Case Report

Hyperbaric oxygen therapy as treatment for bilateral arm compartment syndrome after CrossFit: case report and literature review

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ABSTRACT

Introduction: CrossFit is a physical fitness program characterized by high-intensity workouts that can be associated with serious injury. Acute compartment syndrome in the upper limbs is a rare occurrence. It may occur after intense physical exercise, and its usual treatment is surgical. Hyperbaric oxygen therapy is a treatment described as adjunctive in cases of compartmental syndrome.

Presentation: We describe the case of a CrossFit practitioner who, after intense training, developed progressive symptoms of rhabdomyolysis and acute bilateral arm compartment syndrome, who was successfully treated with hyperbaric oxygen therapy and required no fasciotomy as surgical treatment.

Conclusion: Acute compartment syndrome in the arms after intense physical exercise is a rare occurrence that should be suspected by practitioners of physical activity experiencing intense, disproportionate and progressive pain. In the case presented, hyperbaric oxygen therapy was successfully used in the treatment of the disorder, with satisfactory progress, and without the need for a surgical fasciotomy as therapy.

KEYWORDS: hyperbaric oxygen therapy; acute compartment syndrome; CrossFit; fasciotomy

INTRODUCTION

CrossFit is a physical fitness program characterized by sessions that utilize a variety of exercises, from running and rowing to Olympic lifting and gymnastics movements [1], which currently has many adherents in the physically active population [2]. The workouts are performed at high intensity, quickly, in successive repetitions, with limited or no recovery time [1]. The practice of intense exercise, however, may be associated with serious injuries. According to Bergeron [3], despite the benefits of intense physical fitness programs, there is concern about the rate of injury of its practitioners.

Acute compartment syndrome (ACS) in the upper limbs is a rare entity [4], usually traumatic and related to forearm bone fractures, but it may occur after intense physical exercise [5,6]. ACS is frequently associated with rhabdomyolysis, which requires immediate treatment due to the risk of severe renal repercussions [7,8]. The usual treatment of ACS is surgical, through fasciotomy of the affected limb [4]. Aynardi [5] reported a patient with intense pain in both arms after vigorous cross-training, which developed over the course of three days, who was diagnosed with post-exercise rhabdomyolysis plus ACS of the arms, and who underwent surgical treatment with bilateral fasciotomy.

Hyperbaric oxygen (HBO_2) therapy is a treatment described in the medical literature as an adjunct in cases

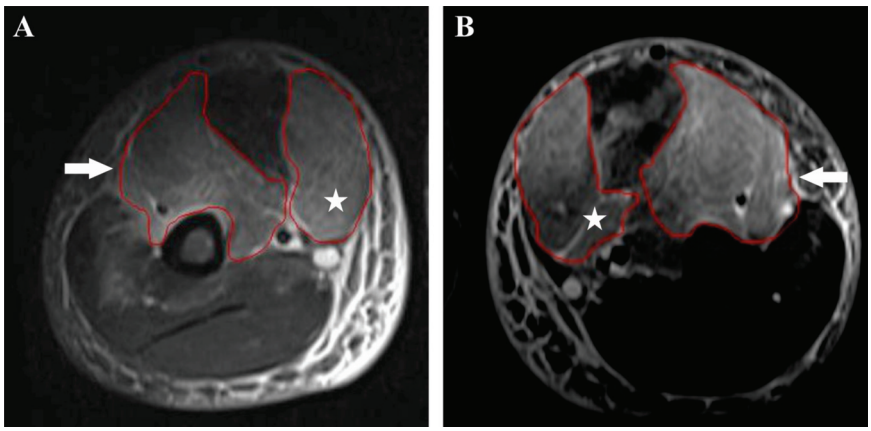

FIGURE 1. Magnetic resonance imaging of the arms, taken at 72 hours of evolution

A: UPPER RIGHT MEMBER

Highlighted: ⇨ Biceps brachii (short head belly) with an area of 17.45 cm^2
☆ Coracobrachialis with an area of 12.54 cm^2

B: UPPER LEFT MEMBER

Highlighted: ⇨ Biceps brachii (short head belly) with an area of 18.02 cm^2
☆ Coracobrachialis with an area of 12.29 cm^2

of compartment syndromes [9-12], since the combination of fasciotomy and HBO_2 reduces the edema and necrosis of the muscle tissue [9]. There are no descriptions regarding the use of HBO_2 as the principal therapy for the treatment of ACS. We describe the case of a CrossFit practitioner who, after doing intense training, developed progressive symptoms of rhabdomyolysis and bilateral ACS of the arm, who was successfully treated with hyperbaric oxygen therapy, and required no surgical treatment.

