CALF MUSCLE INJURIES IN TRACK AND FIELD ATHLETES

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The high prevalence and burden of hamstring muscle strain injuries in track and field has resulted in considerable attention being directed at the management and prevention of these injuries, potentially at the expense of our understanding of other troublesome injuries such as calf muscle strain injuries (CMSI). Accordingly, there are fewer studies providing an in-depth analysis of the risk, impact, burden, characteristics, prevention and rehabilitation of CSMI in sport to guide clinicians, and very few specifically in track and field athletes. This article utilises the current literature, draws upon our clinical experience, and a re-analysis of qualitative transcripts from the project published by Green et al. 2022[1]. In this project we interviewed 20 'expert' sports medicine clinicians to generate rich information on CSMI in sport. For this current paper, we re-analysed the interview transcripts of six experts with past or current experience working in track and field. Advice and direct quotes (italicised) from these experts are included.

"Fast People Break Things": The Epidemiology and Risk Factors

In running-based sports, CMSI represent one of the highest soft tissue injury incidences, recurrences are common (16% in Australian Football), and the burden is significant[2]. A recent evaluation of British Olympic track and field athlete injuries over 3 seasons highlighted soleus strains were the third most common time loss injury overall and resulted in the second highest total days lost[3]. The average time loss per soleus injury (25.1 days) was greater than that of the hamstring (18.8 days) and gastrocnemius injuries (average time loss: 7.7 days)[3]. Since soleus injuries represent a significant injury burden and the soleus functions as the powerhouse of the lower leg, this has implications for assessing risk, managing and preventing injury.

There have been few studies evaluating specific modifiable risk factors for CMSI and the usual suspects of age and past history are considered non-modifiable risk factors[2]. In track and field athletes, in addition to age and past history, local injuries to the ankle, foot and plantar fascia, distal pain-dominant conditions, a *"sloppy or stiff foot"*, or tight calves can *"change the way the calf is being asked to work"* and can increase the injury risk. *"Strength is a big one"* – in particular having a good training history of calf strengthening (*"training age"*), as well as the balance between calf strength and the deeper lower leg, are important for optimising calf function and minimising risk of CMSI. As with many muscle injuries, exposure to the *"intensive loads"* required in competition and scrutiny of acute to chronic load volumes is essential: *"So the years we battled, dare I say, the strength and conditioning people who felt that any work done on the calves was wasted and that if you got people too big in the calves that it would slow down their running because they had more mass below the knee...hopefully they are debunked now"*.

"I Have Always Been a Believer of Just Doing The Simple Things Really Well": Clinical Assessment:

History: The athlete may describe a popping or tearing sensation during acceleration or running, but many injuries develop gradually with no inciting mechanism. Soleus injuries more commonly occur with such cumulative loads, but this is not absolute, and both gastrocnemius and soleus strains can have varied mechanisms[4]. Soleus injuries may result in deep, diffuse pain with symptoms of tightness or cramping.

Image: Illustration.

Physical examination:

Look: At rest, look for visible bruising, swelling, and muscle defects (de-tensioning – exclude an Achilles rupture). Observe quality and ability during functional tasks (e.g. walking, calf raises, squats)

Feel: Palpate for localised symptoms, length of tenderness and any muscle defects. Due to the deep position of soleus, palpation to locate and explore symptoms may not always be as reliable as gastrocnemius injuries. Understanding the location and trajectory of the calf muscle aponeuroses can ensure better information gathering and reduce the risk of misdiagnosing bands of tightness or scar tissue – particularly in the soleus muscle.

Move: Symptoms during performance of length and strength tests of the calf can aid in the diagnosis, understanding calf capacity and formulating a potential prognosis. Muscle extensibility and strength assessed with the knee extended compared with the knee flexed may preferentially provoke the gastrocnemius or the soleus respectively. The capacity of the calf can be examined by graduated loading until symptoms are elicited, with particular attention to the quality of movements. For example, commencing, if possible, with double-leg heel raise, to double raise up and single leg down, to single leg heel raise, to submaximal hopping and so on. This can guide a safe entry point for rehabilitation and provide valuable prognostic information. Throughout, severe CMSI can be expected to show more significant functional impairments and reduced thresholds for symptom-onset.

