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Muscle injuries: optimising recovery

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Muscle injuries are one of the most common traumas occurring in sports. Despite their clinical importance, there are only a few clinical studies on the treatment of muscle injuries. Lack of clinical studies is most probably attributable to the fact that there is not only a high heterogeneity in the severity of injuries, but also the injuries take place in different muscles, making it very

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demanding to carry out clinical trials. Accordingly, the current treatment principles of muscle injuries have either been derived from experimental studies or been tested empirically only.

Clinically, first aid for muscle injuries follows the RICE (Rest, Ice, Compression and Elevation) principle. The objective of RICE is to stop the injury-induced bleeding into the muscle tissue and thereby minimise the extent of the injury. Clinical examination should be carried out immediately after the injury and 5–7 days after the initial trauma, at which point the severity of the injury can be assessed more reliably. At that time, a more detailed characterisation of the injury can be made using imaging diagnostic modalities (ultrasound or MRI) if desired. The treatment of injured skeletal muscle should be carried out by immediate immobilisation of the injured muscle (clinically, relative immobility/avoidance of muscle contractions). However, the duration of immobilisation should be limited to a period sufficient to produce a scar of sufficient strength to bear the forces induced by remobilisation without re-rupture and the return to activity (mobilisation) should then be started gradually within the limits of pain. Early return to activity is needed to optimise the regeneration of healing muscle and recovery of the flexibility and strength of the injured skeletal muscle to pre-injury levels. The rehabilitation programme should be built around progressive agility and trunk stabilisation exercises, as these exercises seem to yield better outcome for injured skeletal muscle than programmes based exclusively on stretching and strengthening of the injured muscle.

Key words: strain; contusion; skeletal muscle; injury; regeneration; rehabilitation; immobilisation.

MECHANISM OF SKELETAL MUSCLE INJURY

Muscle injuries are one of the most common injuries occurring in sports, their frequency varying from 10–55% of all sustained injuries.[1–5] Muscle injuries can be caused by contusion, strain or laceration.[1–5] Over 90% of all sports-related injuries are either contusions or strains, whereas muscle lacerations are uncommon injuries in sports.[1] Muscle contusion occurs when a muscle is subjected to a sudden, heavy compressive force, such as a direct blow. In strains, the muscle is subjected to an excessive tensile force leading to the overstraining of the myofibres and, consequently, to their rupture near the myotendinous junction (MTJ).

THE PATHOBIOLOGY OF MUSCLE INJURY

What distinguishes the healing of injured skeletal muscle from that of fractured bone is that the skeletal muscle heals by a repair process, whereas the bone heals by a regenerative process.[1] When most of the musculoskeletal tissues are being repaired, they will heal with a scar, which replaces the original tissue, whereas when a bone regenerates, the healing tissue is identical to the tissue that existed there before. The healing of an injured skeletal muscle follows a fairly constant pattern irrespective of the underlying cause (contusion, strain or laceration).[1,6,7] Three phases have been identified in this process (Figure 1).[6,7] These are:

1) *Destruction phase*: characterised by the rupture and ensuing necrosis of the myofibres, formation of a haematoma between the stumps of the ruptured myofibres, and an inflammatory cell reaction.
2) *Repair phase*: consisting of the phagocytosis of the necrotised tissue, regeneration of the myofibres and concomitant production of a connective tissue scar, as well as revascularisation by ingrowth of capillaries into the injured area.

