Spanish Consensus Statement: The Treatment of Muscle Tears in Sport

Address correspondence to Tomas F Fernandez-Jaén, MD, PhD, Clinica CEMTRO, Ventisquero de la Condesa 42, Madrid 28035, Spain (phone: +34 676 540 966)

Coauthors:
Tomas F Fernandez-Jaén, MD, PhD
Chief of Sports Medicine and Trauma Unit, Head of Research and Education, Clínica CEMTRO, Madrid, Spain; Spanish School of Sports Traumatology Catholic University of Murcia, Murcia, Spain, SETRADE Secretary.

Guillermo Álvarez Rey, MD
Medical Director at AMS Exercise Medical Center, Málaga, Spain.

Jordi Ardevol Cuesta, MD
SETRADE 1st Vice President; Chief of Surgery Unit, Hospital ASEPEYO Sant Cugat, Clínica Diagonal Trauma Unit, Barcelona, Spain.

Rafael Arriaza Loureda, MD
Arriaza y Asociados Medical Institute, Hospital HM Modelo, La Coruña, Spain.

Fernando Ávila España, MD
Member of the Medical Commission for The International Voleyball Federation, Sevilla, Spain.

Ramón Balius Matas, MD, PhD
Consell Català de l’Esport, Generalitat de Cataluña, Clínica Diagonal, Barcelona, Spain

Fernando Baró Pazos, MD
President of SETRADE; Orthopaedic Surgery and Trauma Service, Traumatology Clinic, Valladolid, Spain.

Juan de Dios Beas Jiménez, MD
Chief of Sports Medicine Unit, Sport Medicine Center for Andalusia, Sevilla, Spain. Coeditor, Andalusian Journal of Sports Medicine.

Jorge Candel Rosell, MD
Chief of Sports Medicine Service, CLINICA TECMA, Valencia, Spain.
César Cobián Fernandez, MD  
Traumavist - Clinica Vistahermosa, Alicante, Spain.

Francisco Esparza Ros, MD, PhD  
ISAK Secretary General; Masters Course in Sports Traumatology Course Director, Murcia Catholic University, Murcia, Spain.

Josefina Espejo Colmenero, MD  
Chief of Spanish Paralympic Committee Medical Service (CPE), Madrid, Spain.

Jorge Fernández de Prado, MD  
Physiotherapy and Touch Therapy Medical Center, Pamplona, Spain.

Juan José García Cota, MD  
Orthopaedic Surgery and Trauma Ward at Hospital Miguel Domínguez, Pontevedra, Spain; Head of The Spain National Football Team and Real Club Celta de Vigo Football Team Medical Services, Pontevedra, Spain.

Jose Ignacio Garrido González, MD  
Medical Director, Dr Garrido Center, Salamanca, Spain.

Manuela González Santander, MD  
Imaging and Postural Dynamics Ward, National Sport Medicine Center, Consejo Superior de Deportes, Madrid, Spain.

Miguel Ángel Herrador Munilla, MD, PhD, Prof  
Sports Medicine and Traumatology Ward, Clinica CEMTRO, Madrid, Spain.

Francisco Ivorra Ruiz, MD  
Mutua Asepeyo, Alicante, Spain; Emergency Ward, Hospital Universitario de San Juan, Alicante, Spain.

Fernando Jiménez Díaz, MD, PhD, Prof  
School of Sports Science, Castilla la Mancha University, Toledo, Spain; Echography MSK International Chair Director, Murcia Catholic University, Murcia, Spain.

Pedro Manonelles Marqueta, MD, PhD  
President of Spanish Federation for Sports Medicine, Spain; Chair Director of International Sport Medicine, Murcia Catholic University, Murcia, Spain.
Antonio Maestro Fernandez MD, PhD  
FREMAP, Chief medical services Sporting Gijon CF, Oviedo, Spain

Juan José Muñoz Benito, MD  
Chief of Spanish Handball Federation Medical Services, Madrid, Spain;  
Member of Spanish Olympic Committee medical commission, Madrid, Spain; Member of the International Handball Federation.

Ramón Olivé Vilás, MD PhD  
Chief of Sports Medicine Ward, Consorcio Sanitario Terrassa – CAR Sant Cugat, Catalunya International University, Barcelona, Spain.

Xavier Peirau Teres, MD, PhD, Prof  
President, The Spanish Association for Football Clubs Medical Services (AEMEF); School of Physical Activity and Sport Sciences (INEF), Lleida University, Lleida, Spain.

José Peña Amaro, MD, PhD, Prof  
Department of Morphological Sciences (Histology Section), School of Medicine and Nursing, Universidad de Córdoba, Córdoba, Spain.

