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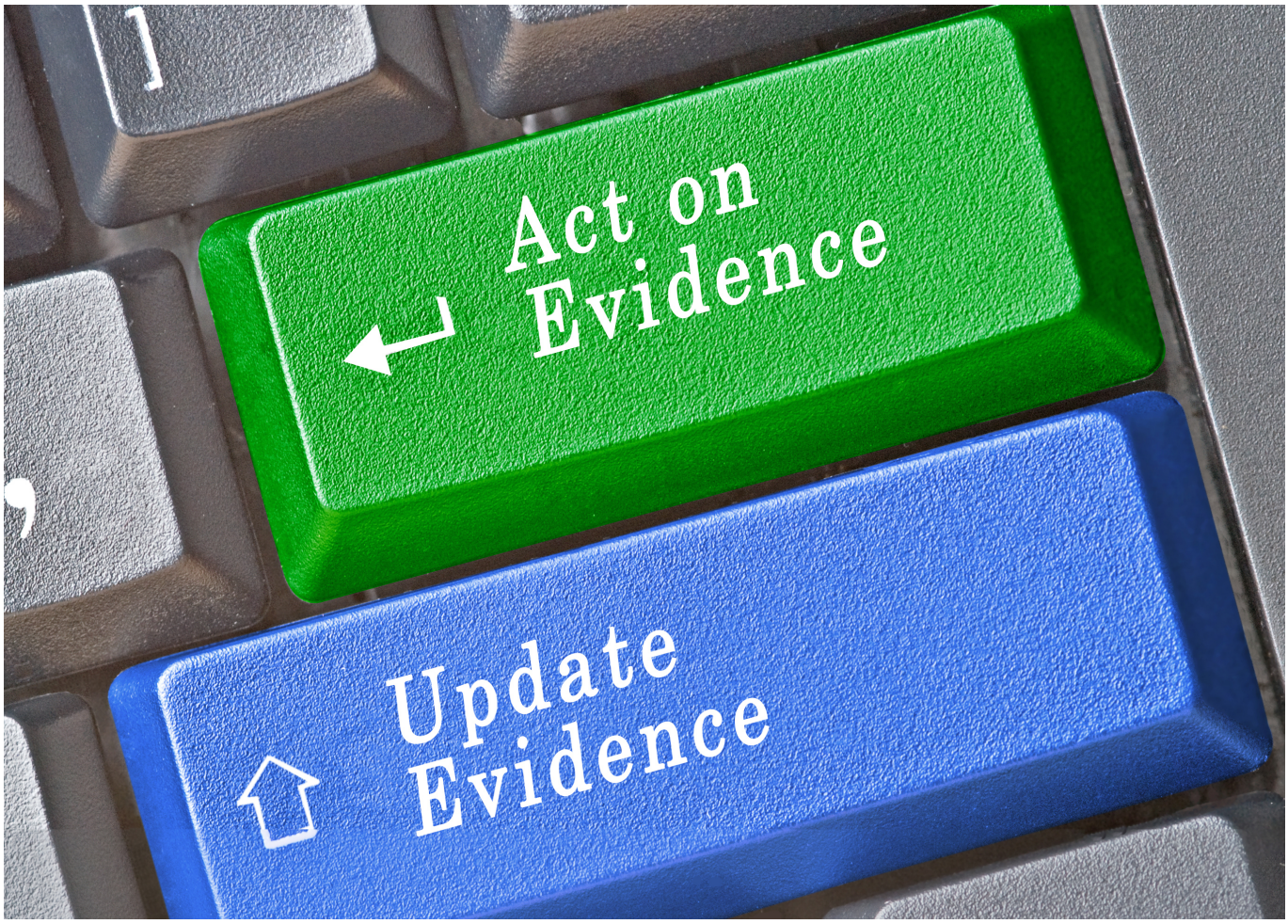
REVIEW

Evidence-based Treatment of Muscle Injuries

MUSCLE / MUSCLE / RTS / SPORTS INJURY / SPORTS PHYSIOTHERAPY



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Abstract

Injuries to skeletal muscle can pose a severe challenge for any team physician or medical professional. They account for up to one third of all sports-related injuries and can result in weeks of recovery and absence from play. Crucial in the successful treatment is the accurate classification of the type of injury, be it fatigue, structural or chronic. The PRICE protocol is a well known first step in the initial treatment, but its shortcomings should be recognized and considered. Currently, a more active treatment approach with early mobilization and moderate activity is being advocated. Chronic muscle problems, such as chronic

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exertional compartment syndrome (CECS), are among the very few indications for surgical treatment.