METHODOLOGY

Along with the case description we developed a narrative review of the medical literature, the PubMed database, using the terms *acute compartment syndrome, delayed onset muscle soreness, Crossfit,* and *hyperbaric oxygen therapy*. The study follows the specifications of the CARE Guidelines [13] for case reports.

CASE REPORT

A male patient, a 29-year-old lawyer, engages in regular physical activity He had no history of anabolics use or previous upper limb injuries, and has been practicing CrossFit for six months. He participated in a CrossFit class that included high-intensity movements and many repetitions for upper limbs (i.e., pull-ups and push-ups). He said that he felt fatigue in the upper limbs after the session, without pain. After 24 hours, he noticed the onset of swelling in the arms, combined with discomfort upon extension and a darkening of the urine. He used painkillers and rested. After 48 hours, he observed a worsening of the edema, with great pain in extending the elbows. His urine remained dark, without other symptoms. After 72 hours, still in persistent intense pain, he sought our services for evaluation.

TEST RESULTS

Physical exam: edema in the arms, with pain on palpation of the middle and distal third of the arm, mainly in the right arm; pain in passive extension of the elbows (VAS 9+/10+); range of motion (ROM) in elbow flexion 130, extension –45; free pronation and supination; full ROM of the fingers; no perfusion deficits; no paresthesia of the fingers; radial and ulnar wrists preserved, bilaterally. Circumferences of the arms (measured at the middle to distal third transition): right (R) = 39.5 cm; left (L) = 39 cm.

Laboratory tests: myoglobinuria (3+/3+); total creatine kinase (CK) = 40,000 U/L (Ref. 35 to 232 U/L); serum creatinine = 1.1 mg/mL (Ref. 0.8 to 1.2 mg/mL).

Imaging exams: radiographs without signs of fractures; magnetic resonance imaging (MRI) of the arms (Figures 1A and 1B) show hypersignal on T2 in the

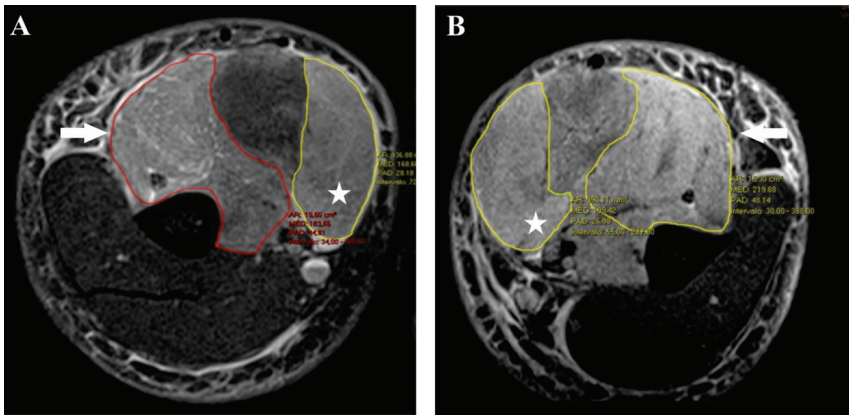

FIGURE 2. Magnetic resonance imaging of the arms, taken six days after the injury and after three days of HBO_2 treatment

A: UPPER RIGHT MEMBER

Highlighted: ⇨ Biceps brachii (short head belly) with an area of 15.65 cm^2
☆ Coracobrachialis with an area of 12.54 cm^2

B: UPPER LEFT MEMBER

Highlighted: ⇨ Biceps brachii (short head belly) with an area of 15.30 cm^2
☆ Coracobrachialis with an area of 12.29 cm^2

coracobrachial and biceps muscle topography, R and L, with no signs of muscle rupture or ischemia.

Therapeutic conduct: Given the suspicion of bilateral ACS associated with rhabdomyolysis, the option taken was for immediate onset of treatment with hyperbaric oxygen therapy at 2.3 atmospheres absolute (ATA) for 90 minutes. After the first session, the patient reported improvement in pain (VAS 9 to 6), with a 1.5cm decrease in the diameter of each arm. In addition, intravenous hydration was started with 3 liters of 0.9% saline solution and hydroelectrolytic control.

On the following three days, the patient continued hyperhydration and HBO_2 therapy twice daily, with an average of 2.5 ATA on each occasion. At the end of the third day of treatment, the patient reported mild discomfort in the arms, pain (VAS 1/10), full ROM of the elbows, arm circumference of 36cm each. New MRI exams (Figures 2A and 2B) demonstrated a decrease in anterior compartment volume, with a significant regression of coracobrachial and biceps brachii edema, bilaterally; lab tests showed a creatinine of 0.9, with CK at normal levels.

