important factor associated with the occurrence of EAMC [1, 3, 5, 14]. Fatigue may negatively influence performance, with the level of its impact depending on the fitness status of the player [15]. Acute fatigue is generally developed during the second half of the match [16], while chronic fatigue may occur owing to a congested calendar period [17]. As the improvement of fitness status is more related to chronic loads, a practical method to monitor the fitness and fatigue relationship would be the acute:chronic workload ratio (ACWR) [15]. This method has been recently proposed to monitor the training load (TL) in team sports to better identify injury risk [18–20]. This monitoring tool relates the recent workload performed in the short term, typically a single week, to the chronic workload during the recent training history, typically the average of 4 previous weeks [18]. ACWR can be calculated in different ways: with the uncoupled method [21], the coupling method [21], or exponentially weighted moving averages (EWMA) [21], with each method presenting different advantages and limitations. For instance, EWMA has been suggested to increase the relative importance of the recent loads, while, on the other hand, the coupling method equates week loads, thus decreasing the load variability between players [19]. These characteristics need to be considered to analyse TL with respect to sport characteristics and competitive calendar [21].

As EAMCs may occur after inadequate physical conditioning, it would be reasonable to consider that ACWR may reflect an inadequate loading, therefore also increasing the risk of EAMC occurrence. Thus, as ACWR has been previously used to verify if a player has undergone a workload spike [15], which could lead to augmented injury risk [1, 5, 14, 22], it may be hypothesized that a workload spike may be associated with inadequate conditioning and, consequently, with an EAMC episode during or after a competitive match.

Therefore, the objectives of the present study were: (1) to describe the training workload before EAMC occurrence in a soccer player by means of different ACWR calculations; and (2) to report CK concentrations during the recovery period after the EAMC episode.

Material and methods

A professional player (body mass: 76 kg; height: 1.76 m; body fat: 6.5% evaluated with the Jackson and Pollock method [23] for the current study) presented an EAMC immediately after a soccer match in which he acted as a midfielder. The player was 21 years old at the time of the study.

At the beginning of the year, during the preseason of the Brazilian Championship, the soccer player underwent a complete medical screening with negative results and therefore was allowed to train and compete regularly. However, the player reported a history of a previous occurrence of EAMC. He completed the Yo-Yo endurance test level 2 [24], which resulted in 2920 m, with an estimated VO_2max of 63 ml · kg^{-1} · min^{-1}.

Throughout the season, the soccer player was monitored by the session rating of perceived exertion (sRPE) [25, 26], with the minutes completed in every session and during matches also recorded. The daily TL was subsequently determined (TL [AU] = sRPE × time) [25, 26]. In addition, TL was analysed by using coupled ACWR as rolling averages by dividing the TL of the last week by the average of the TL of the 4 previous weeks (coupled ACWR = 1:4), and also by using EWMA [21, 26]. According to Malone et al. [27], an ACWR (as rolling averages) exceeding the threshold of 1.25 may indicate an increased risk of injury in professional soccer. ACWR was calculated over the 33 days before the EAMC episode.

In the middle of the competitive period (24th game of the national competition), from day 9 to day 19, the player remained under the supervision of the medical department for rehabilitation of a grade 2 muscle injury in the adductor muscle of the right thigh [28]. The injury was confirmed by magnetic resonance imaging (1.5-tesla Magnetom Vision Plus; Siemens, Germany). After the supervised rehabilitation period, the player completed an individualized physical reconditioning program of 6 days under the supervision of an experienced strength and conditioning coach, with the purpose of being prepared for regular training with the team. After this, the athlete completed 6 training sessions over 6 days with the soccer team until the day of the match in which the EAMC occurred. During this period, no other relevant issues were reported, and the player trained normally.

The hydration status was frequently evaluated during the days before the match. This is important information for discussing its possible influence on EAMC. Thus, 3 days before the match, the hydration status of the player was assessed with the urine-specific gravity method [29] (portable refractometer, ITREF-200, China). Two days before the match, the athlete travelled 2370 km by airplane to the city where the match was held. During this period, he followed the recommendations of the team nutritionist, which included standard macro- and micronutrient intake and hydration strategies.

