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Characterisation of Calf Strain and its healing through Clinical and Functional Assessment and Ultrasonography in the Active Population

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Abstract

Background: Calf muscle strain, particularly at the distal musculotendinous junction of the medial gastrocnemius and soleus aponeurosis ("tennis leg"), is a common sports injury associated with pain, disability, and risk of recurrence. Despite its high incidence, prospective data describing its clinical course and correlation with functional and ultrasonographic recovery are limited. This study characterises the clinical features, functional recovery and ultrasonographic healing of calf strain in physically active adults with the single heel raise being a clinically useful test to assess patients' function. **Methods:** Thirty physically active patients aged 21–65 years presenting within six weeks of acute calf pain were prospectively recruited from a sports medicine clinic. Diagnosis was confirmed by history, clinical examination, and ultrasonography. Exclusion criteria included chronic calf pain, other lower limb pathologies, or absence of a visible muscle defect. Participants underwent serial clinical and ultrasonographic evaluation at baseline, 3 weeks, 6–12 weeks, and 5–6 months. Pain intensity (visual analogue scale, VAS), swelling, tenderness, induration, and single heel raise ability were assessed at each visit. Functional status was evaluated using the Foot Function Index (FFI) and Lower Extremity Functional Scale (LEFS). Ultrasonographic measurements of defect length, width, and depth were recorded. Statistical analysis employed linear mixed-effects models and Kaplan–Meier estimates to assess associations between functional recovery and imaging findings. **Results:** Twenty-eight participants (80% male, mean age 48.3 ± 13.1 years) completed the study. Most injuries (93.3%) involved the distal musculotendinous junction between the medial gastrocnemius and soleus aponeurosis. At presentation, all patients reported acute pain (mean VAS 4.4) and a limp, 93.3% had swelling, and 63.3% had bruising. Mean initial ultrasound defect size was 90.2 × 37.2 × 11.3 mm. Reparative tissue was identified in 80% of cases at the first follow-up. Median time to symptom recovery (VAS < 3) was 5 weeks, while median time to primary union on ultrasound was 10 weeks ($p = 0.01$). Functional scores improved significantly during follow-up: mean FFI decreased from 45.6 to 7.0, and LEFS increased from 41.3 to 73.3. Patients achieving symmetrical single heel raise on clinical examination demonstrated superior function (LEFS 68.2 vs 50.7, $p = 0.002$; FFI 10.0 vs 35.2, $p = 0.0005$). No significant association was observed between functional outcomes and calf circumference or induration length. **Conclusion:** Calf strain primarily affects the medial gastrocnemius–soleus junction and demonstrates good recovery with conservative management. Clinical symptoms resolve before complete ultrasonographic healing, with median recovery times of five and ten weeks, respectively. The single heel raise test is a useful, simple indicator of functional improvement. While clinical improvement supports safe return to daily activities, ultrasonography remains valuable in confirming primary union prior to resuming high-intensity or explosive sports. This study provides prospective evidence correlating clinical, functional, and imaging recovery patterns to guide rehabilitation and return-to-play decisions.

Keywords: Tennis leg; Gastrocnemius; Single heel raise; Ultrasonography; Muscle strains; Return to sport.

INTRODUCTION

Muscle injuries are common in sports, accounting for 31% of all injuries and for a third of the time loss in soccer [1,2]. Injury of the mid-calf, particularly of the medial head of the gastrocnemius and its insertion at the soleus aponeurosis, is a common sports injury and is known colloquially as "tennis leg". It is the 4th most common injury in sports, coming behind adductor, quadriceps and hamstring injuries, and accounts for 13% of muscle injuries in soccer [3,4]. It results in significant loss of time from training in sports and is associated with increased risk of recurrent lower limb injuries as well as recurrent calf muscle injuries [2,3,5].

The classic presentation is that of a middle-aged male tennis player who experiences sudden onset of pain in the midst of executing an abrupt movement e.g., a sprint or a jump, where extension of the knee with the foot in dorsiflexion, results in eccentric loading of the calf. This is followed by swelling in the middle portion of the calf and an antalgic gait. The concomitant popping sensation often leads the patient to

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assume that the injury had been caused by direct impact, for example from a ball or racquet [4]. The resulting pain and disability can last for months depending on the severity and effectiveness of initial treatment, with most recovering well if they receive appropriate diagnosis and treatment [6,7]. The condition can be managed conservatively with a protocol of ice, elevation, compressive dressing to control oedema, non-steroidal anti-inflammatory medications and physical therapy [8].

Despite its high incidence, there is a paucity of information on the natural history of calf strain, the functional impact of the injury and the evolution of clinical features during the course of recovery [9]. Furthermore, there are no clear clinical indicators as to when the injury has healed sufficiently to allow return to sports. Healing is assumed to have occurred with the resolution of initial presenting symptoms [5]. As a result, sports medicine practitioners have relied upon information provided in commentaries and book chapters to guide their clinical decision-making and have based decisions on return to play on clinical reasoning and serial athlete monitoring [5].

