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SCIENTIFIC ARTICLE

MRI assessment of calf injuries in Australian Football League players: findings that influence return to play

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Abstract

Objective Calf muscle strains have become increasingly prevalent in recent seasons of the Australian Football League (AFL) and represent a significant cause of time lost from competition. The purpose of this study was to examine the association between MRI features of calf muscle strains and games missed and to thereby identify parameters that are of prognostic value.

Materials and methods A retrospective analysis of MRI scans of AFL players with calf strains referred to a musculoskeletal radiology clinic over a 5-year period (2008–2012) was performed. The muscle(s) and muscle component affected, the site and size of strain, and the presence of an intramuscular tendon tear or intermuscular fluid were recorded. These data were cross-referenced with whether a player missed at least one game. Imaging features of prognostic value were thus identified.

Results Sixty-three athletes had MRI scans for calf muscle strains. Soleus strains were more common than strains of other muscles. Players with soleus strains were more likely to miss at least one game if they had multiple muscle involvement ($p = 0.017$), musculotendinous junction strains ($p = 0.046$), and deep strains ($p = 0.036$). In a combined analysis of gastrocnemius and soleus strains, intramuscular tendon tears were observed in a significantly greater proportion of players who missed games ($p = 0.010$).

Conclusion Amongst AFL players with calf injuries, there is an association between missing at least one game and multiple muscle involvement, musculotendinous junction strains, deep strain location, and intramuscular tendon tears. In this setting, MRI may therefore provide prognostic information to help guide return-to-play decisions.

Keywords MRI · Athlete · Calf · Muscle injury · Soleus · Strain

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Introduction

Since 2010, there has been a consistent rise in calf strains amongst players of the Australian Football League (AFL). Such strains now constitute the second most common muscular injury in the League after hamstring strains, and represent a significant cause of time lost from competition [1]. Although injuries to the hamstring muscle complex have been extensively studied [2–7], comparatively little research on the prognostic value of MRI in the setting of calf injuries in elite athletes has been performed [8].

Australian Rules Football is played over a 22-game regular season with 4 weeks of finals. There are, on average, 7 days between games. Players in all positions are at risk of injury owing to the combined endurance and collision nature of the sport. The mean distance run by players is 13 km per game [9].

Magnetic resonance imaging (MRI) is the gold standard for soft-tissue injury evaluation and is increasingly the modality of choice for the assessment of elite athletes sustaining a calf muscle injury [8]. In the past, MRI was recommended only when imaging was deemed necessary for diagnosis. However, the role of imaging in acute muscle injury has extended from merely confirming the clinical diagnosis to aiding in prognostication [10]. Return-to-play decisions are often difficult and have significant implications for both player and club. As the time required for recovery from calf strains is often difficult to predict clinically [11], improved prognostic assessment of calf strains with MRI would likely be of great benefit in the elite sport setting [12].

This retrospective cohort study aims to investigate the relationship between return-to=play time and MRI findings.

Materials and methods

The standard AFL player contract includes consent for injury records to be passed from team medical staff to researchers, on the condition that confidentiality is maintained. This research has been approved by the AFL Medical Officers Association.

All MRI scans of AFL players performed on the calf/leg after acute injury at our institution between 2008 and 2012 inclusive were retrospectively analysed. Normal scans and those that revealed muscular or tendinous injuries in the calf were included. Scans that revealed alternate pathological conditions such as tibial or fibular fractures/stress reactions were excluded. The primary outcome was whether at least one AFL game was missed as a result of injury, as provided by the various teams' sports physicians. Any scans performed during the "off season" were excluded, as the primary outcome could not be assessed.

One hundred and ten AFL players from seven clubs underwent MRI scans of their calf/leg at our institution during the study period. Forty-seven cases were excluded, 21 revealing pathological conditions other than a muscle strain and 26 occurring off season. Of the 21 cases excluded because of alternative pathological conditions, 14 were stress reactions, 5 were stress fractures, and 2 were tendinopathies.