The player completed a full match of the second division of the Brazilian Championship, which started at 21:00. The environmental conditions during the match were as follows: mean temperature of ca. 31°C and relative humidity of ca. 67%. Immediately after the match, when entering the locker room, the player experienced an extreme EAMC episode affecting various muscle groups: in the left and right hind thigh, right posterior thigh, right and left adductors, and lumbar muscles. This extreme EAMC episode lasted intermittently for approximately 25 minutes.

On the second and third days after the match, the CK concentration was assessed by reflectance photometry at 37°C with an apparatus (Reflotron Plus, Roche, Germany) previously calibrated in accordance with the manufacturer's instructions [30]. After local asepsis of the finger by using alcohol, a 30-μl blood sample was drawn into a heparinized capillary tube for analysis. This evaluation was routinely performed 35 and 53 hours after the match. The CK concentrations (Table 1) were interpreted individually [30] and were compared with the maximal CK concentration measured after the 20th out of 42 official matches, which has been suggested to be sufficient for identifying the maximal CK of a season according to Lima-Alves et al. [30]. During the 35 hours after the EAMC, the player rested and performed only a regenerative therapy characterized by the use of compression boots for 10 minutes and hydro-massage for 15 minutes; 53 hours after the soccer match, the athlete did not report any limitation for participation in the programmed tactical training session and trained normally.

All the data were collected by the first author and are presented as mean ± standard deviation. The table and the figure were created with custom-designed software (SigmaPlot v. 12.5; Systat Software Inc., San Jose, CA, USA).

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the Federal University of Minas Gerais (protocol 485.0.203.000-10).

Informed consent

Informed consent has been obtained from the individual included in this study.

Results

ACWR displayed several spikes on the days before the EAMC episode, with the highest one observed on the match day (Figure 1). The player presented a value of 1.020 g/ml of urine concentration 3 days after the match. He reported general tiredness and muscle soreness in the region of the anterior and posterior thighs 2 days after the match. The CK concentrations measured on the days after the EAMC episode were extremely high when compared with those reported during the season (Table 1).

Table 1. Creatine kinase (CK) concentration 35 and 53 hours after the match

Maximal CK concentration of the season Mean ± *SD*	703 U/l 558 ± 128 U/l
CK 35 hours after the muscle cramps Percentage increase from maximal CK concentration	1840 U/l 262%
CK 53 hours after the muscle cramps Percentage increase from maximal CK concentration	1280 U/l 182%