Bedside ultrasonography has been employed in the diagnosis of calf strain [10]. In this report, we present ultrasonographic findings of ruptures to the distal musculotendinous junction on the calf and prospectively describe the clinical course from initial presentation to return to baseline activities. Correlation will be made between clinical features, functional status and ultrasonographic findings during the course of recovery.

MATERIALS AND METHODS

Thirty patients that presented at the sports medicine and surgery clinic with acute calf strain were recruited. Demographic data of the patients can be seen in Table 1. The diagnosis of calf strain was established through history, clinical examination and bedside ultrasound.

Patients who fit the following criteria were invited to participate in the study.

Inclusion criteria:

1. Unilateral calf pain of sudden onset
2. Physically active (engages in sports or exercise at least once weekly)
3. 6 weeks or less between onset of pain and presentation
4. Visible defect of the calf muscle on ultrasound
5. Age 21–65 years

Patients with the following criteria were excluded from the study

1. Other causes of calf pain e.g., Achilles tendinopathy
2. Presence of conditions that affect lower limb function such as concomitant painful foot and ankle conditions
3. Calf strain of more than 6 weeks
4. Calf strain without visible defects on ultrasound e.g., Grade one calf strain
5. Pain or ambulatory difficulties before the onset of injury to the calf

Ethical Approval: Approval from the hospital's institutional review board was obtained for the study and written informed consent was obtained from all the patients.

The thirty subjects underwent prospective follow-up of the clinical symptoms and serial ultrasound examinations to document the recovery process.

A detailed history was taken on the initial consultation to ascertain the habitual activity, lifestyle and exercise patterns and occupational background to establish baseline functional status (Table 1). Details on the circumstances and mechanism of the injury were also recorded using a standardised template to ensure consistency (Table 2).

A systematic physical examination was conducted on each visit of the injured calf muscle. A record was made for presence of swelling, tenderness, palpable defect and induration of the muscle, at the site of injury (Table 2). The Achilles tendon would be examined for swelling and defect to exclude Achilles tendon tears.

Assessment of pain level on walking and single leg heel raise was made on an eleven-point (0 – 10) visual analogue scale. Asymmetry in height of single heel raise of more than one centimetre between each limb was noted.

Functional capacity was assessed with Foot Function index (FFI) and Lower Extremity Function Score (LEFS) questionnaires. Both of these questionnaires measured the impact of calf strain on foot function as well as its impact on daily activities, work and recreational activities. Lower total score on the FFI indicates improving pain and function [11] while higher total score on the LEFS indicates improving function [12].

Diagnostic ultrasound was performed by a sports physician with more than ten years of experience in musculoskeletal ultrasound using a Hitachi Noblus – Ultrasound System with a Hitachi L64 Linear with frequency range 12 – 2 MHz.

The ultrasound examination was performed with the patient in the prone position. The scan began at the point of maximal tenderness and the calf was scanned in the longitudinal and transverse planes. The pennate appearance of the medial gastrocnemius was examined in the longitudinal view and fascial plane between the gastrocnemius and soleus was identified as an echogenic line. The probe was moved proximally to examine the upper end of the gastrocnemius head and its insertion into the femoral condyle and then distally to examine the medial gastrocnemius head, the distal musculotendinous junction and the transition to the aponeurosis distally. In each instance, the contralateral calf muscle was also examined to make a comparison. The adjacent veins were visualised for blood flow and compressibility to exclude venous thrombosis. The examination was then extended to the rest of the calf, including the popliteal fossa to exclude a ruptured popliteal cyst and distally to exclude tears of the Achilles tendon.

The area of muscle injury was then examined in greater detail. Typical ultrasonographic findings include disruption of the normal fibrillar and pennate appearance in damaged muscle adjacent to the defect[10]. The distal musculotendinous junction may appear indistinct, and the muscle fibres of the distal medial gastrocnemius may be retracted from the aponeurosis. Fluid collections between the medial head of the gastrocnemius and soleus aponeurosis may contain heterogeneous, hypoechogenic fluid, with extensions into fascial planes between the gastrocnemius and distal soleus muscle aponeurosis in the majority of cases (Figure 1).

Measurements of the muscle defect were taken in the longitudinal and transverse axes. The greatest distance between the muscles as demarcated by undisrupted muscle fibres was taken to represent the size of the defect. Location of defects in relation to the gastrocnemius and soleus aponeurosis was noted.

In addition, the presence or absence of organising tissue was noted (Figure 2). The residual defect of the muscle not occupied by organising tissue was measured in the transverse and longitudinal planes. Any increase in power Doppler signal around the muscle defect was also noted.

At the end of the initial consultation, all patients were prescribed analgesia and advised to rest, ice, and elevate the injured limb. They were referred to a physiotherapist for calf stretches and strengthening exercises and advised to return to normal ambulation as tolerated but to defer athletic activities until the pain has resolved. Sprinting and jumping activities were delayed until primary union of the muscle defect has been confirmed on ultrasound.

