

Acute Gastrocnemius-Soleus Complex Injuries in National Football League Athletes

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Background: Lower extremity muscle injuries are common in professional football. Although less common than hamstring or quadriceps injuries in National Football League (NFL) athletes, calf injuries occur with relative frequency and have not previously been studied.

Purpose: To evaluate gastrocnemius-soleus complex muscle injuries over the past 13 years from a single NFL team to determine the incidence of such injuries, their imaging characteristics, and return to play after such injuries and any correlation between imaging findings and prolonged return to play.

Study Design: Case series; Level of evidence, 4.

Methods: A retrospective review of all acute calf muscle injuries on a single NFL team from 2003 to 2015 was performed. Player demographics and return-to-play data were obtained from the medical records. All available magnetic resonance images (MRIs) were reviewed by a musculoskeletal radiologist for specific imaging findings that correlated with return to play.

Results: A total of 27 calf injuries in 24 NFL players were reviewed, yielding an incidence of 2.3 acute calf injuries per year on a single NFL team. Of these 27 injuries, 20 (74%) were isolated injuries to the gastrocnemius muscle, 4 (15%) were isolated injuries to the soleus muscle, and the remaining 3 injuries (11%) involved both. Defensive players were more likely to sustain injuries ($P = .043$). The mean time to return to play for all 27 players was 17.4 ± 14.6 days (range, 3-62 days). MRIs were available in 14 of the 27 injuries. The average size of the fascial defect ($P = .032$) and the presence of a fluid collection ($P = .031$) both correlated with return to play of longer than 2 weeks.

Conclusion: Although less common than hamstring or quadriceps muscle injuries, calf muscle injuries occur with relative frequency in the NFL, and more so in defensive players. The majority of these injuries occur in the gastrocnemius and result in significant disability, with at least 2 weeks of missed playing time on average. MRI may have an important role in the evaluation of calf injuries in NFL players, as certain injury imaging characteristics, including the anteroposterior size of any fascial tear and the presence of a fluid collection, are associated with longer return-to-play times after injury.

Keywords: gastrocnemius-soleus complex; calf injury; National Football League; NFL; return to play; magnetic resonance imaging

Injuries to the lower extremity muscles and surrounding structures, including the muscle/tendon junction, tendon,

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and surrounding fascia are frequently encountered in professional sports. Lower extremity muscle injuries frequently result in the need for advanced imaging and rehabilitation and often require missed practice or playing time. In the elite athlete, hamstring injuries are the most common muscular injury of the lower extremity and consequently, the most well-studied and characterized.^{7,9,10,13,14} In National Football League (NFL) athletes, hip adductor and quadriceps injuries immediately follow hamstring injuries in frequency, both of which have been the subject of recent studies.^{3,13,20}

Calf muscle injuries, including gastrocnemius and soleus injuries, are the next most frequently occurring muscle injury in the lower extremity in NFL athletes, with 57 injuries per NFL season from 2012 to 2014, occurring only slightly less commonly than quadriceps and hip adductor injuries.¹³

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The goal of the present study was to retrospectively evaluate gastrocnemius-soleus complex muscle injuries over the past 13 years from a single NFL team to determine the incidence of such injuries, their imaging characteristics, and return-to-play time after such injuries. A secondary goal was to evaluate player demographics and imaging characteristics that are associated with a longer return-to-play time.

