Magnetic Resonance Imaging Characteristics of a Lateral Ligament Injury in Acute Ankle Sprains Among Athletes

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Background: It is important to identify the location and pattern of lateral ligament injuries that are related to the development and prognosis of chronic ankle instability in athletes with ankle sprains.

Purpose: To describe the location and pattern of lateral ligament injuries on magnetic resonance imaging (MRI) in elite-level or amateur athletes with acute ankle sprains and to further assess the risk of associated concomitant injuries.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: The anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) of 110 athletes with an ankle lateral ligament injury (mean age, 24.7 years) were evaluated. MRI scans were evaluated for the location and pattern of ATFL and CFL tears such as sleeve avulsions as well as concomitant deltoid ligament injuries, bone contusions, and osteochondral lesions of the talus (OLTs).

Results: On MRI, 52 (47.3%) athletes had an isolated ATFL tear, 56 (50.9%) athletes had both ATFL and CFL tears, and 2 (1.8%) athletes had an isolated CFL tear. ATFL injuries occurred at the fibula, midsubstance, and talus in approximately equal numbers, whereas the majority of CFL injuries occurred at the calcaneal insertion. Concomitant deltoid ligament injuries were identified in 18 (16.4%) athletes. In addition, concomitant bone contusions and OLTs were identified in 38 (34.5%) and 6 (5.5%) athletes, respectively. Using linear-by-linear analysis, CFL injuries correlated with concomitant deltoid ligament and bone injuries (P = .023 and P = .001, respectively) and a sleeve injury pattern (P = .005).

Conclusion: After an acute ankle ligament rupture, almost all athletes involved in this study had injured their ATFL, and approximately 50% had a concomitant injury to the CFL. The rate of sleeve-type CFL injuries at the calcaneal insertion was high, and concomitant deltoid ligament injuries and OLTs were associated with this pattern of injury.

Keywords: anterior talofibular ligament; acute ankle sprain; calcaneofibular ligament; magnetic resonance imaging

An ankle sprain is one of the most frequent sports injuries among athletes and a significant risk factor for chronic ankle instability.[3,8,23] The lateral ligament complex is involved in the majority of ankle sprains and comprises the anterior talofibular ligament (ATFL), which is the weakest of the 3 lateral ligaments of the ankle and is involved in the majority of lateral ankle sprains (up to 85%); the calcaneofibular ligament (CFL), which is involved in 50% to 75% of such injuries; and the posterior talofibular ligament, which is involved in less than 10%.[13,17,19]

The current gold standard for the diagnosis of ankle lateral ligament injuries is an accurate, detailed physical examination combined with plain radiography, according to the Ottawa ankle rules (ie, a validated questionnaire that helps define the need for radiography after ankle sprains), for the exclusion of a fracture and the assessment of mortise alignment.[11,19] However, a clinical examination has relatively low sensitivity to detect secondary injuries, such as osteochondral lesions, bone contusions, or other ligamentous lesions, which can be diagnosed accurately by magnetic resonance imaging (MRI).[16,21] These

The Orthopaedic Journal of Sports Medicine, 11(11), 23259671231207688
DOI: 10.1177/23259671231207688

concomitant structural injuries are common and may cause a poor prognosis. A timely diagnosis is crucial because untreated structural damage may lead to chronic instability of the ankle joint.[16,21] Additionally, suspected ankle ligament injuries in athletes at advanced competitive levels, for whom highly demanding activity is required, are relative indications for MRI.[16,21]

Recent studies have suggested that the ATFL and CFL cannot be delineated clearly in routine axial and coronal planes on MRI because the ATFL and CFL run obliquely.[5,15] Imaging using oblique axial and coronal planes parallel to the ATFL and CFL enables a better anatomic evaluation and improved sensitivity and accuracy in the diagnosis of ankle ligament injuries.[5,15] Few MRI-based studies have performed detailed analyses on the pattern of lateral ligament injuries and concomitant lesions in athletes referred for MRI in specific axial and coronal planes after an acute ankle sprain.

In this study, we aimed to describe the location and pattern of lateral ligament injuries in the plane parallel to each ligament on MRI in athletes with acute ankle sprains. We further assessed the risk of associated concomitant injuries based on the injury pattern of the ligament, as characterized by the status of the lateral and syndesmotic ligaments, as well as deltoid ligament injuries, bone contusions, and osteochondral lesions of the talus (OLTs).