Zusammenfassung

Muskelverletzungen können eine ernsthafte Herausforderung für Teamärzte und medizinisches Personal darstellen. Sie machen knapp 30% aller Sportverletzungen aus und können wochenlange Rekonvaleszenz und Spielabsenzen nach sich ziehen. Für die erfolgreiche Behandlung ist es daher wichtig, eine genaue Einteilung der Art der Verletzungen zu verfolgen, um Ermüdung, strukturelle und chronische Schäden abzugrenzen. Das PRICE-Protokoll ist ein wohlbekannter erster Schritt der Behandlung, aber die Nachteile müssen erkannt und bedacht werden. Gegenwärtig wird eine aktivere Behandlungsstrategie mit früher Mobilisation und moderater Aktivität unterstützt. Chronische Muskelprobleme, wie das chronic exertional compartment syndrome (CECS), gehören zu den wenigen chirurgischen Indikationen.

Introduction

Muscle injuries are known for three characteristics: (I) They are more frequent than commonly accepted, accounting for up to 30% of the overall burden of injuries in soccer [1,2], and ranging among the top five injury patterns in ice hockey [3]. (II) They are frequently underestimated in their severity, when, in fact, they can dramatically affect performance over an extended period of time or even lead to severe health problems [4,5]. (III) Treatment is in many cases still empirical, based on personal experience or anecdotal data, with a poor penetration of the current evidence [6].
However, over the last few years, a considerable body of hard evidence concerning the nature and treatment of muscle injuries has been brought forward. Also, our knowledge of ways to prevent muscle injuries has substantially expanded. It is the purpose of this paper to review the current best evidence for the treatment of athletic muscle injuries. To this end, this text will approach the topic from two angles: first, broken down by select type of injury, followed by second, a per-treatment analysis.

Methods

A systematic search for studies pertaining to the subject was performed in the online databases PubMed, EMBASE, and CINAHL. The search algorithm was kept deliberately inclusive as: *"muscle injury" AND "treatment" NOT ("Tendon" OR "Ligament")*. Given the overwhelming number of eligible studies with an insurmountable level of clinical heterogeneity, no formal quantitative data synthesis was attempted, but a descriptive review of the current evidence was performed.

Results

Evidence-based treatment of muscle injuries

by (select) type of injury

Various classifications systems for muscle injuries exist, based on pathomechanism, acuity, extent of the lesion and loss of function. Only in 2012, a new classification has been put forward from the Munich Consensus Statement [7]. This very detailed classification has been validated, and shown to be able to

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predict return to sport in a reliable manner [8]. (Table 1)
In a 2013 study, Ekstrand et al prospectively followed 31 European professional male football teams competing in the 2011/2012 season [8]. They found 393 muscle injuries, 258 (66%) of which were partial muscle tear (type 3), 86 (22%) were overexertion-related muscle disorders (type I), making types III and I the most common muscle injuries.
However, in the daily practice of most sports medicine specialists, professional soccer players make up a lesser part of the patient population than aspiring young athletes and weekend warriors. Particularly among the former, chronic exertional compartment syndrome (CECS) is an increasingly common problem affecting the leg musculature [9].

Structural muscle injury – Partial muscle tear
(type III Munich Consensus)
These acute, indirect injuries to muscles occur due to a mismatch in external stress and internal muscular resilience, most commonly a forceful, eccentric contraction of an overstretched, biarticular muscle. The patient typically reports a tearing sensation, followed by immediate, localized pain.