METHODS

After institutional review board, NFL Injury and Safety Panel, and NFL Medical Research Subcommittee approval, we performed a retrospective review of all acute gastrocnemius-soleus complex injuries, including regular and preseason camps, practices, and games, on a single NFL team from 2003 to 2015. Off-season workouts were not included, as return to play would be difficult to ascertain. Inclusion criteria were players with an acute calf injury requiring at least 1 missed practice or game recorded in the team electronic medical record (EMR). Only players with calf injuries diagnosed by physical examination were included, as physical examination has been demonstrated to be a reliable method of diagnosis.⁵ A combination of palpation, strength assessment, and stretching was utilized to diagnose and localize calf injuries. Palpation allowed location of the injury (medial vs lateral, proximal vs distal, etc). Strength and stretching assessments allow isolation of the gastrocnemius and soleus by varying knee flexion. With the knee in maximal flexion, the soleus serves as the primary generator of plantar flexion force. With the knee in extension, the gastrocnemius provides a more significant contribution.⁵ Players with Achilles tendon injuries were excluded. Calf injuries were confirmed by review of both documented physical examination findings as well as magnetic resonance imaging (MRI) when available for all included players. MRIs were obtained at the discretion of the evaluating team physician and training staff at the time of injury. Player demographics, including age and position, and return-to-play data were obtained from the team EMR. Return to play was the same for all players and defined as return to full, unrestricted practice or game participation.

Imaging Analysis and Classification

Players who underwent MRI all had imaging performed at the head team physician's institution utilizing consistent sequences and protocols. Each injured calf was imaged utilizing large field-of-view coronal short-tau inversion recovery (STIR) sequences followed by coronal, sagittal, and axial fast spin echo and axial inversion recovery over the area of the region of maximally perceived discomfort (Figure 1).

Specific protocols included fast spin-echo sequencing with a repetition time of 4000 to 6500 ms, echo time of 28 to 38 ms, matrix of 512 × 320-352, slice thickness of 3 to 5 mm with no interslice gap, and inversion time of 150 ms. Depending on the size of the patient or extent of injury, the body, 8-channel extremity, and 8-channel cardiac coils were

used. All MRIs were reviewed by a senior experienced fellowship-trained musculoskeletal radiologist (H.G.P.) for several specific parameters, which are provided in Table 1 and demonstrated in Figure 2. The radiologist was blinded to the player demographics and return-to-play times.

For players with multiple MRI studies of the same injuries, all were evaluated in a similar fashion, and the MRI sequences from the first imaging date were included in the final analysis.

Surgical Cases

Three players required surgical intervention: 1 acutely with interventional radiology (IR) embolization for a suspected arteriovenous malformation confirmed on MR angiography and 2 after failure of prolonged nonoperative rehabilitation more than 2 months. The latter 2 players had extremely similar injury patterns, with significant fascial injuries with retraction, which never completely healed and resulted in re-tear and subsequent recurrent fluid collections. The latter 2 players underwent open surgical intervention, during which the area of fascial injury was identified after evacuation of the hematoma and fluid collection. For both players, the fascial tears were repaired using absorbable sutures.

Statistical Analysis

Descriptive statistics of all demographics, injury location as determined by physical examination, and MRI findings of all included players, including means and standard deviations, were calculated in Microsoft Excel (Microsoft Corp).

The subgroup of players with MRI studies available for review was analyzed separately to ascertain any imaging or demographic characteristics that were associated with longer return to play. These players were divided into 2 groups by length of time to return to play: (1) ≤2 weeks and (2) >2 weeks. The cutoff of 2 weeks was chosen because the median return to play for our series was 13 days. All imaging characteristics and player demographics were then correlated with return to play using univariate analysis. Fisher exact tests were used for categorical data due to the small sample size, and Student *t* tests were used for continuous variables. All statistical calculations were performed in SPSS (version 23; IBM Corp).

RESULTS

Overall Cohort

A total of 27 calf injuries in 24 NFL players were included in the study, yielding an incidence of 2.3 acute calf injuries requiring time missed per year on a single NFL team. The average age of the players at the time of injury was 27.2 years (range, 22-35 years). Significantly more calf injuries occurred in defensive players (67% of injuries; *P* = .043) compared with offensive (6/24; 25%) or special teams (2/24; 8%) players.