METHODS

Study Design and Patients

The research protocol was approved by our institutional review board as it was a retrospective data analysis study, an exemption document for participant consent was submitted. We retrospectively reviewed patients who met the inclusion criteria for a primary acute lateral ligament injury between 2020 and 2021. The inclusion criteria were as follows: (1) patients who underwent their first inversion episode, (2) elite athletes (those who were participating at national- or international-level competitions or those who were paid to participate in their sporting activities) or amateur athletes (those who played for a college team or in a local league and were not compensated for playing) who were evaluated within 2 weeks of their injury, and (3) a lateral ligament injury initially diagnosed through a physical examination and confirmed on MRI. The exclusion criteria were as follows: (1) a history of sprains; (2) os subfibulare; (3) a history of surgery on the affected ankle; (4) severe rotational injuries that included syndesmotic widening, which necessitated a surgical intervention; and (5) dislocations or fractures that required a surgical intervention.

For each included patient, we recorded the age, sex, whether the dominant side was involved, the time between trauma and the MRI evaluation, and involved sports.

MRI Evaluation

Imaging was performed with a 3.0-T MRI scanner (Achieva; Philips), with the ankle in a neutral position. In addition to routine sagittal, coronal, and axial images, oblique coronal images were obtained using a T2-weighted fat-suppressed sequence (repetition time, 2900 ms; echo time, 80 ms; matrix, 400 × 245; field of view, 200 mm; and slice thickness, 2 mm).

The ATFL courses anteriorly, medially, and inferiorly from the fibula to the talus. Kim et al[12] reported that the oblique axial–coronal plane (ATFL view) from the center of the talus to the center of the navicular, 25° inferior from the horizontal plane, provided a better full-length view of the ATFL than the routine axial plane. Therefore, the ATFL view was obtained using axial imaging parallel to the longitudinal axis of the talus and navicular (Figure 1A).

The CFL originates at the tip of the lateral malleolus, runs deep into the peroneus longus and brevis tendons, and connects to a tubercle on the lateral aspect of the calcaneus. To anatomically identify the CFL on oblique coronal images, the full length of the ligament was assessed. The CFL view was obtained in the plane at 45° based on the plantar surface of the foot on the sagittal image at the midcalcaneus level (Figure 1B).[14,15] Additionally, concomitant intra-articular lesions, such as bone marrow edema, OLTs, and injuries to the deltoid ligament complex, were observed.

MRI Interpretation

The assessed ligaments included the lateral collateral ligament complex (ATFL, CFL, and posterior talofibular ligament assessed separately) and medial collateral (deltoid) ligament complex (scored separately for superficial and deep portions).

The ATFL and CFL views on MRI were interpreted independently by 2 orthopaedic surgeons who were blinded to clinical information and radiological reports. The MRI scans were read by 1 radiologist and 2 orthopaedic surgeons who were blinded to group allocation. Interobserver

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Final revision submitted May 18, 2023; accepted May 30, 2023.
One or more of the authors has declared the following potential conflict of interest or source of funding: This research was supported by Wonkwang University (2023). AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from Wonkwang University Hospital (No. WKUHIRB-2022-08-014).

