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Conservative Treatment of Muscle Injuries: From Scientific Evidence to Clinical Practice

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1. Introduction

The musculoskeletal injuries, both acute and chronic, are very common in sport activities accounting from 10% to 55% of all injuries and often results in prolonged rehabilitation and time out from competition (Garrett, 1996; Croisier et al., 2002). Their treatment is a challenge for all health care professionals, which are involved in the management of rehabilitation and return sporting activities of the athletes. Usually, skeletal muscle injuries are common in professional and amateur athletes. Muscle injuries often occur with over 90% caused by excessive strain or by contusion (Järvinen et al., 2005) and may result in the inability to train or compete for several weeks and have a high tendency to recur (Verrall et al., 2001; Orchard and Best, 2002). A 5-year study of European soccer players showed that muscle strain represented 30% of injuries. Among these, those of quadriceps (32%), hamstring (28%), adductor (19%), and gastrocnemius (12%) were the most common (Volpi et al., 2004).

It has been showed that injured muscles can initiate regeneration promptly, but the healing process is often inefficient and hindered by the formation of scar tissue, which may contribute to muscle re-injury (Huard et al., 2002).

The first step in the muscle injuries management is to be able to answer questions that are often asked to physician or physical therapist by the injured athlete: "How long will it take to recover?"; "When can I return to the field?". However, answer to these questions is very difficult because it depend on age, activity level of injured athlete, and by pressure of coaches, parents, managers and media, etc. Unfortunately, until today, the answers to these questions are based on personal experience rather than on clinical evidences.

The management of muscle injuries, despite the lack of high quality studies, can be improved with the knowledge of the possible mechanisms that cause muscle injuries (Ekstrand et al., 1983), and with the identification of risk factors associated with injury occurrence (Verrall et al., 2003; Brockett et al., 2004). Acquisition of these knowledge will lead to an improvement of our preventive, therapeutic and rehabilitative strategies (Gibbs et al., 2004; Cross et al., 2004; Orchard and Best, 2002; Sherry and Best, 2004; Cacchio et al., 2006) for a safe return to sport activities.

Although much progress has been made in understanding the pathogenesis of muscle injuries, to date none of the proposed hypotheses can provide a unique explanation of their occurrence, and the multifactorial etiology is frequently evoked (Gleim and McHugh, 1997).

Depending on the trauma mechanism, muscle injuries can be classified as direct and indirect. The direct form is the *contusion*, and the indirect form is the *strain* (Järvinen and Lehto, 1993). A contusion occurs when a muscle is subject to a sudden and heavy compressive force, such as a direct blow provoked by an opposing player or by an object. Muscle strain usually arises from an indirect insult when an application of excessive tensile forces is produced.

The muscle-tendon junction (MTJ) is the most involved site in the acute muscle injuries (Garrett et al., 1988), and bi-articular muscle with a greater percentage of type II fibres and pennate architecture, as rectus femoris, hamstrings, adductor longus and gastrocnemius are the most commonly injured muscles (Hasselmann et al., 1995; Hughes et al., 1995; Kasemkijwattana et al., 1998; Volpi et al., 2004).

Sprinting and jumping are the most common activities associated with muscle strains (Crisco et al., 1994).

Additionally, repeated eccentric muscle contractions can result in delayed-onset muscle soreness (DOMS) with symptoms similar to muscle injuries, including decreased function, stiffness, and pain (Warren et al., 2002). DOMS is attributable to a distinct pathophysiological process that includes an inflammatory response and structural changes of the sarcomere, with a consequent reduction of muscular functional ability (Barash et al., 2002; Lieber et al., 2002). In fact, mechanical damage and leukocyte infiltration after intense eccentric exercise are known to coincide with torque reductions (MacIntyre et al., 1996).

Although new classification systems of muscle injuries have been recently proposed (Mueller-Wohlfahrt et al., 2013; Chan et al., 2012), the most widely used system classifies muscle injuries (strain and contusion) according to their severity: amount of pain, weakness, loss of extensibility and reduction of ROM, functional impairment as in the walking or running (Kujala et al., 1997; Mason et al., 2007). A mild (grade I) injury involves damage to a small number of muscle fibers and localized pain without loss of strength. A clear loss of strength coupled with pain reproduced on resistance strength test is indicative of a moderate (grade II) injury. A severe (grade III) injury corresponds with complete rupture of the muscle and loss of strength and function (Verrall et al., 2003).

Generally, the risk factors for injury are divided into intrinsic (athlete related) and extrinsic (environment-related) (Inklaar, 1994; Taimela et al., 1990). Among the intrinsic factors most frequently identified by prospective studies are: age (Gabbe et al., 2006), fatigue (Greig and Siegler, 2009), a history of previous injury (Hagglund et al., 2006; Gabbe et al., 2010), postural and biomechanical deficits (Agre, 1985), lack of extensibility, and imbalance of agonist/antagonist muscular strength and power ratio (Askling et al., 2003; Croisier et al., 2008).

Among the extrinsic factors, importance is attributed to inadequate warm-up, climatic factors, inadequate training, playground surface, inadequate sports equipment (Hawkins and Fuller, 1999).

Orchard and colleagues suggested that intrinsic factors are more predictive of a muscle injury than extrinsic factors. However, a recent systematic review concluded that no single risk factor (intrinsic or extrinsic) showed a significant correlation with hamstring muscles injuries (Foreman et al., 2006). For this reason, as mentioned above the multifactorial etiology of muscle injuries is the predominant one.

The prevention of muscle injuries is an ongoing process where intervention is necessary for as long as participants engage in the physical activities that place them at risk (Goldman and Jones, 2011). This process should be based on the four sequential steps of prevention model introduced by van Mechelen in the early 90s (Van Mechelen et al., 1992):

1. determine the size of the problem sports injuries,
2. establish the etiology and mechanism of onset of sports injuries;
3. insert the preventive measures;
4. evaluate the effectiveness of preventive measures introduced by repeating the analysis in step 1.