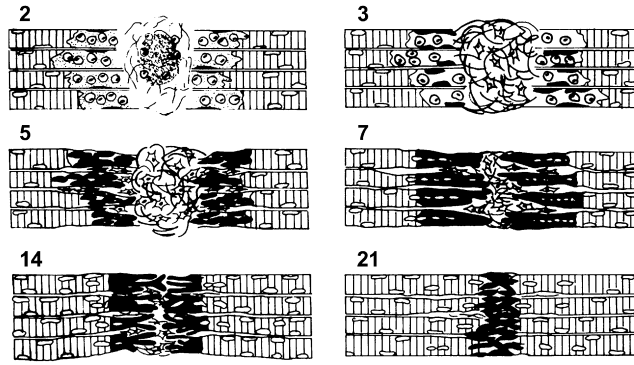

Figure 1. A schematic illustration of the healing of skeletal muscle. Day 2: The necrotised parts of the transected myofibres are being removed by macrophages while, concomitantly, the formation of the connective tissue scar by fibroblasts has begun in the central zone (CZ). Day 3: Satellite cells have become activated within the basal lamina cylinders in the regeneration zone (RZ). Day 5: Myoblasts have fused into myotubes in the RZ and the connective tissue in the CZ has become denser. Day 7: The regenerating muscle cells extend out of the old basal lamina cylinders into the CZ and begin to pierce through the scar. Day 14: The scar of the CZ has further condensed and reduced in size, while the regenerating myofibres close the CZ gap. Day 21: The interlacing myofibres are virtually fused with little intervening connective tissue (scar) in between. (Reproduced, with permission, from Järvinen TAH et al., 2005).[1]

3) *Remodelling phase*: a period during which the maturation of the regenerated myofibres, retraction and reorganisation of the scar tissue and recovery of the functional capacity of the muscle occurs.

As the repair process of injured skeletal muscle has been very recently described in detail elsewhere[1], we will present only a concise summary here (Figure 1). In short, the natural course of muscle injury healing takes place as follows: after the initial trauma, the ruptured myofibres contract and a hematoma fills the gap between the myofibre stumps. The injured ends of the myofibres undergo only local necrosis, because the torn sarcolemma is rapidly resealed allowing the rest of the ruptured myofibres to survive. Macrophages, having first invaded the injury site from the torn blood vessels, remove the cell debris and secrete growth factors that activate the satellite cells, i.e. the regenerative (reserve) stem cells of the muscle tissue residing between the sarcolemma and the basal lamina of the myofibres. The activated satellite cells first form myoblasts, then fuse into myotubes and, finally, mature into myofibres. However, the ends of these repaired myofibres do not usually reunite, but instead their ends attach to the extracellular matrix of the interposed scar via adhesion molecules at the newly formed MTJs.[1,6,7] Thus, each ruptured myofibre remains divided into two independent fibres bound together by the interposed scar (Figure 1).

CLINICAL CLASSIFICATION OF MUSCLE INJURIES

The clinical picture of a muscle injury – strain, contusion or laceration – depends on the severity of the injury and the nature of the haematoma. The intramuscular blood vessels are easily torn as a result of the trauma, leading to either *intra-* or *intermuscular* haematoma. In the case of the *intramuscular* haematoma, the extravasated blood within the intact muscle fascia increases intramuscular pressure, which subsequently

compresses the bleeding blood vessels and thereby eventually limits the size of the haematoma. In contrast, an *intermuscular* haematoma develops if the fascia surrounding the muscle is torn and the extravasated blood has free access to surrounding interstitial and interfascial spaces without a significant increase in the pressure within the muscle. Thus, the blood loss is usually more extensive.

The current classification of muscle injuries identifies mild, moderate and severe injuries based on the clinical impairment they bring about.[8,9] *Mild* (first degree) strain/contusion represents a tear of only few muscle fibres with minor swelling and discomfort accompanied with no or only minimal loss of strength and restriction of movement (ability to mobilise). *Moderate* (second degree) strain/contusion, in turn, involves greater damage to the muscle with a clear loss of function (ability to contract), whereas a tear extending across the entire cross-section of the muscle and, thus, resulting in a virtually complete loss of muscle function, is termed a *severe* (third degree) strain/contusion.

DIAGNOSIS OF MUSCLE INJURIES

The diagnosis of a muscle injury begins with a careful history of the occurrence of the trauma, followed by clinical examination consisting of inspection and palpation of the involved muscles, as well as testing the function of the injured muscles both with and without external resistance. The diagnosis is easy when a typical history of muscle contusion or strain is accompanied by objective evidence of swelling and/or ecchymosis distal to the lesion. Haematomas that are small in size and those deep within the muscle belly can be more difficult to diagnose clinically, but imaging modalities such as ultrasonography, computed tomography (CT) or magnetic resonance imaging (MRI) provide useful means to more precisely verify and characterise the injury (Figure 2).[10–12] Ultrasonography has traditionally been considered the method of choice for clinical diagnosis of muscle injuries, as it is a relatively inexpensive examination. However, it has a clear disadvantage of being highly dependent on the experience of the radiologist and, accordingly, MRI has more recently replaced ultrasonography in the imaging of many musculoskeletal disorders.[11,12] MRI can accurately confirm/rule out the existence of muscle injury and also provides a very detailed characterisation of the lesion (Figure 2), even to the extent of being considered somewhat over-sensitive at times. To summarise, the clinical diagnosis of muscle injury is sufficient in most cases, but ultrasonography can be considered a valid first-line tool if a more exact characterisation of the injury is desired. MRI, in turn, should be preferred if a clear discrepancy exists between the patient's symptoms, the physician's findings and/or the ultrasonography and, in particular, in injuries near and/or at the groin area or close to the MTJ[11,13], where MRI has shown its superiority over ultrasonography.