The patients were followed up subsequently at 3 weeks, 6-12 weeks and 5–6 months. Patients were discharged from follow-up if certain criteria were met. These were resolution of pain, or pain being mild (pain score less than 3), and return to baseline activities or activities of daily living, with or without complete union of the defect on ultrasound examination. In each visit, the patients were re-examined as per protocol and progression of the same clinical parameters as listed in Table 2 were noted and the questionnaires were re-administered.

Repeat ultrasonographic examination of the injured muscle was performed to track changes in size of the muscle defect and residual fluid collections.

Statistical Analysis

The analysis was performed using STATA 16.1. For continuous or discrete variables, summary statistics (arithmetic mean, standard deviation [SD], median, minimum and maximum values) were presented; counts and percentages were presented for categorical variables. An independent t-test was used to compare the functional scores in single heel raise groups. A linear mixed-effects model was used to identify any association between the functional scores and clinical examination tests, adjusting for age, gender, BMI, and time from injury (weeks). The Kaplan-Meier estimate was used to estimate and compare time to clinical recovery and ultrasound recovery.

RESULTS

Initial presentation

Twenty-eight patients completed the study. Two did not present for their final scheduled review but were connected via telephone and the questionnaires were administered over the phone.

The majority of the subjects were participating in their sports or exercise at a recreational level, engaging in it on an average of 2.6 times per week. The sport that the subjects were primarily engaged in was categorised as endurance (e.g., running), strength-based (e.g., weightlifting), or mixed sports involving both strength and dynamic components (e.g., soccer and racket sports). The majority of the subjects (70%) participated in sports in the mixed category as their primary sport.

The majority (86.7%) of the subjects were injured while participating in sports or exercise. About half (53.0%) occurred during accelerating or decelerating movement, jumping (20%), sprinting (13.3%) and walking (13.3%).

Direct contact with another participant was reported in only 1 (3.3%) of the subjects. All reported pain of acute onset, with mean VAS score of 4.43 (SD 2.6) which caused them to limp. In addition, 76.7% reported a sudden popping or cramping sensation at the time of injury. Subsequently, 93.3% and 63.3% of participants noticed swelling and bruising, respectively. The majority of them (76.7%) scored 4 on the Roles and Maudsley scale after the injury.

The vast majority (93.3%) did not have an antecedent calf strain in the same leg.

The mean time between occurrence of injury and presentation at the clinic was 2 weeks (range < 1 to 7 weeks).

At the first consultation, most patients (90%) still reported significant pain on walking (mean VAS 3.8; range 0–8). Bruising (36.7%), swelling (93.3%) and an antalgic gait (100%) were observed in the clinic. Half were unable to perform a single leg heel raise. Of those that could, 86.7% had a difference in height of heel raise of more than one cm (average difference 3.6cm, range 1-10cm), and 60% experienced pain (mean VAS 3.4 and range 0-10) during that manoeuvre.

Calf swelling was observed in 56.7% with an increase in calf circumference (mean 1.6 cm, range 0.5 - 4.0) secondary to swelling of the muscle on the injured side. A minority of 13.3% showed a decrease in calf circumference. Only 13.3% of the patients had a palpable defect. Induration was palpable in 93.3% of the cases (mean length 8.8, range 0-20) over the area of maximal tenderness which corresponded to the muscle defect on ultrasound examination. Bruising was noted in 36.7% of the cases, often distal to the area of the injured muscle.

A minority (3.3% and 6.7%) had been able to return to running and explosive movements, respectively, by the time of initial presentation. Mean FFI and LEFS scores were 45.6 (range = 0 - 96) and 41.3 (range = 2–80), respectively.

Typical ultrasonographic features on initial presentation include disruption of the normal fibrillar hyperechoic appearance of the medial head of the gastrocnemius and blunting of the tapered distal insertion. Haematoma presents as a fluctuant heterogeneous, fusiform fluid collection between the medial gastrocnemius head and the soleus aponeurosis, while a seroma has an anechoic appearance.

On the initial visit, 96.7% of the defects were seen between the medial head of the gastrocnemius and the soleus aponeurosis with mean dimensions of length 90.2mm (range 15.9 to 195), width 37.2mm (range 4.2 - 101) and depth 11.3mm (range: 2.3 - 35). The single exception seen involved a minor degree of strain with disruption of the fibres confined to the medial gastrocnemius.

Subsequent Visits

In subsequent visits, the onset of primary union of the defect can be seen on ultrasonography with a central anechoic fluid collection of seroma and a rim of reparative tissue of heterogeneous hyper-echogenicity between the medial head of the gastrocnemius and soleus aponeurosis.

On the first consultation, 80% showed the presence of reparative tissue with a central anechoic fluid collection with mean dimensions of length 59.4mm (range 4.1 - 138), width 27.0 mm (range 4.2 - 101) and depth 8.8mm (range 1.6 - 31). As primary union progresses, ultrasound imaging shows the hypoechoic rim increases in thickness towards the centre, replacing the anechoic fluid collection and defect. Primary union (absence of defect) was completed in 68.4% and 73.0% in the second and third visits, respectively.