Imaging: Radiological investigations are not required for a diagnosis but might have some value in prognosis[5]. Magnetic resonance imaging (MRI) is considered the gold standard for soleus injuries, and either MRI or ultrasound may suffice for gastrocnemius injuries. The presence of aponeurotic disruption in soleus injuries could result in greater time loss[5], although substantial variation exists in return to activity timeframes and the continued monitoring of clinical progressions throughout rehabilitation help to refine the prognosis[1].

Management:

"The puzzle for me is putting them back together and being able to create the characteristics that I need so that when they return to their sport they are not going to break".

The calf works hard during all running speeds. Compare these loads to traditional gym-based calf exercises and the rehabilitation journey becomes increasingly challenging. Given the calf's high capacities, it can be difficult to assess the competency of tissue tolerance to loading after CMSI: be wary of apparent resolution of clinical signs and symptoms in the early stages of rehabilitation as an indicator to commence running or progress rehabilitation faster. Your clinical assessment and tracking of a CMSI can be deceptive if a rigorous approach is not used. Historically, simple and low-load clinical tests offer insight into the status of recovery for lower limb muscle injuries. However, given the inherent force-generating capacity of the calf muscles, it is unreliable to use manual muscle testing or hand-held dynamometry as strength measures that can accurately guide rehabilitation progression. Quantifying strength (bent and straight knee) across a wider spectrum of qualities is recommended to better determine capacity, such as maximal voluntary isometric strength, loaded strength-endurance (isotonic), and

PILLAR	AIMS	EXAMPLE EXERCISES
1. Introduce specific loads & acute inflammatory phase (POLICER)	Isometric loading: Inner & mid ranges Active joint range: Mobility	a) Active and banded ankle ROM variations b) Toe walking & heel-toe 'A' walk c) Wall drills, triple extension drills: Isometrics, slow switches, hip mobility d) Soleus wall squat and Bulgarian split squat isometric g) Calf raise - Seated and standing
2. Expand tissue tolerance	Increase absolute/relative strength Progress isometric strength capacity & ranges Introduce force absorption	Progress / Add load for phase 1. a) Double leg pulses b) 'Tall to short' drill c) Low step strike d) Farmer's walks and/or stair ascents (walking) e) Calf raise - Single leg heel raise (SLHR)
3. Functional reactives and "prep to run"	Accelerated ground contacts: Reactive strength Foot-ground interaction/stiffness: Reactive strength Low amplitude plyometrics: Rate of force development Progress relative strength: Isometric and eccentric load tolerance focus	a) Plant walks, ankle dribbling, double leg pogo b) Single leg pulses c) Low step reactives / skaters d) Prowler and/or sled e) Stair ascents: Graded progression from walking to running at 170 bpm f) Calf raise - Heavy single leg: Consider variation in isometric, eccentric and concentric biases
4. Rate of force development & return to run	Progress ground contact: Run drills Return to run: Aerobic tempo Increase concentric power & propulsive strength: Horizontal & vertical	a) 'A' Skip, sport-specific run drill battery b) Expand pogo variations c) Dribble bleeds - run throughs >4m/s d) Jump variations (Box, CMJ) e) Progress calf raise loads
5. Absorb to propel	Advanced ground contact drills (Off-axis, multi-directional, continuous, extreme ranges) Running: Extensive tempo & intensive acceleration/deceleration Address sport-specific demands	a) Progress run variations: Run speed, accel, decel, change of direction b) Progress and/or sustain calf raise loads c) Single leg pogos & skipping endurance d) Cone hopping variations
6. Sport-specific capacity and clearance targets	Steady state running: Assess endurance Very high-speed running and max velocity: Assess rapid MTU capacity High effort acceleration + sport-specific demands - Assess muscle and MTU capacity Strength and power benchmarks	a) Steady state running conditioning: Total volume(s) b) Very high-speed running and max velocity conditioning c) High effort acceleration + sport-specific conditioning d) Ongoing gym-based loading to meet benchmarks: Strength, power, SSC e) Advanced plyometrics

Figure 1: An integrated calf rehabilitation pathway.

foundation strength-endurance (single leg heel raise repetitions to failure at 60 bpm). Power and the stretch-shortening cycle are considered to a greater extent after strength-resolution.