A 1.5-Tesla MRI scanner (General Electric Signa HD, GE Healthcare, Cleveland, OH, USA) was used for all scans performed between the beginning of 2008 and November 2009. A 3-Tesla scanner (Siemens Magnetom Verio; Siemens Medical Systems, Erlangen, Germany) was used for all scans performed thereafter. Twenty of the 63 scans were performed on the 1.5-T MRI and 43 of the 63 scans were performed on the 3-T MRI. A vitamin E capsule was taped to the skin at the site of clinical interest, as indicated by the athlete. Unenhanced axial and coronal proton density and fat-saturated proton density sequences were obtained.

All cases were independently assessed by two consultant radiologists, GW, an MRI fellow, and AR, a sub-specialist musculoskeletal radiologist with 10 years' experience. Both were blinded to the number of games the player had missed. Each reader independently noted the muscle(s) and muscle component affected (Fig. 1), the site and size of the strain (Figs. 2, 3), and the presence of an intramuscular tendon tear or intermuscular fluid (Figs. 4, 5, and 6).

The measurement techniques for width, depth, length, and percentage of the axial cross-sectional area affected were agreed upon by the readers before commencing the study. The cross-sectional area measured was at the level of the largest area of signal abnormality on axial images. GW performed all measurements as described in the text and figures. All measurements carried out in the study were performed on only axial and coronal sequences using measurement tools available on the picture archiving and communication system (PACS; InteleViewer). All measurements were then saved to the PACS. AR reviewed the first ten measurements and was in agreement with GW.

A proximal strain was defined as being above the distal tip of the medial head of the gastrocnemius, whereas injuries below this point were deemed distal. Medial or lateral involvement was defined according to the strain position relative to the central intramuscular septum/tendon of the affected muscle. Deep strains were defined as those involving the deep half of the affected muscle; superficial injuries affected the superficial half. Strains were also categorised according to whether they involved muscle tissue alone, myofascial tissue, the musculotendinous junction, or a combination.

These parameters were compared with clinical data provided by the respective AFL Club sports physicians. The data confirmed that the player had sustained a calf injury and revealed whether at least one game was missed as a result of that injury.

Descriptive statistics were used to summarise all the data and results were reported as n (%) for categorical data and median (interquartile range [IQR]) for continuous data. Based on the data provided by clubs' physicians, players were stratified into two groups (those who missed at least one game and those who did not). Fisher's exact test was used to determine whether any significant differences existed in the imaging findings between the two groups. Multivariate logistic regression analysis was undertaken to identify factors associated with a risk of missing at least one game. A p value of <0.05 was considered significant for all tests. The analysis was performed using Stata12 (StataCorp, College Station, TX, USA).

Results

Of the 63 cases included in the study, 33 (52%) missed no games and 30 (48%) missed between one and seven games (median [IQR] 3 [1–3]; (Table 1). No age differences between players were observed in these two groups ($p = 0.878$; Table 2).

In four cases, there was disagreement between the readers about the involvement of the intramuscular tendon. In one case, there was disagreement about the muscle component affected. In all five cases, the more senior author's opinion was recorded.

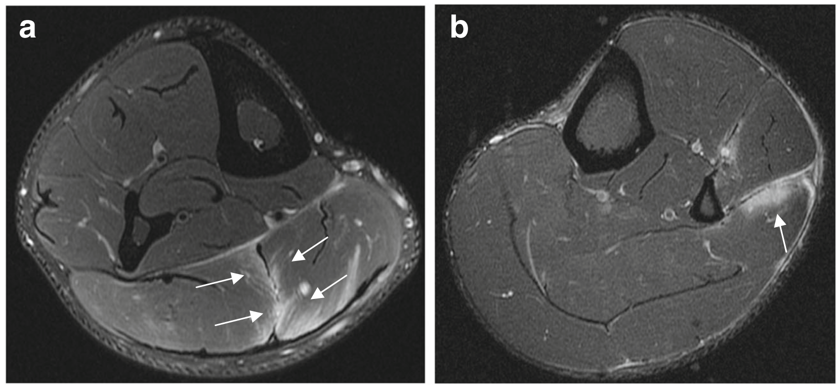

Fig. 1 Axial fat-saturated proton density images of different athletes, demonstrating a typical musculotendinous strain centred upon the central tendon of **a** the soleus (*arrows*) and **b** a myofascial strain centred upon the anterior surface of the lateral soleus (*arrow*)