After 15 days, the patient was asymptomatic, with full range of motion, improvement in laboratory tests, and was released for gradual return to sports. At the six-month follow-up, he remained asymptomatic, already doing his weekly CrossFit sessions, with no reports of new similar episodes.

The full evolution of the case can be seen in the timeline (Table 1).

DISCUSSION

The practice of CrossFit is frequent in our context, and can be related to injuries. Hak, et al. [14] report that in the practice of CrossFit, shoulder and lumbar spine are the most frequently injured regions. Giordano and Weisenthal [15] state, in a study with 386 CrossFit participants, that the lesion rate of their sample was 2.4 lesions per 1,000 hours of practice, equivalent to doing a triathlon. We described the case of a CrossFit practitioner who suffered a serious injury, ACS, after intense exercise. The injury was associated with rhabdomyolysis and was treated primarily with HBO_2. Without the need for fasciotomy, the patient was able to avoid extensive surgical scars and possible elbow movement deficits. Aynardi and Jones [5] described a case similar to ours: A patient reported progressive pain in the arms after intense physical activity, with a progressive three-day course of pain, diagnosed as bilateral ACS and treated with bilateral fasciotomy. In the follow-up after three months the patient demonstrated good healing, but with a 15-degree restriction in extension of the elbow.

TABLE 1. Timeline

time / activity	signs and symptoms	conduct
0h – CrossFit finished	fatigue in the upper limbs	rest
24h	pain in elbow extension, swelling in the arms, darkening of the urine	analgesic and rest
48h	worsening edema, worsening pain in extension, darker urine	continue rest and analgesics
72h – medical evaluation	non-pitting edema, 9+/10+ pain, hard swelling (see report) MRI, arms with anterior compartment edema	**begin HBO_2 at 2.3 ATA**
final session #1	pain 6+/10; reduction of 1.5 cm in diameter of the arms	continue HBO_2 2x/day, 2.5 ATA plus hydration and rhabdomyolysis treatment
6 days after CrossFit (after HBO_2 session # 5)	mild upper limb discomfort pain 1/10, full extension of the elbows (see report) clear urine	**end of HBO_2 sessions** MRI control: see report lab tests: see report
15 days after CrossFit	asymptomatic	**released for work activities**
six months	asymptomatic	regular CrossFit practice, with respect to pain threshold

Kiberd and Campbell [8] reported a case of rhabdomyolysis after weight lifting training. The patient was treated with aggressive venous infusion. The literature shows that the practice of strenuous exercise is associated with the onset of rhabdomyolysis [8,9]. In our case we observed the increase in creatine kinase and creatinine levels, compatible with the diagnosis of rhabdomyolysis, and that it improved with the therapy established. Therapy for rhabdomyolysis treatment with adjunctive HBO_2 has also been described by Abdullah [9].

ACS was first described by Volkmann in 1881, when he reported irreversible muscular contractures due to muscle ischemia [16]. Hildebrand, in turn, was the first to suggest that elevated pressures could be related to muscle ischemia, and Bardenheuer suggested surgical treatment through decompressive fasciotomy [17]. ACS is related to major trauma [4] and its diagnosis is imminently clinical. Its main symptom includes intense pain in passive joint movement that is resistant to the use of analgesics [4]. The symptoms are progressive, and the diagnosis is made after a period of observing the patient. Paresthesia and motor deficits occur later on [4]. Von Keudell, et al. [4] affirm that the progression of ACS cases is rapid and that its usual treatment is surgical decompression of the compartments.

HBO_2 therapy is an intervention in which the individual breathes oxygen intermittently at 100% concentration while remaining inside a hyperbaric chamber. The chamber is pressurized with values above sea-level pressure (1 atmosphere absolute, or 1 ATA) (18). For clinical purposes, the pressure within the chamber should be at least 1.4 ATA while breathing 100% oxygen [18]. HBO_2 is a well-established treatment in the medical literature for cases of diabetic foot, necrotizing fasciitis, wound healing, diving disorders, sports injuries, and for adjunctive use in cases of compartment syndromes [9-12].