The calf is strong but make sure its strong enough to run

Effective therapeutic loading is critical in the acute phase following CMSI (Figure 1). This can be achieved through early loading and foundational calf function exercises in vertical and horizontal planes. Isometric and calf raise variations are common in the acute rehabilitation phase, which seek to address tissue exposure to different muscle-tendon unit lengths and redevelop contractile function. Three cardinal signs of poor calf muscle recruitment and/or function during a single leg heel raise have been reported[1]:

1. *'Sickle sign' – progressive inversion and adduction*
2. *'Clawing the toes' – over reliance on the deep flexors*
3. *'Reduced eccentric control'*

Practitioners should monitor athletes after CMSI for evidence of these signs since they indicate suboptimal calf function and can impede progress during more demanding rehabilitation activities. Progressing loading to include heavy isotonic and isometric strengthening is fundamental prior to re-exposure to high-load and rate of loading activities after CMSI: *"for the isotonic stuff the big thing that you are trying to create there is that ability to change muscle length and contractile properties under load, so you are trying to actually improve its propulsive properties more than anything. But then when you are trying to get it to be able to hit the ground and not collapse, you need isometric strength to manage that".*

Bridging the Gap Between Gym and Running Rehabilitation Activities

At 3.5 m/s the calf complex is already subjected to peak tensile forces of ≈9x body weight (BW)[6]. These loads are comparable to what the hamstrings experience at or close to max velocity at 9m/s. Further, loading rates are >250BW/sec at sprinting speeds, with peak absorption loads occurring in the first 10-50 milliseconds. Given these high demands, it is critical to consider running as a fundamental milestone for rehabilitation of CMSI. The clinician must also uniquely consider strategies to *"bridge the gap"* between traditional, functional rehabilitation exercises such as calf raises and establish a linear, progressive locomotive reconditioning pathway that offers graded tissue exposure to the demands of running. In Figure 1, we present an approach utilising 6 Pillars. While pillars are often completed sequentially – in practice a degree of overlap exists between areas in order to best facilitate athlete recovery: *"distinct blocks make rehab fail".* Key considerations include foot and ankle stiffness, accelerated ground contacts through drilling and building out a plyometric continuum – addressing force absorption and concentric power prior to returning to run. Developing a succinct, linear progression pathway that addresses these factors will better enable the athlete to withstand the high tensile load and loading

Table 1

	Outcome(s):	Criteria:	Yes/ no:
Basic clinical markers	*ROM and extensibility*	*WB dorsiflexion normal and clear → Bent knee → Straight knee*	
	Palpation tenderness	*Resolving*	
	Symptom behaviour	*Walking and ADL's remain clear, including after loading*	
Strength qualities	*Foundation strength-endurance*	*Straight knee SLHR at 60bpm → ≥20R**	
	Maximum isometric capacity	*Plantar flexion MVIC bent knee → >BW**	
Dynamic function	*SSC capacity: Repeatability*	*Single leg submaximal hop test → Tolerance of 15-20s*	
	Ankle dominant	*Single leg pogo test → 15-20R* in-place*	
	Horizontal component	*Single leg forward hop for distance → Confidence → Resolving/ improving performance*	
Other 'non-quantifiables'	*Observed quality and proficiency during rehab work-up*	*→ Eccentric phase control during strengthening → Absence of 'lag' in inner ROM plantar flexion/ 'toe-off' position → Run drills and elementary plyometric batteries are unremarkable/ symptom free E.g. 'A-skip' x15m and 'Ankling' x15m*	

Table 1: Return to running after calf muscle strain injuries in track and field.

Legend: ROM=range of motion; WB= weight bearing; ADLs= activities of daily living; SLHR= single leg heel raise; R=repetitions; SSC= stretch-shortening cycle; MVIC=Maximal voluntary isometric contraction; bpm=beats per minute; ROM= range of motion; *Greater capacity may be required for 'problem calves' or slow clinical progress.

rates the calf is subjected to even at low running speeds. Due to these factors, return to run clearance is a key clinical decision. Table 1 provides a data-led clinical approach to determine running readiness after CMSI in track and field athletes.

