Calf Muscle Strain Injuries

Calf muscle strain is a common sporting injury that can result in significant downtime for the athlete and also has a risk of recurrence if not managed properly. This article will allow you to understand why certain injuries occur to different parts of the calf muscle, and how to assess and treat calf muscle injury for your patient's optimal return to sport with minimal risk of reinjury. Risk factors and prevention are also discussed allowing you to minimise your athlete's risk of injury in the first place. Read this article online https://bit.ly/3yeSqHN

All references marked with an asterisk are open access and links are provided in the reference list

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Calf muscle strain injury (CMSI) is one of the most common muscle injuries in high-performance athletes, across a variety of sporting disciplines. It is an injury that contributes to substantial downtime for the athlete, with a high mean time to return to play (RTP), more than three months in some cases. Further compounding the impact of CMSI can be the occurrence during critical periods in the competitive season, athletes' susceptibility to recurrence and subsequent lower limb injuries, for example hamstring strain (1,2,3*,4). Published research on lower-body injury has provided frequent updates on the rehabilitation of high-profile areas, such as the hamstring muscle and Achilles tendon. Despite its prevalence, and CMSI being problematic across a number of sports, there is a dearth of research to adequately guide clinicians. The past decades have seen a focus of research on epidemiology and risk factors associated with CMSI. Although this evidence is valuable in developing prevention strategies, it forms only one component of dealing with an athlete with calf strain. As yet, only a low level of research using randomised clinical trials is available regarding clinical decision-making, causation, assessment and management.

CALF MUSCLE STRAIN INJURY (CMSI) IS ONE OF THE MOST COMMON MUSCLE INJURIES IN HIGH-PERFORMANCE ATHLETES, ACROSS A VARIETY OF SPORTING DISCIPLINES

In the absence of quantitative research, integrating perspectives and experiences from expert clinicians may be a valuable tool. Hence, the addition of qualitative research may be a powerful instrument to fill the gaps and guide practice. For CMSI, it would seem critical that better guidelines directing identification, management and prevention be established because failed management (ie. a recurrent CMSI) results in an average two-week longer RTP, and the risk of subsequent CMSI is elevated for months (2,5,6*). This article aims to highlight the current perspectives and practices (from both quantitative and qualitative evidence) to guide CMSI diagnosis, management and prevention.

A Bit of Perspective

In the late 1800s when calf strain injuries were first described it was known as 'tennis leg' owing to the occurrence associated with the sport. Although still notable in tennis, calf strain has since been reported with far greater numbers in sports including American football, Australian football, basketball, soccer and running, for example. It is more prevalent among athletes aged 22 to 28 years of age, more frequently affects men and has a recurrence rate of approximately 19–31% (3*,5,6*,7*). Most often rehabilitation is conservative, with a recovery period that ranges from immediate RTP to multiple months of missed training or playing time (3*,4,7*,8*).

It appears that injury to the individual triceps surae muscles may be sport- or activity-dependent. The predominant CMSI in American football is isolated gastrocnemius strain, whereas in Australian football isolated soleus muscle strain is more common (6*,9*). In addition to this, gastrocnemius strain is associated with high-intensity running, acceleration, and deceleration activities – thereby being activity dependant. Soleus strain, however, is more likely to occur during steady-state running activities (6*). This observation may be substantiated by the fibre composition of the muscles and their respective biomechanical functions. The gastrocnemius muscle, responsible for knee flexion and ankle plantar flexion, is dense in fast-twitch muscle fibres, adapted for rapid contraction and response. However, the soleus muscle is dense in slow-twitch muscle fibres and regulates plantar flexion, in a postural control manner, during the gait cycle.

Pathophysiology

Gastrocnemius Strain

When the gastrocnemius muscle is fully stretched, a sudden contraction of the tensioned muscle can rupture the medial head at the musculotendinous junction. Thus the common pathogenesis of a gastrocnemius tear involves knee extension with a sudden, ballistic ankle/foot movement from dorsiflexion to plantarflexion. Since the medial head of the gastrocnemius muscle has a greater contribution to muscle activity it is more prone to injury than the lateral head. Studies have shown a 2:1 ratio of tears to the medial head compared with the lateral head (7*,10*).

Soleus Strain

The mechanism for soleus rupture is associated with overuse, and is thus a subacute injury. It may be caused by repetitive, passive dorsiflexion of the foot with the knee bent (10*). This posture is often observed in runners when running uphill. Most often a soleus strain is of gradual onset and a cumulative effect; however, acute strain can manifest in fatigued athletes (10*).

Plantaris Strain

An isolated rupture of the plantaris muscle is relatively rare but can occur at the proximal muscle belly or the midportion of the plantaris tendon (10*). Similar to a gastrocnemius tear, the pathogenesis involves knee extension with ballistic foot plantar flexion. In the case of an isolated lesion athletes can retain a full range of motion (ROM) without loss of strength. Most often a plantaris injury is diagnosed with concomitant traumatic knee injuries, including lesions of the anterior cruciate ligament or the posterolateral corner (7*,10*).

Subjective Assessment and Presentation

During the initial examination of CMSI, steps should be taken to firstly identify the primary muscle involved (eg. soleus vs gastrocnemius); this may be determined by a combination of patient and injury history, examination and what triaging actions (eg. immediate immobilisation, imaging) were performed.