Many interventions are widely employed by participants, trainers, coaches and physiotherapists specifically aiming to prevent muscle injuries. Among the most used interventions there are: exercises designed to improve muscle flexibility (Van Mechelen et al., 1993) and strength, in particular by means of eccentric exercises; exercises designed to improve balance, proprioception (Emery et al., 2007), neuromuscular control, and motor skills; education among "training and the risk of injury", functional training exercises and sport-specific activities (Verrall et al., 2005).

Despite the relatively high incidence of sport injuries, evidence of the efficacy of preventive interventions is not well established. In the Systematic Review of Cochrane collaboration Goldman and Jones (2011) assumed that there isn't evidence from randomised controlled trials to draw conclusions on the effectiveness of interventions used to prevent hamstring injuries in people participating in football or other high risk activities for these injuries. Manual therapy interventions aimed to prevention of muscle injuries have produced good results, but they need to be confirmed with further research from RCTs of good quality.

2. Context

Preparing this work we wanted to identify a context characterized by muscle injury in an adult person, skeletally mature, involved in sport activities. The target population was identified in high level professional athletes, but it is obvious that the fallout application in clinical practice involves above all amateur athletes, including different sports from soccer. It seems that the sports involving sprinting, acceleration, deceleration, rapid change of direction and jumping (e.g. soccer, American football, rugby, etc.) may exposed athletes to an increased risk of muscle injuries.

The choice of a conservative treatment program for muscle injuries should be based on its effectiveness, its cost-effectiveness analysis, as well as on the expectations and aims of the athlete.

3. Systematic literature review

3.1. Objectives

The purpose of this study is to systematically review the existing literature that addresses the conservative treatment of muscle injuries in adult (skeletally mature) athletes.

3.2. Methods

Electronic databases searched for the purpose of this systematic review included: Medline and PubMed.

The research question (PICO) was defined with the following criteria:

P: Adult (skeletally mature) athletes; I: conservative treatment; C: other treatment or no treatment; O: recovery of pre-injury muscle parameters and functional activities.

<div>P I C O</div>	Populations/ P atient	Adult (skeletally mature) athletes
	I ntervention	Conservative treatment
	C omparison intervention	Other treatment or no treatment
	O utcome	Recovery of pre-injury muscle parameters and functional activities

The following search method was used:

("Athletic injuries"(Mesh) OR "Muscle, Skeletal/injuries"(Mesh) OR "Sprains and strains"(Mesh) OR Muscle injur*(Tw)) AND ("Rehabilitation"(Mesh) OR "Rehabilitation

programs"(TW) OR Treatment(Tw) OR "Physical therapy modalities"(Mesh) OR "Therapeutics"(Mesh)) AND ("Treatment outcome"(Mesh) OR "Muscle strength"(Mesh) OR "Recovery of function"(Mesh) OR "Evidence based medicine"(Mesh))

Filters: Randomized Controlled Trial; Systematic Reviews; Guideline; published in the last 10 years

For more details on the search strategy see Appendix 1.

3.3. Results

Initially, 488 papers were identified for potential inclusion. After an analysis about the internal requirements of the studies, only five reports met the inclusion searching criteria. "The Physiotherapy Evidence Database (PEDro) Scale was used by two independent reviewers to assess the methodological quality of each included full text article" (Centre for Evidence-Based Physiotherapy. Physiotherapy Evidence Database (PEDro) Scale. Available at: http://www.pedro.fhs.usyd.edu.au/scale_item.html.)

To view the studies included and excluded from this review of the literature see appendix 2.

From the analysis of the few items found arises that there is no research on therapeutic interventions of muscle injuries. There are only a few studies on hamstring muscle injuries, which may not provide strong scientific evidence.

A recent Cochrane review (Mason et al., 2012) highlights the lack of studies about the therapeutic interventions of muscle injuries, especially that there are not right drawings studies, precisely Randomized Controlled Trials. The authors contend that at the moment there is limited evidence to suggest an increased frequency of daily stretching to reduce recovery time and the percentage of recurrence.

Some preliminary scientific evidence available, suggests exercises to improve movement dysfunction. Another recent systematic review (Reurink et al., 2012) demonstrates that the therapeutic interventions for acute hamstring injuries such as stretching, agility and trunk stabilization exercises have limited evidence.

Sherry and Best (2004) performed a prospective randomized study to compare two rehabilitation programs for the treatment of acute hamstring muscle injury. The study concludes that a rehabilitation program which consisted of exercises of agility and trunk stabilization was more effective than a program emphasizing isolated stretching and selective strengthening exercises of the hamstring muscles.

3.4. Discussion

Following a comprehensive appraisal of the available literature five studies were included in this systematic review. Our findings suggest a lack of research studies that addresses the conservative management of muscle injuries. All five studies included in this review concern the hamstring muscle injuries. As a consequence this limits the possibility to effectively generalize these findings to the clinical settings. The limited number of relevant articles as well

as their focus only on the hamstring muscle injuries, highlights the need for future well-designed randomized controlled trials to conclusively evaluate the effectiveness of conservative treatment in the management of muscle injuries, particularly for muscles other than the hamstrings.

IMPLICATION FOR RESEARCH

In order to standardize the therapeutic approach and intervention strategies for muscular injuries should produce scientific literature characterized by an appropriate design of studies (RCT) as well as a high methodological quality.

In addition, researchers should also produce studies on alternatives muscle groups and not only hamstring muscles.