Running Variations Alter the Demands on the Calf

Soleus and gastrocnemius muscle fascicles remain relatively isometric during running, particularly at faster speeds whereby the MTU utilises ≈74% of positive work by tendon elastic strain energy[6]. This contribution enables the calf complex to act like a spring, absorbing and recovering mechanical energy during steady state running. As we increase our running speed, we must produce more force more rapidly and forcefully to sustain momentum; especially during the second part of the stance phase of running. Since the relative contribution of work done by the calf (muscle fascicle, tendon and muscle-tendon unit) is dependent on the athlete's running speed, the clinician can strategically use this knowledge to prescribe running rehabilitation pathways. First, the clinician may seek to prioritize the storage and recovery of tendon elastic strain energy over cumulative work by starting athletes at slightly faster running speeds compared to a conventional muscle injury rehabilitation. This is consistent with expert perspectives whereby it has been suggested to avoid very slow, continuous jogging in early phase running rehabilitation for some CMSI[1]: *"I might introduce strides before I introduce jogging. But it may need to be the other way around with gastroc-type injuries. With a gastrocs injury it may be doing some sort of jogging first may be beneficial".*

Similarly, it is suggested to limit high effort acceleration early in return to run pathways. Ideally, consecutive steady-state "run throughs" are successfully prescribed on alternate days without significant progressions in both volume and intensity concurrently. For track athletes, it is important to consider changes in surface and footwear during the return to run pathway.

"Prevention is performance enhancement. Focus on the performance enhancement and don't use the unsexy word 'prevention' too much"

First, develop a shared performance-prevention model using a tiered approach

Prevention approaches where practitioners function in discrete silos are deficient compared to a philosophy that embeds shared implementation. Coordination among the team fosters accuracy in exercise selection and loading across the spectrum of prevention domains (Figure 2). In elite athletics, a coach-athlete model predominates. In other situations, the coach and conditioning staff first collaborate to plan exposure within a periodised training plan. Since workload is a key part of the aetiology of index and recurrent CMSI, clinicians are an important part of these discussions and embedding performance support staff within coach-athlete models adds value in prevention.

Four key implementation domains exist for preventing CMSI (Figure 2). From these domains a tiered approach can be used to prioritise several elements related to athlete capacity, exercise selection and workload, that could impact the aetiology of CMSI in track and field. Failure to meet or consider *Tier 1* factors is likely to be the most problematic in terms of resilience to CMSI. This model should be refined according to a thorough needs analysis of the specific track and field discipline.