Table 1: Initial subjective examination

(Adapted from Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**)

Domain	Key areas	Baseline outcomes
1. Presenting injury	i. History of onset	The presence (yes/no) of an inciting incident. If yes, the mechanism of injury The duration of symptom onset: immediate; cumulative; days
	ii. Self-reported symptoms	Symptom qualities and intensity: pain; unresolved 'tightness' or 'cramping'; paraesthesia; numbness Location(s) of symptoms: focal; diffuse Perceived level of severity or functional impairment
2. The injured athlete	i. Intrinsic factors	Non-modifiable factors: history of CMSI; chronological age; training age; ethnicity; other injury history, including recurrences (foot, ankle, knee, spine, hamstring, quadriceps, adductor) Modifiable factors: mobility; strength-power capacities; fitness/conditioning to running and ballistic activities
	ii. Other predisposing factors	Recent period of relative off-loading or immobilisation (eg. illness, surgery, injury); monitoring or 'wellness' flags: fatigue, recovery, sleep, illness; impairments or functional restrictions related to current clinical/ sub-clinical state: 1st MTPJ, plantar fascia, ankle, Achilles, knee, bone stress, spinal
3. The injury context	i. Extrinsic factors	Demands of the sport: playing position, playing style, stage of the season; recent and long-term history of training and competition
	ii. Other contextual factors	Change in footwear and/or orthotics Potential for training error: large changes in exposure or unaccustomed stimuli (eg. running surface; eccentric exercise)

CMSI, calf muscle strain injury; MTPJ, metatarsophalangeal joint.

1. Acute Strain of the Gastrocnemius

- Mechanism of injury (described above).
- Possibly an audible pop at the time of the injury.
- Dull to severe pain and swelling in the posterior lower limb within 24 hours.
- Pain can be latent, manifesting only after the athlete tries to stand, walk, or plantar flex the foot.
- Unable to perform a heel raise on the affected side.
- Tenderness at the musculotendinous junction, in severe cases a palpable defect in the medial head.
- Mild to severe ecchymosis can appear at the rupture site.

2. Soleus Strain

- Typically subacute.
- Presents with muscle tension and tightness.
- Poorly localised pain on palpation.
- Gradual pain development over the course of days to weeks.
- Mild swelling and disability.
- Tenderness deep within the lateral calf, distal to the gastrocnemius muscle.
- Muscle contraction tested is with the knee in maximal flexion, such that the soleus muscle becomes the primary contributor to plantar flexion.

3. Isolated Plantaris Strain

- Rare and often clinically indistinguishable from a gastrocnemius strain.

Table 2: Initial objective examination

(Adapted from Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**)

Domain	Key areas	Baseline outcomes
1. Observation	i. Local observation	Relative calf bulk (size, shape); observable signs of severe CMSI; observable signs of other injury (eg. contusion, Achilles rupture or tendinopathy)
	ii. Other structures	Relative muscle bulk (size, shape) compared to contralateral limb: posterior gluteus maximus, hamstrings, quadriceps Altered gait pattern
2. Palpation	i. Tenderness	Discrete location if discernible: gastrocnemius (medial, lateral), soleus (usually more distal and lateral), Achilles tendon; pain; maximum length of tenderness (cm); symptom quality Palpable defect indicates a possible muscle retraction with complete fibre disruption Palpable contractions that are spasmodic and involuntary indicate muscle cramps
	ii. Tactile qualities	Focal spasm; palpable defect or deformity: Achilles tendon, medial gastrocnemius, superficial triceps surae confluence; evidence of direct injury where relevant (eg. contusion)
3. Stretch tolerance	i. Passive dorsiflexion: KF, KE	Non-weight-bearing ROM (°); pain; other symptoms; symptom quality
	ii. Knee-to-wall lunge	Weight-bearing ROM and asymmetry (cm); pain; other symptoms; symptom quality
	iii. Straight-leg stretch at wall	Weight-bearing ROM asymmetry (cm); pain; other symptoms; symptom quality
4. Isolated function	i. Isometric contraction: KF, KE	Non-weight-bearing plantar flexion: capacity, pain, other symptoms With KE isolate gastrocnemius With KF isolate soleus contraction
	ii. Single-leg calf raise: KF, KE	Weight-bearing plantar flexion: capacity, pain; other symptoms; symptom quality; antalgic strategy Graded as appropriate: (a) double-leg, (b) double-leg concentric, single-leg eccentric, (c) single-leg calf raise Look for sickle sign and toe clawing during calf raises Bent-knee calf raise isolates soleus muscle
5. Dynamic capacity	i. Plyometric function	Capacity; pain; other symptoms; symptom quality; antalgic strategy Graded as appropriate for jumping and hopping: (a) double-leg vertical, (b) single-leg vertical, (c) single-leg horizontal
	ii. Locomotive activities	Capacity; pain; other symptoms; symptom quality; antalgic strategy Graded as appropriate: (a) walking, (b) submaximal jogging, (c) linear run through, (d) cutting and change of direction, (e) sprinting, (f) maximum acceleration from inert position

Notes: °, degrees measured using goniometer; antalgic strategy, observable presence of antalgic strategy (yes/no); capacity, the ability to perform the task (yes/no); KE, knee position in extension; KF, knee position in flexion; pain, check: (1) presence (yes/no) and (2) extent (VAS:x/10); other symptoms, eg. 'tightness', 'cramping', or neural symptoms elicited; symptom quality, eg. focal versus diffuse.

- Imaging is required for a definitive diagnosis.
- Possible audible pop at time of injury.
- Patient may retain full ROM without reduction in strength.

Table 1 shows what to consider in an initial subjective examination of a patient with suspected calf strain.

Clinical presentations that could have some signs and symptoms similar to CMSI include direct injuries like a contusion, delayed onset muscle soreness, other lower leg muscle strains and an Achilles tendon tear or tendinopathy. Posterior leg pain can originate from other muscles including the popliteus, peroneus longus and deep posterior compartment or lateral compartment (including tibialis posterior, flexor hallucis longus, flexor digitorum longus, peroneals). Medial gastrocnemius tenderness is common on palpation and can be normal, even in uninjured athletes (7*,8*).

