




Medial Gastrocnemius Strain: Clinical Aspects and Algorithmic Approach

Farzin Halabchi¹, Mohammad Mahdi Tavana^{1*} , Vahid Seifi¹, Marzieh Mahmoudi Zarandi¹

Received: 24 Nov 2023

Published: 15 May 2024

Abstract

Medial gastrocnemius strain (MGS), is the most common cause of mid-calf pain in athletes due to the stretch of the gastrocnemius muscle when the knee is in extension and the ankle is in dorsiflexion. Chronological age and previous calf injury are the most substantial risk factors for MGS, including high body mass index, previous lower limb injuries, L5 radiculopathy, and inadequate warm-up. The dominant presentation of MGS is a pain that can be diverse from acute to latent, which is felt in the posteromedial aspect of the calf and is often preceded by a feeling of a pop. The signs of MGS include antalgic gait, ecchymosis, swelling, local tenderness, and sometimes a palpable gap felt along the muscle. Passive dorsiflexion of the ankle or resistive ankle plantarflexion with knee extension can indicate a more severe injury, while functional tests can illicit milder injuries of calf muscles—including gastrocnemius. The diagnosis of MGS is usually made by clinical evaluation. However, imaging modalities—including magnetic resonance imaging and ultrasound—can be helpful in case of suspicion. In most cases of MGS, the cornerstone of treatment is nonoperative rehabilitation, which can be performed as a 4-phase program and should be tailored individually. Some instances of MGS are referred for early or later surgical treatment if indicated.

In this article, we review the literature about various aspects of MGS, from diagnosis to treatment and rehabilitation, and propose a structured approach to this injury.

Keywords: Orthopedics, Sports Medicine, Rehabilitation, Athletic Injuries, Gastrocnemius Muscle

Conflicts of Interest: None declared

Funding: None

***This work has been published under CC BY-NC-SA 1.0 license.**

Copyright© Iran University of Medical Sciences

Cite this article as: Halabchi F, Tavana MM, Seifi V, Mahmoudi Zarandi M. Medial Gastrocnemius Strain: Clinical Aspects and Algorithmic Approach. *Med J Islam Repub Iran.* 2024 (15 May);38:55. <https://doi.org/10.47176/mjiri.38.55>

Introduction

In 1883, Powell described the term “Tennis Leg” as acute mid-calf pain primarily attributed to plantaris injury. However, further studies—including imaging modalities—showed that the most common cause of mid-calf pain among patients is the strain on the medial head of the gastrocnemius, also known as the medial gastrocnemius strain (MGS) (1).

Despite the appellation of “tennis leg” to calf injuries, a

study found that only about 16% of athletes with calf injuries are among tennis players. Another study showed that this injury includes 4% of all tennis-related injuries (2, 3).

Multiple studies have studied calf strain incidence in different sports. It has been shown that the incidence per team per season can be as high as 2.9 in Australian Football, 2.3 in soccer and American football, and 1.2 in basketball, which is most probably caused by MGS (4-7).

Corresponding author: Dr Mohammad Mahdi Tavana, tavana-m@razi.tums.ac.ir

¹ Department of Sports and Exercise Medicine, Imam Khomeini Hospital Complex, Tehran University of Medical Sciences, Tehran, Iran

↑What is “already known” in this topic:

Medial gastrocnemius strain is the most common injury in the calf region among athletes, and multiple studies have been done on it. While some aspects of this injury are studied extensively, studies on other aspects are still few and sparse.

→What this article adds:

This article gathers and analyzes information on medial gastrocnemius strains from every angle, including their nature, risk factors, how they are diagnosed, and different treatments, focusing on nonsurgical rehabilitation. It aims to enhance our approach to treating this injury, providing a more comprehensive perspective.

Being the most superficial muscle of the calf, gastrocnemius is comprised of 2 heads: the more robust and thicker medial head, which originates from the posterior surface of the medial condyle and epicondyle of the femur, and the lateral head, which originates from the lateral condyle and epicondyle of the femur. The 2 heads are directed downward, and their aponeuroses merge to form a large aponeurosis, which forms the Achilles tendon in participation with soleus and plantaris aponeuroses (8, 9).

The gastrocnemius, innervated by the tibial nerve, is the primary plantar flexor of the ankle while the knee is in extension and is a secondary flexor of the knee, hence a bi-articular muscle. Compared to other lower limb muscles, this muscle comprises a relatively higher proportion of type II fibers (about 50%) and is mainly involved in explosive movements (8-10).

In this study, we review the literature on clinical aspects of MGS and then take an algorithmic approach to this injury.

Pathophysiology and Mechanism of Injury

Gastrocnemius is prone to injury more than other calf muscles for 2 possible reasons:

1- Gastrocnemius is a bi-articular (knee and ankle) muscle known to be a risk factor for a muscle to be strained since it can be stretched at more than one joint (11).

2- Compared to soleus (comprising about 30% of type II muscle fibers), gastrocnemius contains about 50% of type II muscle fibers (10). Type II (fast twitch) muscle fibers are more prone to injuries from eccentric forces than other muscle fibers (12).

Evidence shows that the medial head is more active than the lateral head of the gastrocnemius, especially in the toe-out position (13). This is probably related to the greater proximal attachment and a longer distal insertion of the medial head than the lateral head (14).

For the aforementioned reasons, the medial head of the gastrocnemius is the most vulnerable muscular structure in the calf to injury.

The posture in which the knee is in extension and the ankle is in dorsiflexion is a predisposing factor for gastrocnemius strain since this posture puts the muscle in maximal stretch. This stretch can expose the muscle to varying degrees of tear. The much more common mechanism is during the push-off phase of jumping and running, in which the muscle moves from the eccentric phase (stretched while the knee is in extension and the ankle is in dorsiflexion) to the isometric contraction phase (15, 16).

Risk Factors

According to a systematic review by Green and Pizzari, chronological age and previous calf injury are the most substantial risk factors for calf injury in the athletic population (17).

However, high body mass index, previous lower limb injuries (other than calf), L5 radiculopathy, and inadequate warm-up have shown some associations with calf strain, although with limited evidence (17-19).

Clinical Presentation

History

Referring to the mechanism, the patient may point out the feeling of a pop or snap in the calf during a sudden push-off. The presentation of pain can be diverse from acute, sudden, and sharp pain to latent (as much as 24 hours) and dull pain, which is felt in the posteromedial aspect of the calf. This pain may be present during rest but may only be manifested upon standing, walking, passive dorsiflexion, or active plantarflexion of the foot. Feeling cramps or weakness in the calf are among other possible symptoms (15, 18, 20).

Prodromal symptoms such as cramps and dull muscle pain can be seen in as much as 20% of the patients (15, 21).

Physical Examination

The first observable sign by a physician is the patient's antalgic gait since the patient cannot bear weight on the affected limb. Other observational signs that can be detected are ecchymosis and swelling in the injured area (22).

On palpation, a local tenderness can be detected, and in case of complete muscle rupture and muscle retraction, a palpable gap is felt along the muscle (22, 23).

Provocative muscle tests are an essential part of the examination. Simple tests, such as passive dorsiflexion of the ankle or resistive ankle plantarflexion, can indicate a more severe injury. These 2 tests can suggest gastrocnemius strain if performed with knee extension. Functional tests such as running, jumping, and single-leg hopping can illicit milder injuries of the calf muscles, including gastrocnemius (15, 23).

Imaging

Although most MGS cases are diagnosed clinically, imaging may be used to exclude other diagnoses and surveillance of the rehabilitation process (24, 25).