	Differentiating Features Athletes Heart	**Differentiating Features Myocarditis**
Symptoms	**Asymptomatic**	**Symptomatic**
ECG/Holter	1. Specific ECG changes such as early repolarization/ST segment elevation, T- wave inversion in V1–V3 in the young, ST-elevation followed by T-wave inversion V1–V4 in black athletes.	1. Unspecific ECG changes. Possible PQ depression, ST-elevation in multiple leads.
Biomarkers/Inflammatory markers	1. Troponin elevation only mild and normalizes quickly. May be present in ultra-endurance athletes. 2. Others: Brain natriuretic peptide mildly elevated after ultra-endurance exercise	1. Troponin elevation mild to high 2. Others: Brain natriuretic peptide elevation, Creatine-Kinase, Leucocytosis, elevated C-reactive Protein, elevated Erythrocyte sedimentation rate
Table adapted from Eichhorn C. et al. JACC Cardiovasc Imaging, 2019.		

From: Mueller-Wohlfahrt H-W, Haensel L, Mithoefer K, Ekstrand J, English B, McNally S, et al. Terminology and classification of muscle injuries in sport: the Munich consensus statement. BJSM 2013;47(6):342-350

Most often, these injuries occur at or near a muscle-tendon junction. A palpable defect and/or a loss in function (=type IIIB) correlate with a prolonged recovery and a higher chance of scar tissue formation rather than restiutio ad integrum.
The process of muscle healing starts with an acute phase lasting roughly 3 to 5 days. During this initial period, the main objective of treatment is limiting further injury by minimizing bleeding and edema. The (P)RICE principle, consisting of Protection, Relative Rest, Icing, Compression, and Elevation has been heavily tested in the last couple of years, and prevailed [10]. Anti-inflammatory medication (NSAIDs) is a valuable addition in this limited window of time. Other supportive techniques, such as ultrasound therapy or kinesiotape, are being intensively investigated for their use in the acute phase [10]. The results of this

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research are summarized further below.
The exact end of the first phase is difficult to establish, but for the use in the field, the third or fourth day after injury can be used as a general guide. If at that point no sufficient improvement in injury progression has been observed, further imaging, such as ultrasound (US) or MRI, should be obtained to rule out an extensive structural lesion or a sizable hematoma. Imaging before 24h (MRI with fat suppression) to 48h (US) after injury usually will not produce accurate results [11]. There is a proportion of muscle injuries, especially in the hamstrings, that is associated with false negative findings on MRI! [12], suggesting to make the diagnosis of a type III injury primarily from clinical findings (history, localized pain, increased pain with passive stretch, possibly palpable defect, no loss of function yet).
If the patient shows satisfactory improvement, a more active treatment regimen is to be initiated. It is commonly accepted to progress the patient from isometric to isotonic and finally isokinetic training, each starting with no resistance and then gradually increasing weight. The key marker allowing for transition into the next level of training is pain free completion of the prior exercise. In this phase, icing and medication such as NSAIDs have been shown to have detrimental effects on muscle healing, as is true for prolonged immobilization.

Overexertion-related muscle disorder
Delayed onset muscle soreness (DOMS) is diagnosed from pain even at rest over a complete muscle group 24–72h after exercise, reduced strength and limited range of motion temporarily interfering with athletic performance and the ability to continue effective training.
Most commonly, NSAIDs are sought to alleviate the typical symptoms [13]. In individuals older than 60, it has been suggested, that there might be a use for prophylactic administration as well [13]. Massage therapy has been shown to reduce DOMS and muscle swelling by up to 30% [14]. Both cryotherapy and contrast water therapy have been shown to be (about equally) effective in treating DOMS [15,16]. Finally, compression garments have proven effective as well, but only to about half the extent of cold and contrast therapies [17].