Muscles affected

Six players had a normal scan, with no evidence of an injury. None of these players missed any games. Fifty-seven cases revealed a muscle injury. Forty-nine players had a single muscle affected, 23 of whom (47%) missed at least one game. Of the 8 players who had multiple muscles affected, 7 (88%) missed at least one game, confirming that a player injuring multiple muscles is more likely to miss at least one game ($p = 0.017$).

The soleus muscle was injured in 39 out of 63 (62%) cases, 32 in isolation, 6 in combination with gastrocnemius and 1 in combination with tibialis posterior. Gastrocnemius injuries were comparatively uncommon, occurring in 15 out of 63 (24%) cases, 8 in isolation, 6 in combination with soleus, and 1 in combination with peroneus longus.

Soleus strains were more common in the group of players who missed games (25 out of 30, 83%), compared with the group of players who did not (14 out of 33, 42%). Of the 32 players who sustained an isolated soleus strain, 19 (59%) missed games and 13 (41%) did not ($p = 0.058$). Of the 8 players with an isolated gastrocnemius strain, 3 (38%) missed games and 5 (62%) did not. All 6 players who injured the soleus and gastrocnemius in combination missed games.

Given the large proportion of isolated soleus strains (32 out of 57, 56%), we elected to focus on this subset in the analysis of the muscle component affected, the site and size of injury and the role of an intramuscular tendon tear and intermuscular fluid (Table 3). This removed the potential confounding influences of involvement of multiple muscles and of anatomical and functional differences between the soleus and other muscles of the calf.

Muscle component affected

Of the 32 isolated soleus strains, none was confined to muscle tissue alone. Twenty-seven cases (84%) involved the musculotendinous junction, 3 affected the myofascial interface (9%) and 2 (6%) were combined musculotendinous junction and myofascial strains. Eighteen of the 19 players with an isolated soleus strain who missed at least one game (95%) sustained a musculotendinous junction strain. Of the 13 players with an isolated soleus strain who did not miss a game, 9 (69%) had a musculotendinous junction strain. There is

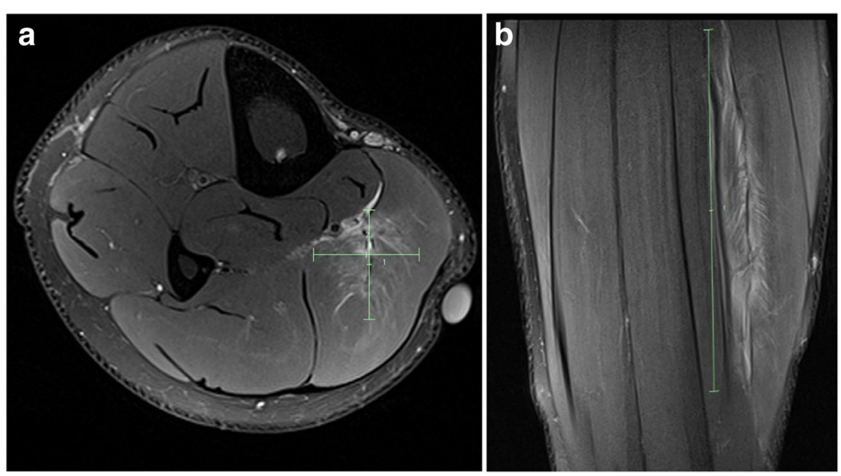

Fig. 2 **a** Axial and **b** coronal fat-saturated proton density images demonstrating the orthogonal anteroposterior, mediolateral, and supero-inferior measurements obtained for each strain