Juan Pérez San Roque, MD  
Trauma ER Ward, Hospital General Universitario de Alicante, Alicante, Spain.

Christophe Ramírez Parenteu, MD  
Medical Director, Real Federación Española de Atletismo, Madrid, Spain;  
Medical Director, Clínica Dr. Sanz Vázquez, Guadalajara, Spain.

Juan Ribas Serna, MD, PhD  
Chair, Department of Medical Physiology and Biophysics, School of Medicine, University of Seville. Seville, Spain.

Mikel Sánchez Álvarez, MD  
Chief, Arthroscopy Surgery Unit Trauma Ward, Hospital San Jose Vithas, Vitoria-Gastéis, Spain.

Carlos Sanchez Marchori, MD, PhD  
Clínica Sánchez Marchori, Hospital 9 de Octubre, Valencia, Spain.

Miguel del Valle Soto, MD, PhD, Prof
On the 21st of March, 2015, experts met at Clínica CEMTRO in Madrid, Spain, under the patronage of The Spanish Society for Sports Traumatology (SETRADE), The Spanish Federation of Sports Medicine (FEMEDE), The Spanish Association of Medical Services for Football Clubs (AEMEF), and The Spanish Association of Medical Services for Basketball Clubs (AEMB) with the aim of establishing a round table that would allow specialists to consider the most appropriate current general actions to be taken when treating muscle tears in sport, based on proven scientific data described in the medical literature. Each expert received a questionnaire prior to the aforementioned meeting comprising a set of questions concerning therapeutic indications generally applied in the different stages present during muscle repair.

The present Consensus Document is the result of the answers to the questionnaire and resulting discussion and consensus over which are the best current indications in the treatment of muscle tears in sport. Avoiding immobilization, not taking nonsteroidal anti-inflammatory drugs (NSAIDs) randomly, fostering early mobilization, increasing vascularization of injured, site and regulating inflammatory mechanisms—without inhibiting these from the early stages of the recovery period—all stood out as main points of the Consensus Document. Additionally, there is controversy concerning cell stimulation techniques and the use of growth factors or cell inhibitors. The decision concerning discharge was unanimous, as was the
criteria considered when it came to performing sport techniques without pain.

**Keywords:** consensus document; injuries; muscle; treatment; therapeutic guide

Numerous scientific advances have been published concerning the knowledge of muscle repair, and yet there are no unified criteria when establishing therapeutic indications. There is a great variety of treatment patterns, many of which are based on individual clinical experience, and multiple Internet entries have been registered discussing partial indications and muscle repair models. Such a situation renders comparing results useless and provides an enormous array of research studies, which show that results remain uncertain on the subject of muscle repair.

We have thus considered it necessary to establish, using translational medicine, a knowledge link between basic science and clinical practice in order to point out the most appropriate therapeutic measures.

We know that muscle repair processes are continuous processes consisting of overlapping stages. Based on the works of Huard et al. and Järvinen et al. and with the aim of establishing a systematic approach instructively and unarbitrarily, the repair process has been broken down into several stages based on the predominant biological event taking place in each of these. Timespans mentioned have been approximately agreed based on published mean durations for muscle tears. The present consensus does not differentiate whether the origin of the injury is at the musculotendinous junction, the main muscle body, or at the myofascial area, nor does it specify the degree of muscle injury or each muscle’s specific features. Vascularization and metabolic and oxygenation levels together with genomic response levels were not mentioned. Muscular tear is considered as a general concept.

It is therefore our aim, and the aim of all institutions included in the current document, to issue a consensus-based guide for muscle tears based on current biological and physiological knowledge.

**Methods**

Thirty experts in sports traumatology, all medical doctors with more than 15 years experience in this specialty and nationwide-substantiated acknowledgement, have participated (university professors, orthopaedic surgeons, and/or sport medicine specialists).

With the aim of properly presenting the questions, the issued questionnaire differentiated 4 phases during muscle repair in a systematic and instructive way:
1. Inflammatory phase, duration 1-2 days: 15 questions
2. Degenerative and vascularization phase, until day 14 after injury onset: 17 questions
3. Cell-stimulating, proliferative, and fibrotic phase, until day 28 after injury onset: 8 questions
4. Remodeling phase, up to 3 to 6 months after injury onset: 2 questions

The questionnaire was prepared, revised, and completed by the experts themselves. Additionally, a conflict of interest declaration was signed with no expert receiving economical compensation of any kind from any of the companies for taking part in this event.