Although the diagnosis of calf strain is often based on clinical findings, imaging is valuable to confirm the location of the strain and the grade of the injury. The information may help to guide the choice and duration of rehabilitation, and influences RTP considerations. Imaging may detect intramuscular fluid collection or connective tissue defects which are associated with delayed RTP. In elite sports, the decision-threshold for imaging is low (8*). It is preferred to wait 24–48 hours post-injury to confirm if it is warranted and to gain a thorough impression of injury severity before presenting biases inherent in imaging results. Magnetic resonance imaging (MRI) may be used as the gold standard, followed by ultrasound (which has the benefits of ease of use and rapid results), to establish the extent of disruption and injury pathology. However, over time the most valuable prognostic information comes from the rate of functional progression (8*). The use of imaging can be counter-productive as many athletes present with tissue changes that may not have been pathological, symptomatic or related to the current injury. The degree of tissue change seen during imaging does not

●● THE GASTROCNEMIUS MUSCLE, RESPONSIBLE FOR KNEE FLEXION AND ANKLE PLANTAR FLEXION, IS DENSE IN FAST-TWITCH MUSCLE FIBRES, ADAPTED FOR RAPID CONTRACTION AND RESPONSE ●●

positively correlate with symptom severity (11,12). This can result in catastrophising, overly cautious rehabilitation programmes and a negative psychological bearing on the athlete (8*).

Objective Assessment and Physical Examination

The initial objective examination should be used to refine the clinical impression of injury location, severity and directed immediate management – this includes what have they done since the injury, were they immobilised, did they cease or continue play, etc. (Table 2).

Traditionally, muscle strains have been graded, but one should not be defined or limited by the grade initially given upon diagnosis – see Table 3. Injury grades for CMSI and recovery times in Meek et al. (7*; https://bit.ly/3xLDPU7). Although the injury grade may guide rehabilitation

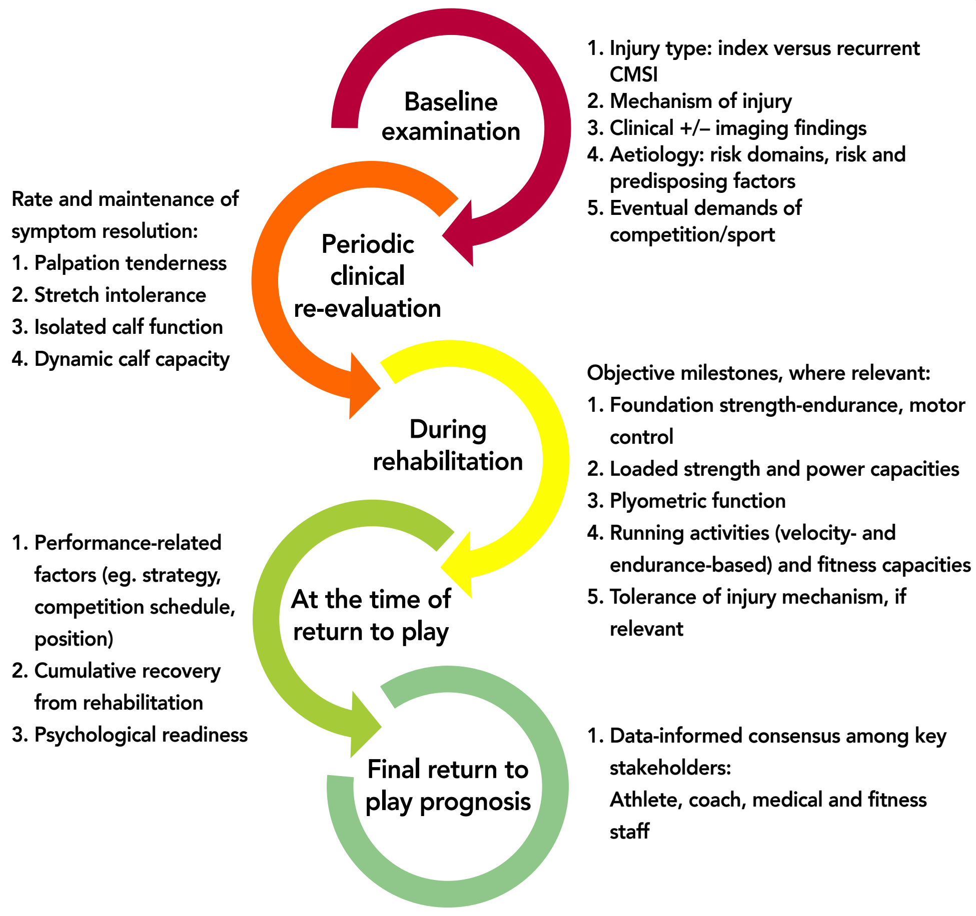


Figure 1: Evaluating prognosis after calf muscle strain injury (CMSI)

Numbered points refer to the primary themes and/or concepts that influence decision-making at each stage.
(Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*), reproduced under the Creative Commons Attribution 4.0 International License, https://bit.ly/3bjavN7)

THE DESIGNATED GRADE OF MUSCLE INJURY MAY GUIDE BUT SHOULD NOT DEFINE OR LIMIT REHAB/RTP DECISIONS

and RTP, many athletes improve at different speeds, based on multiple factors including age, past injury history, motivation and fear. The grade should not hold someone back nor should it push an individual on if they are not ready to RTP within the given time frame.

Typically, once assessed and diagnosed, the very next questions are: When can I run again? When can I play sport again? Will I be ready for next weeks game? Initially, one shouldn't feel pressured into giving definitive timelines and a prognosis in the early stages. It is necessary to disseminate information to the athlete and any interested parties. At baseline, early expectations should be stated broadly; for example information about RTP can be described as 'none' (ie. following an on-field assessment), 'short' (possibly a week or two) versus 'extended' (possibly 6–8 weeks) (8*).