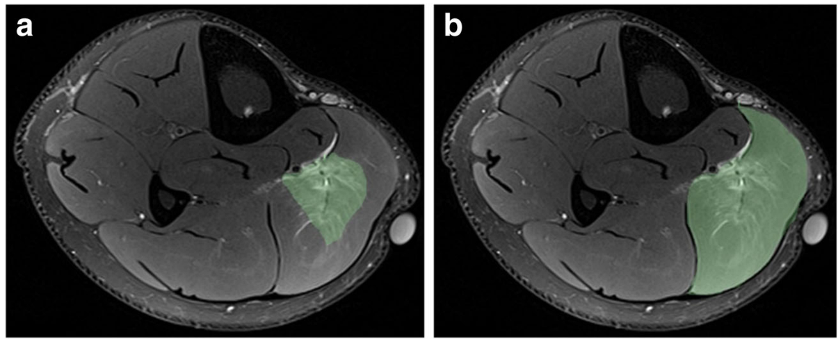

Fig. 3 Axial fat-saturated proton density images demonstrating the technique for calculating the cross-sectional area of involvement with **a** the injured area measured as a percentage of **b** the muscle belly involved

therefore an association between musculotendinous junction involvement and missing at least one game ($p = 0.046$).

Injury site

Twenty-six of the 32 (81%) soleus strains occurred in the proximal calf, 5 (16%) occurred in the distal calf and 1 (3%) affected both the proximal and distal calves. These groups were similarly represented in the populations of those who missed games and those who did not miss any games.

There was near equal distribution of strains across the medial soleus and lateral soleus, with 12 (38%) affecting the medial muscle and 13 (41%) the lateral muscle. The remaining 7 strains (22%) were centred upon the central tendon, with involvement of both the medial and lateral soleus. Although medial involvement was more common in the missed games group (10 out of 19, 53%) compared with the no missed games group (2 out of 13, 15%), this was not statistically significant ($p = 0.062$).

With regard to the location of the soleus strains, deep strains occurred in 9 (28%) cases, superficial strains in 17 (53%) cases and a combination of deep and superficial strains in the remaining 6 (19%) cases. Of the 19 players who missed games, 8 (42%) had an isolated deep strain, compared with a single (8%) isolated deep strain among those who did not miss a game. This was statistically significant ($p = 0.036$).

Injury size

There was no significant association between whether at least one game was missed and strain size parameters, including width, depth, length, and cross-sectional area. In the group of players who did not miss a game, the range of measurements were 19–133 mm for length (mean 62 mm), 5–27 mm for depth (mean 13 mm), 6–42 mm for width (mean 18 mm), and 1–42% for cross-sectional area (mean 18%). In the group of players who missed at least one game, the range of measurements were 27–144 mm for length (mean 83 mm), 8–37 mm for depth (mean 18 mm), 5–54 mm for width (mean 21 mm), and 4–52% for cross-sectional area (mean 21%).

Intramuscular tendon tear

Twelve (38%) of the 32 soleus strains were associated with an intramuscular tendon tear, 10 occurring in the population of players who missed games and 2 in the population of players who did not. The proportion of the missed game population that sustained an intramuscular tendon tear (10 out of 19, 53%) was not significantly different from the proportion that sustained such a tear and did not miss a game (2 out of 13, 15%; $p = 0.062$). If the 15 gastrocnemius injuries were included in the evaluation, however, a total of 16 intramuscular tendon tears were observed, 14 in the group of players who