Two imaging modalities used for investigating MGS are ultrasonography (US) and magnetic resonance imaging (MRI).

Being affordable and dynamic imaging are the 2 main advantages of the US. The US is indicated for locating the exact injury site, grading the injury, surveillance of the healing process and inflammation (doppler ultrasound), and ultrasound-guided hematoma or accumulated fluid aspiration (26, 27) (Figure 1). Using US for MGS diagnosis is performed with the high-frequency linear probe. Patients are placed in a prone position with a pillow placed immediately proximal to the ankle and foot hanging from the edge of the examination table to allow ankle movement if needed (28). In a case report, Chen et al described a novel gastrocnemius medial head sonography positioning. In this approach, the patient is placed in the supine position with the knees flexed at 90 degrees and the probe pointing upwards to examine the muscle. This position helps to move the fluid caused by inflammation from the depth of the muscle to its surface using gravity. This can help detect muscle injury in cases where no evidence of damage can be seen in the US despite the positive findings in the examination (29). The structure of gastrocnemius medial head should be investigated in longitudinal and transverse

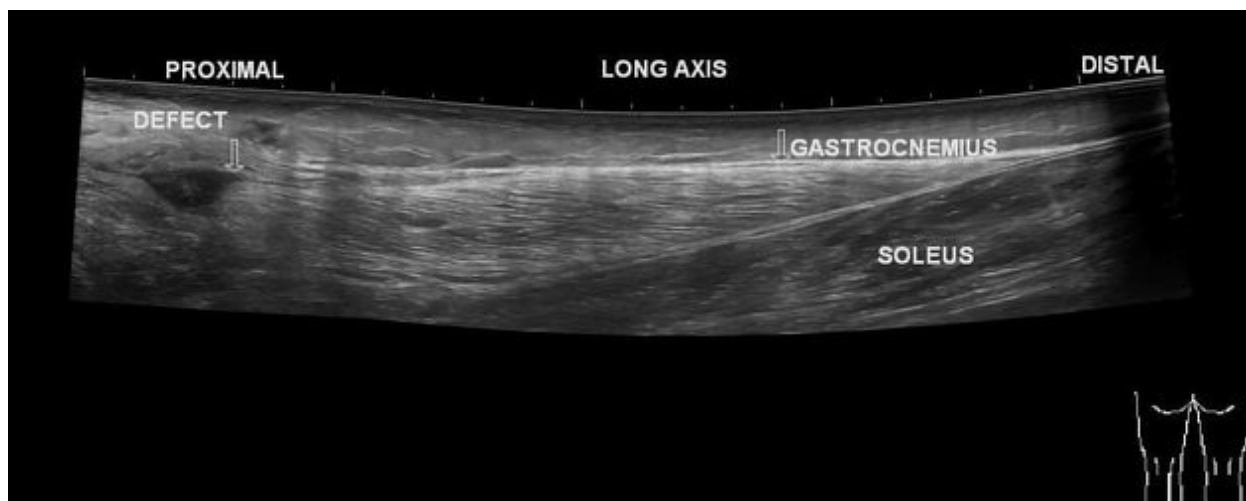


Figure 1. Panoramic ultrasound view reveals a discontinuity of proximal tendon of medial head of gastrocnemius with retraction. The defect is filled with a collection and there is overlying subcutaneous edema. Case courtesy of Dr Maulik S Patel, rID 61865, Radiopaedia.org (with Permission).

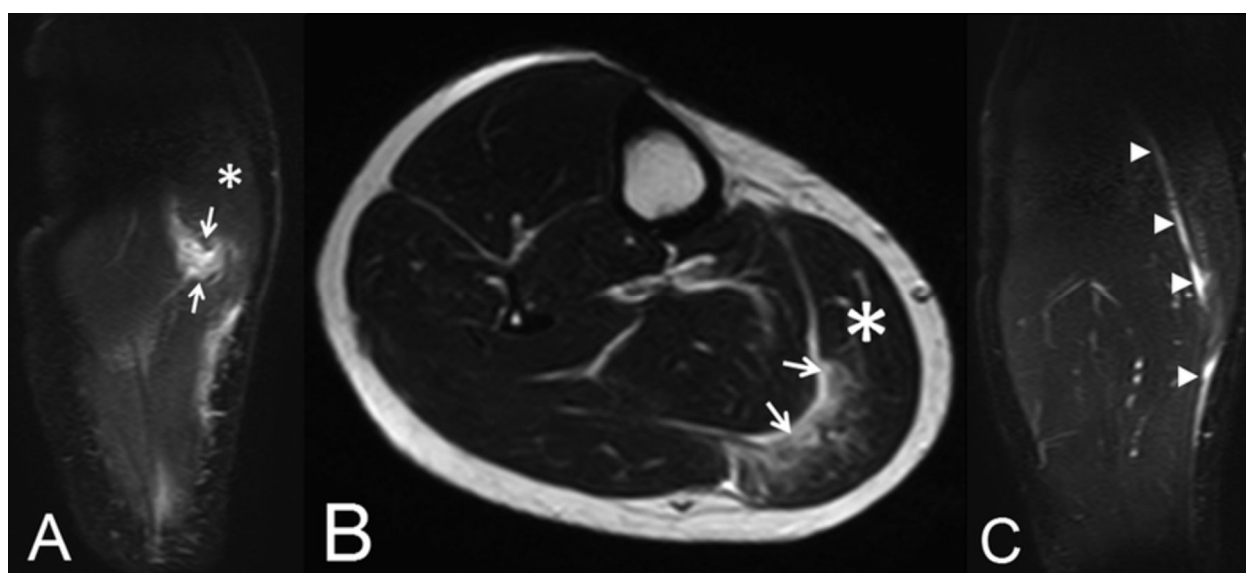


Figure 2. Coronal fat-saturated (A) and axial T2-weighted (B) MRI images reveal a partial tear (indicated by arrows) in the upper region of the right gastrocnemius muscle's medial head (marked with an asterisk). Additionally, a coronal fat-saturated T2-weighted MRI (C) displays a slight presence of fluid (denoted by arrowheads) along the surrounding fascial layer.

Source: Ozyurek, S, et al. (2013). Isolated partial rupture of the medial head of the gastrocnemius muscle (tennis leg). *BMJ Case Reports*. <https://doi.org/10.1136/bcr-2013-009347> (with Permission).

planes. In case of doubt, the US should be performed in the planes above and other locations to exclude other diagnoses (28).

A noncontrast MRI, albeit being an expensive option relative to other imaging modalities, gives a more precise image of the soft tissue injuries and can be indicated in case of discordance between physical examination and US findings, suspicion of subtotal or complete muscle lesions, suspicion of tendon involvement or bone-tendon avulsions and looking for other structural injuries in elite athletes (26, 30). In the case of MGS, MRI should be assessed in the axial plane for muscle contours and musculotendinous junction and in coronal and sagittal planes for the extent of the injury. A normal skeletal muscle will have an intermediate to

low signal intensity on T1 and T2-weighted images and short tau inversion recovery (STIR) sequences. Regarding MGS, T1-weighted imaging is suitable for assessing the gastrocnemius medial head's anatomy and degree of intratendinous injury. Like other muscular injuries, edema and fluid collection have a high signal and feathery appearance on T2-weighted and STIR sequences (Figure 2). A common place for hematoma formation is between the medial head of the gastrocnemius and soleus, which has a high signal and V-shaped appearance on sagittal T2-weighted and STIR sequences (31-33).