On the March 21, 2015, a clinical meeting was arranged at Clínica CEMTRO, Madrid, Spain, so that experts could clearly define and reach a consensus for each of the included questions. The following table describes the level of consensus reached.

| Level       | Consensus |
|-------------|-----------|
| 100%        | Unanimity |
| 99%-75%     | Strongly recommended |
| 74%-55%     | Recommended |
| <55%        | Controversy |

Statistical Analysis

A descriptive analysis was carried out since we are dealing with categorical variables, and each has been expressed as an absolute number or percentage.

Results

Inflammatory Phase

Unanimity

Cryotherapy to the affected area was considered by 100% of experts; analgesic drugs such as paracetamol or metamizol where also accepted based on pain intensity together with elevation of the affected limb. With regard to physical activity, sports rest must be followed. Consensus was also reached on the non-use of complete immobilization.

Strongly Recommended

Highly recommended indications are considered when no unanimity has been reached yet at least 75% of experts agree on their use. The most agreed upon indication, showing a 93% level of agreement, is the use of vascular-type bandage or taping over the affected area, closely followed by the non-use of nonsteroid anti-inflammatory drugs (NSAIDs), with 90% level of agreement; 90% level of agreement was also shown for the need to empty the hematoma only in the presence of intense pain or when neurovascular compression phenomena occur, thus relieving the area from
any unnecessary pressure. Eighty-three percent of experts begin mobilization of the affected area based on level of pain. Echography of the affected area after 48 to 72 hours is recommended by 80% of experts, as well as the administration of inflammation bioregulators (Table 1).

**Table 1. Therapeutic Indications in the Inflammatory Phase**

| Unanimity               | Strongly Recommend                |
|-------------------------|-----------------------------------|
| Cryotherapy             | Compressive bandage               |
| Elevation               | Non-use of NSAIDs                 |
| Sport Rest              | No weightbearing of affected limb |
| No complete immobilization | Drain haematoma with symptoms   |
| Analgesia               | Inflammation bioregulators        |
|                         | Ecography after 48/72 hours       |
|                         | Mobilize affected area as tolerated |

**Recommended**

Seventy percent of experts have agreed on extracting the hematoma whenever possible.

**Controversies**

Requesting magnetic resonance imaging (MRI) study in this early inflammatory stage is considered useful by only 40% of participants.

**Degenerative and Vascularization Phase**

**Unanimity**

Unanimity was reached concerning the indication for performing contractions based on tolerance, painless stretching, isometric exercises, maintaining aerobic condition (eg, water exercises), and a progressive increase of specific technical drills for each sports activity, not including the affected area.

Additionally, non-use of painful stretching and use of semi-invasive techniques (dry puncture, intratissue percutaneous electrolysis [IPE], etc) inside the injury site have also reached a consensus (Table 2).
Table 2. Therapeutic Indications in Degenerative/Vascularization Phase

| Unanimity                                      | Strongly Recommend                                      |
|-----------------------------------------------|---------------------------------------------------------|
| Contractions based on tolerance               | Echography                                              |
| Pain-free stretching                          | Vascular physiotherapy                                   |
| Isometric drills                              | Degradation-enhancing enzimotherapy                       |
| Maintain aerobic capacities avoiding affected area |                                                         |
| Non-use of semi-invasive techniques on affected area (dry punctures, IPE, etc) |                           |
| Gradual increase of specific technique avoiding affected area |                                                              |

**Strongly Recommended**

With a 93.3% level of agreement reached, the list of highly recommended indications is headed by physiotherapy techniques, which increase vascularization in affected area. MRI is also highly recommended, with a 90% value, and an 80% level of agreement follows the application of enzyme therapy, with the aim of increasing the degradation of damaged extracellular fibers and matrix.

**Recommended**

Vascularization-enhancing techniques and drugs show a 73.3% level of agreement, and thermotherapy techniques and drugs 70%.

**Controversies**

Actions that did not reach a 55% level of agreement were the use of transforming growth factor beta (TGF-beta), massaging the affected area, drugs or techniques that increase oxygen supply, and satellite stem cell-stimulating drugs.

**Cell-Stimulating, Proliferative, and Fibrotic Phase**

**Unanimity**

In this third phase of muscle tears, stretching based on pain, increasing mechanical demands on the muscle based on pain (isometric, concentric, eccentric), as well as initializing basic movements with specific techniques for each sports activity, all reached consensus (Table 3).
Table 3. Therapeutic Indications in Cell-Stimulating, Proliferative, and Fibrotic Phase

| Unanimity                                               | Strongly Recommended                                           |
|---------------------------------------------------------|----------------------------------------------------------------|
| Stretching as tolerated                                 | Reinforce use of antithrombotic therapies                      |
| Increase mechanical demand on muscle as tolerated       | Echography                                                    |
| Basic sport technique movements                         | Increase metabolic supply                                     |
| Gradual increase of sport-specific technique            |                                                               |

Strongly Recommended
The majority (86.7%) of experts agreed on performing echography studies and considered promoting the use of antifibrotic substances and techniques, and 76.7% acknowledged the need to ensure an increase in protein administration.