In comparison, the reported pain (mean VAS) on initial consultation was 3.7, rapidly declining to 1.0, 0.5 and 0 on subsequent visits. Thus, a significant proportion had persistent defect on the latter visits despite clinical recovery.

The median time needed for symptom recovery as well as primary union on ultrasound was also recorded, with symptom recovery being defined as VAS improving to < 3. The Kaplan-Meier estimate was used to compare time to symptom recovery and primary union. Median time to symptom recovery was 5 weeks, and median time to primary union on ultrasound was 10 weeks (Figure 3). A paired log-rank test was performed, and the p-value was 0.01, indicating that time to symptom recovery was shorter than time to ultrasound recovery.

The proportion of subjects with Roles and Maudsley 3 or 4 was 40% and 10% on the second and third visits, respectively. Of note was the low incidence of power Doppler signal on initial presentation (36.7%) with steady decline on serial ultrasound measurements in subsequent visits.

Improvement in functional scores was also noted in the subsequent visits. The mean Foot Function index (FFI) improved from 45.58 to 6.96 and the mean Lower Extremity Function Score (LEFS) improved from 41.27 to 73.25 in the third visit. A summary of the progress of the functional scores from the initial to subsequent visits is presented in Table 3.

Linear mixed effects models were fitted to investigate the association between functional scores over the visits and certain clinical examination tests (such as calf circumference, induration length and single heel raise asymmetry), adjusting for age and BMI; the quadratic term of time since injury was also included in the model. There was no clear association between functional scores over the visits and induration length or calf circumference. Similar models were fitted for LEFS over the visits; the results showed no association between LEFS and induration length or calf circumference.

The boxplot of LEFS and Foot Function Index (FFI) versus single heel raise asymmetry is presented below (Figure 4). For single heel raise, the mean LEFS in the symmetrical single heel raise group (heel raise difference = 0) tends to be higher than the asymmetrical single heel raise group (heel raise difference >0), whilst the mean FFI in the symmetrical single heel raise group tends to be lower. These are supported by the t-test in Table 4.

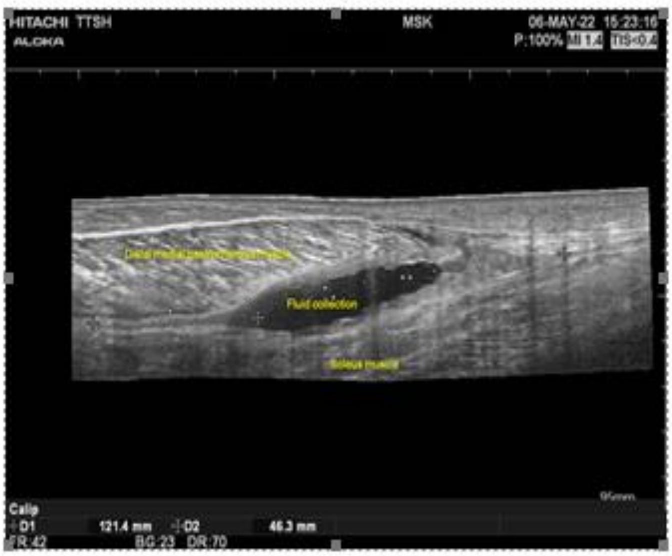

Figure 1: Ultrasound image of Patient A on initial consultation

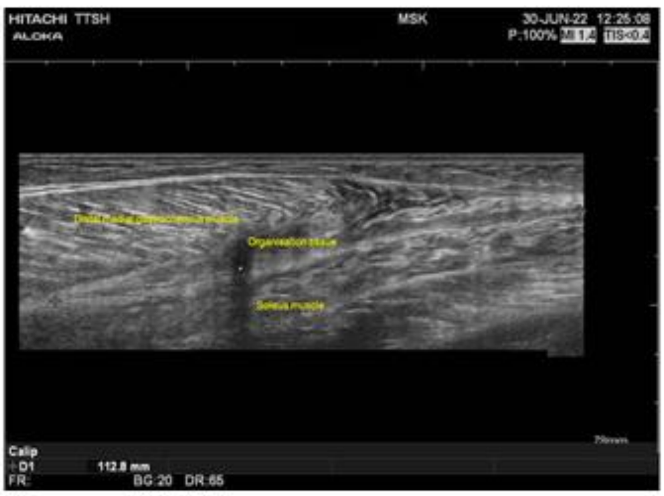

Figure 2: Ultrasound image of Patient A on final review visit

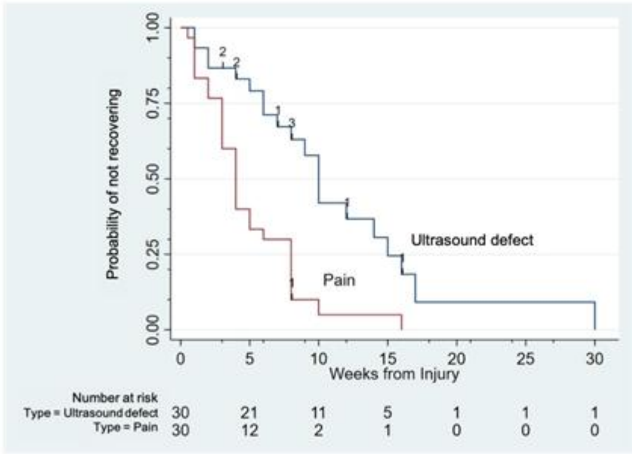

Figure 3: Kaplan-Meier plot of time to symptom recovery (VAS <3) and primary union on ultrasound (absence of ultrasound defect)