As diagnosed by physical examination, 20 of 27 injuries (74%) were isolated injuries to the gastrocnemius muscle

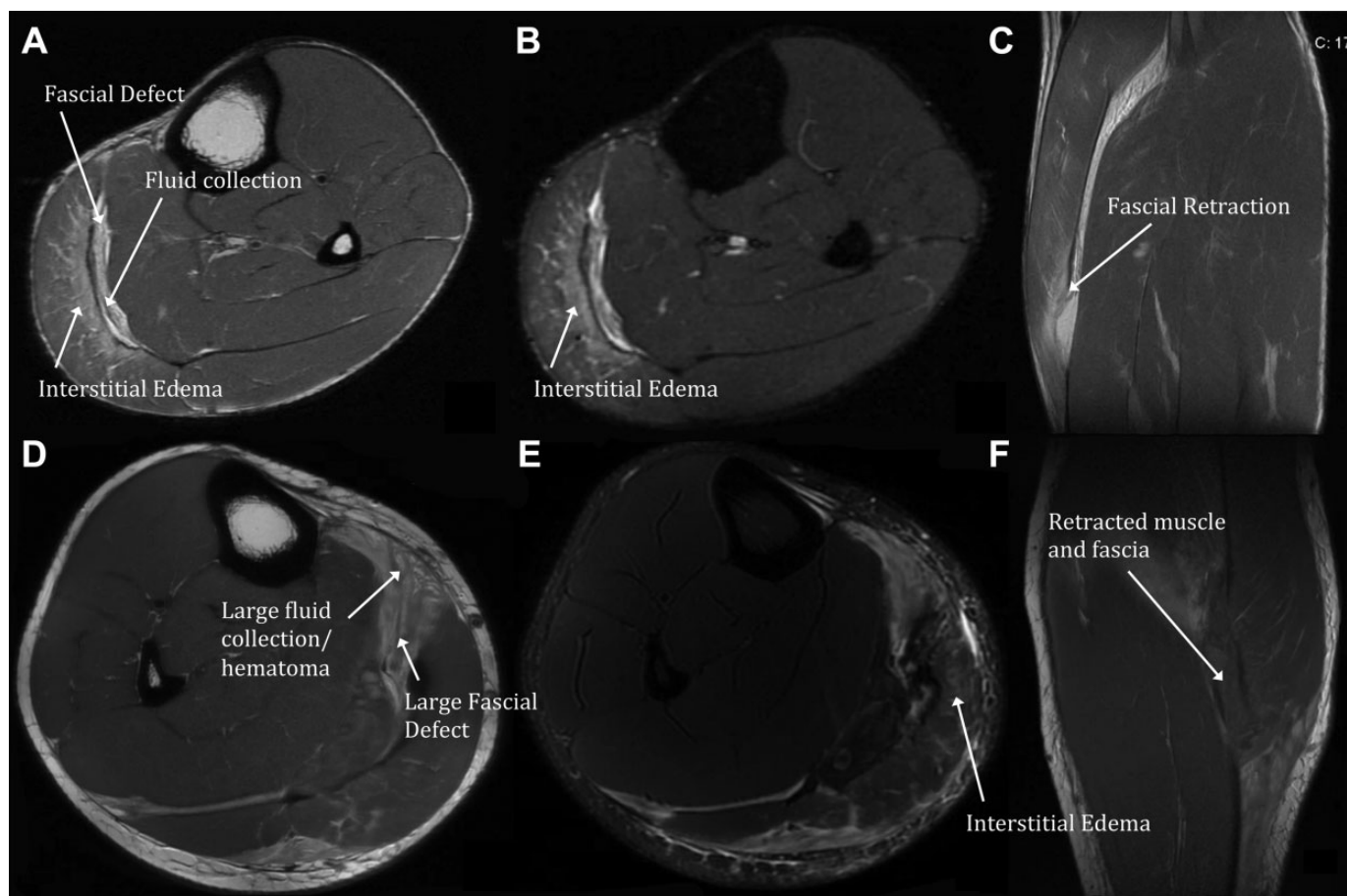


Figure 1. (A and D) Axial proton density, (B and E) axial short-tau inversion recovery, and (C and F) coronal proton-density images of 2 National Football League athletes with gastrocnemius-soleus complex injuries. For the first player (A-C), there was isolated involvement of the medial gastrocnemius muscle with >75% interstitial edema. A deep fascial tear was present (A and B), measuring 40 mm at its greatest anteroposterior dimension. Retraction of the fascia and some muscle was present on the coronal images (C). The second player (D-F) had involvement of both the medial and lateral heads of the gastrocnemius but less interstitial edema. A significantly retracted fascial tear was present, with a defect measuring 62 mm.

TABLE 1
Descriptive MRI Parameters for Calf Injury

1. Number of muscles injured
2. Identity of injured muscles (including medial or lateral for gastrocnemius)
3. Presence and quantity of interstitial edema in each injured muscle (<25%, 25%-49%, 50%-74%, ≥75%)
4. Presence of fascial tear
5. Location of fascial tear (superficial or deep)
6. Size of fascial defect in mm
7. Presence of retraction of fascial tear or muscle
8. Presence and location of fluid collection
9. Other imaging characteristics (fascial tethering, vascular imaging, etc)

and/or fascia, 4 of 27 injuries (15%) were isolated injuries to the soleus muscle and/or surrounding fascia, and the remaining 3 injuries (11%) involved both the gastrocnemius and soleus muscles. One player had an extensive injury that involved both the peroneal muscles and muscles of the

deep posterior compartment in addition to both the gastrocnemius and soleus.

Players had returned to play from 25 of 27 injuries; the average (\pm SD) return to play was 17.4 ± 14.6 days, with a large range (3-62 days). The average time to return to play was not significantly different between injuries without MRI (12.9 ± 5.9 days) and injuries with MRI (22.8 ± 17.7 days; $P = .07$). The 2 players without return-to-play data had undergone surgical treatment and had not returned to play as of the time of manuscript preparation, but both had been out of practice or play for at least 4 months. The player who returned after surgical treatment had an embolization of an arteriovenous malformation as described and returned in 49 days.

Cohort With MRI

MRIs were available for 14 of the 27 injuries; all players who underwent MRI had imaging available for analysis. All MRIs were evaluated for the parameters described in Table