Remodeling Phase

Unanimity
The most important event at this phase, apart from continuing with previously mentioned indications, is when to decide on the patient’s return to sports training regimen. The only accepted factor in this phase that would indicate such a return is performing basic sports techniques under no pain at all.

Recommended
Painless stretching and contractions as an indicator of return to sports training did not reach consensus (Table 4).

Table 4. Therapeutic Indications in Remodeling Phase

| Unanimity                                               | Strongly Recommended                                           |
|---------------------------------------------------------|----------------------------------------------------------------|
| OK to join work-out sessions if sport technique is pain-free | OK to join work-out sessions if stretching and contractions are pain-free |

Decision on when to return to sports activity:
100% IF basic sports technique movements in absence of pain.
92.3% IF stretching in absence of pain.
IF contractions in absence of pain.

Discussion

Conservative treatment is most commonly applied in muscle tears, with surgery not being necessary in most cases. Surgery is exclusively indicated in the presence of massive tears showing functional impairment or massive hematoma accompanied by great blood loss.22,30

Once surgical procedures have been discarded, any applied therapeutic process should consider time from onset of injury and the predominant biological phase when treatment is applied.16,28,29

Inflammatory Phase

This phase lasts approximately 2 to 3 days, depending on the size of the tears and the extension of the histological muscle break-down. Points upon which consensus by all experts was reached are: the non-use of immobilization with rigid systems such as posterior splints, considering that relevant literature indicates it leads to total muscle immobilization, which produces shortening and other secondary effects to immobilization.1,25,32,50

All authors agree on the use of cryotherapy, although there is still controversy concerning time and frequency of its application due to the fact that it has been proven that an excessive application produces a decrease in cell metabolism and a subsequent slowing down of the entire muscle repair process.19,47

Paracetamol or metamizol-like drugs do not interfere with other biochemical processes during the inflammatory phase. Limb elevation and sport rest are classic synergistic measures.2,33,35,44,51

Vascular bandages or other types of elastic compression are highly recommended with the aim of improving venous drainage, blood flow, and interfiber hematoma compression and reabsorption.52

Administration of inflammatory bioregulators regulates any response, promoting an anti-inflammatory process activation.14 The literature has an ever-increasing number of articles showing that anti-inflammatory administration must be avoided since it greatly affects biochemical reactions present in inflammation, thus causing muscle recovery to slow down.24,33

Load diminishing in torn muscles is positive, but not so through the use of raised insoles or other orthotics, which can lead to muscle shortening and subsequent muscle repair complications. Benefits of early mobilization have often been described and proven as long as they are pain-free, thanks to their activation of cell-regenerating processes and enhancement of extracellular matrix production.32,54 Most authors apply combined therapies: topical or oral administration of drugs and bioregulators while
avoiding parenteral, intravenous, or intramuscular administration directly at the injury site.

Hematoma evacuation is unanimously recommended in the presence of a great amount of blood, causing intense pain with neurovascular symptoms by compression, in cases of muscle tears by direct impact, or when the hematoma is extremely close to the bone periostium, which may cause myositis ossificans. Intermuscular hematomas must always be evacuated. However, minimal interfiber or intramuscular hematomas that have not caused full rupture of the injured fiber ends do not require hematoma evacuation. These hematomas may very well favor muscle fiber tip penetration and regeneration within the muscle fibers.²⁰,²³

Echography studies are highly recommended as image diagnosis procedures as long as they are performed between 48 and 72 hours of injury onset. Earlier use may lead to wrongly diagnosed cases. Ruled application of magnetic resonance is highly controversial, proving useful in those cases in which echography has not been conclusive, in cases of “invisible” muscles, or when determination of the exact muscle tear boundaries (or any other associated injury) is necessary. Magnetic resonance would therefore be mainly recommended in those cases in which there is an obvious discrepancy between the patient’s symptoms, clinical findings, and/or the need to clearly define the echography image in areas such as the groin or musculotendinous junction and cases where NMR shows to have a higher definition and thus possible associated injuries may be assessed.⁴,⁸,⁹,¹²,¹³,²⁶,²⁷,³⁸,⁴³