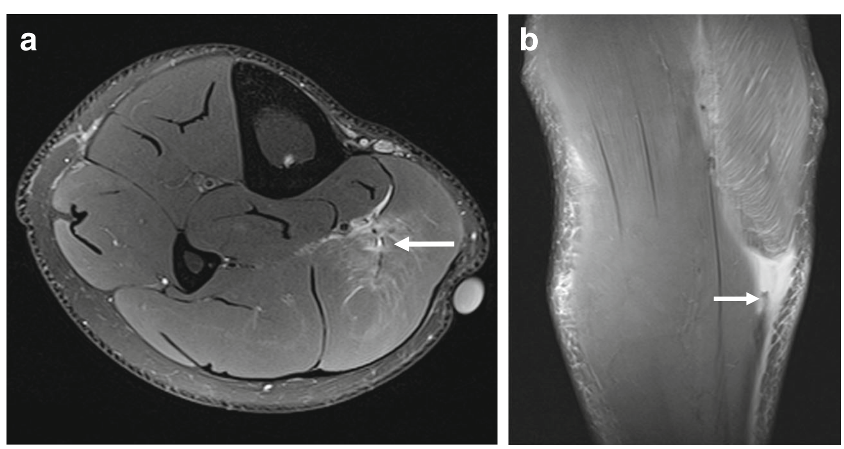

Fig. 4 The spectrum of tendon tears. **a** Axial fat-saturated proton density image demonstrating subtle disruption of the intramuscular tendon of the medial soleus, with fluid lying in the defect (*arrow*). **b** Coronal fat-saturated proton density image in a different athlete demonstrating a more marked tendon tear of the medial head of the gastrocnemius with retraction of the tendon (*arrow*), a bull-nosed contour to the distal muscle, and an intervening fluid-filled defect

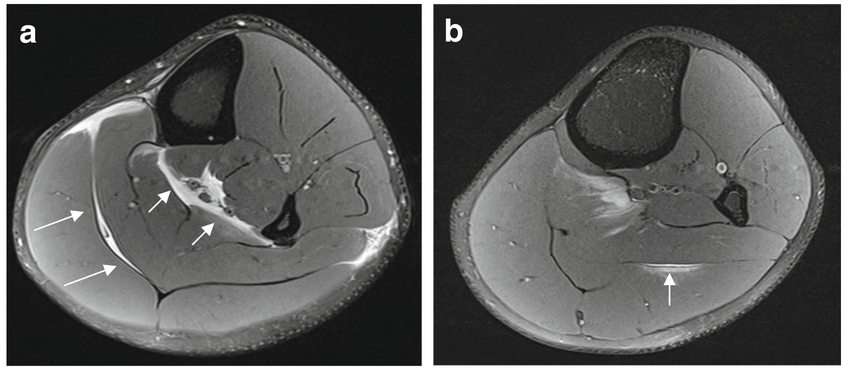

Fig. 5 The spectrum of intermuscular fluid/haemorrhage. **a** Axial fat-saturated proton density images in different athletes demonstrating a moderate amount of fluid between the gastrocnemius and soleus (*long arrows*), and between the soleus and the deep flexors (*short arrows*), compared with **b** a trace of fluid between the gastrocnemius and soleus (*arrow*)

missed games and 2 in the group of players who did not. This was a significant difference ($p = 0.010$).

Intermuscular fluid

Eighteen (56%) of the 32 soleus strains were accompanied by intermuscular fluid, whereas 14 (44%) were not. These groups were similarly represented in the populations of players who missed games and those who did not.

Discussion

Our study showed that the soleus muscle was the most frequent site of calf injury (62%). Whilst soleus strains were formerly thought to be relatively rare [13], an analysis of MRI findings in calf injuries by Koulouris et al. revealed an approximately equivalent number of soleus and gastrocnemius strains [14]. It is likely that soleus strains had previously been underdiagnosed due to their low conspicuity on ultrasound, which was historically the modality of choice for calf muscle injuries [8, 11].

Soleus strains were more common in the group of players who missed games, a finding that approached statistical significance ($p = 0.058$). It may be that with its sustained stabilising action, the soleus is more difficult to rest than the gastrocnemius and therefore takes longer to heal. Furthermore, the soleus may demand greater healing than the gastrocnemius before it can perform its sustained action upon a return to play.

Amongst players with soleus strains, we found a relationship between at least one game lost from competition and multiple muscle involvement ($p = 0.017$). Of the 8 players that had multiple muscles affected, 7 (88%) missed at least one game. This would seem intuitive, as involvement of multiple muscles likely reflects a larger mechanical force applied to the calf at the time of injury. Alternatively, as has been previously postulated, failure of one muscle may cause increased force upon another, resulting in sequential injury to that muscle [14].