TREATMENT PRINCIPLES FOR MUSCLE INJURIES

The current treatment principles for injured skeletal muscle lack a firm scientific basis. In the following section, we will review the existing literature on different treatment modalities for muscle injuries. We have attempted to elucidate the theoretical basis for some of the basic principles in the treatment of injured skeletal muscle, we briefly review the various specific modalities currently in use in clinical practice and provide our recommendations accompanied with a rationale for the suggested actions.

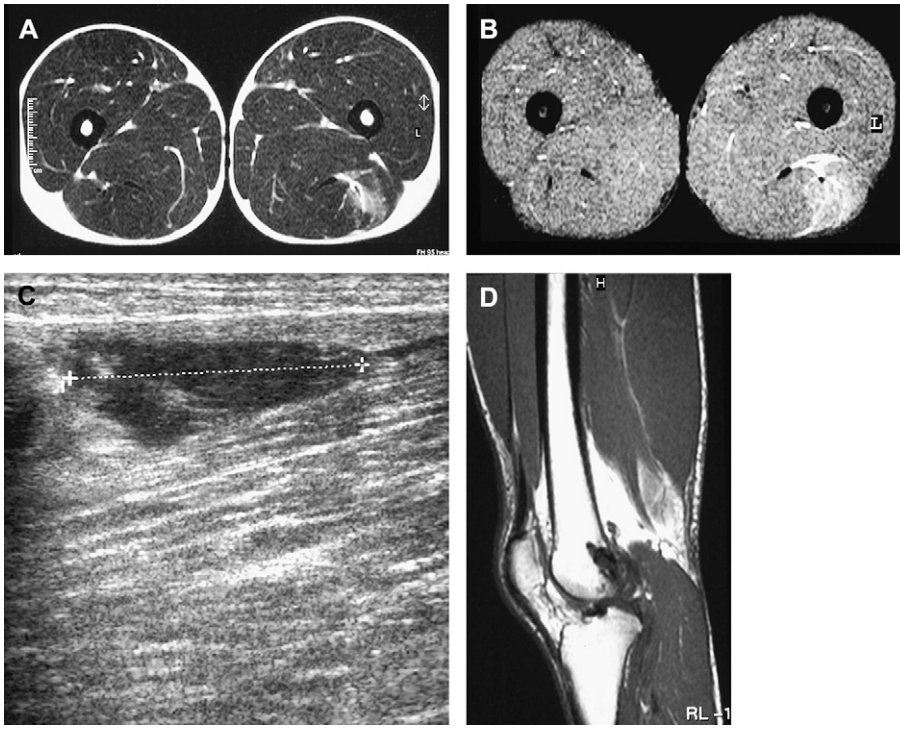

Figure 2. (A) T2-weighted and (B) fat-suppressed (STIR) magnetic resonance imaging (MRI) image of an acute (approximately 7 day old) gradus I muscle strain in the left hamstring muscle: this injury was not detectable by ultrasound (US). A demonstration of the corresponding longitudinal US (C) and MRI (D) images of an acute tear of the hamstring muscle insertion. (Reproduced, with permission, from Järvinen TAH et al., 2005).[1]