Chronic muscle injury / CECS
CECS is a temporary increase of intracompartmental pressure with activity, most frequently in adolescent female runners. Originally believed to primarily affect the anterior compartment of the leg, recent research has revealed this to be a multicompartmental disease, yet with different levels of severity among the compartments [9].
The diagnosis is fairly easily established by measuring compartment pressures pre-exercise and at 1 and 5 minutes post-exercise, but a high level of clinical suspicion is sometimes needed to order the test [18].
While conservative treatment is the first line of management of CECS, a large portion of patients will progress to surgical treatment. Endoscopic fasciotomy can be done as a minimally invasive procedure, resulting in >80% success. There is a risk of recurrence, which is 4-times higher if only a single compartment is treated [9].

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Evidence-based treatment of muscle injuries

by type of treatment

Cryotherapy

Cryotherapy is among the best known and most widely spread modalities to manage pain and swelling in a low-cost, easy accessible and high-impact fashion. Current evidence shows beneficial results for the use of cold therapy. There is no final recommendation as to how to perform cryotherapy, but temperatures around 10° to 15°C, applied locally for 10–15 min every hour have produced reliable results. Lower temperatures can lead to vasodilation, and longer exposure can slow metabolism and may cause tissue damage. In the early 2000s, cryotherapy had come under intense scrutiny because of potentially causing interruptions in muscle healing [19]. However, subsequent studies did not find changes in intra-muscular gene expression after well balanced cold exposure [20,21].

Somewhat recently, whole-body cryotherapy, where the patient is exposed to ambient temperatures of about -110°C for 2–5 minutes, was introduced. A recent Cochrane trail failed to find evidence in support of this treatment, and it obviously refutes any claims of low-cost and ubiquitous availability [22].

Another alternative form is contrast water therapy (CWT) [16], i.e. the alternating exposure to or immersion in hot/warm and cold water. The synthesized data from a range of studies has shown, that CWT affords a positive effect on strength and soreness in overexertion-related muscle damage(16). The exact mechanisms of these effects are still unknown.

NSAIDs

Nonsteriodal anti-inflammatory drugs have an extremely high availability for the use in pain and swelling. In the short term, they have been shown to improve exercise-induced soreness from DOMS. It has also been demonstrated that the analgesic effect correlates to the level of soreness [23]. However, recent data has shed light on detrimental effects of NSAIDS in muscle healing after injury. Animal research has shown that NSAID reduce muscular adaption processes [24], but there is also human data published that reveals a reduction in post-exercise muscle protein synthesis after ibuprofen or acetaminophen use [25]. These findings underscore that NSAID can have a detrimental effect on both muscle healing after injury and muscle adaption to exercise. However, in the limited, short term management of strength loss and soreness, NSAIDS have proven their effectiveness [26].

Compression garments

Compression garments have become very popular for postulated improvements in athletic performance and fastened recovery after exercise. Studies assessing running performance in marathon runners and triathletes were able to produce data in support of better performance with compression garments or less soreness after exercise [27,28].

Two recent meta-analyses collected and analyzed the available evidence on the use of compression garments in post-exercise recovery. While both studies' authors stress the high levels of clinical heterogeneity amongst the included primary studies, the found a consistent – and moderately sized – positive effect on recovery and muscle function [17, 29].

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Stretching

Both stretching and warm-up are standard practice in almost all sports at practically all levels. However, the literature fails to support the use of stretching before or after exercise to reduce muscle injury risk or DOMS on a clinically relevant scale [30]. Of course, this does not negate the other benefits of regular stretching and good joint mobility. Of note, while stretching failed to reach defined thresholds of clinical and statistical significance, pre-exercise warm-up has been shown to reduce overall and muscle injury rates [31,32]!

Massage Therapy

Post-exercise massage therapy has been shown to reduce subjective sensation of DOMS and provide a heightened perception of recovery, especially in the first 48h after exercising [14,33]. Interestingly, this subjective improvement could not be corroborated by increased muscle blood flow, capillary exchange, or blood lactate removal [34]. Hence, the exact mechanism of this clinical improvement remains elusive.

Platelets/Autologous Blood

Autologous blood preparations or platelet concentrates are currently found in virtually all areas of sports medicine, also in muscle injury treatment. The application of the patient's own blood as a source of growth factors is hoped to promote healing ad integrum over scar formation. However, high level-of-quality randomized controlled trials and systematic reviews on the topic failed to produce data in favor of such treatment [35,36].