3.5. Author's conclusions

There is no consensus regarding treatment for muscle injuries. Most proposed conservative rehabilitation treatment of muscle injuries have not been assessed using randomized controlled trials. Even when randomized controlled trials have been conducted, most have low total numbers of injured athletes, which potentially explains the variability among study results. Most other studies do not provide a level of evidence greater than expert opinion. Although the initial treatment of rest, ice, compression, and elevation is accepted for muscle injuries, no consensus exists for their rehabilitation. Until further evidence is available, current practice and widely published rehabilitation protocols cannot either be supported or refuted. As medical science does not help us we have to turn our attention to the basic sciences to have an approach based on biomedical fundamentals. Thus, factors that impact skeletal muscle structure, function and regeneration are of great importance and interest not only scientifically but also clinically.

TAKE HOME MESSAGE

There is no consensus regarding the rehabilitation treatment for muscle injuries.

There is a very low production of research studies about therapeutic interventions.

The basic sciences are a benchmark for developing a rehabilitation program to manage the muscle injuries.

Despite the inconclusive results of our review, we will try to provide the reader with the tools to build a reasoned approach to manage the muscle injuries, having as a benchmark the basic sciences and the few available evidences from clinical studies.

4. Conservative treatment: from scientific evidence to clinical practice

Keys points

- Describe the stages of tissue healing and the importance of application of this knowledge in rehabilitation.
- Identify characteristics of the different grades of strains and application of this to rehabilitation.
- State aspects of the clinical evaluation.
- Design appropriate interventions for describe the conservative treatment from scientific evidence to clinical practice.

4.1. End points of therapy

Although a variety of conservative treatment strategies exist for the management of muscle injuries, and the "RICE (Rest, Ice, Compression, Elevation) approach" is widely accepted, there is still no consensus regarding the best conservative treatment to offer to patients with muscle injuries.

Knowledge of basic principles of skeletal muscles regeneration and repair mechanisms may help to define a rational rehabilitation program. Many authors highlighted that the healing process of an injured skeletal muscle is characterized by three phases. The first phase or *destruction phase*, is characterized by disruption and subsequent necrosis of muscle myofibrils, by the formation of a hematoma between the stumps muscle and by the inflammatory reaction. The second phase or *repair phase* consists in the phagocytosis of necrotized tissue with the regeneration of myofibers and the concomitant production of connective tissue scar and revascularization into the injured area. The third phase or *remodeling phase*, characterized by the maturation of the regenerated myofibers, contraction and reorganization of the scar tissue and recovery of the functional capacity of the muscle. Relying on the basic knowledge on connective tissue healing, an ideal treatment and rehabilitation program of an acute soft-tissue injury has been formulated to fulfill some requirements.

Firstly, immediately after the injury, the ideal treatment should follow RICE (rest, ice, compression, elevation) principles; allowing to minimized pain, swelling, inflammation, and hemorrhage, to offering the best possible condition for the healing process.

The second requirement is protection and immobilization of the damaged muscle area. To prevent additional bleeding to injury site, muscle secondary strains, and early lengthening of injured structures. A short period of immobilization following muscle injury is beneficial for the healing process. However, it was suggested that restricting the length of immobilization to a period of less than a week, the adverse effects of immobility per se can be minimized.

Thirdly, 2-3 weeks after injury, during the maturation and remodeling phase, scar tissue forms initially in a random pattern. However, perform gentle and controlled movements along the main axis of injured muscle that does not produce or increase pain at the injury site leads to a better healing process allowing to the scar tissue to align parallel to muscle fascicles ("mobile scar"). Gentle and controlled movements along the main axis of injured muscle that do not produce or increases pain at the injury site stimulates the healing process allowing to the scar tissue to assume a structural architecture with an alignment parallel to the muscle fascicles.

Finally, 6-8 weeks after injury, there are no reasons to continue to protect the affected area.

And so the rehabilitation is directed towards quick and complete return to exercise and sport activities.

From these principles we must try to build our treatment plan; will develop methods of approach to the pathological condition and therapeutic intervention strategies to be used.

It's important to understanding tissue-healing phases before discussing pathology and ultimately deciding appropriate treatment, because knowledge of tissue-healing phases will help guide the decision-making process during patient rehabilitation treatment.

Most muscle injuries will respond to rehabilitation treatment without complications. However, in cases of excessive fibroblast proliferation or of abnormal response of myoblasts to bone morphogenetic protein, exuberant scar tissue or myositis ossificans can form, respectively.

4.2. Purposes of therapy

As with other athletic injuries, the primary objective of a rehabilitation treatment for muscle injuries management is to return the athlete to sporting activities at the pre-injury level of performance with a minimal risk of injury recurrence. There are some factors that can increase the recurrence in a muscle injury such as the formation of non-functional scar tissue that is associated with an alteration in muscle tissue lengthening mechanics, reduced flexibility, muscle weakness, alteration in lower limb biomechanics (Malliaropoulos et al., 2010). It should keep in mind these factors when a rehabilitation program is prepared.

4.3. Clinical and diagnostic evaluation

As previously suggested (Askling et al. 2006), the diagnosis of muscle injuries is mainly clinical, based on detailed history of trauma and physical examination with inspection, palpation, ROM tests, manual muscle testing, and special tests.

Although clinical evaluation remain very important, imaging examinations such as ultrasound (US) and magnetic resonance (MR) provide useful information for defining the injury more

precisely. It has been shown that appropriate management decisions, return to training and competitions, and prediction of injury recurrence may all be enhanced with appropriate imaging examination (Verrall et al., 2003; Gibbs et al., 2004; Cross et al., 2004; Hasselman et al., 1995). Usually, US is the imaging modality of choice in visualizing sport-related muscle injuries, since it is widely available, safe, and inexpensive tool and allows dynamic evaluation which often can be helpful in distinguishing between a partial or complete tear of injured muscle. It has the disadvantage of being examiner-dependent. In athletes in whom an US examination does not provide an adequate assessment of a suspected muscle injury, MRI should be the next imaging modality to be used. MR imaging is more sensitivity in depicting edema and extent of injury, as well as in evaluating muscle-tendon injuries.