During the healing process, a persistent high T2 signal indicates an ongoing healing process, which can be seen for weeks to months, even after returning to play. A low T2

signal during the healing process can indicate scar formation or hemosiderin deposition due to previous hemorrhage (26).

Differential Diagnosis

MGS's most common differential diagnoses are strains of other calf muscles (soleus and plantaris) and types of calf muscle injuries—including cramps, contusions, and delayed onset muscle soreness. The different diagnoses with less prevalence include superficial and deep posterior compartment syndromes of the calf, referred pain from the knee, superior tibiofibular joint, lumbar region and other myofascial structures, vascular problems (atherosclerosis, popliteal artery entrapment and endofibrosis of external iliac artery), nerve entrapments (tibial and sural nerve), stress fractures of leg and varicose veins. Deep vein thrombosis (DVT), arterial aneurysm, cellulitis, osteomyelitis, tumors, and distal avulsion fracture of the femur due to traction force of proximal medial head of gastrocnemius, although with far less prevalence, should be taken into account according to clinical suspicion (14,34-40).

Differential diagnosis of MGS and their respective features are presented in Table 1.

Grading System

Diverse systems have been proposed for grading muscle injuries. These systems use different types of criteria for their proposed gradings. Tscholl et al have merged different

grading systems based on various criteria—including signs and symptoms, pathologic correlation, and imaging—which are both simple and comprehensive and can be used to grade MGS (41). Therefore, we decided to provide a modified MGS grading based on this classification (Table 2).

Treatment

Accurate and early diagnosis and treatment of MGS can significantly reduce the duration of its related disabilities. Before returning to the previous activity level, a complete recovery of strength and flexibility should be achieved. (23). The treatment process starts with acute injury management and continues with nonoperative or operative treatment based on the clinician's decision.

Operative vs Nonoperative Treatment

Although the cornerstone of treatment in most MGS cases is nonoperative rehabilitation, some cases are referred for early surgical treatment. These early indications include complete and severe rupture of the gastrocnemius medial head, large hematomas, and compartment syndrome (20,42).

In some cases, during or after the completion of nonoperative treatment, some patients may be required to undergo a surgical operation based on some indications, which include severe loss of plantarflexion force where the injury is preventing the patient from returning to the previous level

Table 1. Differential Diagnosis of MGS

Differential Diagnosis	Distinguishing Features	Other Important Points
Soleus strain	<ul style="list-style-type: none"> ● Pain is more commonly felt at the posterolateral aspect of the calf (22). ● Pain on passive ankle dorsiflexion or resistive ankle plantarflexion with the knee in the flexed position (22). 	<ul style="list-style-type: none"> ● Soleus should be evaluated in patients with suspicion of MGS. ● MRI is the imaging modality of choice due to muscle depth and structure (33).
Achilles' tendon injury	<ul style="list-style-type: none"> ● Performing Simmond's triad (Palpation, Matles' test, Thompson's squeeze test) which has 100% sensitivity when two of three tests are positive (36). 	<ul style="list-style-type: none"> ● Evaluation of this structure is mandatory in patients suspicious of MGS (20).
Referred pain (from knee, superior tibiofibular joint, lumbar region)	N/A	<ul style="list-style-type: none"> ● Examination and imaging should be done if the patient's history and clinical presentation are suspicious of the mentioned injuries.
Nerve entrapments	<ul style="list-style-type: none"> ● Tibial nerve: Sensory signs and symptoms in the posteromedial of lower leg, posterior and inferior of calcaneus and lateral border of foot (37). ● Sural nerve: Sensory Signs and symptoms in the posterolateral aspect of the distal third of the leg and the lateral aspect of the foot, heel, and ankle (38). 	<ul style="list-style-type: none"> ● Can happen as a consequence of Hematoma (37, 38). ● Motor signs and symptoms are rarely seen in case of tibial nerve entrapment (37).
Arterial Problems	<ul style="list-style-type: none"> ● Intermittent claudication and pain which is being aggravated by walking and running and dissipates with rest (14, 39). ● Abnormal peripheral pulses and arterial bruits can be present (14). 	<ul style="list-style-type: none"> ● Can be confirmed by Doppler ultrasound, ankle-brachial index and angiography (14, 39).
Deep Vein Thrombosis (DVT)	<ul style="list-style-type: none"> ● Cyanosis, a palpable cord, superficial vein dilation and positive Homan's sign (14, 40). 	<ul style="list-style-type: none"> ● DVT can happen in isolation or as a complication of MGS (14). ● The diagnosis of DVT should be confirmed by more accurate imaging modalities such as duplex sonogram (14, 22).

Table 2. MGS Grading

Grade	Amount of Muscle Damage	Clinical Sign and Symptoms	Imaging
Mild	5 -10%	<ul style="list-style-type: none"> Mild pain Mild tenderness, spasm and swelling Normal Function (minimal loss of strength and range of motion (< 10°)) Usually able to continue activity 	<ul style="list-style-type: none"> MRI shows normal muscle structure with or without edema and hemorrhage. Feathery appearance <5% muscle fiber involvement.
Moderate	10 – 50%	<ul style="list-style-type: none"> Moderate pain Moderate tenderness and swelling Palpable defect (>10-25%) Dysfunctional sprinting (moderate loss of strength and range of motion (10°-25°)) Unable to continue activity 	<ul style="list-style-type: none"> US may show muscle disruption < 5% MRI shows < 50% tearing with or without retraction. Edema and hemorrhage can be seen. US shows muscle disruption > 5% with edema and hemorrhage and possible fascial damage.
Severe	> 50%	<ul style="list-style-type: none"> Severe pain Significant palpable defect Disability in sprinting (severe loss of strength and range of motion (>25°)) 	<ul style="list-style-type: none"> MRI shows complete tearing with or without retraction. Extensive edema and hemorrhage can be seen. US shows complete muscular and fascial disruption.

of activities, prolonged pain and contractures for more than 4 to 6 months, despite following the nonoperative protocol, and cases with debilitating complications such as fibrosis and heterotopic ossification (20, 43).

Nonoperative Treatment

Generally, MGS nonoperative management and physical therapy take approximately 3 to 6 weeks, depending on the patient's status and injury severity (22). Unfortunately, the literature on the MGS rehabilitation process is few and sparse. However, by summarizing different findings and opinions (18, 22, 30, 44-51), we have reached our 4-phase protocol. The details of this protocol and the rate of progression should be tailored based on the patient's physical condition and the severity of the injury.

Phase 1

- The primary management for MGS, as with other muscular injuries, is to apply the POLICE (Protection, optimal loading, ice, compression, and elevation) principle for approximately 24 to 48 hours after injury.

- Icing and compression by the sleeve (20 to 30 mmHg) should be started initially and continued for at least 1 week until the physician can detect no swelling or hematoma, either by physical examination or US imaging.

- Crutches can be used for ambulation during the first 1 to 2 weeks. Normal weight bearing and walking can be started with and without crutches as tolerated by the patient.

- Using a walking boot with a heel lift on the injured side, which minimizes the stretch on calf muscles, can be an alternative option, and a heel lift can be used for up to 12 weeks during walking. However, some experts recommend bilateral heel lifts (6 mm in height) for much shorter periods.

- Physical therapy modalities can further reduce inflammation and pain and promote the healing process. These modalities include continuous or pulsed low-intensity therapeutic ultrasound (0.5-1W/cm²), low-level laser therapy, and electrotherapy. Recent consensus recommends against the mentioned modalities due to their endothermic effects (increasing tissue temperature) during the initial 72 hours

after injury.

- Soft tissue techniques such as mobilization and massage are contraindicated at this stage, as they may cause bleeding in the injured area.