Our results demonstrate that the majority (84%) of soleus strains occurred at the musculotendinous junction, and that involvement of the junction was a predictor of missing at least one game ($p = 0.046$). The musculotendinous junction is the weakest point in the myotendinous unit and is therefore predisposed to injury [15, 16]. This concept has been substantiated by previous research on patterns of calf and hamstring strains [5, 14]. The relatively high incidence of musculotendinous junction strains amongst soleus injuries may be further explained by the fact that much of the muscle volume lies in close proximity to a

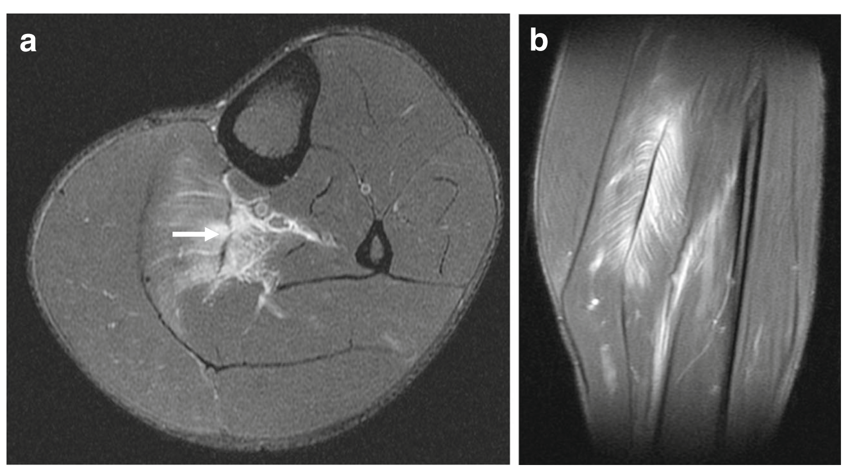

Fig. 6 Typical imaging findings associated with missing at least one game. **a** Axial and **b** coronal fat-saturated proton density images demonstrating a deep soleus musculotendinous injury with a subtle tendon tear (*arrow*)

Table 1 Distribution of number of games missed

Games missed	Number of players
0	33
1	9
2	5
3	9
4	3
5	3
6	0
7	1

musculotendinous junction, either the distal central tendon, the proximal medial tendon or the proximal lateral tendon. The finding of a relationship between musculotendinous junction involvement and missing at least one game from competition is in accordance with outcomes of studies on the hamstring and quadriceps muscle complexes, which showed longer recovery times in injuries involving the musculotendinous junction [7, 17].

Given that tendons generally heal at a slower rate than muscles [18], it is not surprising that in a combined analysis of gastrocnemius and soleus strains, intramuscular tendon tears were more highly represented in the group of players who missed games ($p = 0.010$). A similar observation has been made in hamstring injuries, where disruption of the intramuscular tendon was shown to have a significantly worse prognosis than injuries that involve only muscle [6].

Amongst players with soleus strains, there was a significant correlation between games missed and a deep strain location ($p = 0.036$). Within the proximal calf, the intramuscular tendon of the soleus is located within the deep half of the muscle. All of the deep soleus strains in our study involved the proximal calf and occurred along the musculotendinous junction, with some of the strains also involving an intramuscular tendon tear. We hypothesise that the strong correlation between deep strain location and missing at least one game may be explained by the fact that these strains commonly occur in the proximal calf and involve the musculotendinous junction and intramuscular tendon.

Our study did not show a significant correlation between games missed and strain size parameters, including width, depth, length, and cross-sectional area. This differs from the findings of several studies of the hamstring muscle complex, which found relationships between muscle size and convalescence period [5, 7, 19]. We hypothesise that the volume of oedema is dependent on multiple factors, such as the time from injury to scan and recent high altitude flights, but is not significant with regard to function.

The presence of intermuscular fluid/haemorrhage was equally present in the group of players who missed games and the group of players who did not, suggesting that it is not of prognostic value in the calf. This is contrary to the findings of Slavotinek et al., who found a trend between these two parameters in hamstring injuries [5].