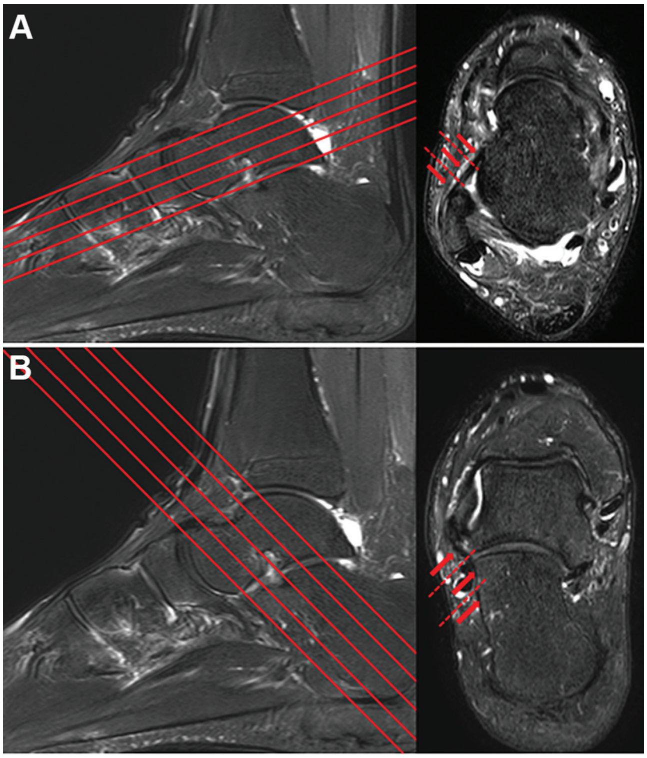

Figure 1. Magnetic resonance imaging showing sagittal (left) and oblique coronal (right) views of the (A) anterior talofibular ligament (ATFL) and (B) calcaneofibular ligament (CFL) of a healthy ankle. The arrows indicate the path of the ligament. The ATFL view was obtained with the axial image that was parallel to the longitudinal axis of the talus and navicular, and the CFL view was obtained in the plane at 45° based on the plantar surface of the foot on the sagittal image.

reliability for lateral ligament injuries, deltoid ligament injuries, and bone marrow edema (including OLTs) was assessed using the kappa statistic, with values of 0.86, 0.87, and 0.93, respectively.

The MRI evaluation focused on the site of structural discontinuity and high signal intensity through the entire length of the ATFL and CFL. Each ATFL and CFL was divided into 3 sections (proximal, middle, and distal) to evaluate the rupture site (Figure 2). Moreover, the sleeve avulsion pattern of injury was identified for both the ATFL and CFL. A sleeve avulsion (Figure 3) was defined as when the ligament was avulsed from its bony insertion proximally or distally as a continuous "sleeve" without a large bony fragment, as previously described for Achilles tendon sleeve avulsions.[4,10]

Bone injuries, including OLTs, were assessed using coronal and sagittal fat-suppressed proton density–weighted sequences (0 = normal, 1 = subchondral edema, and 2 = acute osteochondral lesion). Acute osteochondral lesions were defined as areas of diffuse hyperintensity of the talar dome directly adjacent to the subchondral plate on proton density–weighted sequences, with or without cartilage surface damage. A chronic osteochondral lesion was defined as a well-demarcated or partially cystic lesion in the same location, with or without surrounding edema.[9]

Statistical Analysis

Statistical analyses were conducted using SPSS for Windows (Version 18.0; IBM). Linear-by-linear association analysis, the Pearson chi-square test, and the Fisher exact test were used to assess the relationship between ligamentous and associated factors. For all tests, statistical significance was set at $P < .05$.

RESULTS

Of the 217 elite-level or amateur athletes initially reviewed, 107 patients were excluded for the following reasons: previous sprains (n = 71), os subfibulare (n = 14), previous surgery (n = 17), severe dislocations (n = 3), and ankle fractures (n = 2). Consequently, 110 patients were included in the final cohort (mean age, 24.7 ± 8.7 years). The baseline characteristics of the patients are described in Table 1.

The location and pattern of lateral ligament injuries as well as concomitant injuries are described in Table 2. On MRI, the ATFL was injured in all but 2 patients, who sustained isolated CFL tears. Of the 108 patients with ATFL ruptures, 38 (34.5%) had ruptures in the proximal portion, 38 (34.5%) in the middle portion, and 32 (29.1%) in the distal portion. The ATFL rupture locations were relatively evenly distributed. Overall, 56 (50.9%) patients had both ATFL and CFL injuries. Notably, the rate of distal CFL injuries was high, and sleeve avulsions occurred mostly at the calcaneal insertion and not at the fibula. In addition, a high proportion of CFL tears at the calcaneal insertion were not affected by the location of ATFL tears (Table 3). Concomitant deltoid ligament injuries were identified in 18 (16.4%) patients; among them, 10 were identified as having superficial deltoid ligament injuries (9.1%), and 8 had injuries in the deep deltoid ligaments. Concomitant bone marrow edema of the talus was identified on MRI in 38 (34.5%) patients; the location of the bone contusion was on the medial side in 15 (39.5%) patients and on the lateral side in 23 (60.5%) patients. Furthermore, acute OLTs with bone marrow edema were identified in 6 (5.5%) patients; the location of the OLT was on the medial side in 2 (33.3%) patients and on the lateral side in 4 (66.7%) patients.