Immobilisation and remobilisation in muscle healing

Early mobilisation was first recommended for the acute treatment of muscle trauma by Woodard in 1953[14], largely based on his vast personal experience in treating injured athletes. Today, the empirical observation Woodard made more than half the century ago is supported by a considerable amount of scientific evidence (Figure 3).[1,15–20] To summarise these experimental studies, a short period of immobilisation following muscle injury is beneficial, but it should be limited to the first few days after the injury only. This allows the scar tissue connecting the injured muscle stumps to gain the required strength to withstand the contraction-induced forces applied on the regenerating tissue without re-rupturing. By restricting the length of immobilisation to a period of less than a week, the adverse effects of immobility *per se* can be minimised.[1,16–19] Re-ruptures at the site of the original muscle trauma are common if active mobilisation is begun immediately after the injury.[16–19] By placing the injured muscle at rest for the first couple of days after the injury, excessive scar formation and re-rupture at the injury site can be best prevented.[16–19] Avoiding re-ruptures is important, as it was shown in a recent prospective study that re-ruptures are actually the most severe skeletal muscle injuries causing the greatest amount of time lost from sporting activity.[21] That study emphasised the importance of carrying out the initial treatment of injured skeletal muscle with

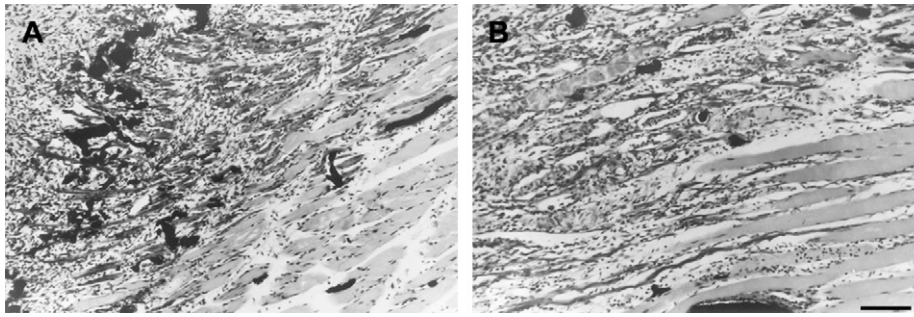

Figure 3. (A) Numerous young, regenerating myotubes are seen in close connection with the capillaries in the regeneration zone of the skeletal muscle injury treated by mobilisation 5 days after a contusion injury. (B) Only a few, small myotubes as well as few capillaries are found in the granulation tissue of the regenerating zone of the injured skeletal muscle when the muscle is treated by immobilisation. Van-Gieson-hematoxylin counterstain. Scale bar = 150 μm. (Reproduced, with permission, from Järvinen TAH et al., 2005).[1]

caution.[21] After the short, initial immobilisation period, the mobilisation of the injured skeletal muscle should be started gradually (i.e. within the limits of pain) as soon as possible, as early mobilisation has been shown to best enhance the regeneration phase in the injured skeletal muscle.[1,15–20]

Largely based on these experimental findings, we have adopted the following practice for the treatment of those of our athletes with an acute muscle injury: the required *relative immobility* can be achieved simply by applying a firm adhesive taping or similar over the injured muscle, so a cast is naturally not needed. We highly recommend the use of crutches for those athletes with the most severe lower extremity muscle injuries, as well as when the injury is located at a site where adequate immobilisation is otherwise difficult to attain, such as in the groin area.[13] We also instruct the athlete to take things very carefully for the first 3–7 days after the injury to prevent the injured muscle from stretching in any way. After this period of relative immobility, more active use of the injured muscle can be started gradually within the limits of pain.

Immediate treatment – the 'RICE' principle

The immediate treatment of an injured skeletal muscle (or any soft-tissue injury, for that matter) should follow the 'RICE' principle: Rest, Ice (cold), Compression and Elevation. The overall justification for the use of this RICE-principle is very practical, as all these four methods aim to minimise bleeding into the injury site. It needs to be stressed that there is not a single randomised, clinical trial that has validated the effectiveness of the RICE-principle in the treatment of soft tissue injuries.[22] However, there is scientific proof for the appropriateness of the distinct components of the concept, the evidence being derived largely from experimental studies.