- Active and passive range of motion exercises can be implanted in pain-free range to recover flexibility (Figure 3). Stretching is prohibited in this phase, as it may exacerbate the injury.

- To restore the strength of the gastrocnemius and other calf muscles, isometric plantarflexion can be started at different angles, followed by isotonic plantarflexion in a non-weight-bearing position (Figure 3). If tolerated, double leg calf raises with extended or flexed knee can be prescribed in this phase.

- For proprioception, Biomechanical Ankle Platform System (BAPS) board training in a nonweight-bearing position is recommended.

- Level 1 core muscle exercises, providing minimal pressure on calf muscles (eg, abdominal draw-in, prone cobra, diagonal crunches) can be done for stabilization of core muscles.

- Cardiovascular fitness can be maintained by upper body ergometer training.

- Milestones for progression to the next phase:

- Resolution of initial swelling/hematoma.
- Pain-free active and passive range of motion within a safe range.
- Isometric plantarflexion without pain and discomfort.
- Walking without pain while maintaining a regular gait pattern.

Phase 2

- In addition to the physical therapy modalities mentioned, soft tissue techniques that were prohibited during the initial phase can be utilized here.

- To improve the range of motion in this phase, non-weightbearing, low load, high duration, static stretching with a towel can be done.

- High velocity nonloaded weightbearing plantarflexion (ie, double and single leg calf raise) can be used in the



Figure 3. Examples of exercise for phase 1 of MGS Rehabilitation. A- Active ankle ROM with flexed knee (1. Plantarflexion, 2. Dorsiflexion, 3. Inversion, 4. Eversion), B- Passive ankle ROM with flexed knee (1. Plantarflexion, 2. Dorsiflexion, 3. Inversion, 4. Eversion), C- Isotonic ankle plantarflexion with elastic band (1. Starting position, 2. Ending position), D- Isometric ankle plantarflexion against the wall (1. Knee extended, 2. Knee flexed)

strengthening component of this phase, and it can be progressed to loaded exercises (Figure 4).

- Strengthening other ankle movements (eg, dorsiflexion, inversion and eversion) and intrinsic foot muscle exercises can be done in this phase (Figure 4).

- BAPS board training in partial to full weightbearing positions can be prescribed to enhance proprioception.

- Level 2 core muscle exercises can strengthen core muscles by providing mild to moderate pressure on calf muscles (eg, stability ball straight leg raising, prone hip extension, double leg bridging with and without stability ball, stability ball diagonal crunches).

- In addition to upper body exercises, walking and running on gravity-reduced devices or walking in water can be recommended to maintain cardiovascular fitness. All the walking and running exercises in this category should be done on flat and hard surfaces; therefore, inclined and uneven surfaces should be avoided. In addition to the mentioned exercises, stair climbing and stair machines can enhance cardiovascular fitness; however, stair descending is not recommended in this phase.

- Milestones for progression to the next phase:
 - Demonstrate 5/5 strength in plantar flexion exercises—

including both concentric and eccentric movements without pain.

- Brisk walking without pain
- Performing phase 2 exercises with minimal to no pain.

Phase 3

- Deep transverse friction massage is advised at this stage, as it can enhance the healing process and tissue regeneration.

- Weightbearing, low-load, static stretch with the knee in extended and flexed positions (wall lean stretching) is recommended for flexibility enhancement in this phase (Figure 5).

- Different types of isotonic (concentric and eccentric) exercises can be prescribed in this phase and should be progressed according to the patient's symptoms and tolerability (Figure 5).

- BAPS board training in full weightbearing position with and without posterior peg overload helps enhance proprioception in this phase.

- Level 2 and 3 core muscle exercises, providing mild to moderate pressure on calf muscles (eg, stability ball wall slides, single leg bridge with and without stability ball, and

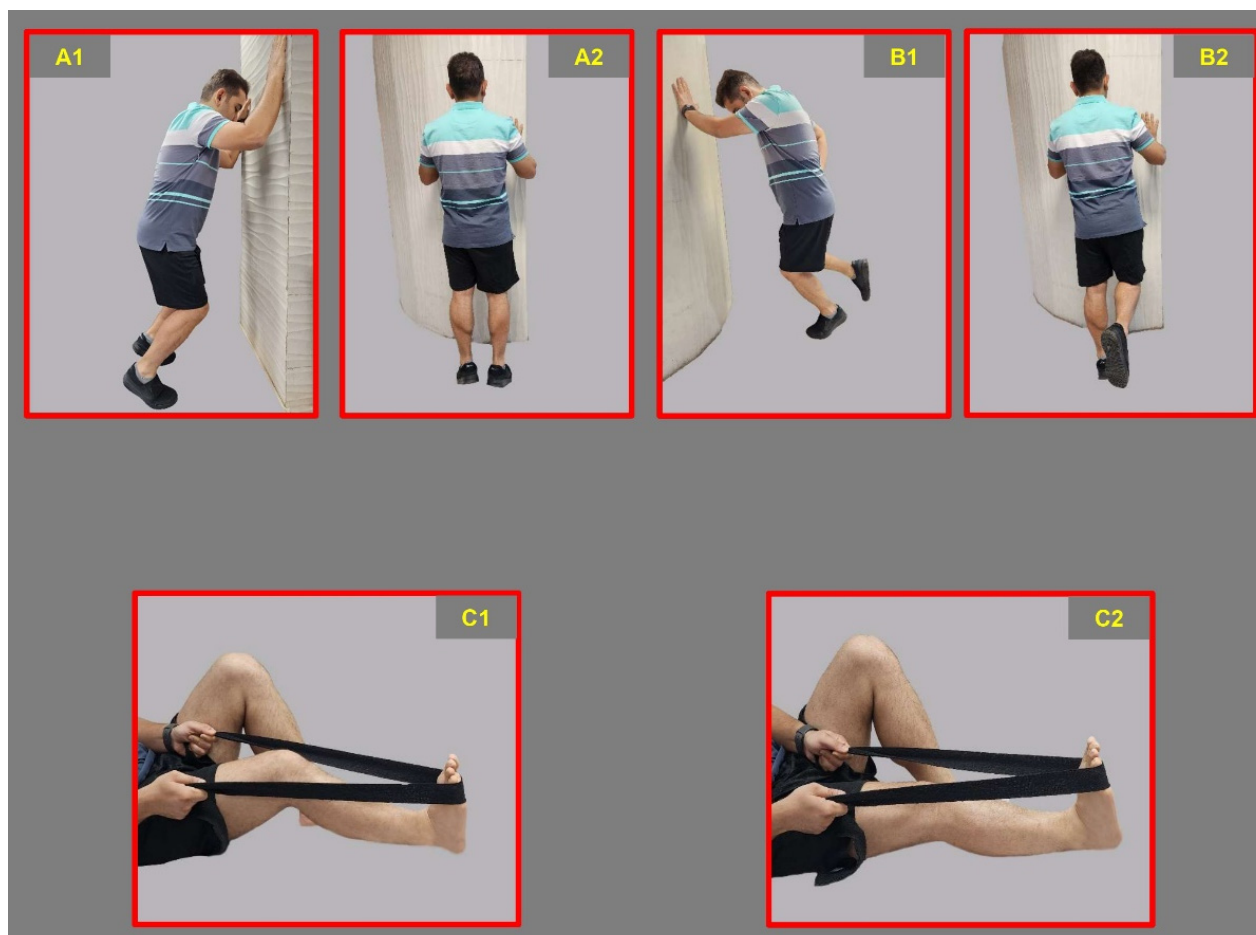


Figure 4. Examples of exercise for phase 2 of MGS Rehabilitation. A- Double leg heel raise (1. Knee flexed, 2. Knee extended), B- Single leg heel raise (1. Knee flexed, 2. Knee extended), C- Calf towel stretch (1. Knee flexed, 2. Knee extended)

stability ball pullover crunch) can be done for increasing strength and power of core muscles.