During rehabilitation, the prognosis can be refined, using functional progression milestones and ongoing assessment. The rate of resolution of pain-free walking is a good indicator of progress. Identifying other potential risk factors and concomitant impairments may hinder progress through rehabilitation (8*). The final prognosis should be confirmed at the time of RTP and should be a consensus. Rather than

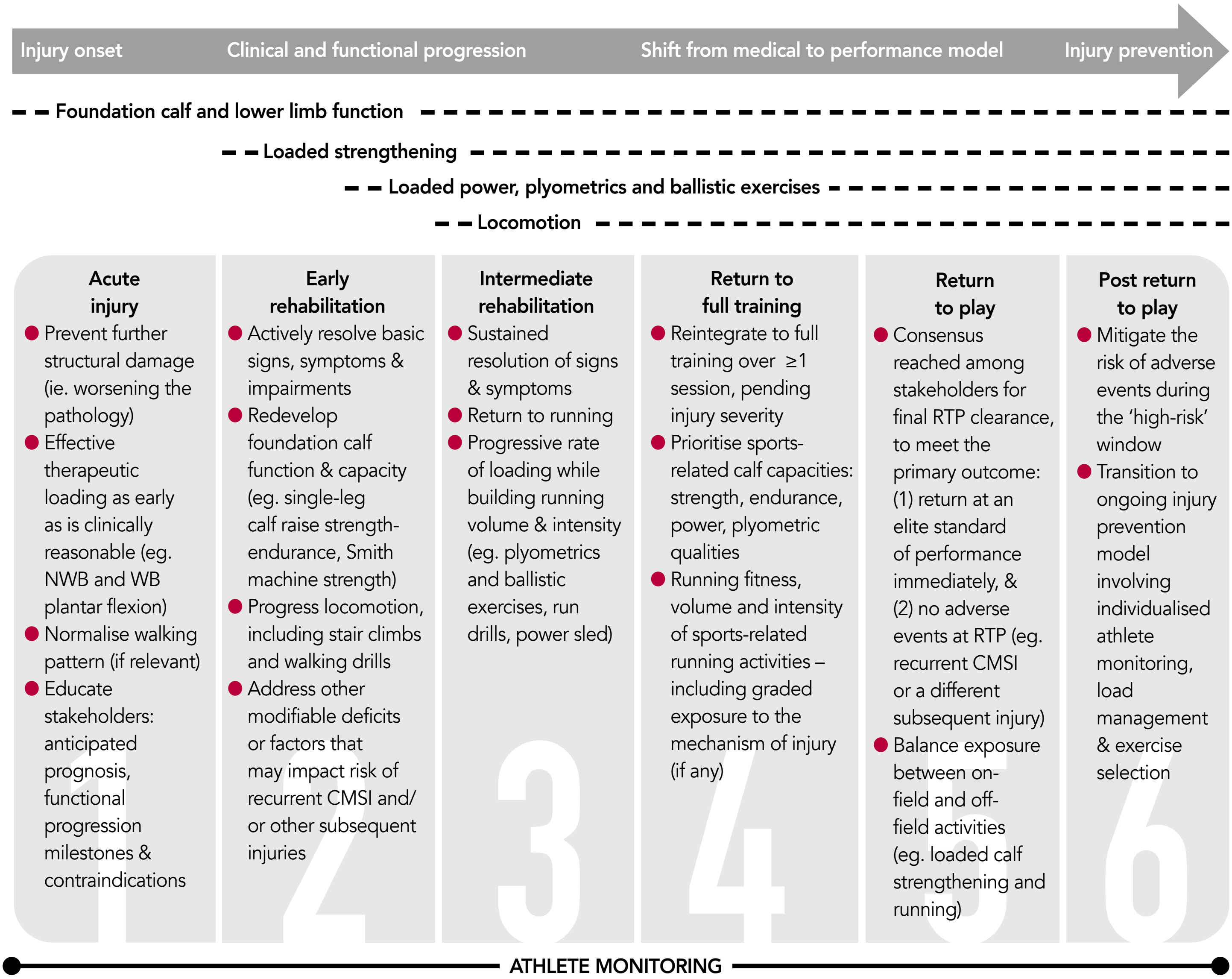
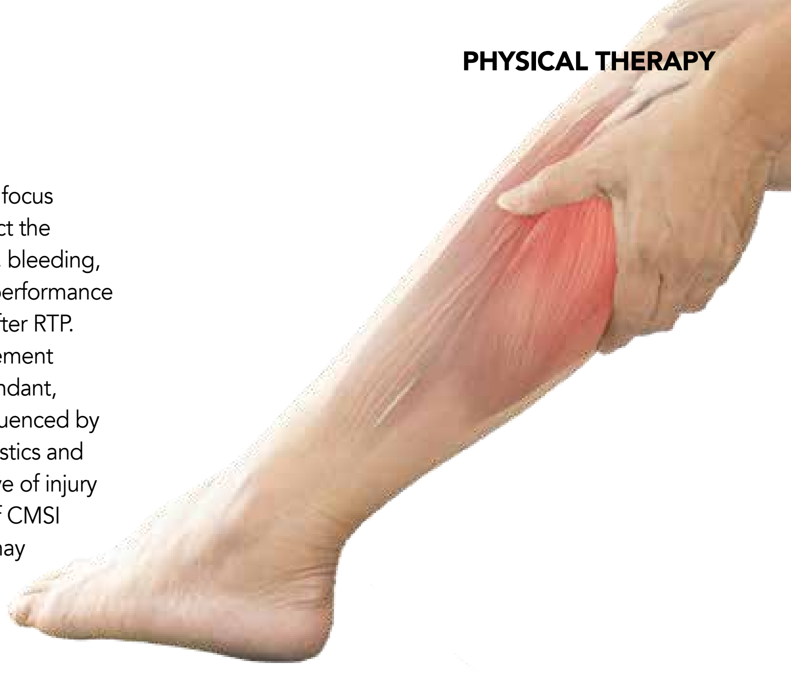


Figure 2: Overview of optimal management of CMSI, following six phases

NWB, non-weight-bearing; RTP, return to play; WB, weight-bearing.
(Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**, reproduced under the Creative Commons Attribution 4.0 International License, https://bit.ly/3bjavN7)



pathology and/or re-imaging being the determining factor, RTP should be based on performance-related factors, psychological factors of the athlete, residual fatigue, competition readiness, and limited training chronicity (13,14,15).