The most persuasive proof for the use of 'rest' has been obtained from studies on the effects of immobilisation on muscle healing.[1,16] By placing the injured extremity to rest immediately after the trauma, one can prevent further retraction of the ruptured muscle stumps (and thus the formation of a large gap within the muscle), reduce the size of the haematoma and, subsequently, the size of the connective tissue scar.[1] Regarding the use of 'cold' on injured skeletal muscle, it has been shown that early use of cryotherapy is

associated with a significantly smaller haematoma between the ruptured myofibre stumps, less inflammation and tissue necrosis and somewhat accelerated early regeneration.[23–25] Although 'compression' reduces the intramuscular blood flow into the injured area, it is debatable whether compression applied immediately after the injury accelerates the healing of the injured skeletal muscle.[26] However, according to prevailing understanding, it is recommended that the combination of ice (cryotherapy) and compression are applied in bouts of 15- to 20-minutes in duration, repeated at intervals of 30–60 minutes for at least several hours. According to very recent data, icing of the injured skeletal muscle should continue for an extended period of time (6 hours) to obtain a substantial effect on limitation of the haemorrhaging and tissue necrosis at the site of the injury.[25] Finally, concerning the last component of the RICE, 'elevation', the rationale for its use is based on the fundamental principles of physiology and traumatology; the elevation of an injured extremity above the level of the heart results in a decrease in hydrostatic pressure and, subsequently, reduces the accumulation of interstitial fluid.

Treatment after 3–7 days

If the acute phases after the injury have passed uneventfully and the recovery of the injured limb seems to be progressing favourably, more active treatment of the injured extremity should be started gradually. There is a single study in the literature comparing different treatment regimens for skeletal muscle injuries in a prospective randomised setting.[27] According to this study performed on hamstring strains, a protocol consisting of progressive agility and trunk stabilisation exercises yields a significantly better outcome (reduced re-injury rate and more rapid return to sport activity) than a regimen focusing on stretching and strengthening of the injured hamstring muscles.[27] Thus, placing all of the emphasis in the rehabilitation specifically on the injured muscle might not be as beneficial as envisioned previously.[27]

Although the rehabilitation programme for injured skeletal muscle should be built around agility and trunk stabilisation exercises[27], severe muscle injuries cause substantial down-time which, in turn, results in the atrophy of the injured skeletal muscle. We have adopted the following sequence of specific exercises during the rehabilitation of the injured skeletal muscle:

1. *Isometric* training (i.e. muscle contractions where the length of the muscle remains constant and the tension changes), first without a resisting/counter load and then later with increased loads. Special attention should be paid to ensure that all of these isometric exercises are performed only within the limits of pain.
2. *Isotonic* training (i.e. the length of the muscle changes while the tension remains constant during muscle contraction) can be started once isometric training can be performed pain-free with resisting loads. Similar to isometric training, isotonic exercises should also be first carried out without a resisting/counter load and the loading should then be progressively increased.
3. *Isokinetic*, dynamic training (e.g. done with specialised apparatus that provides a varying amount of resistance to movement so that the movement takes place at constant speed) with minimal load should be started once the two above-mentioned exercises can be performed pain-free.

In this phase other physical activities aimed at maintaining cardiovascular fitness can be initiated. This could be done without the risk of re-ruptures by means of stationary bike riding or swimming.

It is of particular importance to note that all physical rehabilitation activities should always start with an adequate warming-up of the injured muscle[28–31], as adequate warming-up has been shown to reduce muscle viscosity and relax muscles neurally. Furthermore, the stimulated, warm muscles absorb more energy than unstimulated muscles and can thus better withstand loading.[29–31] When warming up is combined with stretching, the elasticity of the muscle is improved.[29,30] The other purpose of stretching is to distend the maturing scar at a phase where it is still plastic, but already has the required strength to prevent a functionally disabling retraction of the muscle stumps. Painless elongation of the maturing scar can be achieved by gradual stretching, beginning with bouts of 10–15 seconds at a time and then proceeding up to a period of 1 minute. Stretching should also involve repeated stretches of the same muscle because repeated elongation has been shown to decrease the (counter) resistance of the muscle to stretching.[28]

However, if the symptoms caused by the injured muscle fail to improve 3–5 days after the trauma, this is the stage at which it is necessary to reconsider the existence of an intramuscular haematoma or extensive tissue damage that might require special attention.[1] Accordingly, a thorough clinical re-examination should be carried out with special emphasis on the contractile status of the injured muscle, which ultimately dictates the need for surgical intervention. Imaging (ultrasound or especially MRI) is highly recommended under these circumstances.[12] The puncture and aspiration of the injured area (if fluctuation is present) are among the procedures that are sometimes required.