Analysis of the relationship between the location and pattern of ligamentous injuries and associated bone contusions or osteochondral lesions indicated that CFL injuries were significantly correlated with concomitant deltoid ligament and bone injuries ($r = 0.261$, $P = .023$ and $r = 0.429$, $P = .001$, respectively; Pearson chi-square test). Further, CFL injuries in the distal portion (calcaneal insertion) were significantly correlated with the sleeve pattern of injury ($r = 0.358$, $P = .005$; Pearson chi-square test) (Table 4).

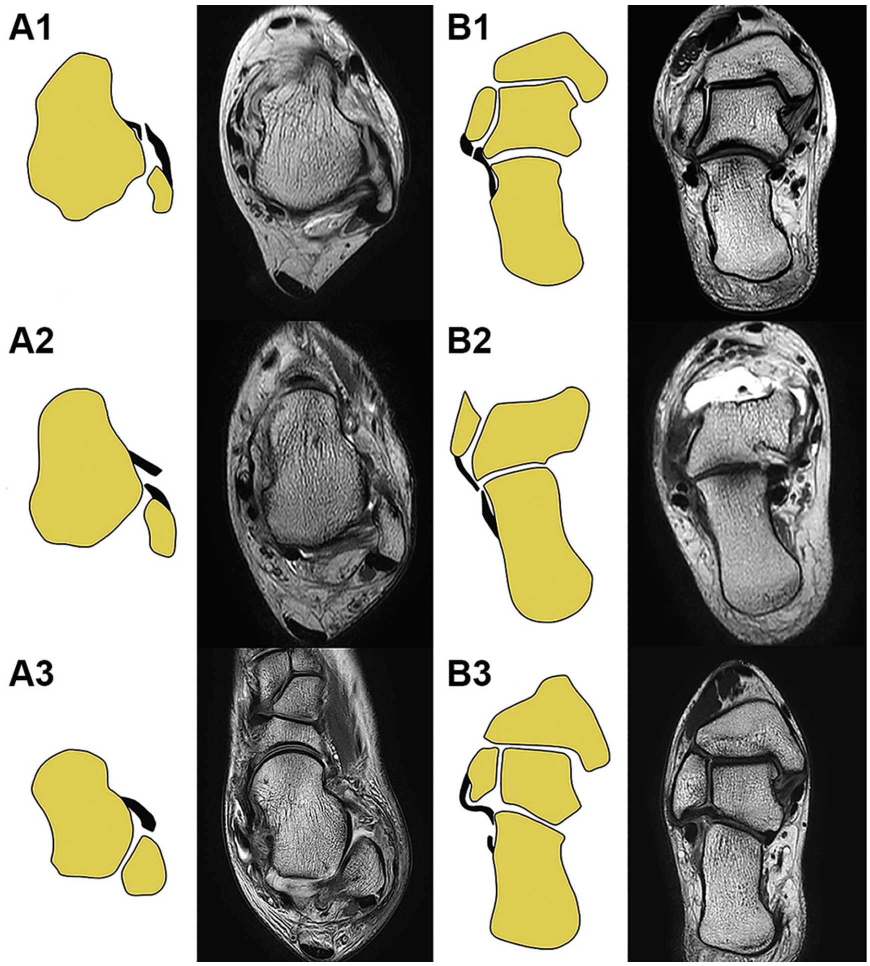

Figure 2. Schematic images (left) and oblique coronal magnetic resonance imaging scans (right) of the (A) anterior talofibular ligament and (B) calcaneofibular ligament, divided into (1) proximal, (2) middle, and (3) distal sections.

The incidence of complete tears of the superficial or deep deltoid ligament, bone marrow edema, and acute OLTs was higher in patients with CFL injuries, especially CFL tears at the calcaneal insertion. Additionally, the sleeve pattern of injury was identified at the calcaneal insertion of the CFL. These results showed a significant positive correlation in linear-by-linear association analysis.

DISCUSSION

The present study analyzed, using MRI, the location and pattern of lateral ligament injuries as well as the relationship between ankle ligament injuries and associated bone marrow edema with or without osteochondral lesions in athletes. In addition to routine sequences, we utilized specific MRI planes parallel to the ATFL and CFL. The ATFL tear locations and patterns varied from the proximal fibular origin to the distal talar insertion. Contrastingly, 62.1% (36/58) of acute CFL tears were identified at the calcaneal insertion, and most sleeve patterns of CFL injuries were identified at the calcaneal insertion. Moreover, CFL injuries correlated with deltoid ligament injuries, bone marrow edema, and OLTs.