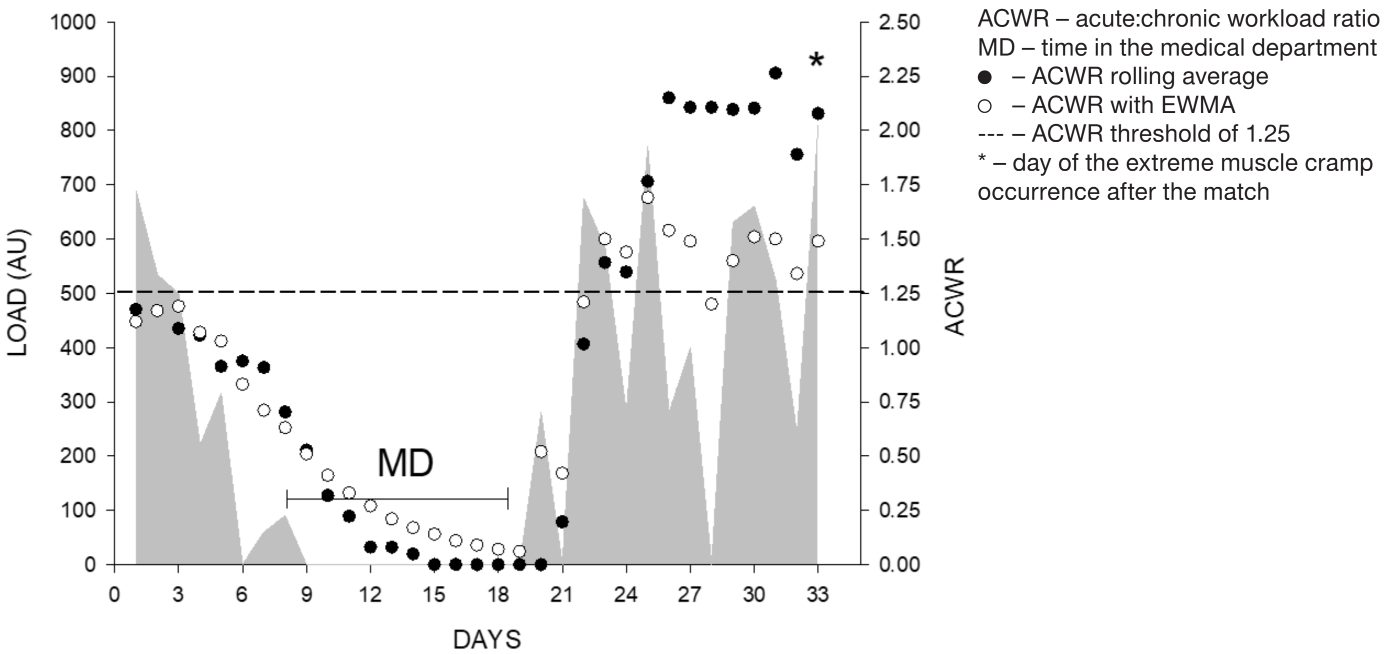

Figure 1. Monitoring of the training load expressed in arbitrary units (session rating of perceived exertion × time) and the acute:chronic workload ratio for 33 days

Discussion

To the best of our knowledge, this is the first study identifying an EAMC episode after a workload spike monitored with ACWR. In addition, the EAMC after the official soccer match was followed by an exacerbated increase in CK concentrations. The EAMC observed in the present study occurred within the 3 initial weeks of training after a break for recovering from an injury. This time window is considered a period of a more probable EAMC occurrence, possibly because of the imbalance between adaptation levels and TL [5].

The CK concentrations after the match were probably influenced by the EAMC episode, which may have generated more muscle damage and, consequently, a higher release of CK into the bloodstream [30]. According to Ispirlidis et al. [13], increased muscle damage after a soccer match may be followed by decreased performance and delayed onset of muscle soreness. The mean CK concentration of the soccer player in the present study during the season (558 ± 128 U/l) is within the range of those reported in previous studies [30, 31]. Therefore, the EAMC episode after the spike identified with ACWR may have potentiated the CK responses and thus compromised the interpretation of CK responses to exercise, as well as the athlete's recovery status. The monitoring of CK concentrations in soccer has been mostly done on an individual basis [30]. However, external factors as the occurrence of muscle injury [30] may increase CK responses. Therefore, EAMC could be also considered a factor that compromises the interpretation of CK values. Thus, when recording and interpreting the level of muscle damage from CK concentrations, the occurrence of any EAMC episode should be noted as a factor that may interfere. Another caution to be considered would be the training workload that an athlete can tolerate on the days following an EAMC episode because if they are exposed to an inadequate training workload on the days after an EAMC episode, the probabilities of another EAMC episode [5, 9, 14] and other injuries [11] may be importantly increased.