RETURNING TO SPORTS-SPECIFIC TRAINING

The decision regarding the appropriate timing of the return to sports-specific training can be based on two simple and inexpensive measures: (1) The ability to stretch the injured muscle as much as the healthy contralateral muscle. (2) The pain-free use of the injured muscle in basic movements. When the patient states that she/he has reached this point in recovery, then permission to gradually start sports-specific training is granted.[1,13,28] However, it should always be emphasised that the final phase of the rehabilitation, sport-specific training, should preferably begin under the supervision of a coach or a trainer.

Operative treatment

One should exercise extreme caution when considering surgical intervention in the treatment of muscle injuries, as a properly executed conservative treatment results in a good outcome in most cases.[1,28] In fact, the phrase '*muscle injuries do heal conservatively*' should be used as a guiding principle in the treatment of muscle traumas. Having said that, there are certain highly specific indications in which surgical intervention might actually be beneficial. These include the athlete with a large intramuscular haematoma(s), a complete (third degree) strain or tear of a muscle with few or no agonist muscles, or a second degree strain if more than half of the muscle belly is torn.[13,32] We wish to emphasise the importance of recognising those rare muscle injuries that require surgery very early, because operative treatment performed within 3 weeks of injury provides significantly better outcome than when the operation is postponed beyond that point.[33] Furthermore, there are certain chronic situations where surgical intervention should also be considered; if the patient complains of persisting extension

pain (duration > 4–6 months) in a previously injured muscle, particularly if the pain is accompanied with a clear extension deficit. In such a case, one has to suspect the formation of scar adhesions restricting the movement of the muscle at the site of the injury, a phenomenon that often requires surgical liberation of the scar adhesions.

After the operation, the affected skeletal muscle should be supported with an elastic bandage wrapped around the extremity to provide some compression (relative immobility, although immobilisation in a cast is not needed). Despite the fact that experimental studies suggest that immobilisation in the lengthened position substantially reduces the atrophy of the myofibres and the deposition of connective tissue within the skeletal muscle in comparison to immobilisation in the shortened position[1], the lengthened position has an obvious drawback of placing the antagonist muscles in the shortened position and, thus, subjecting them to the deleterious effects of immobility. The postoperative treatment regimen for muscle injuries is as follows: the operated on muscle is immobilised in a neutral position with an orthosis that prevents weight-bearing on the injured extremity. The duration of immobilisation naturally depends on the severity of the trauma, but patients with a complete rupture of the m. quadriceps femoris or gastrocnemius are instructed not to bear any weight for 4 weeks, but cautious stretching of the operated muscle within the limits of pain is allowed already at 2 weeks postoperatively. Four weeks postoperatively, the weight-bearing and mobilisation of the extremity are gradually begun and approximately 6 weeks after the surgery there is no need to restrict the weight-bearing at all.

THERAPEUTIC ALTERNATIVES

Medication

Similar to many of the issues regarding the most appropriate treatment of muscle traumas, there are few controlled studies on the use of non-steroidal anti-inflammatory drugs (NSAIDs) or glucocorticoids in the treatment of muscle injuries in humans. However, one study exists on the use of NSAIDs in the treatment of *in-situ-necrosis*, (i.e. injury in which only the myofibres are damaged, but the connective tissue sheaths remain intact). In this less severe type of muscle injury, a short-term use of NSAIDs resulted in a transient improvement in the recovery from exercised-induced muscle injury.[34] Despite the lack of direct human evidence, the effects of NSAIDs have been quite well documented experimentally.[35–39] A short-term use of different NSAIDs in the early phase of healing has been shown to lead to a decrease in the inflammatory cell reaction[35,36] with no adverse effects on the healing process or on the tensile strength or ability of the injured muscle to contract.[35,37] Furthermore, the NSAIDs do not delay myofibre regeneration.[38] However, it seems that the use of NSAIDs should be restricted to the early phases of muscle repair as their long-term use might have undesired effects on the regenerating skeletal muscle[37], although these detrimental effects were not reported in the most thorough experimental study.[35]