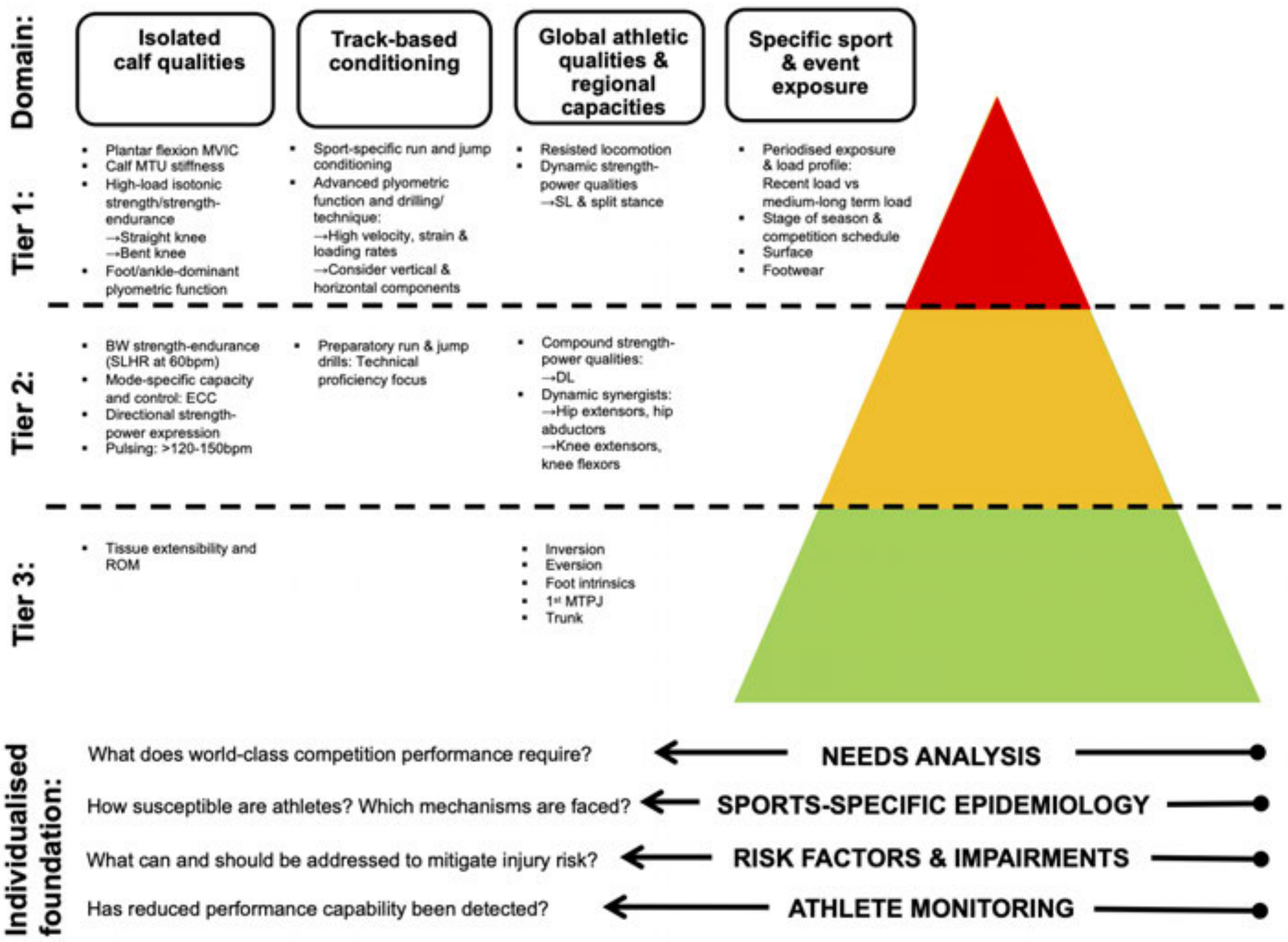

Figure 2: A tiered-approach for preventing calf muscle strain injuries in track and field.

Prioritise high-value prevention strategies
Sports-related conditioning and event exposure are high-value prevention domains (Figure 2)[1]. These priority areas are likely to substantially and simultaneously impact: (a) Performance capability; and, (b) tissue-specific resilience and tolerance of sports-related mechanisms of CMSI. Graded, periodised and appropriately undulating exposure to activities that are most demanding of the calf is critical. This ensures athletes are prepared for what they are (and will be) exposed to, which is a key tenet of primary prevention of CMSI. For these reasons exercise/load-based interventions that support chronic and uninterrupted participation are likely to have a significant preventative effect – in addition to their direct benefits such as building isolated structure-specific capacity within susceptible muscles (e.g. soleus) (Figure 2)[3].

Optimally integrating the *"competing interests"* of performance and prevention domains within complex athlete management systems is a practical challenge. To prevent CMSI, the team should consider the calf requirements during the spectrum of track- and non-track-based activities. Taking the time to recognise and synthesise the work demands of the calf muscles (i.e., soleus vs gastrocnemius) and their elements (contractile vs elastic) can help to stratify risk. Team-led determinations across track- and gym-based loading may be especially helpful for avoiding overload-related soleus pathology. Quantifying tissue-specific loads at locations susceptible to CMSI is a potential future consideration. Practitioners can consider several key parameters to implement this approach and generate a profile of relative muscle and tissue loads (high vs medium vs low):

1. Intrasession volume(s) across the activities completed: *How demanding is the session?* (a) Load magnitude(s) (i.e., peak forces): *How high are the calf demands?* (b) Loading rate(s): *How quickly are the loads applied?*
2. How (1 - above) stacks up against what athletes have been prepared for: *How conditioned are athletes to these demands?*

If the athlete is not adequately prepared for the session and/or one or more of its component activities – the team can alter (1) accordingly.

Next, consider benchmarks and profiling to help guide implementation
Current evidence provides little primary research to guide clinicians aiming to prevent CMSI[7]. Establishing athlete benchmarks from published and pilot data