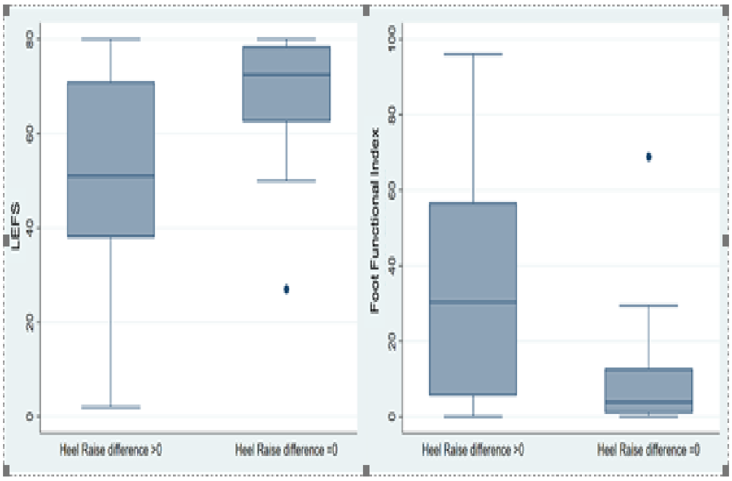

Figure 4: Boxplot of LEFS and FFI vs Single Heel Raise

DISCUSSION

The gastrocnemius muscle consists of two heads. The medial and lateral heads originate from the posterior aspects of medial and lateral femoral condyles respectively. These converge and insert into the posterior surface of the soleus aponeurosis to form the upper part of tendo-achilles which inserts into the calcaneus.

The bi-arthrodial architecture of the calf, combined with excessive stretch and rapid forceful contraction from the high density of fast-twitch muscle fibres, results in increased risk of injury [6,13].

The medial head of the gastrocnemius muscle is injured more often than the lateral head due to greater muscular activity [14]. Muscle fatigue leads to reduced muscle relaxation, which may make these fibres more vulnerable to stretching injury [15].

Diagnosis and clinical features

A strain of the medial gastrocnemius is a relatively common muscle injury that occurs typically in middle-aged individuals engaged in activities that overstretch the calf muscle with the knee fully extended e.g. during sprinting, jumping, and the decelerating phase in rapid direction changes. This results in sudden pain and an audible pop, followed by ongoing pain and disability. Some (20%) experience prodromal muscle ache before the acute symptoms [16].

Table 1: Demographics and Baseline Functional Characteristics

	Overall (N=30)
Age (year)	
Mean (SD)	48.29 (13.09)
Median (min, max)	45.96 (24.92, 64.67)
Gender (n, %)	
Male	24 (80)
Female	6 (20)
Weight (kg)	
Mean (SD)	78.85 (13.85)
Median (min, max)	76.55 (55, 102.1)
Height (m)	
Mean (SD)	1.70 (0.09)
Median (min, max)	1.69 (1.54, 1.92)
BMI	
Mean (SD)	27.02 (3.5)
Median (min, max)	26.5 (19.9. 33.4)
Years of sports	
Mean (SD)	10.03 (9.37)
Median (min, max)	8.5 (0.08, 30)
Chronic Disease (n, %)	
Yes	14 (46.67)
No	16 (53.33)
Previous surgery on the same limb	
Yes	4 (13.33)
No	26 (86.67)
Concomitant Medication	
Yes	10 (33.33)
No	20 (66.67)
Recurrent calf strain in same leg	
Yes	2 (6.67)
No	28 (93.33)
Occupation	
Manual	11 (36.67)
Mixed	3 (10.0)
Retired	4 (13.33)
Sedentary	12 (40.0)
Type of sports /exercise (usual)	
Endurance	6 (20.0)
Mixed	21 (70)
None	3 (10.0)
Level of Sports	
Professional	1 (3.70)
Club	3 (11.11)
Recreational	23 (85.19)