- Previous aerobic exercises, walking on uneven or inclined surfaces, stationary biking, and stair descending are recommended to enhance cardiovascular fitness in this phase.

- In addition to previous conjunctive exercises (for other ankle movements and intrinsic foot muscles), other lower limb stretches should be commenced in this stage.

- Milestones for progression to the next phase:

- A plantarflexion to dorsiflexion strength ratio of 3-4:1
- Maintain dynamic balance and support on the affected leg.

- Jog or perform light running activities without pain.

- Performing phase 3 exercises with minimal to no pain.

Phase 4

- Flexibility exercises can be done with a combination of static, dynamic, and ballistic stretching exercises.

- Plyometric and functional exercises should be initiated in this phase and should be progressed toward sport-specific exercises.

- Different types of neuromuscular, balance and proprioception exercises (eg, single leg stance on BAPS board, single leg windmill touches, single leg Romanian dead lift, single leg two arm chest press, etc) should be implemented and progressed depending on the patient's condition and function.

- Level 3 core muscle exercises (eg, weighted ball single and double leg jump and weighted ball forward jump from squat) can be done to increase power of core muscles.

- A gradual 5% increase in duration, frequency, and intensity of exercises should be considered.

- Return to running is a crucial part of this phase. Stair exercises such as stair climbing in phase 2 and stair descending in phase 3 can be considered a bridge between walking and normal running.

In this phase, slow running exercises on flat surfaces should gradually progress to running on even and uneven surfaces, followed by sprinting, cutting, acceleration, and deceleration exercises.

It is recommended that before athletes start running in athletic conditions, they be without any signs or symptoms, have normal calf muscle strength, and have normal hopping function.



Figure 5. Examples of exercise for phase 3 of MGS Rehabilitation. A- Seated heel raise with dumbbell (1. Starting position, 2. Ending position), B- Squat to heel raise (1. Starting position, 2. Ending position), C- Wall lean stretch, D- Tip toe walking, E- Eccentric heel raise

Operative Treatment

Following acute management of the injury, an early surgical operation is accompanied by a better prognosis relative to chronic cases in patients with surgical indications (42).

Concisely, the operation consists of making a longitudinal incision on the center of the defect and reattaching the proximal and distal ends of the ruptured muscle by sutures with the foot being held in a plantar flexion position (43).

After the surgery, the lower limb is immobilized in a long leg cast for 3 weeks with 60 degrees of flexion of the knee and approximately 30 degrees of plantar flexion of the ankle. This period of immobilization is followed by another 3 weeks of short leg casting with the same degree of ankle plantar flexion. Gradual rehabilitation, in a similar fashion to nonoperative management, should be started after surgery, and weightbearing should be commenced after about 4 to 6 weeks of using crutches (14, 42).

Adjunctive Treatment Methods

Kinesio Taping

Several studies have attributed potential effects to Kinesio taping (KT) with regard to its manipulative effects on mechanoreceptors, nociceptors, proprioceptors, and local blood circulation. These potential effects include motor

neuron facilitation, pain reduction, and improved blood circulation (52-54).

Despite these potential effects, clinical evidence about the effect of KT on musculoskeletal injuries is still lacking and is not currently recommended as an adjunctive tool for rehabilitation (55, 56). However, since no serious adverse effects have been reported in KT users and because of its noninvasive nature, it can be offered to athletes who wish to use them.

Dry Needling

Although it has not been evaluated by any study, dry needling, theoretically, may have some benefits in the case of MGS treatment and rehabilitation.

Trigger points are defined as taut points of skeletal muscle, which can be palpated as tender small nodules in muscles. These trigger points are divided into 2 subtypes: active trigger points that cause local and referral pain spontaneously and latent trigger points that may cause stiffness, restriction of range of motion, and muscle fatigue and elicit pain only upon stretch or compression (57, 58).

Muscle stiffness and dull calf pain may be the prodromal symptoms of MGS. Therefore, it is very likely that people at risk or sufferers of MGS have trigger points, especially latent type, in their gastrocnemius muscle.

The use of dry needling to relieve these trigger points not only reduces the pain associated with these trigger points but also enhances the mechanical aspects of the gastrocnemius. Therefore, this procedure can be used to help with preventing, treating, and rehabilitating MGS.

Other mechanisms by which dry needling may help with MGS treatment and rehabilitation include enhancement of perfusion in the injured tissue due to resultant local vasodilation, relaxation of the injured muscular tissue, and short-term peripheral and long-term central analgesic effects (59).

Non-steroidal Anti-inflammatory Drugs

Although controversial, the use of nonsteroidal anti-inflammatory drugs (NSAIDs), especially inhibitors of cyclooxygenase-2, is not recommended for the first 48 hours after injury, as they may slow down the healing process. It has also been hypothesized that NSAIDs may increase the rate of injury recurrence due to their pain-masking properties. Therefore, the better choice for controlling the pain and congestion would be to apply ice and use acetaminophen (46, 60).

Platelet Rich Plasma Injection

Platelet-rich plasma (PRP) is a biological agent which is obtained by centrifuging blood and extracting its plasma with a high concentration of platelets. Containing various types of cytokines and growth factors, the effects of PRP on the repair of various injured tissues have been the focus of many studies (61).

Multiple studies have evaluated the effect of PRP on acute muscle injuries. Despite significant heterogeneity among their methods and outcome measures and controversial results, PRP injections have shown potential benefits on multiple treatment outcomes such as reduction of pain and swelling, acceleration of the healing process, and faster return to play with the last one being the most promising (62, 63).

Regarding the particular effect of PRP on MGS, a retrospective study by Borrione et al showed that 3 PRP injections at the first visit and then 1 and 3 weeks later, may have beneficial effects on immediate pain and discomfort of the patients, which in turn can help with the acceleration of rehabilitation process. This study also showed that injured patients may recover faster and return to play compared with patients who went under standard rehabilitation protocol without PRP injections (64).

Corticosteroid Injection

The potential effects of corticosteroids on the inhibition of inflammation and consequent reduction of pain and swelling have made it an available option for the acceleration of the rehabilitation process, although few studies have been in favor of this theory (65).

In contrast to hypotheses, most studies have shown a detrimental effect of corticosteroids on muscle injuries and their healing process, especially in the long term, because of multiple mechanisms such as myotoxicity, irreversible damage to the structure and function of the healing muscle fibers, hindering the absorption of hematoma, and adverse

effects on neuromuscular properties (66, 67).

In conclusion, corticosteroid injection is not recommended in the case of MGS.

Hyaluronic Acid Injection

Hyaluronic acid positively affects muscle proliferation in vitro and animal models (68-70). Although it has been shown that hyaluronic acid can improve function and pain in certain musculoskeletal and soft tissue injuries, its certain effect and superiority to other types of treatments remain a doubt to date (71). Therefore, hyaluronic acid injection is not recommended for MGS treatment at this time.

Prolotherapy

Prolotherapy consists of multiple injections of irritant solutions such as hypertonic saline or dextrose into degenerated or injured musculoskeletal tissues to start an inflammatory process and release mediators that eventually lead to healing and recovery of the target tissue (72, 73).

In vitro and animal studies have shown that prolotherapy may trigger cell proliferation and neovascularization, and even theoretically, it may have analgesic properties. (74, 75).