Almost half of all ankle sprains occur during athletic activities, most commonly in basketball, football, soccer, and running.[20] In a systematic review, the ankle was the most commonly injured body region in 24 of 70 sports examined.[7] As MRI is not routinely performed in patients with acute ankle sprains, data on the prevalence of associated injuries are sparse. Furthermore, the ATFL and CFL run obliquely and are difficult to identify in orthogonal axial and coronal planes on MRI.[12,15] Previous studies have suggested that the ATFL and CFL can be identified in axial and coronal planes that are parallel to the direction of each ligament.[12,15] To our knowledge, the present study is the first to assess the location and pattern of ATFL and CFL tears after ankle sprains in athletes using MRI with axial and oblique coronal planes parallel to the ATFL and CFL. Additionally, the correlation between each ligament tear and concomitant injury was evaluated.

An interesting finding of the present study was that the majority of acute CFL injuries occurred at the calcaneal

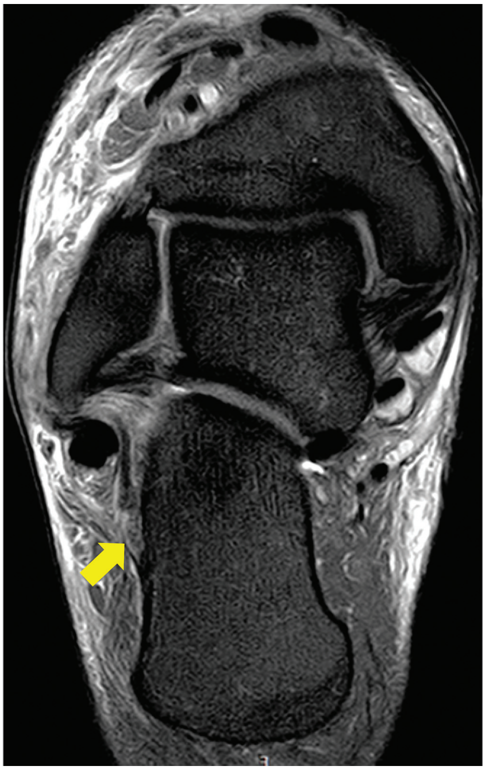

Figure 3. Oblique coronal magnetic resonance imaging showing a calcaneofibular ligament sleeve avulsion at the calcaneal insertion (yellow arrow).

TABLE 1
Baseline Characteristics of Patients (N = 110)[a]

	Value
Age, y	24.7 ± 8.7
Male sex	64 (58.2)
Dominant side affected	57 (51.8)
Time between trauma and MRI evaluation, d	10.2 ± 2.4
Involved sports	
Soccer	67 (60.9)
Basketball	21 (19.1)
Track and field	12 (10.9)
Volleyball	7 (6.4)
Other	3 (2.7)

[a]Data are presented as mean ± SD or n (%). MRI, magnetic resonance imaging.

insertion, particularly with the sleeve pattern. Few studies have investigated CFL injuries on MRI in acute sprains, as the CFL is difficult to identify on conventional orthogonal MRI.[14,15,18] Previous studies have suggested that oblique coronal imaging of the CFL (CFL view) enables a better anatomic evaluation and improved sensitivity and accuracy of the diagnosis of a CFL injury; therefore, the CFL view should be used to evaluate potential CFL injuries.[14,15] In the present study, acute tears at the calcaneal insertion

TABLE 2
Characteristics of Ligamentous Injuries and Concomitant Lesions (N = 110)[a]

ATFL rupture	
None	2 (1.8)
Proximal	38 (34.5)
Middle	38 (34.5)
Distal	32 (29.1)
ATFL sleeve avulsion	
None	64 (58.2)
Proximal	22 (20.0)
Distal	24 (21.8)
CFL rupture	
None	52 (47.3)
Proximal	7 (6.4)
Middle	15 (13.6)
Distal	36 (32.7)
CFL sleeve avulsion	
None	87 (79.1)
Proximal	1 (0.9)
Distal	22 (20.0)
Deltoid rupture	
None	92 (83.6)
Superficial	10 (9.1)
Deep	8 (7.3)
Concomitant bone injury	
None	66 (60.0)
Bone marrow edema	38 (34.5)
Osteochondral lesion	6 (5.5)

[a]Data are presented as n (%). ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament.