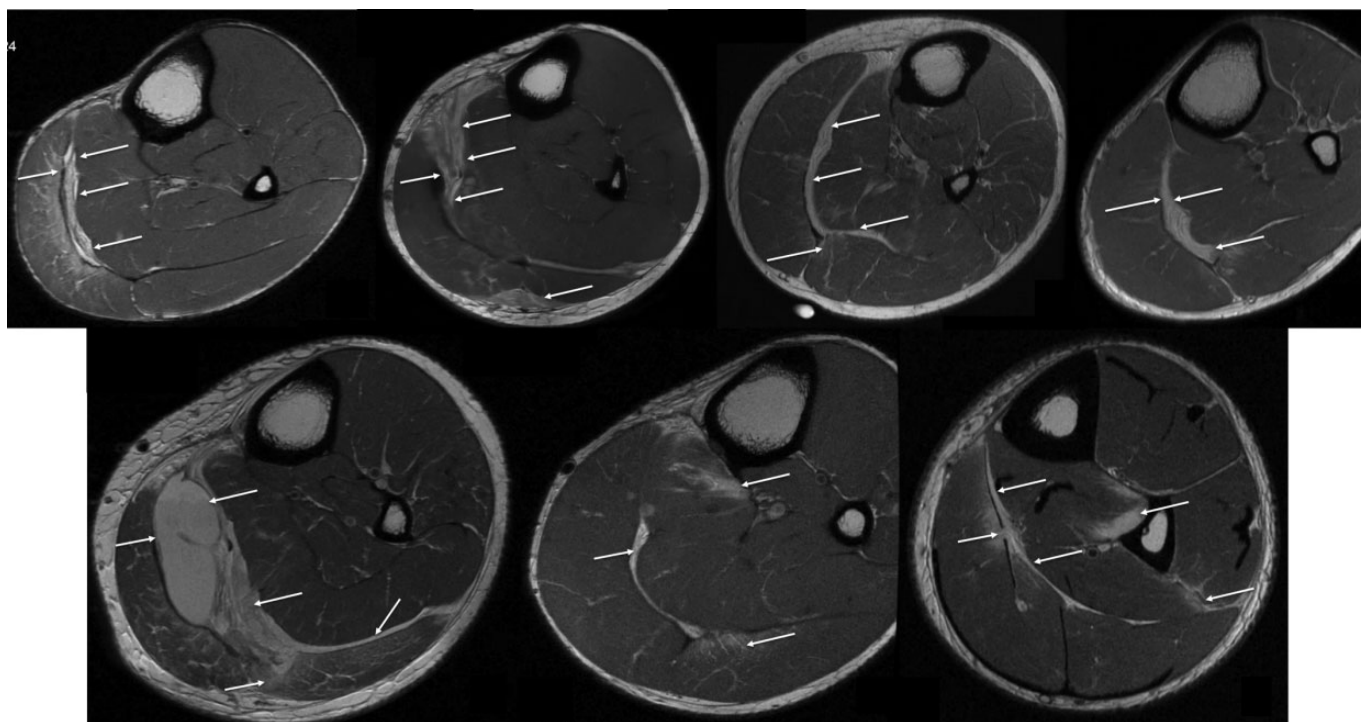


Figure 2. Axial proton-density images of 7 different National Football League players with gastrocnemius-soleus complex muscle injuries, highlighting the variability in the number of muscles with injuries, the presence and size of fascial tears, and the presence, size, and location of fluid collections (arrows).

TABLE 2
Data for Players With Calf Injuries and MRIs (n = 14)^a

Player	Age, y	No. of Injured Muscles	Interstitial Edema, %	Fascial Tear Location and Size	Fascial Retraction	Fluid Collection	Surgery	RTP Time, d
1	28.3	1 (soleus)	<25	Superficial; 5 mm	None	None	No	12
2	28.6	2 (lateral gastrocnemius, soleus)	<25	None	N/A	None	No	15
3	28.8	1 (medial gastrocnemius)	≥75	Deep; 40 mm	Yes	Yes	Yes	>120
4	23.9	2 (medial and lateral gastrocnemius)	25-49	Deep; 62 mm	Yes	Yes	Yes	>120
5	33.7	2 (medial and lateral gastrocnemius)	<25	Deep; 11 mm	None	Yes	No	56
6	26.5	2 (medial and lateral gastrocnemius)	25-49	Deep; 17 mm	Yes	None	No	11
7	26.9	2 (medial and lateral gastrocnemius)	<25	Deep; 16 mm	Yes	Yes	Yes	49
8	27.4	2 (medial and lateral gastrocnemius)	25-49	Deep; 24 mm	None	Yes	No	44
9	25.0	1 (medial gastrocnemius)	None	Deep; 13 mm	None	None	No	5
10	31.7	1 (soleus)	25-49	None	N/A	None	No	12
11	26.6	2 (lateral gastrocnemius, soleus)	<25	Deep; 3 mm	None	Yes	No	5
12	27.9	1 (medial gastrocnemius)	<25	Deep; 6 mm	None	None	No	30
13	26.5	4 (medial gastrocnemius, soleus, peroneals, FHL)	25-49	Deep; 6 mm	None	None	No	4
14	29.3	1 (medial gastrocnemius)	25-49	Deep; 21 mm	Yes	Yes	No	30

^aFHL, flexor hallucis longus; N/A, not applicable; RTP, return to play.