While the early short-term use of NSAIDs can be considered a relatively well-justified treatment[34–39], the situation seems to be completely opposite regarding the glucocorticoids.[35,40] Delayed elimination of the haematoma and necrotic tissue, retardation of the muscle regeneration process and, ultimately, reduced biomechanical strength of the injured muscle have been reported with the use of glucocorticoids in the treatment of muscle injuries.[35,40]

Therapeutic ultrasound

Therapeutic ultrasound (US) is widely recommended and is also used in the treatment of muscle injuries, although the scientific evidence obtained from animal studies on its effectiveness can not be considered promising.[41–43] In addition to the fact that the micromassage produced by high-frequency US waves apparently works as a pain reliever, it has been proposed that US could somehow enhance the initial stage of muscle regeneration. However, despite the apparent promotion of the proliferation phase of myoregeneration[41], therapeutic US unfortunately does not seem to have a positive (muscle healing enhancing) effect on the final outcome of muscle healing.[41–43]

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBO) has been proposed as another promising therapeutic option for improving the regeneration of the injured skeletal muscle.[44] An experimental study showed that the use of HBO during the early phase of repair considerably accelerated the recovery of the injured skeletal muscle.[44] Despite the positive animal study, a recent meta-analysis on HBO and soft tissue injuries showed that not a single randomised prospective study has been performed on the treatment of severe skeletal muscle injuries by HBO.[45] Actually, this meta-analysis disclosed that HBO might increase the sensation of pain in less severe forms of muscle injury, i.e. delayed onset muscle soreness (DOMS) or in situ necrosis.[45] Thus, there is a complete lack of clinical studies on the effects of HBO on severe muscle injuries and the clinical trials on less severe injuries fail to show beneficial effects of HBO in the treatment of muscle or other types of soft tissue injuries in athletes.[44,45]

COMPLICATIONS – MYOSITIS OSSIFICANS TRAUMATICA

Myositis ossificans is a non-neoplastic proliferation of bone and cartilage within the skeletal muscle at the site of a previous single major trauma or repeated injury and/or haematoma. Being a relatively rare complication of muscle injury, the scientifically valid evidence regarding either the pathogenesis or the most optimal treatment is virtually non-existent.[1,46] In sports, myositis ossificans is typically associated with prior sports-related muscle injury, the incidence being the highest in the high-contact sports in which the use of protective devices is uncommon (e.g. rugby).[46] Increased susceptibility to myositis ossificans has also been described in individuals with haemophilia or other bleeding disorders in conjunction with a soft-tissue injury.[46]

Clinically, myositis ossificans should be suspected if pain and swelling are not clearly subsiding 10–14 days after an injury to a skeletal muscle or if the healing does not seem to progress normally despite the execution of a proper conservative treatment regimen. One should be particularly alert if the symptoms intensify weeks (or months) after the trauma, especially if the site of injury becomes more indurated and the injured extremity displays reduced joint range of motion (ROM).[1,46] Although it is sometimes possible to detect the first signs of the ectopic bone in radiographs as early as 18–21 days after the injury, the formation of ectopic bone usually lags behind the symptoms by weeks and, thus, a definite radiographic diagnosis can be made substantially later.[46]

Due to its rarity, the treatment principles of myositis ossificans are based, even more so, on empirical experience rather than on clinical or experimental evidence,

than in any other type of muscle complaint.[1] The proper first aid for muscle trauma (the prevention of the formation of a large haematoma) naturally creates the foundation for the treatment of this complication. However, if myositis ossificans still occurs despite the best prevention efforts, there is little that can or should be done in the acute phase. Although indomethacin is quite commonly used in orthopaedics to prevent heterotopic ossification, it has not been validated for the prevention and/or treatment of myositis ossificans.[1] The surgical excision of the bone mass can be considered at later phases, if the symptoms do not subside despite 12 months of watchful waiting. However, according to our experience, surgery should not be performed until the ectopic bone has fully 'matured', which is 12–24 months after the onset of the symptoms, as the excision of immature bone often results in local recurrence.[1] Overall, myositis ossificans could be considered to underscore the importance of proper initial treatment of athletes with muscle injury: Despite the fact that a great majority of muscle injuries heal virtually irrespective of the primary treatment, compromised healing of muscle injury (myositis ossificans) results in a delay in return to sports that is highly comparable – and often even longer – than that associated with the failed treatment of other sports-related major injuries.[46]

PREVENTION

As already reviewed above, passive and active warm-up and muscle stretching have been shown to have beneficial effects on muscle function and thus they should be advocated also for the prevention of muscle injuries. However, a critical review of the medical literature reveals that there is limited evidence to demonstrate that these activities actually reduce the incidence of muscle injuries.[47] Thus, the focus to the prevention of skeletal muscle injuries has recently shifted from mere stretching to specifically tailored muscle strengthening protocols.