Table 2: Mechanism of Injury, Initial Symptoms and Clinical Examination Findings

	Overall (N=30)
Mechanism of Injury	
Sports or exercise type during injury	
Endurance	4 (13.33)
Intermittent	3 (10.0)
Mixed	19 (63.33)
None	4 (13.33)
During or after exercise	
After	3 (10.71)
During	25 (89.29)
Contact injury	
Yes	1 (3.33)
No	29 (96.67)
Movement leading to injury	
Jump	6 (20.0)
Sprint	4 (13.33)
Start/ stop	16 (53.33)
Others	4 (13.33)
Symptoms	
Pop sound experienced (%)	
Yes	23 (76.67)
No	7 (23.33)
VAS at Onset	
Mean (SD)	4.43 (2.6)
Median (min, max)	4.25 (0, 9)
Limping (%)	
Yes	30 (100)
VAS on Walking	
Mean (SD)	3.7 (3.5)
Median (min, max)	4 (0, 8)
Swelling (%)	
Yes	28 (93.33)
No	2 (6.67)
Bruise (%)	
Yes	19 (63.33)
No	11 (36.67)
Roles & Maudsley	
Mean (SD)	3.62 (0.82)
Median (min, max)	4 (1, 4)
Clinical Examination Findings	
Antalgic Gait (%)	
Yes	22 (73.33)
No	8 (26.67)
Bruising on examination (%)	
Yes	11 (36.67)
No	19 (63.33)
Tender (%)	
Yes	25 (83.33)
No	5 (16.67)

Palpable Defect (%)	
Yes	4 (13.33)
No	26 (86.67)
Induration Length	
Mean (SD)	8.78 (4.71)
Median (min, max)	8 (0, 20)
Calf Circumference Difference	
Mean (SD)	0.78 (1.29)
Median (min, max)	0.75 (-2, 4)
Ability to single heel raise (%)	
Yes	15 (50)
No	15 (50)
Asymmetry in single heel raise (%)	n=15
Yes	13 (86.7)
No	2 (13.3)
VAS on single heel raise (%)	
Mean (SD)	3.4 (2.4)
Median (min, max)	4 (1, 6)

Table 3: Functional scale scores over time

	N	Mean (SD)	Median (min, max)
FFI			
First Consultation	29	45.58 (27.97)	48.2 (0, 96)
Review 1	30	13.05 (17.96)	5.29 (0, 82.9)
Review 2	20	6.96 (7.32)	2.37 (0, 19.4)
Review 3	8	5.0 (4.83)	4.12 (0, 12.35)
LEFS			
First Consultation	30	41.27 (20.7)	45.5 (2, 80)
Review 1	30	65.43 (16.54)	70.5 (1, 80)
Review 2	20	73.35 (7.44)	74.5 (53, 80)
Review 3	8	75.25 (5.82)	77.5 (64, 80)

Table 4: T-test for LEFS and FFI vs Single Heel Raise Difference Groups

	Single Heel Raise Difference		Difference	p-value
	0	>0		
FFI	10.01	35.20	25.19 (11.42, 38.96)	0.0005
LEFS	68.15	50.73	-17.42 (-28.02, -6.81)	0.002

The majority of calf strains occur during non-contact situations, at the muscle-tendon junction, when the force applied exceeds tissue capacity. In contrast, soleus strain presents as an overuse injury due to an increase in uphill running with the ankle in dorsiflexion with the knee in a flexed position [17,18].

The typical presentation in this study is a middle-aged individual with sudden-onset calf pain while engaged in physical activity. There is a sensation of popping or cramping followed by delayed onset of swelling or bruising. Persistent pain may cause limping in the next few weeks. Most of these occurred without direct contact, often during acceleration or sudden deceleration associated with a change in direction, consistent with current research [17,18]. The male preponderance (80% male vs 20% female) may reflect the higher level of participation of men in sports of an intermittent nature.

Clinical findings include oedema, ecchymosis and tenderness at the medial myotendinous junction. A gap may be palpable if there is a significant tear. Passive ankle dorsiflexion or active ankle plantar flexion may be painful. Rarely, loss of sensation can occur with compression of the sural nerve by a large haematoma [6]. Single leg heel raise is often limited by pain. Examination of the Achilles is important to exclude Achilles tendon rupture.

Despite being a common injury, there is a paucity of robust prospective data that systematically describe the evolution of clinical features during the course of healing, its functional impact on daily activities and correlation of clinical features with structural healing of the muscle on imaging. As such, the management of calf strain and decisions on return to play are still guided largely by expert opinion [4].

We selected clinical features and measurements that are readily elicited in a busy clinic and may potentially be useful to monitor recovery and guide return to sports. Common early clinical findings include antalgic gait, asymmetry of the calf circumference, palpable induration over the calf strain site and painful single heel raise. The affected calf typically has a larger circumference due to swelling and haematoma in the initial stages. A minority (13.3%) did present with disuse atrophy of the calf, likely due to limping. This accounts for the lower percentage of observed vs reported calf swelling in the initial visit. The lower rates of observed versus reported bruising could be due to the resolution in the time interval between occurrence of injury and presentation at the clinic. The FFI and LEFS point towards significant functional impairment during the first few weeks.

Tenderness over the site of injury and induration are common findings. The absence of palpable defect on initial presentation may be attributable to the location of the defect sandwiched between the medial gastrocnemius and the soleus aponeurosis, making it too deep for it to be palpable, especially in the presence of a fluid collection and reparative tissue occupying the defect.

The clinical presentation overlaps with deep-vein thrombosis or thrombophlebitis of the lower extremity and a ruptured Baker's cyst. In a study of 141 patients with clinically diagnosed tennis leg, ten percent were found to have deep vein thrombosis instead. Two thirds had a partial tear of the medial gastrocnemius; 21% had an intermuscular fluid collection without a medial gastrocnemius muscle tear [15].