Hyperbaric Oxygen

Hyperbaric oxygen therapy has a consistent track record of improving muscle healing in animal studies. However, trying to translate these findings into potential human treatments, controlled trials have not revealed beneficial effects on experimentally induced DOMS [37]. At the same time hyperbaric oxygen therapy has an inherent risk of severe iatrogenic damage, which, together with the high cost of treatment, needs to carefully balanced against potential benefits.

Electromyostimulation

Electrical stimulation of skeletal muscle is a valuable tool in plegic patients with spinal cord injury [38]. It has been postulated that the same electrically stimulated muscular contractions will exert a beneficial effect on muscle damage. However, while some studies showed an positive net gain in muscle strength from using electrical stimulation in training [39], no beneficial effect on muscle injury or DOMS could be found thus far. One recent systematic review showed not difference between electrical stimulation options and passive recovery [40].

Interventional treatment

Generally speaking, muscle injuries do not lend themselves to surgical treatments. Yet, as with every rule, there are exceptions. (1) Patients with large hematomas will benefit from aspiration or drainage. Patients with hemophilia, or anticoagulation, with hypertension or participating in contact sports are more prone to larger hematoma formation. Smaller hematomas may warrant drainage if they result in compression of

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nerves or vascular structures. (2) Swelling or bleeding causing compartment syndrome should be treated as a surgical emergency. (3) Complete disruption of a muscle with corresponding loss of functions should trigger the discussion of a possible surgical intervention. Given the friable nature of the muscle tissue, direct end-to-end repair is difficult and usually not mechanically strong. Various suture configurations or artificial materials can be used to augment such a repair.

Others
Various other treatment options exist, including various types of injections, growth factors, low-level laser therapy, ultrasound, and natural remedies. A full description is not possible within the scope of this paper.

Return to sport after muscle injuries

The prime objective in dealing with muscle injuries is to allow a timely, yet safe, return to sport for the affected athlete. Little surprising, it has been shown that the severity of muscle trauma corresponds well with the duration of recovery. In the above-mentioned study of professional soccer players, it was shown, that type I injuries (Overexertion-related muscle disorder) result in a mean absence from play of between 5 and 8 days. Partial muscle tears (type III) caused between 16 and 38 lay-days, or 5 weeks of absence from play. A complete muscle injury resulted in 62 days of recovery.

Discussion

Muscle injuries in sports tend to be somewhat underestimated, when in fact, they are very frequent and can cause severe disruptions in athletic performance. Furthermore, despite the best efforts of numerous physicians and scientists, there is still a considerable lack of knowledge in this field.
Protective treatment and rest are warranted in the very early phase of a muscle injury to avoid further damage. The current evidence supports early mobilization with moderate, well dosed activity, resulting in improved vascularization and quicker recovery of the damaged area.
NSAID and cryotherapy have been suggested to harm muscle healing by reducing beneficial inflammatory processes, slowing down the overall metabolism at the injury site, and affecting genome expression. The current evidence cannot prove or refute these claims with certainty, but both modalities should be sparingly administered.
Currently, ways to enhance biological healing are being intensively studied. The local injection of growth factors holds promise of improving and accelerating healing, but there might be unwanted interactions.

Acknowledgments, conflict of interest

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Practical implications

- Muscle injuries are very frequent, accounting for up to 30% of all sports injuries.
- The PRICE protocol is still valid for early treatment (3–5d), but should be discontinued thereafter
- Clinical classification of the injury will allow choosing an appropriate treatment and predicting the duration away from play. Imaging can be done via MRI or ultrasound from very early stages, but can be misleading
- No single best treatment option exists for muscle injuries. The right mix and number of treatments has to be selected together with the patient, his trainers and coaches and the medical team. Surgical interventions are rarely needed.

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CHRONIC EXERTIONAL COMPARTMENT SYNDROME CRYOTHERAPY DELAYED ONSET MUSCLE FATIGUE HAMSTRING MUSCLE TEAR