1; the findings are summarized in Table 2. The majority of muscle injuries (13/14; 93%) had less than 50% of the muscle cross-section with interstitial edema, with about half of these having less than 25% interstitial edema.

The majority of players had fascial tears (12/14; 86%), and the majority of these were deep in location, typically between the gastrocnemius and soleus muscles (11/12, 92%). Of those players with fascial injuries, 5 (42%) had

retraction of the fascia. The average fascial defect was 18 ± 16 mm, ranging between 3 and 62 mm.

Univariate analysis associating player and imaging characteristics with return to play are provided in Table 3. Players with return to play greater than 2 weeks had a larger average size of the fascial defect ($P = .032$) and more frequent presence of fluid collection ($P = .031$) compared to players with average return to play less than 2

TABLE 3
Player and Imaging Characteristics by RTP Time^a

	RTP >2 wk	RTP ≤2 wk	P Value
Player age, y, mean ± SD	28.3 ± 2.8	27.4 ± 2.4	.54 ^b
Player position, n (% defensive)	6 (75.0)	4 (66.7)	.798 ^c
MRI characteristic			
No. of muscles, avg ± SD ^d	1.6 ± 0.5	1.8 ± 1.2	.659 ^c
Interstitial edema, %, avg ± SD ^e	44 ± 25	25 ± 16	.144 ^c
Fascial defect, n (% deep)	7 (87.5)	4 (66.7)	.556 ^b
Size of fascial defect, mm, avg ± SD	27.1 ± 18.0	8.3 ± 5.5	.032^c
Retraction, n (% yes)	4 (50.0)	1 (16.7)	.198 ^b
Fluid collection, n (% yes)	6 (75.0)	1 (16.7)	.031^b

^aBoldfaced *P* values indicate statistically significant difference between groups (*P* < .05) MRI, magnetic resonance imaging; RTP, return to play.

^bCalculated using Fisher exact test.

^cCalculated using Student *t* test.

^dMedial and lateral gastrocnemius considered separate muscles for this analysis.

^eConverted to a continuous variable for analysis using the upper end of quartile % range.

weeks. Player age, player position, the number of injured muscles, and the presence of a fascial defect were not significantly correlated with return to play of longer than 2 weeks.

DISCUSSION

Lower extremity muscle injuries are common in professional football, resulting in significant time missed from play. Although less common than hamstring or quadriceps injuries in NFL athletes, a recent study reported that 57 calf injuries (about 2 injuries per team) occur per season in the NFL.¹³ In our review of gastrocnemius-soleus complex injuries on a single NFL team, we found a similar incidence of 2.3 per year. We also found that in players with MRI, certain injury imaging characteristics, including the anteroposterior size of any fascial tear and the presence of fluid collection, were associated with longer return to play after injury.

A single NFL team was chosen for this study as opposed to using data from the NFL Injury Surveillance System database as in many NFL studies^{3,4,6,10-12,15,16,20} because the imaging characteristics of the injuries were best reviewed with MRIs obtained at a single institution using identical sequences and protocols to allow valid comparison between athletes. In addition, if league-wide data had been used, we would not have had access to documented physical examinations or specific diagnoses for the studied injuries. Additionally, the specific muscle(s) or structures injured are usually not accurately specified in league-wide injury databases.

With the exception of acute Achilles tendon ruptures, which were not the subject of our present study, no previous literature has assessed gastrocnemius-soleus complex

muscle injuries in NFL athletes.¹⁸ Considerably more effort has been dedicated to the study of hamstring injuries in NFL players, likely because the injury is more common.^{7,9,14,17} Cohen et al⁷ reported that on average, NFL players with hamstring muscle injuries missed 2.6 games. Levine et al¹⁴ reported an average of 7.6 days of missed time due to hamstring injuries and only 16% of players with missed game time after hamstring injuries in the NFL. We found that gastrocnemius-soleus complex muscle injuries resulted in a return to play or practice of 17.4 days, which is similar to the amount of time missed for hamstring injuries in the study by Cohen et al,⁷ and longer than that reported by Levine et al.¹⁴ The majority of the remaining literature on lower extremity injuries in NFL athletes involves tendon injury, including adductor tendon rupture,²⁰ quadriceps tendon tears,³ patellar tendon ruptures,² and Achilles tendon ruptures,¹⁸ which often require surgery and typically result in substantially longer time missed than muscle injury.