The convenience, lack of ionising radiation, cost savings and ease of access compared to MRI, make ultrasound useful for confirming diagnosis of calf strain, delineating the extent and location of the muscle defects and monitoring for structural recovery and guiding haematoma drainage [10,18]. The size of the muscle defect may be used to prognosticate and gauge time to recovery. Larger defects as well as haematoma of the musculotendinous junction have been associated with poorer prognosis [19-21].

Tennis leg often involves the medial gastrocnemius with avulsion at the aponeurosis, the tendon or the muscle. The lateral gastrocnemius is less often injured, accounting for 14% of calf strains [22]. Typical ultrasonographic features include disruption of the linear intramuscular septa by haematoma caused by the tear, oedema of the adjacent muscle, and loss of the pennate appearance of surrounding muscle [10, 22].

The vast majority of the injuries in this series occurred at the junction of the fascia between the gastrocnemius head and the soleus. At the time of the first presentation, a significant majority already showed signs of reparative tissue with approximately only 37% showing an increase in power Doppler signal around the muscle defect and half of the subjects reporting VAS of at least 3 while walking.

Functionally, the majority of the subjects reported little or no pain after the first visit although an antalgic gait could still be seen. Minimal or no pain was also reported despite the presence of a significant proportion of subjects who did not show complete union on ultrasound. Over time, there is progressive resolution of antalgic gait, calf swelling, calf tenderness and asymmetrical calf raise in tandem with ultrasonographic reduction in the volume of the anechoic region as primary union occurs. This study highlights that clinical resolution of symptoms occurs first before the eventual resolution of the calf strain defect as seen on ultrasound (Figure 2). The median time of 5 weeks for resolution of symptoms and 10 weeks for resolution of defect on ultrasound noted in this series would be a useful guide to counsel patients on the estimated duration of recovery. The location of the defect might facilitate early return to walking as the injury occurs at the anatomical plane between the gastrocnemius and the soleus, thus preserving the majority of the muscle fibres along the line of traction of the muscles in the push-off phase of walking. The 5-week time frame for resolution of symptoms would be a fair estimate as to when patients might be able to return to walking, symptom free. In the context of athletic activities such as running with a larger range of movement around the knees and ankles, this might introduce additional and larger shear forces between the planes of the gastrocnemius and the soleus, which may lead to recurrence of the injury and symptoms. As such, athletic activities should be deferred until complete union of the defect is noted on ultrasound or other forms of imaging.

The functional status (FFI, LEFS) scores also trend towards improvement in tandem with ultrasonographic progression in primary union. The single heel raise can be a quick and clinically useful test to assess the patient's function in a busy clinic. The patient's ability to achieve symmetrical single heel raise height at review visits suggests improved overall function, as demonstrated by its positive association with better functional scores.

To our knowledge, this is the first study that has correlated the serial ultrasound findings with clinical features and functional parameters in the course of recovery. The data support early return to daily activity and provide a useful clinical measure to add to our physical exam of calf strain patients in the form of single heel raise to monitor recovery and guide return to athletic activities. High-demand athletes may benefit from serial imaging to ascertain complete healing of the defect before returning to explosive sports that require strong concentric and eccentric calf contractions, e.g., jumping and sprinting.

Limitations

Limitations in this study include lack of confirmation of diagnosis on MRI or through surgical exploration. This is due to the cost and availability of MRI. Surgery was not indicated as all subjects recovered with conservative management.

This study only involved 30 subjects, which is a small number, and the majority of the subjects were male. This might result in gender bias. However, we are not aware of any data to support gender differences that might influence the location and size of calf injuries as well as the course of recovery.

In the absence of longer-term data, it is difficult to determine if the size of the original defect or the residual defect after primary union has occurred might represent a risk for recurrence of calf injuries.

CONCLUSION

In summary, most calf strains occur at the medial head of the gastrocnemius and have a good prognosis with conservative management. Ultrasonography is a readily accessible, safe and cost-effective imaging modality for confirmation of clinically suspected strains of the medial head of the gastrocnemius and for serial follow-up. Symptomatic recovery precedes complete primary union in the muscle and the single heel raise is a useful clinical test to guide clinicians on the functional recovery of the patient. While clinical features and simple clinical tests are useful indicators to guide return to activities of daily living, ultrasound is a valuable modality for determining primary union in order to safely return to athletic activities with explosive movements.

Author Contributions

Dr Jason Kok Kiong Chia conceptualized, designed, supervised the study and did the literature search. Data acquisition was done by Dr Jason Kok Kiong Chia and Dr Nicholas Jiajie Leong. Manuscript preparation was done Dr Jason Kok Kiong Chia. Statistical analysis was performed by Ms Xiaoe Zhang. Manuscript editing was done by Dr Nicholas Jiajie Leong. All authors reviewed and approved the final version of the manuscript.

Data Availability Statement

The data that support the findings of this study are available and will be made available upon request.