Several potential limitations in our study should be acknowledged. First, as our cohort comprised exclusively AFL footballers, the results may have limited applicability across other sports groups and the general population. Furthermore, as a proportion of players who sustained calf injuries were likely diagnosed and managed clinically, any conclusions from our study should be applied only to the imaged population and not the calf injury population as a whole.

Second, the primary outcome of whether at least one game was missed may have been influenced by the timing of the injury within the season and by the position of the player in the team. For example, it is possible that injuries occurring earlier in a season may have been afforded a longer recovery period than those occurring later, in the lead up to the finals. Moreover, different players with similar injuries may have missed a different number of games, depending on their role on the ground.

Table 2 Distribution of calf muscle strains among Australian Football League (AFL) athletes

	No missed games	Missed games	Total
Number	33	30	63
Age, mean (SD)	24.8(3.8)	24.7 (2.1)	
Muscle, *n* (%)			
No muscles injured	6 (18.2)	0	6
Single muscle injured	26 (78.8)	23 (76.7)	49
Multiple muscles injured	1 (3)	7 (23.3)	8
Soleus	13 (39.4)	19 (63.3)	32
Gastrocnemius	5 (15.2)	3 (10)	8
Deep flexor	6 (18.2)	1 (3.3)	7
Peroneal	2 (6)	0	2
Soleus and gastrocnemius	0	6 (20)	6
Soleus and tibialis posterior	1 (3)	0	1
Gastrocnemius and peroneus longus	0	1 (3.3)	1

Table 3 Features of soleus muscle strains among AFL athletes

	No missed games	Missed games	Total
Number	13	19	32
Muscle component, *n* (%)			
Musculotendinous junction	9 (69.2)	18 (94.7)	27
Myofascial	2 (15.4)	1 (5.3)	3
Musculotendinous and myofascial	2 (15.4)	0	2
Position, *n* (%)			
Proximal	10 (76.9)	16 (84.2)	26
Distal	3 (23.1)	2 (10.5)	5
Proximal and distal	0	1 (5.3)	1
Medial	2 (15.4)	10 (52.6)	12
Lateral	6 (46.2)	7 (36.8)	13
Medial and lateral	5 (38.5)	2 (10.5)	7
Deep	1 (7.7)	8 (42.1)	9
Superficial	8 (61.5)	9 (47.4)	17
Deep and superficial	4 (30.8)	2 (10.5)	6
Size, *n* (%)			
Depth ≤ 20 mm	11 (84.6)	13 (68.4)	24
Depth > 20 mm	2 (15.4)	6 (31.6)	8
Width ≤ 20 mm	8 (61.5)	11 (57.9)	19
Width > 20 mm	5 (38.5)	8 (42.1)	13
Length ≤ 50 mm	6 (46.2)	4 (21.1)	10
Length > 50 mm	7 (53.8)	15 (78.9)	22
Area ≤ 25%	9 (69.2)	12 (63.2)	21
Area 26–50%	4 (30.8)	5 (26.3)	9
Area > 50%	0	2 (10.5)	2
Intramuscular tendon tear, *n* (%)	2 (15.4)	10 (52.6)	12
Intermuscular fluid, *n* (%)	9 (69.2)	9 (47.4)	18

Third, there are several variables that were not accounted for in our dataset that may have influenced recovery time, including a history of previous injury to the calf and the nature of any treatment that occurred between the scan and return to play.

Finally, the very MRI results that we are retrospectively analysing may have influenced return-to-play decisions at the time, with soleus injuries and those associated with an intramuscular tendon tear potentially being managed more conservatively. Unfortunately, in the absence of blinding club physicians to the results of players' scans, this potentially confounding factor seems unavoidable.

Conclusion

Amongst AFL players with calf injuries, soleus strains were considerably more common than strains of other muscles. An association was seen between missing at least one game and multiple muscle involvement, musculotendinous junction strains, deep strain location, and intramuscular tendon tears. In the setting of calf strains, MRI may thus provide prognostic information to help guide return-to-play decisions.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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