Similar to our study, Cohen et al⁷ reported a correlation between MRI characteristics of hamstring muscle injury and return to play. The authors evaluated the correlation of patient age, number of muscles involved, the proximal/distal injury location, the percentage of perimucular edema, the amount of muscle retraction, and the presence of fluid collection, among other parameters. The factors found to be associated with prolonged recovery included multiple muscle injuries, injuries to the musculotendinous junction, greater than 75% involvement/perimucular edema, and muscle retraction.⁷ We utilized a similar method of systematically evaluating the MRI findings of gastrocnemius-soleus complex muscle injuries in NFL players but interestingly found that return to play after calf injuries is associated more with the extent of fascial injury and the presence of a fluid collection rather than the number of muscles injured, the location of injury, or the amount of muscle or fascial retraction. MRI is particularly effective in defining such injury given the low signal intensity of normal fascia, allowing for defects to be noted, measured, and contrasted to the intermediate signal intensity of normal muscle and high signal intensity of injured muscle.

Gastrocnemius-soleus complex muscle injuries have been studied previously in other populations outside the NFL, including triathlon and soccer athletes, where they occur with somewhat greater frequency, although the injury mechanisms and sport demands vary greatly compared with the NFL, making it difficult to apply the findings from other sports to the NFL.^{1,8} Pedret et al¹⁹ described a series of 61 professional athletes with isolated soleus injuries from varying disciplines, including soccer, tennis, track, basketball, triathlon, and field hockey, of which 44 had MRIs available for review.¹⁹ The median recovery time for the athletes in their series was 29.1 days. While there was a wide variation among the different types of soleus injuries and the corresponding recovery time, injuries in the central aponeurosis had a significantly longer recovery time than injuries in the lateral or medial aponeurosis or myofascial sites.¹⁹ Isolated soleus injuries represented a small percentage of our overall cohort, and the demands of professional football are different from the

sports described in the study by Pedret et al,¹⁹ which highlights why comparing results between ours and non-NFL studies is challenging.

There are several limitations of this case series. The first is the small sample size, which results in underpowering and subjects all statistical calculations to type II errors. Despite the small sample size, we were able to detect some statistically significant associations; however, we cannot convincingly rule out other associations. Another limitation is the retrospective nature of the study. The majority of study endpoints such as MRI findings and return to play, however, should be affected minimally by this type of study design. We could not, however, control for treatment methods for the injuries, which likely has an effect on time to return to play. MRI findings could have affected the decision for surgery in the 3 players, and thus length of time to return to play. Another limitation is that the study group consisted of players from a single NFL team. While it is reasonable to assume that the findings of the study can be applied to the entire NFL, we cannot assure that a similar injury frequency or pattern occurs for all NFL teams over the study period. Finally, this study lacks validated subjective patient-reported outcome measures for the players. The authors are unaware of any validated outcome measures for gastrocnemius-soleus complex injuries in professional athletes and believe that return to play in the NFL serves as a good objective measure of recovery and rehabilitation.³

CONCLUSION

Although less common than hamstring or quadriceps muscle injuries, calf muscle injuries occur with relative frequency in the NFL, and more so in defensive players. The majority of these injuries occur in the gastrocnemius and result in significant disability with at least 2 weeks of missed playing time on average. MRI may have an important role in the evaluation of calf injuries in NFL players, as certain injury imaging characteristics, including the anteroposterior size of any fascial tear and the presence of fluid collection, are associated with longer return-to-play times after injury.

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