The initial assessment is often carried out within 12h to 2 days post-injury (Askling et al., 2007).

Possible signs of swelling and ecchymosis may arise a few days later the injury and consequently may not be noticed at the initial examination (Wood et al., 2008; Askling et al., 2006).



Figure 1. The cadaver anatomy hamstring

A rapid phase change of muscle contraction from eccentric to concentric has been suggested as the underlying mechanism for hamstring injuries. During running, especially fast running, the bi-articular arrangement of the hamstring muscles across the hip and knee allow the hamstrings to work eccentrically during late swing phase to decelerate the lower leg and control knee extension. A concentric contraction follows to initiate hip extension prior to heel strike. So that hamstrings are maximally loaded and lengthened during this rapid change from

eccentric to concentric contraction (Proske et al., 2004). In case of an acute hamstring injury, the hip and knee ROM of the injured leg is significantly decreased compared to the uninjured leg. However, the flexibility of the hip in the acute situation is often influenced by pain as a consequence of which the test may be poor accurate.

Active ROM is decreased in the acute phase of the injury and it is advised to be measured at the end of the second day. Knee active ROM deficit 48 h after a unilateral posterior thigh muscle injury is an objective and accurate measurement.

No difference was found between active and passive ROM tests. Knee flexion and extension ROM can be estimated with a goniometer.

Strength of the hamstring muscles can be tested with the patient lying in a prone position by applying a manual resistance at the heel. The prone-resisted knee flexion should be done with different angles of knee flexion (e.g. 90°, 30°, and 15°), and with internal or external tibial rotation to target the medial (semimembranosus and semitendinosus) and lateral (biceps femoris) hamstring muscles, respectively. Due to their biarticular nature, the hamstring muscles also extend the hip, so it is recommend that hip extension strength is assessed with the knee positioned at 90° and 0° of flexion while resistance is applied to the distal posterior thigh and heel, respectively.

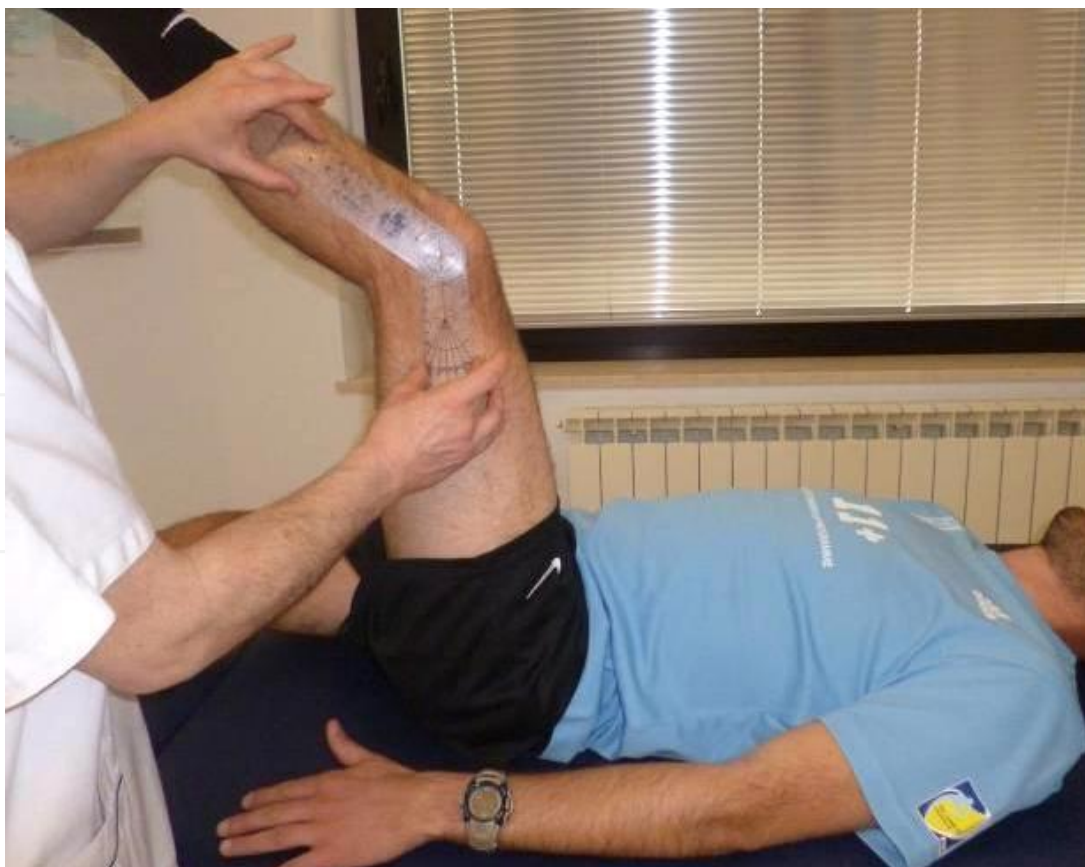


Figure 2. Test ROM knee with goniometer

Although it is important to evaluate also the eccentric component of strength, this should not be evaluated after an acute muscle injury due to the high load that eccentric contraction causes on the muscle structures.

Differential diagnosis of posterior thigh pain should include sciatic pain caused by nerve roots compression by herniated disc at L4-L5 or L5-S1 levels, sacro-iliac joint referred pain, gluteal trigger point referred pain, as well as other neural syndromes such as piriformis syndrome and hamstring syndrome.