Although prolotherapy has shown promising positive effects on pain and function in different types of tendinopathies and osteoarthritis, investigations are few and restricted to chronic cases (73, 75).

Until further studies on the effects of prolotherapy, especially on acute muscle injuries, prolotherapy is not recommended in the case of MGS.

Actovegin

Injection of highly purified deproteinized calf serum derivates, also known as Actovegin, has shown promising effects in muscle repair because of its antioxidant, antiapoptotic, proliferative, and endothelial enhancing aspects. However, because of the lack of sufficient evidence to support its benefit in treating muscle injury, experts do not recommend this method (47, 76, 77).

Traumeel

Traumeel, a mixture of herbal and mineral extracts, is a homeopathic agent believed to have comparable anti-inflammatory and analgesic properties to NSAIDs with fewer adverse effects. It can be administered as tablets, drops, injection solution, ointment, and gel (78). Since studies on the effect of Traumeel on muscle injury are still sparse, use of this agent is not recommended in patients with MGS.

Return to Play

The literature on the time and criteria of return to play among those who suffered from MGS is few to date; nonetheless, some recommendations for athletes to return to play after MGS can be stratified as follows:

- Full resolution of self-reported symptoms, for example, pain, tightness, and cramps, et cetera.
- Full resolution of clinical signs, for example, tenderness.

- Psychological readiness and acceptable self-confidence.
- Recovery of strength, power, endurance, and dorsiflexion range of motion with less than 10% asymmetry compared with the uninjured side.
- Ability to perform sport-specific tasks and return to full training for at least 1 session (45).

MGS Algorithmic Approach

Figure 6 provides an algorithmic approach, which can be a helpful guide for clinicians in the case of MGS.

Ethical Considerations

None.

Acknowledgment

Declared none.

Conflict of Interests

The authors declare that they have no competing interests.

References

1. Harwin JR, Richardson ML. "Tennis leg": gastrocnemius injury is a far more common cause than plantaris rupture. *Radiol Case Rep.* 2017;12(1):120-3.
2. Millar AP. Strains of the posterior calf musculature ("tennis leg"). *Am J Sports Med.* 1979;7(3):172-4.
3. Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. *Br J Sports Med.* 2012;46(7):492-8.
4. Werner BC, Belkin NS, Kennelly S, Weiss L, Barnes RP, Potter HG, et al. Acute gastrocnemius-soleus complex injuries in National Football