Degenerative and Vascularization Phase

This phase lasts from injury onset day until 14 days after. Continuation of therapeutic measures applied during the inflammatory phase will depend on clinical findings and the athlete’s pain. Authors unanimously recommend starting muscle contractions according to pain tolerance, painless stretching, and isometric exercises. The athlete’s aerobic condition is also a concern and must be maintained with water exercises or the like. There must be an increase in the specific sports technique for each sport, avoiding using the injured site to maintain physical condition and proprioception. Semi-invasive techniques such as dry punctures and intratissue percutaneous electrolysis (IPE) at the injury site are not indicated, although some authors perform these techniques in perilesional sites to treat complications and secondary muscle contractures.³,⁴⁶,⁵⁷

Physiotherapy techniques that increase vascularization at the injury site and thermotherapy techniques are highly recommended together with orally administered enzyme therapy to intensify and shorten the fiber and extracellular matrix injury degradation process as well as other substances
that increase vascularization of injury site, despite showing some limitations, according to certain authors.\textsuperscript{31}

Echography studies are highly recommended in this phase since the 72-hour limit after injury onset has been overpassed.

Controversy exists regarding growth factor inhibitors such as the TGF-beta family since there are certain factors that promote fibrosis while others have the same effect concerning satellite cell stimulation and extracellular matrix repair.\textsuperscript{7,14,18,34,57,59} Certain inhibitors such as curcumine, decorine, and suramine have proven their efficiency in clinical practice.\textsuperscript{5,7,15,40,45,49,59}

Controversy is further present regarding the application of measures that may stimulate satellite cells, as it is yet to be fully proven, and further research studies are needed to confirm their efficacy, doses, indications, and duration of application. Platelet-rich plasma is included among this group—a measure that is used by only 15.38% of consulted experts.\textsuperscript{36,48}

An additional measure that has proven to be efficient is active mobilization of muscular structures that allow satellite cells to be stimulated. Extra oxygen supply has not proven to be efficient despite certain authors trying to use hyperbaric chamber, aerobic exercises, or tecartherapy techniques.\textsuperscript{14,37,51,53,56}

\textbf{Cell stimulating, Proliferative, and Fibrotic Phase}

For practical purposes, we have considered the length of this phase to include 4 weeks after the onset of muscle fiber tear. The continuation of stretching exercises and increasing muscular mechanical demands as tolerated has unanimously been agreed upon: isometric, concentric, and eccentric contractions are indicated, carefully considering their load, frequency, and load angle since inadequate eccentric contractions may provoke onset of reinjured muscle tears.\textsuperscript{6,10,11,21,55}

Fundamental sport technique movements may be initialized, leading to specific techniques for each sport, always bearing in mind clinical symptoms and muscle pain while working out.

Antifibrotic substances and techniques are highly recommended in this phase as well as metabolic provision (proteins, metabolic supplements, etc) in cases of deficient nutrition. Healthy, well-fed athletes would not need such measures, although a rich aminoacid environment appears to favor muscle injury repair.\textsuperscript{41}

Scheduled echography studies may allow for the assessment of muscle tears and control their evolution.\textsuperscript{9,13,38}

\textbf{Remodeling Phase}

This is the final stage toward work-load and sports technique adaptation. All experts agree on progressively continuing with mechanical
demands on the affected muscle while taking care with the nature of contractions performed. From the clinical point of view, the patient is given the ok to begin sport-specific workouts when basic sports techniques are pain-free and show the same range of mobility as the unaffected limb. Nevertheless, pain-free stretching and contractions, which represent 80% to 85% of the contralateral muscle strength while also showing an adequate speed of contraction, may also be performed in this phase.\textsuperscript{10,11,17,39,42,58}

Acknowledgments
To Mario Wensell for his inestimable assistance in translating this document. To Paloma Pradera and Dolores Morales for contributing in the completion of the database. To BSJ Technical Assistance for their straightforwardness and transparency in keeping both the meeting and the follow-up interest-free

Competing Interests
No participant in this event or any follow-up proceeding has received any type of retribution whatsoever, be it economic or of other nature. So as to avoid such conflict of interests, an independent Technical Assistance service provider (BSJ) was prompted to dispense participants any kind of need in this event.