Keeping in mind that “back related” hamstring injuries are characterized by a gradual buildup of pain, if these conditions are suspected, the active slump test can be used to confirm whether a patient has a neural component to their hamstring pain (Orchard et al., 2004). To complete patient evaluation also an MRI could be used to rule out these conditions.

Although imaging evaluation may not be necessary in all cases of muscle injuries, its use not only confirms the diagnosis of muscle injury but also supplies information that helps to determine the degree and location of a muscle injury, and to predict the time to sport resumption in professional and recreational athletes.

Several groups (Koulouris and Connell, 2006; De Smet and Best 2000) compared the performance of US and MRI. Among them, a prospective study (Connell et al., 2004) found US to be as useful as MRI in detecting the presence of an acute muscle (hamstrings, in this case) injury. However, the same authors affirm that more detailed analysis of the injury profile was achieved using MRI during the healing phase.

Gibbs et al. (2004) and Verrall et al. (2003) found that MRI negative hamstring strains had a significantly faster rehabilitation interval (6.6 and 16 days, respectively) compared with MRI positive strains (20.2 and 27 days, respectively) in their studies of elite Australian footballers. However, it should be kept in mind that repeat MR imaging of athletes who have been cleared to return to sport, often show persistent high signal changes and muscle edema (Slavotinek et al., 2002; Connell et al., 2004).

In the only study to relate radiological parameters of hamstring injury to injury recurrence on return to competition Verrall et al. (2006) showed that a larger size of hamstring injury was indicative of higher risk for recurrent injury but only after the subsequent playing season was considered along with the same playing season.

4.4. Treatment strategies: How – to – treat

Determining the appropriate grade of strain will help guide the clinician through the rehabilitation process. A grade 1 strain may leave the athlete with slight discomfort and minimal swelling but full ROM and little functional deficit. A grade 2 strain is characterized by a small to moderate palpable area of involvement along with increased pain and swelling. A grade 2 muscle strain will often demonstrate restricted ROM and impaired gait. A grade 3 muscle strain is typified by a moderate to severe palpable area of involvement and sometimes a defect at the site of injury. The patient demonstrates significant deficits in ROM, and functional mobility will be severely impaired (Järvinen et al., 1978).

Today, we have a considerable amount of scientific, mostly experimental, evidence to support the early mobilization treatment approach of muscle injuries. It has been shown that early mobilization induces more rapid and intensive capillary ingrowth into the injured area, better regeneration of muscle fibers and more parallel orientation of the regenerating myofibers in comparison to immobilization, the previously preferred treatment for injured muscle (Järvinen, 1976; Järvinen and Sorvari, 1975; Järvinen, 1975; Järvinen, 1978).

The positive effects of early mobilization on the regeneration of the injured skeletal muscle are not only limited to morphostructural changes, since it has been shown that the biomechanical strength of the injured muscle achieved the level of uninjured muscle more rapidly using active mobilization rather than immobilization after a muscle injury. (Järvinen, 1976)

A short period of rest relative after muscle injury is beneficial, but it should be limited only to the first few days after the injury. This rest period allows the scar tissue connecting the injured muscle stumps to gain the required strength to withstand the contraction-induced forces applied on it without a re-injury, but being restricted to the first few days only, the adverse effects of immobility can be limited to a minimum. The experimental data showing that beginning active mobilization after the short period of immobilization enhances the penetration of muscle fibers through the connective tissue scar, limits the size of the permanent scar, facilitates the proper alignment of the regenerating muscle fibers, and helps in regaining the tensile strength of the injured muscle.

The immediate treatment of the injured skeletal muscle is known as RICE principle - Rest, Ice, Compression and Elevation. The overall justification for the use of the RICE principle is very practical, as all 5 means aim to minimize bleeding into the injury site. It needs to be stressed that there is not a single, randomized clinical trial to prove the effectiveness of the RICE principle in the treatment of soft tissue injury. However, there is scientific proof for the appropriateness of the distinct components of the concept, the evidence being derived from experimental studies. The most persuasive proof for the use of rest has been obtained from studies on the effects of immobilization on muscle healing. By placing the injured extremity to rest immediately after the trauma, one can prevent further retraction of the ruptured muscle stumps (the formation of a large gap within the muscle) as well as reduce the size of the hematoma and, subsequently, the size of the connective tissue scar. Regarding the use of ice, it has been shown that the early use of cryotherapy is associated with a significantly smaller hematoma between the ruptured myofiber stumps, less inflammation, and somewhat accelerated early regeneration (Deal et al., 2002; Hurme et al., 1993).

Although compression reduces the intramuscular blood flow to the injured area, (Kalimo et al., 1997) it is debatable whether compression applied immediately after the injury actually accelerates the healing of the injured skeletal muscle (Thorsson et al., 1997).

However, according to the prevailing belief, it is recommended that the combination of ice (cryotherapy) and compression be applied in shifts of 15 to 20 minutes in duration, repeated at intervals of 30 to 60 minutes, as this kind of protocol has been shown to result in a 3° to 7° C decrease in the intramuscular temperature and a 50% reduction in the intramuscular blood flow (Thorsson et al., 1987; Thorsson et al., 1985).

Finally, concerning the last component of the RICE principle, elevation, the rationale for its use is based on the basic principles of physiology which suggests as 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.

The patient to move very carefully for the first 3 to 7 days after the injury to prevent the injured muscle from stretching. (Järvinen and Lehto, 1993).

After this period of relative rest, more active use of the injured muscle can be started gradually within the limits of pain.

The use, in this phase, of some neuromuscular control exercises of the lumbo-pelvic region are essential for optimal functional recovery. Furthermore, the normal gait should be implemented as soon as the pain allows.