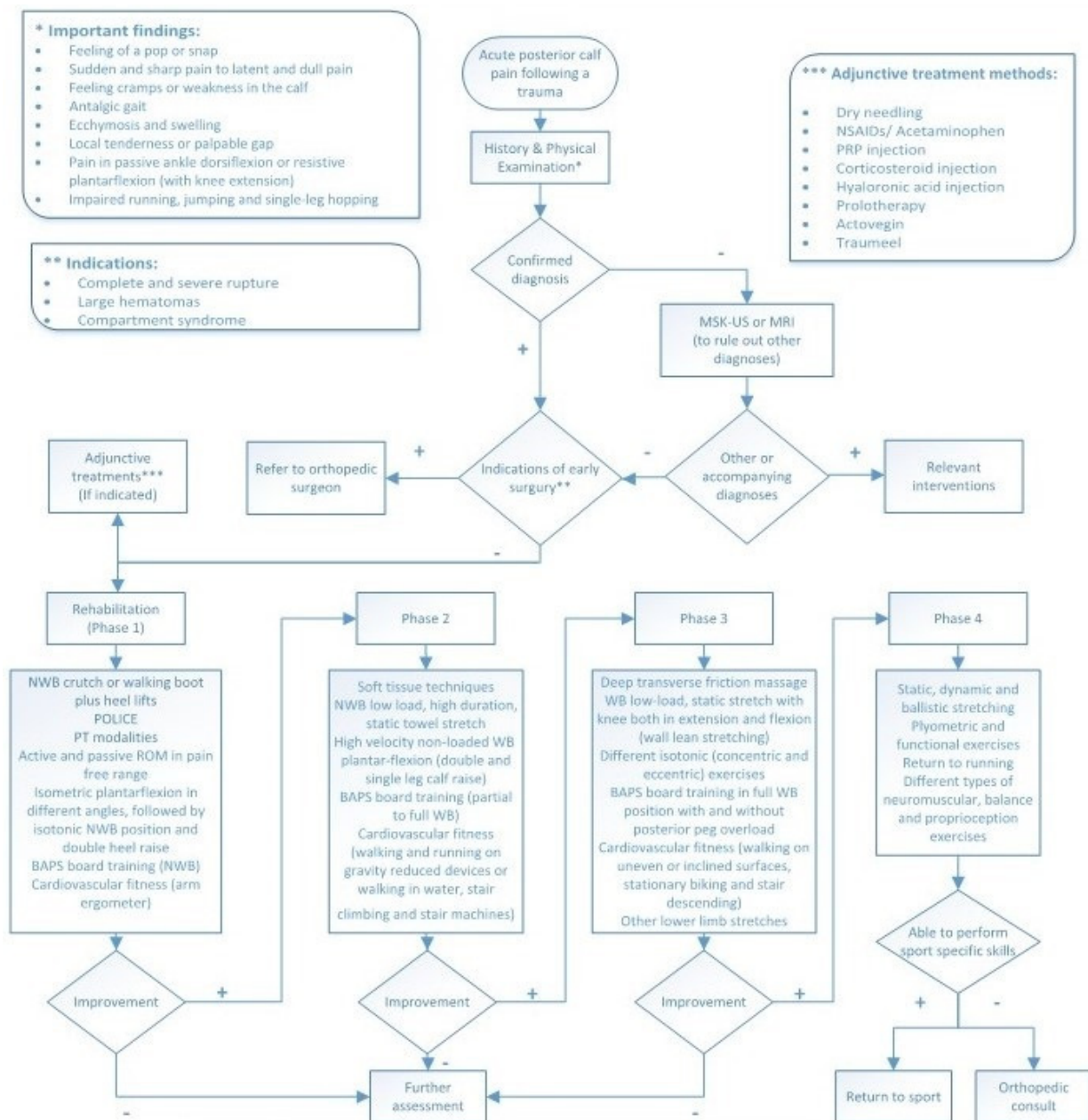


Figure 6. Algorithmic approach to MGS

- League Athletes. *Orthop J Sports Med.* 2017;5(1):2325967116680344.
5. Green B, Lin M, Schache AG, McClelland JA, Semicw AI, Rotstein A, et al. Calf muscle strain injuries in elite Australian Football players: A descriptive epidemiological evaluation. *Scand J Med Sci Sports.* 2020;30(1):174-84.
 6. McKay GD, Goldie PA, Payne WR, Oakes BW, Watson LF. A prospective study of injuries in basketball: a total profile and comparison by gender and standard of competition. *J Sci Med Sport.* 2001;4(2):196-211.
 7. Nilstad A, Andersen TE, Bahr R, Holme I, Steffen K. Risk factors for lower extremity injuries in elite female soccer players. *Am J Sports Med.* 2014;42(4):940-8.
 8. Bordonni B, Varacallo M. *Anatomy, bony pelvis and lower limb, gastrocnemius muscle.* Treasure Island, Florida: StatPearls; 2022.
 9. Mostafa E, Graefe SB, Varacallo M. *Anatomy, bony pelvis and lower limb, leg posterior compartment.* Treasure Island, Florida: StatPearls; 2023.
 10. Edgerton VR, Smith JL, Simpson DR. Muscle fibre type populations of human leg muscles. *Histochem J.* 1975;7(3):259-66.
 11. Garrett WE, Jr. Muscle strain injuries: clinical and basic aspects. *Med Sci Sports Exerc.* 1990;22(4):436-43.
 12. Choi SJ. Differential susceptibility to myosin heavy chain isoform following eccentric-induced muscle damage. *J Exerc Rehabil.* 2014;10(6):344-8.
 13. Cibulka M, Wenthe A, Boyle Z, Callier D, Schwerdt A, Jarman D, Strube MJ. Variation in medial and lateral gastrocnemius muscle activity with foot position. *Int J Sports Phys Ther.* 2017;12(2):233-41.
 14. Brukner P, Khan K, Cook J, Cools A, Crossley KH, M., McCrory P, Bahr R. *Brukner & Khan's Clinical Sports Medicine.* 6 ed. Australia: McGraw-Hill Education; 2017.
 15. Hsu D, Chang KV. *Gastrocnemius strain.* Treasure Island, Florida: StatPearls 2022.
 16. Orchard JW, Alcott E, James T, Farhart P, Portus M, Waugh SR. Exact moment of a gastrocnemius muscle strain captured on video. *Br J Sports Med.* 2002;36(3):222-3.
 17. Green B, Pizzari T. Calf muscle strain injuries in sport: a systematic review of risk factors for injury. *Br J Sports Med.* 2017;51(16):1189-94.
 18. Coffey R, Khan YS. *Gastrocnemius rupture.* Treasure Island, Florida: StatPearls 2022.
 19. Orchard JW, Farhart P, Leopold C. Lumbar spine region pathology and hamstring and calf injuries in athletes: is there a connection? *Br J Sports Med.* 2004;38(4):502-4; discussion -4.
 20. Meek WM, Kucharik MP, Eberlin CT, Naessig SA, Rudisill SS, Martin SD. Calf strain in athletes. *JBJS Rev.* 2022;10(3):e21.00183.
 21. Shields CL, Jr., Redix L, Brewster CE. Acute tears of the medial head of the gastrocnemius. *Foot Ankle.* 1985;5(4):186-90.
 22. Nsitem V. Diagnosis and rehabilitation of gastrocnemius muscle tear: a case report. *J Can Chiropr Assoc.* 2013;57(4):327-33.
 23. Bryan Dixon J. Gastrocnemius vs. soleus strain: how to differentiate and deal with calf muscle injuries. *Curr Rev Musculoskelet Med.* 2009;2(2):74-7.
 24. Pereira VL, Andreoli CV, Santos RFV, Belangero PS, Ejnisman B, de Castro Pochini A. Surgical repair of the medial head of the gastrocnemius: two case reports and review. *J Surg Case Rep.* 2022;2022(7):rjac335.
 25. Bright JM, Fields KB, Draper R. Ultrasound diagnosis of calf injuries. *Sports Health.* 2017;9(4):352-5.
 26. Hayashi D, Hamilton B, Guermazi A, de Villiers R, Crema MD, Roemer FW. Traumatic injuries of thigh and calf muscles in athletes: role and clinical relevance of MR imaging and ultrasound. *Insights Imaging.* 2012;3(6):591-601.
 27. Paoletta M, Moretti A, Liguori S, Snichelotto F, Menditto I, Toro G, et al. Ultrasound Imaging in Sport-Related Muscle Injuries: Pitfalls and Opportunities. *Medicina (Kaunas).* 2021;57(10).
 28. Jamadar DA, Jacobson JA, Theisen SE, Marcantonio DR, Fessell DP, Patel SV, Hayes CW. Sonography of the painful calf: differential considerations. *AJR Am J Roentgenol.* 2002;179(3):709-16.
 29. Chen CP, Tang SF, Hsu CC, Chen RL, Hsu R, Wu CW, Chen MJ. A novel approach to sonographic examination in a patient with a calf muscle tear: a case report. *J Med Case Rep.* 2009;3:7291.
 30. Maffulli N, Oliva F, Frizziero A, Nanni G, Barazzuol M, Via AG, et al. ISMuLT guidelines for muscle injuries. *Muscles Ligaments Tendons J.* 2013;3(4):241-9.
 31. Weishaupt D, Schweitzer ME, Morrison WB. Injuries to the distal gastrocnemius muscle: MR findings. *J Comput Assist Tomogr.* 2001;25(5):677-82.
 32. Koulouris G, Ting AY, Jhamb A, Connell D, Kavanagh EC. Magnetic resonance imaging findings of injuries to the calf muscle complex. *Skeletal Radiol.* 2007;36(10):921-7.
 33. Sergot L, Leaper O, Rolls A, Williams J, Chakraverty R, Chakraverty J. Navigating the complexity of calf injuries in athletes: a review of MRI findings. *Acta Radiol.* 2022;63(6):767-74.
 34. Kane D, Balint PV, Gibney R, Bresnihan B, Sturrock RD. Differential diagnosis of calf pain with musculoskeletal ultrasound imaging. *Ann Rheum Dis.* 2004;63(1):11-4.
 35. Hirotsu M, Kakoi H, Taniguchi N. Avulsion fracture of the medial head of the gastrocnemius muscle associated with multiple ligament injuries before closure of the growth plate: a case report. *J Med Case Rep.* 2019;13(1):382.
 36. Singh D. Acute Achilles tendon rupture. *Br J Sports Med.* 2015;351:h4722.
 37. Mastaglia FL. Tibial nerve entrapment in the popliteal fossa. *Muscle Nerve.* 2000;23(12):1883-6.
 38. Miniato MA, Nedeff N. *Anatomy, bony pelvis and lower limb, sural nerve.* Treasure Island, Florida: StatPearls 2022.
 39. Meru AV, Mittra S, Thyagarajan B, Chugh A. Intermittent claudication: an overview. *Atherosclerosis.* 2006;187(2):221-37.
 40. Kahn SR. The clinical diagnosis of deep venous thrombosis: integrating incidence, risk factors, and symptoms and signs. *Arch Intern Med.* 1998;158(21):2315-23.
 41. Tscholl P, Meynard T, Le Thanh N, Neroladaki A. Diagnostics and classification of muscle injuries in sports. *Swiss Sports Exerc Med.* 2018;67:8-15.
 42. Cheng Y, Yang HL, Sun ZY, Ni L, Zhang HT. Surgical treatment of gastrocnemius muscle ruptures. *Orthop Surg.* 2012;4(4):253-7.
 43. Cooper J, Arner JW, Peebles LA, Provencher MT. Surgical treatment of medial gastrocnemius tear. *Arthrosc Tech.* 2021;10(2):e519-e23.
 44. Andrews JH, G., Wilk K. *Physical rehabilitation of the injured athlete.* 3 ed. Pennsylvania: Saunders; 2004.
 45. Green B, McClelland JA, Semicw AI, Schache AG, McCall A, Pizzari T. The assessment, management and prevention of calf muscle strain injuries: A qualitative study of the practices and perspectives of 20 expert sports clinicians. *Sports Med Open.* 2022;8(1):10.
 46. Schwitzgubel AJ-P, Muff G, Naets E, Karatzios C, Saubade M, Gremeaux V. The acute management of muscle injuries in 2018. *Rev Med Suisse.* 2018;14(613):1332-9.
 47. Bisciotti GN, Volpi P, Amato M, Alberti G, Allegra F, Aprato A, et al. Italian consensus conference on guidelines for conservative treatment on lower limb muscle injuries in athlete. *BMJ Open Sport Exerc Med.* 2018;4(1):e000323.
 48. Prentice W. *Rehabilitation techniques for sports medicine and athletic training.* 7 ed. Thorafare, New Jersey: Slack Incorporated; 2020.
 49. Best TM, Wilk KE, Moorman CT, Draper DO. *Low Intensity Ultrasound for Promoting Soft Tissue Healing: A Systematic Review of the Literature and Medical Technology.* *Intern Med Rev (Wash D C).* 2016;2(11).
 50. Fields KB, Rigby MD. Muscular calf injuries in runners. *Curr Sports Med Rep.* 2016;15(5):320-4.
 51. Uebliacker P, Haensel L, Mueller-Wohlfahrt HW. Treatment of muscle injuries in football. *J Sports Sci.* 2016;34(24):2329-37.
 52. Uzunkulaoglu A, Güneş Aytakin M, Ay S, Ergin S. The effectiveness of Kinesio taping on pain and clinical features in chronic non-specific low back pain: A randomized controlled clinical trial. *Turk J Phys Med Rehabil.* 2018;64(2):126-32.
 53. Bagheri R, Pourahmadi MR, Sarmadi AR, Takamjani IE, Torkaman G, Fazeli SH. What is the effect and mechanism of kinesiology tape on muscle activity? *J Bodyw Mov Ther.* 2018;22(2):266-75.
 54. Lin Z-M, Yang J-F, Lin Y-L, Cheng Y-C, Hung C-T, Chen C-S, Chou L-W. Effect of Kinesio Taping on Hand Sensorimotor Control and Brain Activity. *Applied Sciences.* 2021;11(22):10522.
 55. Mostafavifar M, Wertz J, Borchers J. A systematic review of the effectiveness of kinesio taping for musculoskeletal injury. *Phys Sportsmed.* 2012;40(4):33-40.
 56. Trofa DP, Obana KK, Herndon CL, Noticewala MS, Parisien RL, Popkin CA, Ahmad CS. The Evidence for Common Nonsurgical Modalities in Sports Medicine, Part 1: Kinesio Tape, Sports Massage Therapy, and Acupuncture. *J Am Acad Orthop Surg Glob Res Rev.* 2020;4(1):e1900104.
 57. Pérez-Bellmunt A, Casasayas-Cos O, López-de-Celis C, Rodríguez-Sanz J, Rodríguez-Jiménez J, Ortiz-Miguel S, et al. Effects of dry