Funding
Bioiberica, Diafarm, Heel

Supported by: SETRADE, FEMEDE, AEMEF, AEMB

References
1. Allbrook DB, Baker NC, Kirkaldy-Willis WH. Muscle regeneration in experimental animals and in man. \textit{J Bone Joint Surg.} 1966;48B:153-169.
2. Almekinders LC. Anti-inflammatory treatment of muscular injuries in sport. \textit{Sports Med.} 1999;28:383-388.
3. Balis R, Guía de Práctica Clínica de las lesiones musculares. Epidemiología, diagnóstico, tratamiento y prevención versión 4.5. \textit{Apunts Med Esport.} 2009;44:179-203.
4. Bianchi S, Martinolli C. Thigh. In: Bianchi S, Martinoli S, eds. \textit{Ultrasound of the Musculoskeletal System}. New York: Springer; 2007:611-636.
5. Brandan E, Fuentes ME, Andrade W. The proteoglycan decorin is synthesized and secreted by differentiated myotubes. \textit{Eur J Cell Biol.} 1991;55:209-216.
6. Brockett CL, Morgan DL, Proske U. Human hamstring muscles adapt to eccentric exercise by changing optimum length. *Med Sci Sports Exerc.* 2001;33:783-790.
7. Casar JC, McKechnie BA, Fallon JR, Young MF, Brandan E. Transient up-regulation of biglycan during skeletal muscle regeneration: delayed fiber growth along with decorin increase in biglycan-deficient mice. *Dev Biol.* 2004;268:358-371.
8. Connell DA, Schneider-Kolsky ME, Hoving JL, et al. Longitudinal study comparing sonographic and MRI assessments of acute and healing hamstring injuries. *AJR Am J Roentgenol.* 2004;183:975-984.
9. Crema MD, Yamada AF, Guermazi A, Roemer FW, Skaf AY. Imaging techniques for muscle injury in sports medicine and clinical relevance. *Curr Rev Musculoskelet Med.* 2015;8:154-161.
10. Croisier JL. Factors associated with recurrent hamstring injuries. *Sports Med.* 2004;34:681-695.
11. Croisier JL. Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med.* 2002;30:199-203.
12. De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. *AJR Am J Roentgenol.* 2000;174:393-399.
13. Delgado GJ, Chung CB, Lektrakul N, et al. Tennis leg: clinical US study of 141 patients and anatomic investigation of four cadavers with MR imaging and US. *Radiology.* 2002;224:112-119.
14. Del Valle Soto M, Jiménez Díaz F, Manonelles Marqueta P, et al. Consenso sobre utilización de la vía parenteral en el deporte. Utilización de medicación homeopática, terapias biológicas y biorreguladoras. Documento de Consenso de la Federación Española de Medicina del Deporte. *Arch Med Deporte.* 2013;153:8-13.
15. Durham WJ, Arbogast S, Gerken E, Li YP, Reid MB. Progressive nuclear factor-kappaB activation resistant to inhibition by contraction and curcumin in mdx mice. *Muscle Nerve.* 2006;34:298-303.
16. Fernandez Jaen TF, Guillen Garcia P. New protocol for muscle injury treatment. In: *Sports Injuries, Prevention, Diagnosis, Treatment and Rehabilitation.* New York: Springer; 2012:887-893.
17. Hallén A, Ekstrand J. Return to play following muscle injuries in professional footballers. *J Sports Sci.* 2014;1:1-8.
18. Hill M, Wernig A, Goldspink G. Muscle satellite (stem) cell activation during local tissue injury and repair. *J Anat.* 2003;203:89-99.
19. Howatson G, Gaze D, van Someren KA. The efficacy of ice massage in the treatment of exercise-induced muscle damage. *Scand J Med Sci Sports.* 2005;15:416-422.
20. Huard J, Li Y, Fu FH. Muscle injuries and repair: current trends in research. *J Bone Joint Surg Am.* 2002;84-A:822-832.
21. Hyldahl RD, Hubal MJ. Lengthening our perspective: morphological, cellular, and molecular responses to eccentric exercise. *Muscle Nerve.* 2014;49:155-170.
22. Järvinen TA, Järvinen TL, Kääriäinen M, et al. Muscle injuries: optimizing recovery. *Best Pract Res Clin Rheumatol.* 2007;21:317-331.
23. Järvinen TA, Järvinen TL, Kääriäinen M, Kalimo H, Järvinen M. Muscle injuries: biology and treatment. *Am J Sports Med.* 2005;33:745-764.
24. Jiménez Díaz JF. Lesiones musculares en el deporte. *Rev Int Ciencias Deporte.* 2006;3(2):45-67.
25. Kannus P. Immobilization or early mobilization after an acute soft-tissue injury? *Phys Sportsmed.* 2000;28:1-8.
26. Koulouris G, Connell DA, Brukner P, Schneider-Kolsky M. Magnetic resonance imaging parameters for assessing risk of recurrent hamstring injuries in elite athletes. *Am J Sports Med.* 2007;35:1500-1506.