Use of AI in Drafting of Manuscript

The authors declare that they have not used any generative AI/AI-assisted technologies in the writing of this manuscript.

Conflicts of interest

None declared.

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Abbreviations: SD: Standard Deviation, Min: Minimum, Max: Maximum, VAS: Visual Analogue Scale, FFI: Foot Function Index, LEFS: Lower Extremity Function Score, MRI: Magnetic Resonance Imaging

REFERENCES

1. Bengtsson H, Ekstrand J, Hägglund M. Muscle injury rates in professional football increase with fixture congestion: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med*. 2013;47(12):743-7.
2. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). Am J Sports Med. 2011;39(6):1226-1232.
3. Shah JR, Shah BR, Shah AB. Pictorial essay: Ultrasonography in 'tennis leg'. *Indian J Radiol Imaging*. 2010;20(4):269-73.
4. Green B, McClelland JA, Semciw 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;1-28.
5. Ishøi L, Krommes K, Husted RS, Juhl CB, Thorborg K. Diagnosis, prevention and treatment of common lower extremity muscle injuries in sport - grading the evidence: a statement paper commissioned by the Danish Society of Sports Physical Therapy (DSSF). *Br J Sports Med*. 2020;54(9):528-37.
6. Toohey LA, Drew MK, Cook JL, Finch CF, Gaida JE. Is subsequent lower limb injury associated with previous injury? A systematic review and meta-analysis. *Br J Sports Med*. 2017;51(23):1670-78.
7. Orchard JW, Chaker Jomaa M, Orchard JJ, Rae K, Hoffman DT, Reddin T, *et al*. Fifteen-week window for recurrent muscle strains in football: a prospective cohort of 3600 muscle strains over 23 years in professional Australian rules football. *Br J Sports Med*. 2020;54(18):1103-7.
8. Dixon JB. Gastrocnemius vs. soleus strain: how to differentiate and deal with calf muscle injuries. *Curr Rev Musculoskelet Med*. 2009;2(2):74-7.
9. Coughlin MJ, Mann RA, Saltzman CL. Surgery of the foot and ankle. 8th ed. St. Louis: Mosby-Elsevier; 2007.
10. Jamadar DA, Jacobson JA, Theisen SE, Marcantonio DR, Fessell DP, Patel SV, *et al*. Sonography of the painful calf: differential considerations. *AJR Am J Roentgenol*. 2002;179(3):709-16.
11. Budiman-Mak E, Conrad KJ, Roach KE. The Foot Function Index: a measure of foot pain and disability. *J Clin Epidemiol*. 1991;44(6):561-70.
12. Mehta SP, Fulton A, Quach C, Thistle M, Toledo C, Evans NA. Measurement properties of the Lower Extremity Functional Scale: a systematic review. *J Orthop Sports Phys Ther*. 2016;46(3):200-16.
13. Ozyurek S, Erol B, Guler F, Atbasi Z. Isolated partial rupture of the medial head of the gastrocnemius muscle (tennis leg). *BMJ Case Rep*. 2013;2013: bcr2013009347.
14. Lawrence DW, Hutchison MG, Comper P. Descriptive epidemiology of musculoskeletal injuries and concussions in the National Football League, 2012-2014. *Orthop J Sports Med*. 2015;3(5):2325967115583653.
15. Cibulka M, Wenthe A, Boyle Z, Callier D, Schwerdt A, Jarman D, *et al*. Variation in medial and lateral gastrocnemius muscle activity with foot position. *Int J Sports Phys Ther*. 2017;12(2):233-41.
16. Anouchi YS, Parker RD, Seitz WH Jr. Posterior compartment syndrome of the calf resulting from misdiagnosis of a rupture of the medial head of the gastrocnemius. *J Trauma*. 1987;27(6):678-80.
17. Froimson AI. Tennis leg. *JAMA*. 1969;209(3):415-6.
18. Shields CL Jr, Redix L, Brewster CE. Acute tears of the medial head of the gastrocnemius. *Foot Ankle*. 1985;5(4):186-90.
19. Werner BC, Belkin NS, Kennelly S, Weiss L, Barnes RP, Potter HG, et al. Acute gastrocnemius-soleus complex injuries in National Football League athletes. *Orthop J Sports Med*. 2017;5(1):2325967116680344.
20. Mueller-Wohlfahrt HW, Haensel L, Mithoefer K, Ekstrand J, English B, McNally S, *et al.* Terminology and classification of muscle injuries in sport: the Munich consensus statement. *Br J Sports Med*. 2013;47(6):342-50.
21. Ueblacker P, Müller-Wohlfahrt HW, Ekstrand J. Epidemiological and clinical outcome comparison of indirect ('strain') versus direct ('contusion') anterior and posterior thigh muscle injuries in male elite football players: UEFA Elite League study of 2287 thigh injuries (2001-2013). *Br J Sports Med*. 2015;49(22):1461-65.
22. Bright JM, Fields KB, Draper R. Ultrasound diagnosis of calf injuries. *Sports Health*. 2017;9(4):352-5.