- needling of latent trigger points on viscoelastic and muscular contractile properties: Preliminary results of a randomized within-Participant clinical trial. *J Clin Med*. 2021;10(17).
58. Dommerholt J. Dry needling - peripheral and central considerations. *J Man Manip Ther*. 2011;19(4):223-7.
 59. Cagnie B, Dewitte V, Barbe T, Timmermans F, Delrue N, Meeus M. Physiologic Effects of Dry Needling. *Curr Pain Headache Rep*. 2013;17(8):348.
 60. Orchard JW, Best TM, Mueller-Wohlfahrt HW, Hunter G, Hamilton BH, Webborn N, et al. The early management of muscle strains in the elite athlete: best practice in a world with a limited evidence basis. *Br J Sports Med*. 2008;42(3):158-9.
 61. Kunze KN, Hannon CP, Fialkoff JD, Frank RM, Cole BJ. Platelet-rich plasma for muscle injuries: A systematic review of the basic science literature. *World J Orthop*. 2019;10(7):278-91.
 62. Setayesh K, Villarreal A, Gottschalk A, Tokish JM, Choate WS. Treatment of muscle injuries with Platelet-Rich Plasma: A Review of the literature. *Curr Rev Musculoskelet Med*. 2018;11(4):635-42.
 63. Grassi A, Napoli F, Romandini I, Samuelsson K, Zaffagnini S, Candrian C, Filardo G. Is Platelet-Rich Plasma (PRP) effective in the treatment of acute muscle injuries? A systematic review and meta-analysis. *Sports Med*. 2018;48(4):971-89.
 64. Borrione P, Fossati C, Pereira MT, Giannini S, Davico M, Minganti C, Pigozzi F. The use of platelet-rich plasma (PRP) in the treatment of gastrocnemius strains: a retrospective observational study. *Platelets*. 2018;29(6):596-601.
 65. Drakos M, Birmingham P, Delos D, Barnes R, Murphy C, Weiss L, Warren R. Corticosteroid and anesthetic injections for muscle strains and ligament sprains in the NFL. *HSS J*. 2014;10(2):136-42.
 66. Hotfiel T, Seil R, Bily W, Bloch W, Gokeler A, Kriffter RM, et al. Non-operative treatment of muscle injuries - recommendations from the GOTS expert meeting. *J Exp Orthop*. 2018;5(1):24.
 67. Beiner JM, Jokl P, Cholewicki J, Panjabi MM. The effect of anabolic steroids and corticosteroids on healing of muscle contusion injury. *Am J Sports Med*. 1999;27(1):2-9.
 68. Rasouli SH, Farzanegi P, Abbaszadeh H. The effect of aerobic training and hyaluronic acid on expression of MYOD and MURF-1 genes in experimental arthritis model rats. *Razi J Med Sci*. 2021;28(3):48-58.
 69. Tajik M, Azarbayjani M, Peeri M, Farzanegi P. Effects of endurance training, Hyaluronic acid and stem cell treatments on the quadriceps muscle fiber count: Study on the knee osteoarthritis rats. *Thrita*. 2020;9(1):e105820.
 70. Stellavato A, Abate L, Vassallo V, Donniacuo M, Rinaldi B, Schiraldi C. An in vitro study to assess the effect of hyaluronan-based gels on muscle-derived cells: Highlighting a new perspective in regenerative medicine. *PLoS One*. 2020;15(8):e0236164.
 71. Khan M, Shanmugaraj A, Prada C, Patel A, Babins E, Bhandari M. The role of Hyaluronic acid for soft tissue indications: A systematic review and meta-analysis. *Sports Health*. 2023;15(1):86-96.
 72. Bae G, Kim S, Lee S, Lee WY, Lim Y. Prolotherapy for the patients with chronic musculoskeletal pain: systematic review and meta-analysis. *Anesth Pain Med (Seoul)*. 2021;16(1):81-95.
 73. Rabago D, Slattengren A, Zgierska A. Prolotherapy in primary care practice. *Prim Care*. 2010;37(1):65-80.
 74. Eldeen Ed, El Din Soliman AS, El Din RAS, Hanna GFB, Saad SA. A histological study on the effect of Dextrose prolotherapy on skeletal muscle injury in adult male albino rats. *QJM*. 2021;114(Supplement_1).
 75. Reeves KD, Sit RW, Rabago DP. Dextrose prolotherapy: A narrative review of basic science, clinical research, and best treatment recommendations. *Phys Med Rehabil Clin N Am*. 2016;27(4):783-823.
 76. Stelmakh A, Abrahamovych O, Cherkas A. Highly purified calf hemodialysate (Actovegin®) may improve endothelial function by activation of proteasomes: A hypothesis explaining the possible mechanisms of action. *Med Hypotheses*. 2016;95:77-81.
 77. Reichl FX, Holdt LM, Teupser D, Schütze G, Metcalfe AJ, Hickel R, et al. comprehensive analytics of Actovegin® and its effect on muscle cells. *Int J Sports Med*. 2017;38(11):809-18.
 78. Schneider C. Traumeel - an emerging option to nonsteroidal anti-inflammatory drugs in the management of acute musculoskeletal injuries. *Int J Gen Med*. 2011;4:225-34.