27. Lee JC, Mitchell AWM, Healy JC. Imaging of muscle injury in the elite athlete. *Br J Radiol.* 2012;85:1173-1185.
28. Lehto M. Healing of skeletal muscle injury: an ultrastructural and immunohistochemical study. *Med Sci Sports Exerc.* 1991;23:801-810.
29. Lehto MU, Jarvinen MJ. Hurme T, Kalimo H, Muscle injuries, their healing process and treatment. *Ann Chir Gynaecol.* 1991:80:102-108.
30. Lempainen L, Sarimo J, Heikkilä J, Mattila K, Orava S. Surgical treatment of partial tears of the proximal origin of the hamstring muscles. *Br J Sports Med.* 2006;40:688-691.
31. Li ZB, Kollias HD, Wagner KR. Myostatin directly regulates skeletal muscle fibrosis. *J Biol Chem.* 2008;283:19371-19378.
32. López A. Bases científicas para el tratamiento del desgarro muscular: movilización versus inmovilización. *Rev Esp Cir Osteoartic.* 1996;31:192-196.
33. Mackey AL, Mikkelsen UR, Magnusson SP, Kjaer MS. Rehabilitation of muscle after injury - the role of anti-inflammatory drugs. *J Med Sci Sports.* 2012;22(4):e8-14.
34. Massagué J, Cheifetz, S, Endo, T, Nadal-Ginard B. Type beta transforming growth factor is an inhibitor of myogenic differentiation. *Proc Natl Acad Sci U S A.* 1986;83:8206-8210.
35. Mehallo CJ, Drezner JA, Bytomski JR. Practical management: nonsteroidal antiinflammatory drug (NSAID) use in athletic injuries. *Clin J Sport Med.* 2006;16:170-174.
36. Mishra A, Woddall J, Vieira A. Treatment of tendon and muscle using platelet-rich plasma. *Clin Sports Med.* 2009;28:113-125.
37. Mondardini P, Tanzi L, Verardi S et al. Nuove metodologie nel trattamento della patologia muscolare traumatica dell’atleta. La T.E.C.A.R. terapia. Med Sport. 1999;52:201-213.
38. Muñoz S. Lesiones musculares deportivas: diagnostico por imagenes. Rev Chil Radiol. 2002;8(3):127-132.
39. Orchard J, Best TM, Verrall GM. Return to play following muscle strains. Clin J Sport Med. 2005;15:436-441.
40. Pan Y, Chen C, Shen Y, et al. Curcumin alleviates dystrophic muscle pathology in mdx mice. Mol Cells. 2008;25:531-537.
41. Pasiakos SM1, Lieberman HR, McLellan TM. Effects of protein supplements on muscle damage, soreness and recovery of muscle function and physical performance: a systematic review. Sports Med. 2014;44:655-670.
42. Pedret C, Rodas G. Lesiones Musculares en el Deporte. Miguel Hidalgo, Mexico: Ed Panamericana; 2013:107-112.
43. Reurink G, Brilman EG, de Vos RJ, et al. Magnetic resonance imaging in acute hamstring injury: can we provide a return to play prognosis? Sports Med. 2015;45:133-146.
44. Reynolds JF, Noakes TD, Schwellnus MP. Non-steroidal anti-inflammatory drugs fail to enhance healing of acute hamstring injuries treated with physiotherapy. S Afr Med J. 1995;85:517-522.
45. Riquelme C, Larrain J, Schonherr E, Henriquez JP, Kresse H, Brandan E. Antisense inhibition of decorin expression in myoblasts decreases cell responsiveness to transforming growth factor beta and accelerates skeletal muscle differentiation. J Biol Chem. 2001;276:3589-3596.
46. Sadil, V., Sadil, S.Elektrotherapie. Wien Med Wschr. 1994;144:09-520.
47. Schaser KD, Disch AC, Stover JF, Lauffer A, Bail HJ, Mittlmeier T. Prolonged superficial local cryotherapy attenuates microcirculatory impairment, regional inflammation, and muscle necrosis after closed soft tissue injury in rats. Am J Sports Med. 2007;35:93-102.
48. Schoff R. The satellite cell and muscle regeneration. In: Engel AG, Franzini-Armstrong C, eds. Myology. Basic and clinical, 2nd ed. New York: McGraw-Hill; 1994:97-118.
49. Sener M, Akhan S, Kazimoglu C, Karapinar H, Tuna B, Cecen B. The effects of suramin in prevention of peritendinous adhesions following flexor tendon injury in a chicken model. Orthopedics. 2008;31:542.
50. Tabary J, Tabary C, Tardieu C, Tardieu G. Goldspink G. Physiological and structural changes in the cat's soleus muscle due to immobilization at different lengths by plaster casts. J Physiol. 1972;224:231-244.
51. Thorsson O, Rantanen J, Hurme T, Kalimo H. Effects of nonsteroidal antiinflammatory medication on satellite cell proliferation during muscle regeneration. Am J Sports Med. 1998;26:172-176.
52. Thorsson, O, Lijia, B, Nilsson, P. Immediate external compression in the management of an acute muscle injury. *Scand J Med Sci Sports*. 1997;7:182-190.