Overall, EAMCs may be provoked by different mechanisms, including neuromuscular factors [5] and disturbances of electrolyte balance [5]. Therefore, the implementation of a single strategy for EAMC prevention or treatment is unlikely to be successful [5]. In the current study, acute fatigue emerges as an important factor that may be related to the EAMC episode. When the soccer player returned to the normal training process after the medical department period, he exhibited several times an ACWR (both rolling averages and EWMA) above the threshold of 1.25, which is considered to be related to an augmented injury risk [25]. The main factor contributing to this value was the absence of training activities during the period of rehabilitation from the injury, when he showed a low chronic workload. As a consequence, several workload spikes were induced, which probably contributed to an increased level of acute fatigue [3]. As an example, one workload spike reflects that, in the last 7 days, the acute workload was greater than in the previous 28 days (i.e., chronic workload) by ca. 25% [15]. This means that there was an inadequate progression in the TL, which, in turn, led the athlete to reach an ACWR value of 2.4 on the EAMC day. In other words, the acute workload was 140% above the chronic workload on the match day. The augmented acute fatigue, added to other potentially contributing factors, such as the previous history of EAMC episodes, may have contributed to the EAMC episode on the day of the match [1, 3, 9]. However, it is unknown if the EAMC episode was more influenced by the highest workload spike on the match day or the summatory effect of several workload spikes during the previous days. Therefore, it would be advisable, in similar cases, not to accelerate the recovery process of players to avoid the occurrence of workload spikes, which would likely lead to increased injury risk.

In the present study, 3 days before the soccer match, the player presented a euhydrated status [29]. Moreover, on the days the player stayed in the Northeast Region of Brazil, because of the hot and humid environment, he was supervised by the team nutritionist to maintain appropriate levels of hydration and nutritional status. According to the literature, the occurrence of EAMC does not have a specific cause [1, 2]. However, there are 2 main factors believed to explain its occurrence: muscle fatigue and an electrolyte deficit [2, 5, 6, 14]. Thus, in the present study, despite not having a measure of the post-match hydration status, we may suggest that the electrolyte deficit was not likely the factor behind the EAMC episode. In this regard, Hoffman and Stuempfle [9] did not find an association between sodium concentration and EAMC during an ultramarathon race, while Maughan and Shirreffs [5] suggested that cramps might be associated with sustained abnormal spinal reflex activity following fatigue. Our findings are in agreement with the evidence that points out EAMC as multifactorial in nature and stemming from an imbalance between the excitatory drive from muscle spindles and the inhibitory drive from Golgi tendon organs to the alpha motor neurons. This imbalance is believed to stem from neuromuscular overload and fatigue [1, 5, 14]. Therefore, ACWR could be used to monitor TL for the prevention of acute fatigue and, consequently, potential EAMC episodes. Further studies with neuromuscular assessments would better elucidate the origin of similar EAMC episodes.

The limitations of the study are as follows: (a) the hydration status was not assessed on the match day; however, we do not expect a dehydration status on the match day because the player was under strict supervision of the team nutritionist; (b) there are no data on the intensity of muscle contractions during the EAMC episode; (c) other muscle damage markers could strengthen the characterization of our result; (d) we do not have the nutritional intake record of the player; (e) the interpretation of the ACWR calculations should take into consideration their mathematical characteristics and sport-specific competitive calendar [21]. However, owing to the unpredictability of EAMC episodes occurrence, it was not possible to be prepared to appropriately monitor all these factors.

On the basis of the current case report, we may suggest some practical applications. First, workload spikes, which can be easily monitored with ACWR, should be avoided as they may increase the odds of EAMC episodes. However, it is still to be solved if a more conservative approach after the rehabilitation period would be enough to avoid the workload spikes. Second, the occurrence of an EAMC episode may not allow the correct interpretation of CK values within the normal variability range of an individual athlete. Therefore, strength and conditioning coaches and other staff professionals should also monitor the occurrence of EAMC episodes of different grades to appropriately interpret CK data on an individual basis [32].

Conclusions

This case report illustrates the occurrence of an extreme EAMC episode after a workload spike monitored with ACWR in a professional soccer player. The episode was followed by blood CK concentrations beyond the normal individual range. From the current results, we may suggest that the odds of EAMC episodes may be further increased after workload spikes and that CK values after an EAMC episode should be analysed with caution when used as markers of exercise-induced muscle damage. Therefore, progressive loading should be recommended during the recovery period after an injury to avoid any load spike. An EAMC episode may be considered a factor that influences CK responses to exercise.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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