Thus, a staged approach may more accurately determine prognosis (Fig. 1). This approach may (i) prevent injury recurrence due to overly aggressive rehabilitation or premature RTP; (ii) prevent unnecessarily conservative RTP time frames due to ongoing assessment; and (iii) allow performance-related factors to be considered and planned for (8*,16*).

Rehabilitation and RTP

Very, very rarely is surgery required in the management of CMSI. Non-operative management is effective for the majority of CMSIs. The early stages of treatment may follow a 'PEACE and LOVE' protocol (https://bit.ly/34SQlyK) (17*). Over the course of rehabilitation, the clinical management may shift focus from a medical mindset (protect the injury, prevent further damage, bleeding, sweeling, pain) to prioritising performance and then preventing reinjury after RTP. It is believed that best management should be context/sport-dependant, individualised and strongly influenced by the athlete's intrinsic characteristics and external factors (8*). Irrespective of injury characteristics, early loading of CMSI results in faster recovery and may reduce pain and improve confidence (18*,19). It has been suggested that management should progress through six phases with the ultimate goal being successful RTP – which is deemed as (1) RTP as soon as possible; (2) restoration of athletic performance to the expected level; and (3) no adverse events, be it reinjury or other subsequent lower limb injury (Fig. 2) (8*).

Rehabilitation Principles

1. Early Loading

Early loading is perceived to fast-track

THE SOLEUS MUSCLE IS DENSE IN SLOW-TWITCH MUSCLE FIBRES AND REGULATES PLANTAR FLEXION, IN A POSTURAL CONTROL MANNER, DURING THE GAIT CYCLE

Table 3: Early loading exercises for CMSI rehabilitation

(Adapted from Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*))**

Early loading	
Objective	**Examples**
Normalise gait pattern	First step to restoring normal movement patterns
Find their optimal starting point for loading	How much load ? Find their barrier and work just below it, this may change daily Start loading on day 2 or 3 Isometric only, exercise band work only Or if they can do double-leg calf raises, start there with two-leg weight-bearing exercises Or if they can do single-leg calf raises, start there with single-leg weight-bearing exercises
Prescribe multiple loading bouts throughout the day	Aim for 4 loading sessions per day, pain free and without detriment the following day
Use activation exercises to prevent inhibition	Gastrocnemius especially is highly susceptible to pain inhibition and wasting Activation can be non-weight-bearing and isometric
Foundation exercises build to dynamic actions of muscle-tendon unit	Once 2 sets 15 repetitions slow and controlled single-leg calf raises can be done, add: ● 1 set of oscillations 'up top' 'middle' 'down below' to plantar grade ● Oscillations off a step in full dorsiflexion ● 'Drop and catch' at different positions Retraining balance and proprioceptive function, the foot intrinsic muscles and deep lower leg muscle exercises will aid in improving dynamic control
Condition uninjured body-parts	Do not allow de-training of other muscles where possible. Keep their routine simple modify the activity
Avoid excessive eccentrics and passive stretching in the early stages	Pain may inhibit the athlete recovery physically and emotionally

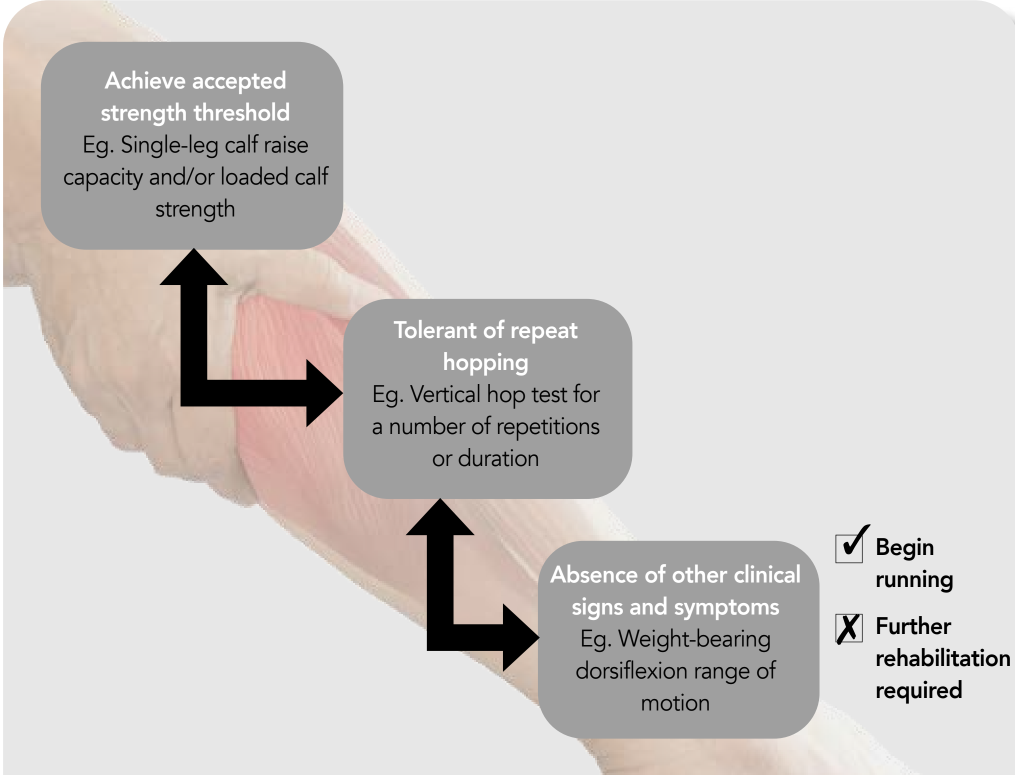


Figure 3: Determining readiness to run after CMSI

(Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**, reproduced under the Creative Commons Attribution 4.0 International License, https://bit.ly/3bjavN7)