Both passive and active exercises that apply a longitudinal strain to the injured structure will help the tissue accommodate to the new stress.

The treatment practiced in most of the muscle injury is the "deep transverse friction" massage. This procedure is widely used, and based on a biological hypothesis feasible with regard to the proposed mechanism of action, but the scientific evidence regarding the clinical effectiveness of "deep transverse friction" has been negative.

The request for sports massage among competitive athletes is high, but the scientific support for the effect of sport massage is very limited.

In the DOMS, massage administered 2 hours after muscle insult did not improve the function of the hamstring, but reduced the intensity of pain 48 hours after the muscle insult (Hilbert et al., 2003).

Pain-free stretching and strengthening exercises are essential to regain flexibility and strength and prevent further injury and should be initiated quickly at the end of inflammatory response phase.

Stretching exercises should be included to determine the stress lines along which collagen will be oriented. The type, duration, and frequency of stretches are three factors, which may influence or even determine its effectiveness.

Strengthening exercises program is a composite of different variables that include: muscle actions used, resistance used, volume (total number of sets and repetitions), exercises selected and workout structure (e.g., the number of muscle groups trained), the sequence of exercise performance, rest intervals between sets, repetition velocity, and training frequency. Manipulation of the program variables should be performed to be beneficial to recovery progression. Progression may be maximized by the incorporation of progressive overload, specificity, and training variation in the program.

During a rehabilitation program, strengthening exercises should begin with isometric type, and progress with isotonic type, initially without and then with the application of an external resistance such as elastic devices, dumbbells, barbells, weight-machines, etc.

In the isometric training (ie, muscle contractions in which the length of the muscle remains constant and the tension improves) all the contractions must be done without pain. Isometric training can begin with short-duration and progress to long-duration muscle contractions. Strength training with isometric contractions produces large but highly angle-specific adaptations, thus it is important to exert the muscle at different joint angles as well as in sport specific positions.

Isotonic training (i.e., the muscle length changes and the tension remains constant during muscle contraction) can be started when long-duration muscle contraction of isometric training can be performed pain free. Isotonic exercises should be firstly performed without an external resistance, which should then be introduced and progressively increased. The strength training includes single-joint exercises, multiple-joint exercises, but above all functional exercises that mimic the actual sport actions. Weakness after painful musculoskeletal injury is typically mediated by both muscular and neural adaptations. After a knee injury with anterior cruciate ligament rupture, maximal voluntary activation of the quadriceps is reduced despite restoration of knee stability over the years. In the muscle injuries little attention has been paid to the possibility that prolonged deficits in muscular activation due to a reduction of the nervous system constitutes a strategy to unload damaged tissues. The athlete often expressed fear in carrying out the action that caused the injury. The execution of this action must be re-programmed, performed, and correct if necessary. The training in specific position may prepare in an optimal manner the structure to stress that then can expect during sport activities. The progression of exercises should consider also the ROM andThe training in specific position may prepare in an optimal manner the structure to stress that then can expect during sport in to injuryangular velocity of joint. The eccentric exercises are also important. It consists in a "negative" muscular activity (muscle-tendon system absorbs energy) in which there is an overall lengthening of the muscle while under tension, in response to an external load (such as a weight) that is greater than the force generated by the muscle.

Scar tissue increasing passive stiffness of the muscle-tendon unit and making it more susceptible to injury during large eccentric contractions. Optimum tension-length curve of healthy or injured muscle can be optimized (such that peak tension is generated at longer muscle lengths) by eccentric training. Given the length-dependent nature of muscle damage in hamstring strains near end range, this structural adaptation optimizes the angle of peak torque to reduce the risk for potential injury. Despite the inherent limitations and lack of supporting evidence, Croisier et al. (2002) recommended that eccentric exercise should be included in the rehabilitation of hamstring injuries to help prevent recurrent injuries.

It has been suggested that all rehabilitation treatments should always start with an adequate warm-up of the injured muscle (Magnusson et al., 1995; Safran et al., 1988; Safran et al., 1989).

When warm-up is combined with stretching, the flexibility of muscle is improved. Painless elongation of the scar tissue can be achieved by stretching the duration of which should be gradually increased from 15 seconds to 1 minute.



Figure 3. The patient is lying on the ground: submaximal to maximal isometric contractions at different knee angles. 5 sec of contraction 5 sec of rest for 6 times. 4 – 5 times / day.



Figure 4. The patient should rotate the trunk as for kicking with the aim to train the core musculature.



Figure 5. Walking hamstring stretch: the patient is in standing position. The injured limb is extended. Trunk flexion to stretch the hamstring muscles.



Figure 6. Hamstring stretch: swing phase position with slow side to side rotation and flexion extension of the knee.



Figure 7. Lunges in all planes of motion. The patient is in standing position: must make small steps in all directions as to a change of direction.



Figure 8. Foot catch exercise. The athlete stands parallel to a wall, and simulates the swing phase of walking at the first phase and after of the running. During the swing phase, the athlete performs a quick quadriceps contraction and then attempts to catch or stop the lower leg before reaching full knee extension by a hamstring contraction. In first phase with a little hip and knee extension. In a second phase increase hip and knee extension and the velocity.

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Figure 9. The patient is in an upright position on a single leg. Flexion of the trunk in all directions.



Figure 10. The patient is in an upright position on a single leg: flexion of the trunk with arms that push forward to increase the difficulty.



Figure 11. Lunges in all planes with return to start position. Increasing the length of the step and / or the execution speed of each sitting to vary the training stimulus.

4.5. How to monitor treatment and clinical outcomes

Although many athletes will return to activity before the MR imaging findings are resolved, follow-up imaging is useful in the case of complications and in order to provide additional information of clinical progress through a rehabilitation program and consequently to support the decision-making for return to sports. US and MRI are both useful imaging modalities in defining the location, extent and severity of muscle injury.