Simply by improving hamstring flexibility, lower limb injuries in general can be significantly reduced in physically active individuals[47], while programmes aimed at strengthening hamstrings reduce the number of hamstring injuries.[48,49] Eccentric muscle strengthening exercises (also called Nordic strengthening) are being widely advocated to provide additional preventative benefit over the classical strengthening programmes. Two recent trials indicated that strength training programmes based on eccentric exercises indeed seem to reduce hamstring injuries significantly more than do conventional strengthening programmes.[21,50]

SUMMARY

Only a few clinical studies exist on the treatment of muscle injuries and, thus, the current treatment principles for muscle injuries are mostly based on experimental studies or empirical evidence only.

Clinically, first aid for muscle injuries follows the RICE principle (Rest, Ice, Compression and Elevation), the principle that is common to the treatment of any soft tissue trauma. The objective of the use of RICE is to stop intramuscular bleeding and thereby minimise the progression of the muscle injury. Clinical examination should be carried out immediately after the trauma and 5–7 days thereafter, at which point imaging modalities such as MRI or ultrasound can provide useful insights into the severity of the injury. During the first few days after the injury, a short period of immobilisation accelerates the formation of granulation tissue at the site of the injury,

but it should be noted that the duration of reduced activity (immobilisation) should be limited to only until the scar has reached sufficient strength to bear the muscle-contraction induced pulling forces without re-rupture. At this point, gradual mobilisation should be started followed by a progressively intensified exercise programme to optimise healing by restoring the strength of the injured muscle, preventing muscle atrophy and the loss of strength and extensibility, all of which can follow prolonged immobilisation. Based on current knowledge, the rehabilitation programme should consist of progressive agility and trunk stabilisation exercises.

Practice points

- Muscle injuries are one of the most common injuries in sports.
- Muscle injuries heal with a scar that impedes complete regeneration.
- Muscle injuries are classified according to the clinical impairment they cause.
- Diagnosis of a muscle injury is clinical.
- Ultrasonography and magnetic resonance imaging (MRI) can be used to assist diagnosis.
- MRI is clearly more sensitive than ultrasonography, especially on injuries in the groin area or close to the myotendinous junction (MTJ).
- Injured skeletal muscle should be placed to rest (immobilisation) after the injury for 3–7 days.
- Early, active re-mobilisation should be started within the pain limit.
- Immediate first aid aims at reducing the bleeding to the injured area.
- Diagnosis can wait for the immediate treatment, icing should last for hours after the injury.
- Immediate treatment follows the 'RICE'-principle; Rest, Ice, Compression and Elevation.
- Mobilisation of the injured muscle should be carried within limits of pain.
- Mobilization program should not only include exercises for the injured muscle, but should be loaded with exercises improving agility and trunk stabilization.
- Stretching is an important part of the mobilisation programme.
- 'Muscle injuries do heal conservatively'.
- Rare cases of injuries with major haematoma or complete rupture of the muscle should be diagnosed and operated on early.
- Non-steroidal anti-inflammatory drugs (NSAIDs) are recommended after skeletal muscle injury.
- Corticosteroids should not be injected nor given orally to the patient with a skeletal muscle injury.
- Therapeutic ultrasound does not have proven therapeutic effect on the regeneration of injured skeletal muscle.
- The complete lack of clinical evidence for the therapeutic effects of hyperbaric oxygen (HBO) warrants cautiousness in its use for skeletal muscle injuries.
- Myositis ossificans is a rare complication of injured skeletal muscle.
- Ectopic bone should not be operated on before it has 'matured' i.e. more than 12 months from the onset of symptoms.
- Specifically tailored muscle strengthening protocols consisting of eccentric exercise are very effective in preventing muscle injuries.

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