symptom resolution and disability associated with CMSI (18*,19). Illustrations of some of the exercises mentioned in Table 3 can be found at Green and McClelland et al. (8*).

The single-leg calf raise underpins advanced functional rehabilitation and should, therefore, follow strict cues (See Video 1 and Green and McClelland et al. (8*)):

1. Perform work along the axis of the second metatarsal.
2. Maintain neutral foot and ankle positions throughout the prescribed range.
3. Control the loading rate (eg. 1 second up; 1 second down).

Things to watch for as indicators of poor calf muscle function or control/recruitment include sickle sign (progressive inversion or adduction of the foot), clawing toes (excessive reliance on deep foot flexors), and reduced eccentric control (8*). Poor calf or lower limb control may be evident through the entire kinetic chain; athletes may extend their lumbar spine during calf raises or they won't be stiff in their pelvis (gluteal muscles) and quadriceps. These signs highlight other areas that need to be addressed during the strengthening phase of rehabilitation (8*).

Table 4: Loaded strengthening exercises for calf muscle strain rehabilitation

(Adapted from Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**)

Loaded strengthening	
Objective	**Examples**
Maximising capacity is first priority	Straight-leg or bent-knee calf raises Small loads with 10–15 or 10–12 reps Increasing loads, reduce reps to 3 or 4 sets of 6–8 reps
Sport-specific strengthening	Strength-endurance required for prolonged running and work (eg. Australian football, football/soccer) versus maximum force-generating capacity for shorter durations (eg. rugby, sprinters)
Consider horizontal and lateral load capacity	Particularly in sports with rapid acceleration or cutting (eg. rugby) ● Leaning-tower position calf raises
Single-leg strength is foundation for dynamic exercises	Fewer double-leg exercises as dynamic movement involves all single-leg activity ● Single-leg jumping and hopping
Soleus strength is critical for **all** athletes	Soleus strength capacity and endurance is critical for problem calves, severe calf strains (even if gastrocnemius strain), athletes with history of calf injuries, or lower limb injuries
Load compound exercises	In preparation for movement and sport, incorporate entire kinetic chain, gluteal, hamstring, quadricep and hip flexor muscles ● Squats, lunges, pulleys

2. Loaded Strengthening

Once an early benchmark of single-leg calf raise capacity (body-weight only, 20–25 repetitions continuous) is achieved, then adding load can progress (20). Common starting points include a Smith machine and seated calf raise machine. Progression can be made by increasing loads and moving from a flat foot surface to an inclined surface to alter the ROM. See Table 4 for further details regarding loaded strengthening exercises.

It is believed that eccentric loading can be augmented with heavy isometric strengthening at various MTU lengths and altered whole-body positions (eg. ankle dorsiflexion, knee flexion, trunk lean) (8*).

3. Loaded Power, Plyometrics and Ballistic Exercises

Firstly, this involves re-exposing the calf to volume and its ability to contract and work repeatedly in a sport-specific manner. Secondly, this ensures that the muscle can generate sufficient force at sufficient speed (the rate of loading) to safeguard its spring-like mechanism. The calf is the first point of loading in the kinetic chain, which is maybe not considered critical in rehabilitation. Proximally, multiple muscles and structures can jointly absorb the loads of dynamic movement; however, the calf muscle requires sufficient elastic properties to tolerate the running loads alone. Plyometrics and explosive exercises (loaded and unloaded) are necessary to restore elastic function. Dynamic exercises involving predominantly vertical actions, should be followed by exercises involving greater horizontal, lengthening, and stiffness demands (8*).

Two main exercise streams have been identified:

1. repeated stretch-shortening-cycles (SSCs) over small length excursions (or pseudo-isometric), associated with a rhythmic MTU action (eg. single-leg pogos); and
2. single or several SSCs over larger length excursions (eg. single-leg countermovement jump, forward hopping) associated with an accelerative MTU action (8*).

A novel concept would be to develop both instantaneous and repeated power of the calf MTU for sports that require both of these qualities, such as Australian football, soccer and long sprinters. This may, however, present a clinical challenge owing to the competing adaptations that these qualities require (8*).

4. Running Rehabilitation

Running prematurely has been cited as a leading cause of early recurrent CMSI (8*,21*). A slight delay in commencing running, may result in a lower risk, without negatively impacting rehabilitation time frames (13). The three primary elements for 'running readiness' include strength, hopping capacity and the absence of other clinical signs and symptoms (Fig. 3). A more comprehensive build-up before running may enhance outcomes, without extending RTP timeframes (8*,13).

Table 5. Objective testing options to evaluate power qualities at RTP after CMSI

(Sourced from Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**)

	Vertical	Horizontal
Instantaneous	SL CMJ SL DJ SL concentric-only jump SL box-jump height	Single hop for distance Resisted acceleration Resisted SL push off
Repeated	SL CMJ: 5–10 reps SL hopping: reps or time Loaded squat jumps	Forward hops in-series: 5–10 reps SL bounding distance: reps or time Broad jumping Resisted SL catch-ups

CMJ, countermovement jump; DJ, drop jump; SL, single leg.