Table 2

Quality measured:	*Information obtained:*	*Test(s):*	*Proposed benchmarks and/ or data:*
Foundation strength-endurance	*Repeated force-generating capacity against body weight: Contractile elements*	*Single leg heel raise at 60bpm* *→ Plantar grade or dorsiflexion & technique cues*	*≥25 RTF*
Loaded strength-endurance	*High-load repeated force-generating capacity: Contractile elements*	*Single leg isotonic 6-8RM (kg)* *→ Full/ available range of motion*	*Standing: ≥1.5xBW system load (+50%BW)* *Seated: >BW*
Maximum isometric strength	*Maximum force-generating capacity/ isolated structure-specific capacity: Soleus*	*Seated plantar flexion MVIC (N)* *→ From dorsiflexion*	*2-2.5xBW*
Maximum isometric strength	*Maximum force-generating capacity/ System capacity*	*Standing plantar flexion MVIC (N)*	*3-4xBW*
MTU elasticity: All-out	*Vertical SSC capacity and proficiency*	*Reactive strength index (RSI): Drop jump protocol*	*Discipline-specific or historical individual data*
MTU elasticity: Repeatability	*Vertical SSC capacity and proficiency over 10 jumps*	*RSI: 10-5 protocol*	
Horizontal function: All-out	*Horizontal capacity and proficiency*	*Single leg maximum forward hop*	
Vertical function: All-out	*Vertical capacity and proficiency*	*Single leg maximum vertical hop*	
MTU elasticity and horizontal function	*SSC capacity during high-load, loading rate and lengthening with greater horizontal demands*	*Single leg bound test x15-20m* *Single leg bound test x3-5 reps*	

Table 2: Potential preventative benchmarks to help reduce the risk of future CMSI.

Legend: bpm= beats per minute; RM= repetition maximum; MVIC= maximum voluntary isometric contraction; BW= body weight; MTU= muscle-tendon unit; SSC= stretch-shortening cycle; RSI=reactive strength index; RTF=repetitions to failure; N=newtons.

provides practical direction (Table 2). When considering maximum capacities, a high degree of performance is warranted due to the large work demands faced by the calf during track and field events. Breadth across qualities is also worthwhile due to the diverse demands and functional roles of soleus and gastrocnemius. For example, to avoid CMSI, many athletes must express repeatability in high-end outputs/ function . When evaluating athletes against proposed benchmarks, a reduction in one or more of the qualities that the calf requires to function optimally can help to generate a calf-specific prevention profile, highlighting an objective way forward for preventative exercise selection/ loading. Consideration for coordination, technique and skill may also form a unique area of implementation in track and field. In sports where performance is impacted by technique, and technical practice remains a prevailing focus of coaches, large workloads are devoted to this area.

Individualisation at baseline: Risk factors and impairments

The presence of risk factors and/or impairments that increase susceptibility to CMSI should drive individualised prevention from the outset. Building calf capacities broadly (Table 2) may dampen the strong negative impact of non-modifiable risk factors such as older age and a history of CMSI. Modifiable impairments (e.g. soleus weakness, reduced stiffness) within the calf muscle tendon unit should be addressed as soon as they are detected. In addition to representing a reduced tissue threshold to failure, these impairments can compound susceptibility to CMSI by negatively impacting non-modifiable factors.

Individualisation on the fly: Athlete monitoring

Team-led prevention should involve individualisation in response to transient changes in athlete capability and susceptibility to CMSI. Athlete monitoring to prevent hamstring strains has been demonstrated (Wollin et al., 2019) – a model that can be modified for CMSI in practical settings. Elite clubs/sporting organisations can serially monitor calf function, such as plantar flexion maximal voluntary isometric strength and stretch-shortening cycle/elastic function. Identifying and quantifying *'flags'*, such as reduced capacity (e.g. maximal voluntary isometric strength) or the presence of symptoms (e.g. soleus tightness) can be used to initiate further subjective and objective determination of an athlete's training preparedness, as well as exploring the possibility of a latent injury. Embedding athlete monitoring to prevent CMSI provides a dynamic system that can be implemented in the real-time to support an individual's performance outcomes.

"Having a recurrent injury is a failure for all,": Monitoring to prevent recurrence should persist

Athletes remain at risk of recurrent CMSI for longer than many other muscle strains[8], but an individual's relative susceptibility to recurrence can fluctuate as well[1]. Transient changes to an individual's calf capacity and injury susceptibility are expected within rehabilitation, particularly around times of exercise and running progression (volume, intensity). They can also be anticipated immediately after a return to full training and competition. The managing team can plan workloads at these times to mitigate the risk of recurrence. Expected changes to the risk profile can also be referenced against findings from athlete monitoring and an athlete's baseline in real-time, prompting intervention if *'flags'* are identified.

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