According to the Undersea and Hyperbaric Medical Society (UHMS), HBO_2 therapy can be used to treat cases of ACS [18]. Strauss [19] divides ACS cases into three categories: suspected, imminent and established. According to the author, if it is not possible to measure the intracompartmental pressure, the diagnosis of the degree of ACS can be clinical. Imminent ACS is characterized by progressive pain, hyperesthesia, decreased strength, discomfort in passive extension, or increased tenderness on palpation of the compartment. These signs and symptoms would be indications for primary HBO_2, two daily sessions, without the need for fasciotomy [19]. Our patient presented the characteristics of imminent ACS, which fit the profile for primary

HBO_2. Furthermore, the 72-hour period of evolution of the condition and the absence of neurological deficits favored a non-invasive treatment option, but one that would reduce aggression in the compromised region. With HBO_2 therapy used in combination with the clinical support of vigorous adjuvant hydration for the treatment of rhabdomyolysis, it is possible to have a favorable resolution without the need for fasciotomy.

HBO_2 therapy is used successfully in adjunctive treatment of ACS, as well as other orthopedic lesions [11]. Skyhar demonstrated muscle weight reduction and regression of edema of the anterior leg compartment [11]. Webster, et al. [12] observed that individuals who performed strenuous eccentric exercises in the gastrocnemius muscle and received HBO_2 treatment afterward had improved recovery compared to the group without this therapy.

The main differential diagnosis for post-exercise ACS is delayed onset muscle soreness (DOMS) [7,20], which is characterized by intense limb pain, edema and weakness, which appear between 12 and 24 hours after exercise, and improve in up to seven days. This treatment observed in the great majority [21]. Differentiation between ACS and DOMS is not well established in the literature, but the two have distinct treatments: ACS has an essentially surgical treatment [17], while treatment for DOMS is commonly clinical, with rest, analgesics, cryotherapy, massage and stretching [22]. We believe that the patient's symptomatology did not fit the usual cases of DOMS and ACS, although the progressive increase of his symptoms – mainly pain and limb edema – is more characteristic of ACS. HBO_2 can be used as adjunctive treatment for DOMS, as it has proven to be effective in reducing the duration of pain [22] and, in the present case, was used successfully as a therapy in ACS.

In severe cases of DOMS as well as in ACS, rhabdomyolysis can coexist with either of the two injuries. This requires treatment with intravascular volume expansion, carefully observing serum creatine, creatine kinase, and electrolyte levels due to the high risk of renal failure [23]. In this reported case, the patient presented good responses to the treatment of rhabdomyolysis.

Complementary exams may assist in the diagnosis of ACS. The measurement of intracompartmental pressure is the method of choice [24], but it is invasive and was not available in our situation. MRI allows assessment of the involved muscle groups and the extent of impairment. It can reveal possible irreversible damage and secondary complications in chronic cases [25,26]. The initial findings from MRI in ACS are non-specific [27] and are characterized by diffuse swelling of the muscle belly of a compartment, with loss of muscle septations on T1 and signal hyperintensity on T2 [28]. There is also a volumetric increase and loss of the usual pattern of muscle striations [24,29]. If there is an intramuscular hemorrhage component, the signal intensity on T1 can be increased [25,26,29]. The use of an intravenous contrast agent (gadolinium) is important for detecting possible areas of necrosis in more severe cases, characterized by areas that are not penetrated by the contrast agent due to reduced vascularization [25,26,29]. In the examination of the patient in question, no areas with evidence of myonecrosis were found, which supported the option for non-interventional therapy.

As a positive point of the case, we can emphasize the successful therapy, without surgical intervention, without having to submit the patient to a surgical procedure with its inherent risks and probable aesthetic consequences. However, it is important to stress that if there is no satisfactory evolution, HBO_2 therapy should not delay the fasciotomy procedure, and should be used as an adjunctive method postoperatively to help reduce edema and in wound healing [19].

Patient perspective

"My experience with the hyperbaric chamber treatment lasted about five sessions. In the first session, I had a great sense of relief knowing that there was a chance of not being operated on. Except for a bad feeling of anxiety, from the second to the fifth session, I had no pain, no trouble breathing, dizziness, or anything strange, neither during nor after the sessions. Without a doubt, a great treatment alternative saved me from a complicated surgery."

CONCLUSION

ACS in the arms after intense physical exercise is a rare occurrence. However, it should be suspected by practitioners of physical activity who experience intense, disproportionate, and progressive pain. We describe the case of a CrossFit practitioner who, after an intense training session, progressed with rhabdomyolysis and ACS of the arms, who was successfully treated with primary HBO_2, without the need for fasciotomy.

In select cases, HBO_2 may be the main treatment for ACS, but more studies are needed on the criteria that are used in this choice. ■

Ethical considerations

The study presented was approved by the ethics committee of the institution where it was developed, under protocol 65637516.2.0000.5133; The report received consent with the patient's authorization.

Conflict of interest statement

The authors report that no conflicts of interest exist with this submission.

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