Video 1: How good is your calf function? What is the norm & common compensations? (Courtesy of YouTube user Physiotutors)
https://youtu.be/apRDvOLqTrE

Low-load locomotion should be started as early as possible, in the form of 'normal gait' walking, stair ascents, toe walking, loaded walking using kettlebells or dumb-bells, bear-crawls, lunge-walk drills. Normally running drills can be performed at walking speeds including ladder-based drills, 'under-overs', 'ecky-shuffle', side skips and grapevine on their toes. In preparation for running, visualisation and verbal queues using words like 'pitter patter' may help prevent the athlete from plodding initially (8*).

Prescribing an athlete to 'jog, slowly' may do more harm initially. Slower continuous running can result in plodding, which produces high impact forces in the calf and can predispose to fatigue-related recurrence of injury. Submaximal run throughs (60% effort; 8×80m) may be more productive when starting running again. Increasing the number of sets of shuttle runs (3 sets of 8×80m submaximal runs) can be a way of building volume without plodding or sprinting (8).

Six 'rules of thumb' have been identified as a guide to running rehabilitation after CMSI:

1. Initially run on alternate days.
2. Avoid 'plodding' early.
3. Do not progress volume and intensity on consecutive days.
4. Schedule off-field exercises (eg.

loaded strengthening) after running.
5. Shape running progressions to meet the demands of the sport – don't overshoot with excessive volume.
6. Avoid sudden changes in conditions, such as the surface and footwear (8*).

Over time, running rehabilitation can involve gradual exposure to greater volume and intensity, with prescriptions aligned to rehabilitate the entire spectrum of activities performed in the sport, including sprinting (not early due to the high contractile forces), cutting, acceleration and endurance.

Table 6: Clinical checklist to determine RTP following CMSI

(Adapted from Green B, McClelland JA, Semciw AI et al. The assessment, management and prevention of calf muscle strain injuries: a qualitative study of the practices and perspectives of 20 expert sports clinicians. **Sports Medicine – Open 2022;8(1):10:doi:10.1186/s40798-021-00364-0 (8*)**)

RTP criteria		✓ or ✗
Symptom resolution and psychological readiness	● Self-reported symptoms: VAS 0/10 (pain, tightness, 'cramping' sensation) ● Self-perceived readiness & confidence to return to performance	
Residual clinical signs and impairments	● Palpation tenderness: VAS 0/10, length: 0cm ● Weight-bearing ankle dorsiflexion ROM: normalised knee-to-wall lunge (cm) and straight-leg stretch, asymmetries ≤ 10% ● Single-leg calf raise test from the floor*: capacity (≥30 repetitions), asymmetry ≤ 10%	
Normalised strength-power qualities	● Loaded strength: sport-specific benchmark (knee extended, knee flexed) ● Power: normalised vertical and horizontal calf function; instantaneous and repeated tests; asymmetries ≤ 10%	
Reconditioned for exposure to sport demands	● Running conditioning: total volume, volume across speed bandwidths, accelerations, decelerations ● Intensity of running and other dynamic activities: cutting, reactive agility, jumping, maximum velocity, maximum acceleration ● The mechanism of injury	
Successful re-integration into full training	● Return to full training for ≥ 1 session, pending the length of the rehabilitation period ● Consensus among stakeholders about readiness to perform at the required level (eg. elite vs sub-elite vs amateur)	

VAS, visual analogue scale, whereby '0' represents no symptoms and '10' represents the maximum of symptom severity.
✓, achieved during rehabilitation; ✗, not achieved and further rehabilitation may be required.
*Note: testing single-leg calf raise capacity from the floor (rather than a step) was perceived to limit the potentially significant impact of individual variation in ankle dorsiflexion ROM.

RTP Decisions

As mentioned earlier, while endeavouring to establish a prognosis for an athlete, fixing a date or time for RTP can be very challenging. Ongoing assessment is required but ultimately the decision to RTP should be a consensus between the athlete, therapists, coach and other stakeholders (22*). RTP is essentially weighing up the risk of 'do I wait and rehab longer' or 'if I RTP now will I re-injure myself or be ok?' Ideally an athlete will have had a time of full return to training to gauge load tolerance and functional improvement. Objective testing may be of value to aid RTP decisions, bearing in mind side-to-side asymmetries often exist even in healthy individuals which may confound outcomes (4). Objective tests assessing instantaneous and repeated power capacities are useful following CMSI (Table 5).

Experts have compiled a checklist that may aid in determining RTP readiness, with emphasis that decisions should be strongly guided by exposure to sport-specific activities (Table 6) (8*,15).

A recent study of elite Australian football players showed that not all calf strains responded to the same time frames for RTP. Calf strains from running activities needed longer recovery periods than calf strains from non-running activities, irrespective of the muscle injured (6*). It may be assumed that running activities involving high-intensity and steady-state running, acceleration, deceleration, or cutting has greater tissue disruption of the muscle-tendon unit and thus require longer times for RTP (6*).

Risk Factors and Injury Prevention for CMSI

Athlete reinjury is always a concern, but especially with CMSI, which has a recurrence rate of approximately 19–31% (2,3*,5). Reinjuries are associated with even longer recovery times and often involve older, more experienced players (7*). Premature RTP increases the risk of reinjury as tissues have not completely healed (5). An appropriate rehabilitation timeline must consider other factors including, sport-specific demands, player position, seasonality, and athlete psychology (5,23*).