These modalities can assess healing or scar formation, detect associated complications, predict prognosis and monitor treatment response in muscle injuries. Greater availability, low cost, short imaging time, no contraindications (e.g., pacemakers), and dynamic capability of US favors its use in the initial assessment and subsequent follow-up of the majority of muscle injuries. However, overall its limitations, including user dependence and lower sensitivity, tend to outweigh its advantages as far as accurate pathology delineation in elite athletes is concerned. Moreover, MRI due to its higher contrast resolution appears to be the technique of choice for follow-up imaging evaluations.

The optimum time to carry out assessments of imaging follow-up is different for each case, and so it is difficult to generalize. However, it should be kept in mind that abnormalities appear to resolve sooner on US than on MRI, and US detected fewer abnormalities than MRI at 2 and 6 weeks.

The choice of imaging modality selected for the evaluation of muscle injuries will also depend on availability, cost, and operators expertise.

Since the re-injury rate can be as high as 34% after 1 year, it's very important to monitor rehabilitation treatment progress by imaging evaluations. (Orchard and Best, 2002)

5. Conclusions

While efforts have been made to minimize their effect, several limitations are present in this review and it is possible that some relevant articles may have been overlooked. However, we can conclude that due to a real lack of published scientific studies until now there is no consensus about the rehabilitation treatment of muscle injuries.

A consensus classification system for muscle injuries currently does not exist, but classifying muscle injuries according to their severity may be useful for a prognosis and for establishing an adequate rehabilitation treatment program.

Diagnosis of a muscle injury is mainly clinical, but enhanced by imaging findings which allow to determine its degree and location, and to predict return to sport in professional and recreational athletes.

Although commonly recommended, there is little evidence to support the RICE principles. Early mobilization for lower grade injuries and brief (1-3 days) immobilization of the extremity for higher grade injuries appear to be beneficial.

Most muscle injuries will respond to rehabilitation treatment without complications. Grade I strains have a low risk of tear extension and heal within 2 weeks with conservative management. Grade II strains require at least 4 weeks of conservative management, with a significant risk of tear extension if the patient returns to full exercise too early. It has been shown that if more than 50% of the cross-sectional area of the hamstring is torn, this correlates well with a convalescence period of greater than six weeks. Increasing length of a strain has also been correlated with an increased period of convalescence.

Prevention strategies, although promising, have not yet proven their effectiveness. Currently, there are very few scientific evidences that a determined preventative protocol has been effective, leading to a statistically significant decrease in muscular injuries. Therefore further research is needed to define its role.

Due to the lack of experimental studies on treatment of muscle injuries, basic sciences are fundamentals to build up a rationale rehabilitation treatment program.

From scientific evidence to clinical practice

- # 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 instrumental
 - # Ultrasonography and magnetic resonance imaging (MRI) can be used to assist diagnosis in the elite sportive
 - # Ultrasonography is equally useful at identifying hamstring muscle injuries and may be preferable because of lower costs.
 - # Injured skeletal muscle should be placed to relative rest after the injury for 3–7 days.
 - # Immediate first aid aims at reducing the bleeding to the injured area.
 - # Diagnosis can wait for the immediate treatment, icing should last for 48 hours after the injury.
 - # Immediate treatment follows the 'RICE'-principle; Rest, Ice, Compression and Elevation.
 - # Mobilization with manual therapy and active exercise of the injured muscle should be carried within limits of pain.
 - # Mobilization program include exercises for the injured muscle, with exercises improving agility and trunk stabilization.
 - # Stretching is an important part of the mobilization programme.
 - # For the most part muscle injuries to heal conservatively.
 - # 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.
 - # Muscle strengthening consisting of eccentric exercise are very effective in preventing muscle injuries.
 - # Massage in reducing pain instead seems to be unique on the psychological effects.
-

Among different therapeutic interventions, exercise plays a very important role in the prevention and treatment of muscle injuries.

Appendix

Therapeutic exercise

<p>PHASE 1</p> <p>Goals:</p> <p>Correct gait</p> <p>Start Isometric training</p> <p>Gentle stretch pain free</p>
<p>1. 5' of low stationary biking with no resistance or 5' walking if it possible</p> <p>2. Supine hip flexion with knee exstension stretch 3 x 30 sec</p> <ul style="list-style-type: none"> •Submaximal isometric hamstrings sets 5 sec x 6 times 4 – 5 times/days •Neuromuscular exercise for the lumbopelvic region. 20 – 30 repetitions (foto 6 – 7) •Ice in long sitting position for 20min.

1. Progression from phase 1 to phase 2 is allowed when the athlete showed a normal gait pattern, and can perform a pain-free isometric contraction against submaximal (60%-80%) resistance during prone knee flexion (90°) manual strength test.

<p>PHASE 2</p> <p>Goals:</p> <p>Start isotonic training</p> <p>Stretching training</p> <p>Cardiovascular training</p>
<ul style="list-style-type: none"> •10' of low stationary biking with little resistance or 10' walking •Standing hip flexion with knee extension stretch with slow side to side rotation. <p>Standing</p> <ul style="list-style-type: none"> •hamstring stretch sport position. 3 x 30 sec •Prone or standing position knee flexion . 3 – 4 x 12 – 15 •Light lunges in all planes (foto 10) 5 x 15 sec

2. progression from phase2 to phase 3 is allowed when the athlete can perform all activities without pain.