53. Tiidus PM. Alternative treatments for muscle injury: massage, cryotherapy, and hyperbaric oxygen. *Curr Rev Musculoskelet Med*. 2015;8:162-167.

54. Tiidus, PM. *Skeletal Muscle Damage and Repair*. Champaign, IL: Human Kinetics Pub; 2007.

55. Tornese D, Bandi M, Melegati G, Volpi P. Principles of hamstring strain rehabilitation. *J Sports Traumatol*. 2000;22:70-85.

56. Tornese D, Melegati G, Volpi P. Tecarterapia. Muscle Strains. In: Volpi P (ed). *Football Traumatology*. New York: Springer; 2006:153-164.

57. Wang CJ. An overview of shock wave therapy in musculoskeletal disorders. *Chang Gung Med J*. 2003;26:220-232.

58.-Wong S, Ning A, Lee C, Feeley BT. Return to sport after muscle injury. *Curr Rev Musculoskelet Med*. 2015;8:168-175.

59. Zhu J, Li Y, Shen W, Qiao C, Ambrosio F, Lavasani M. Relationships between transforming growth factor-beta1, myostatin, and decorin: implications for skeletal muscle fibrosis. *J Biol Chem*. 2007;282:5852-5863.
Supplementary file
Based on current scientific findings, do you agree on the below outlined general treatment guidelines applied to muscular repair processes and their multiple phases regardless of the degree of injury sustained and its location?

A) **Inflammatory phase**, duration 1-2 days:
1) Complete immobilization (eg, splint)
2) Vascular taping or similar elastic compression system
3) Cryotherapy
4) Administration of inflammation bioregulators
5) Administration of NSAIDs (ibuprofene, diclofenac, etc)
6) Always release hematoma
7) Release hematoma only under intense pain or in the presence of neurovascular compressive syndrome symptoms
8) Administration of analgesics based on pain intensity (paracetamol, metamizole, etc)
9) No weightbearing on affected limbs (ie, crutches, heel)
10) Mobilization based on pain tolerance
11) Drug administration: parental/oral/topical/combined
12) Elevation
13) Sport rest
14) Echography test
15) Magnetic resonance test

B) **Degenerative and vascularization phase**, until day 14 after injury onset:
1) Maintain previously adopted measures:
   - Full immobilization
   - Elastiac bandage
   - Cryotherapy
   - Inflammatory bioregulators
   - NSAIDs
   - Always release hematoma:
   - Release hematoma only under intense pain or in the presence of neurovascular compressive syndrome symptoms
2) Vascularization enhancing physiotherapy techniques
3) Administration of enzyme therapy to increase degradation
4) Administration of TGF-beta growth factor inhibitors
5) Perform muscle contractions as tolerated
6) Use of techniques and substances to stimulate satellite cells; if so, please specify
7) Use of techniques and substances to increase oxygen supply; if so, please specify
8) Use of thermotherapy techniques
9) Massage
10) Semi-invasive techniques (dry puncture, IPE, etc)
11) Pain-free stretching
12) Stretching with pain
13) Administration of vascularization-enhancing substances
14) Start isometric drills
15) Maintain aerobic capacities (eg, water exercises)
16) Gradual increase of sport technique avoiding use of affected area
17) Echography test

C) **Cell-stimulating, proliferative and fibrotic phase**, until day 28 after injury onset:
   1) Maintain previously adopted measures:
      - Complete immobilization
      - Elastic bandage
      - Cryotherapy
      - Inflammation bioregulators
      - NSAIDs
      - Drain all hematomas
      - Drain hematoma if intense pain or compression is present:
        - Analgesics
        - No weightbearing
   2) Reinforce use of antifibrotic substances and techniques
   3) Stretching as tolerated
   4) Increase metabolic supply (proteins, food supplements, etc)
   5) Increase mechanical demand on muscle as tolerated (isometric, concentric, excentric contractions, etc)
   6) Begin basic sport technique movements as tolerated
   7) Gradual increase of specific sport technique for each sport
   8) Echography study

D) **Remodeling phase**
   1) Maintain previously adopted measures
   2) Decision on return to sports activity, when
      - Pain-free stretching
      - Pain-free contractions
      - Pain-free basic sport technique movements