A study by Green and Lin et al. (14) showed reinjuries to be almost exclusively following soleus muscle strain (91.4%). The cumulative incidence for reinjury was highest within 2 months of the index/primary strain (46.9%) (14). Interestingly, having a history of previous CMSI at the time of the index/primary strain was the only predictive factor for reinjury. The strongest risk factor for reinjury is a recent history of CMSI, followed by a past history of CMSI. Increased risk of reinjury persists beyond 15 weeks after RTP. Increasing age is an independent risk factor for calf muscle strain with an odds ratio of 1.6 (2).

An identification of the risk factors, combined with aetiological factors, may be a practical approach to injury prevention, as a single factor acting alone is rarely the cause (24*,25*,26*). The potential impact of intrinsic and extrinsic factors acting on the individual and their exposure include:

1. Intrinsic factors

1.1. Non-modifiable
- increasing age
- decreased training age
- history of CMSI
- history of lower limb injury
- ethnicity
- genetics
- general hypermobility
- other injury history or sub-clinical state

1.2. Modifiable
- increased body mass index (BMI)
- decreased calf strength
- decreased co-ordination
- decreased compound strength
- decreased calf power capacities
- decreased function during ballistic and plyometric activities
- decreased running capacities
- increased fatigue (acute and cumulative)
- running biomechanics or technique
- knee-to-wall lunge
- distal impairments
- proximal impairments

2. Extrinsic factors

2.1. Activity related
- preseason period
- demands of sport
- player position/role
- competition schedule
- training errors (running workload)
- recent immobilisation
- equipment (footwear)
- environment (surface)

2.2. Non-activity related
- performance culture
- coach expectations (8*,27,28,29,30).

The four most-prevalent factors that may have a significant impact on injury recurrence (and their reasons) include:
- increased age: this is the result of decreased tissue quality (atrophy), stiffness, decreased fascia length and reduced recoverability;
- previous CMSI: due to inhibition, decreased strength and power capacity, altered tissue dynamics, decreased tissue length and extensibility;
- other injury history: decreased capacity altered mechanics, persistent deficits (in lumbar spine, hip, knee, ankle or foot); and
- exposure history: recent immobilisation or interruption training (surgery or illness), novel or unfamiliar stimuli, training design, match schedule/congestion, decreased training chronicity (8*).

A universal injury prevention programme does not exist for calf muscles. The barrier to implementing traditional prevention strategies for CMSI is that 'protective' calf qualities undergo fluctuations. Screening and ongoing athlete monitoring of all or any of the above risk factors should underpin optimal management. This approach permits individualised prevention using load management and exercise selection strategies, while considering the multitude of factors that impact an athlete's risk profile (eg. behavioural qualities, training design, individual skill, coach expectations/club culture and environmental factors) (25*,31,32). Overall, chronic and uninterrupted exposure to the athlete's sport combined with specific activities involved in that sport are considered the most important strategies for resilience to CMSI (8*).

Historically, research has shown that pre-participation stretching may improve ROM and muscle compliance, which was believed to protect against muscle strain. Although stretching supports muscle performance in elastic movements like hops or leaps, it is associated with decreased muscle power in concentric contractions such as steady-state cycling or jogging (33,34*). For this reason, the benefits of stretching alone are unclear. However, combining stretching with dynamic and sport-specific pre-participation drills may be able to restore stretch-induced performance loss (34*).

Conclusions

CMSI is a common condition. In high-performance athletes, calf strain contributes to missed practice, playing time or competition. Timely diagnosis and treatment can improve outcomes and can facilitate earlier return to sport. Optimised clinical reasoning at the time of injury, using a structured approach diagnosis and estimating prognosis is advised. Management following CMSI should involve

A UNIVERSAL INJURY PREVENTION PROGRAMME DOES NOT EXIST FOR CALF MUSCLES, SO THE APPROACH SHOULD BE TAILORED TO THE INDIVIDUAL transitioning the athlete through phases extending beyond specific calf strengthening, to general strength and sport-specific work, dynamic ballistic and plyometric work, and progressive running rehabilitation. Early loading, within the athlete's ability, is deemed safe and promotes early symptom relief and faster recovery. The final RTP decision should be a consensus, driven and informed by the athlete, therapists and their entire support team. A universal prevention programme may not be possible owing to diversity in calf demands between sports and individuals. A multifaceted approach involving individualised load management and exercise selection, as well as sport-specific training, and greater 'on-field' conditioning could provide the best preventive effect.

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DISCUSSIONS

- Do you use any specific tests or have any key pointers from a patient's subjective assessment to differentiate between a gastrocnemius or soleus muscle strain?
- What verbal and visual cues do you use to guide your patient to correctly performing calf raises (double- or single-legged)?
- What dynamic and plyometric exercises do you find beneficial in progressing an athlete from basic strength exercises to running and sport-specific activities?

KEY POINTS

- **Calf muscle strain injury (CMSI) is a common condition; in high-performance athletes, calf strain contributes to a substantial absence from competition.**
- **There is a high risk of reinjury following CMSI, extending beyond 15 weeks following return to play (RTP).**
- **Player age and history of a calf strain or other leg injury are the strongest risk factors for calf strain injury and reinjury.**
- **Diagnosis is largely clinical, supported by MRI and ultrasound.**
- **Loading early can fast-track symptom resolution and disability associated with CMSI.**
- **Single-leg calf raise, performed correctly, underpins advanced functional rehabilitation.**
- **An athlete should transition through rehabilitation phases extending beyond specific calf strengthening, to general strength and sport-specific work, dynamic ballistic and plyometric work, and progressive running rehabilitation.**
- **The final RTP decision should be a consensus, driven and informed by the athlete, therapists and their entire support team.**
- **A universal prevention programme may not be possible owing to diversity in calf demands between sports and individuals.**
- **A multifaceted approach involving individualised load management and exercise selection, as well as sport-specific training, and greater 'on-field' conditioning could provide the best preventive effect.**

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