PHASE 3
Goals: Stretch training Isotonic training
<ul style="list-style-type: none"> •10' of low stationary biking with little resistance or 10' walking •Non-weight-bearing "foot catches" 6 – 8 rep •Single leg deadlifts 5 x 8 – 10 rep •Single leg standing 2 x 6 – 8 rep •Nordic hamstring exercise 2 x 6 rep <p>lunges in all planes with return to start position with different velocity 5 x 30 sec</p>

Key: All the exercises must be performed without pain. In a first phase low intensity, a velocity of movement that is less than or near that of normal walking; in a second phase moderate intensity, a velocity of movement greater than normal walking but not as great as sport; in a third phase high intensity, a velocity of movement similar to sport activity.

Appendix 1: Search strategies

Pubmed/Medline

1. "Athletic injuries"(Mesh)
2. "Muscle, Skeletal/injuries"(Mesh)
3. "Sprains and strains"(Mesh)
4. Muscle injur*(Tw)
5. "Athletic injuries"(Mesh) OR "Muscle, Skeletal/injuries"(Mesh) OR "Sprains and strains"(Mesh) OR Muscle injur*(Tw)
6. "Rehabilitation"(Mesh)
7. "Rehabilitation programs"(TW)

8. Treatment(Tw)
9. "Physical therapy modalities"(Mesh)
10. "Therapeutics"(Mesh)
11. "Rehabilitation"(Mesh) OR "Rehabilitation programs"(TW) OR Treatment(Tw) OR "Physical therapy modalities"(Mesh) OR "Therapeutics"(Mesh)
12. "Treatment outcome"(Mesh)
13. "Muscle strength"(Mesh)
14. "Recovery of function"(Mesh)
15. "Evidence based medicine"(Mesh))
16. "Treatment outcome"(Mesh) OR "Muscle strength"(Mesh) OR "Recovery of function"(Mesh) OR "Evidence based medicine"(Mesh))
17. "Athletic injuries"(Mesh) OR "Muscle, Skeletal/injuries"(Mesh) OR "Sprains and strains"(Mesh) OR Muscle injur*(Tw) AND "Rehabilitation"(Mesh) OR "Rehabilitation programs"(TW) OR Treatment(Tw) OR "Physical therapy modalities"(Mesh) OR "Therapeutics"(Mesh) AND "Treatment outcome"(Mesh) OR "Muscle strength"(Mesh) OR "Recovery of function"(Mesh) OR "Evidence based medicine"(Mesh))
18. "Athletic injuries"(Mesh) OR "Muscle, Skeletal/injuries"(Mesh) OR "Sprains and strains"(Mesh) OR Muscle injur*(Tw) AND "Rehabilitation"(Mesh) OR "Rehabilitation programs"(TW) OR Treatment(Tw) OR "Physical therapy modalities"(Mesh) OR "Therapeutics"(Mesh) AND "Treatment outcome"(Mesh) OR "Muscle strength"(Mesh) OR "Recovery of function"(Mesh) OR "Evidence based medicine"(Mesh))Filters: Randomized Controlled Trial; Systematic Reviews; Guideline; published in the last 10 years

Appendix 2

Included studies

- Mason DL, Dickens VA, Vail A. Rehabilitation for hamstring injuries. Cochrane Database Syst Rev. 2012 Dec 12;12:CD004575.
- Reurink G, Goudswaard GJ, Tol JL, Verhaar JA, Weir A, Moen MH. Therapeutic interventions for acute hamstring injuries: a systematic review. Br J Sports Med. 2012 Feb;46(2):103-9.

- Copland ST, Tipton JS, Fields KB. Evidence-based treatment of hamstring tears. *Curr Sports Med Rep*. 2009 Nov-Dec;8(6):308-14.
- Petersen J, Hölmich P. Evidence based prevention of hamstring injuries in sport. *Br J Sports Med*. 2005 Jun;39(6):319-23.
- Sherry MA, Best TM. A comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. *J Orthop Sports PhysTher*. 2004 Mar;34(3):116-25.

Excluded studies

Study	Reason for exclusion
ElMaraghy AW, Devereaux MW. A systematic review and comprehensive classification of pectoralis major tears. <i>J Shoulder Elbow Surg</i> . 2012 Mar;21(3):412-22.	This systematic review examines scientific literature of pectoralis major tears to identify incidence and injury patterns, while doesn't investigate interventions to treat muscle injuries.
Andia I, Sánchez M, Maffulli N. Platelet rich plasma therapies for sports muscle injuries: any evidence behind clinical practice? <i>Expert OpinBiolTher</i> . 2011 Apr;11(4):509-18.	Platelet-rich plasma (PRP) therapies don't represent a physical therapy treatment.
Hamilton BH, Best TM. Platelet-enriched plasma and muscle strain injuries: challenges imposed by the burden of proof. <i>Clin J Sport Med</i> . 2011 Jan;21(1):31-6.	Platelet-enrich plasma (PRP) therapies don't represent a physical therapy treatment.
Prins JC, Stubbe JH, van Meeteren NL, Scheffers FA, van Dongen MC. Feasibility and preliminary effectiveness of ice therapy in patients with an acute tear in the gastrocnemius muscle: a pilot randomized controlled trial. <i>ClinRehabil</i> . 2011 May;25(5):433-41.	This report don't study a specific sports athletes population.
Harris JD, Griesser MJ, Best TM, Ellis TJ. Treatment of proximal hamstring ruptures - a systematic review. <i>Int J Sports Med</i> . 2011 Jul;32(7):490-5.	This systematic review analyzes surgical repair treatments of tendinous or bony tuberosity avulsion in the proximal hamstring. This is not a systematic review of muscle injuries.
O'Sullivan K, Murray E, Sainsbury D. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. <i>BMC MusculoskeletDisord</i> . 2009 Apr 16;10:37.	This study examined the short-term effects of warm-up, static stretching and dynamic stretching on hamstring flexibility in individuals with previous hamstring injury. It didn't analyze actual muscle injuries and so treatment techniques for the rehabilitation.

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