TABLE 3
Tear Location Among Patients With Both ATFL and CFL Tears (n = 56)[a]

	ATFL		
CFL	Proximal	Middle	Distal
Proximal	2 (3.6)	3 (5.4)	2 (3.6)
Middle	7 (12.5)	4 (7.1)	4 (7.1)
Distal	13 (23.2)	9 (16.1)	12 (21.4)

[a]Data are presented as n (%). ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament.

with a sleeve pattern were identified in the majority of CFL tears on oblique coronal (CFL view) MRI. Although the effect of a CFL injury at the calcaneal insertion on the prognosis and development of chronic ankle instability cannot be postulated, it is important to identify this pattern of CFL tears. In some patients, the torn CFL can become displaced superficial to the peroneal tendon, similar to a Stener lesion in the thumb. This may result in chronic ankle instability (Figure 4). Furthermore, the proportion of CFL injuries at the calcaneal insertion was not affected by the location of ATFL tears. In addition, further

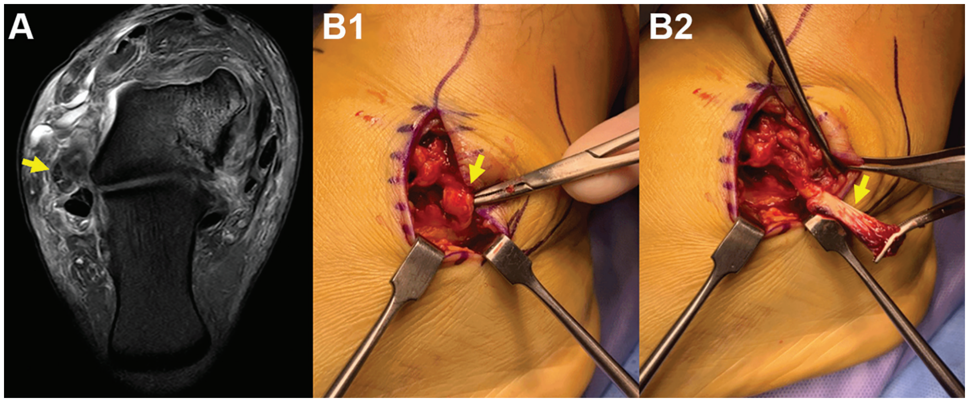

Figure 4. (A) Magnetic resonance imaging scans and (B1, B2) intraoperative images of a torn calcaneofibular ligament (arrows) popped out proximally and outside of the peroneal tendon.

TABLE 4
Correlation Between Ligamentous Injury Characteristics and Concomitant Injuries[a]

	ATFL Injury	ATFL Sleeve Type	CFL Injury	CFL Sleeve Type	Deltoid Injury	Talus Injury
ATFL injury	1.000					
ATFL sleeve type		1.000				
r	0.135					
P	.751					
CFL injury			1.000			
r	0.054	−0.196				
P	.646	.090				
CFL sleeve type				1.000		
r	0.203	0.143	0.358			
P	.078	.219	.005[b]			
Deltoid injury					1.000	
r	0.029	−0.163	0.261	0.084		
P	.802	.159	.023[b]	.473		
Talus injury						1.000
r	−0.169	−0.214	0.429	0.081	−0.136	
P	.144	.064	.001[b]	.487	.243	

[a]ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament.
[b]Statistically significant ($P < .05$; Pearson chi-square test).

studies are required on the biomechanics of CFL injuries and the clinical outcomes of CFL tears at the calcaneal insertion.

In the present study, a CFL injury correlated with a deltoid ligament injury, bone marrow edema, and an OLT. The most common trauma mechanism in sprains is inversion and adduction of the plantarflexed foot.[22] When the ankle is subjected to a considerable force that causes inversion, the ATFL, which is the weakest ligament of the lateral ligament complex, is the most commonly injured ligament, with approximately 85% of cases involving the lateral ligaments of the ankle.[6,13,17,19] Previous biomechanical studies have shown that the ATFL is subjected to a greater amount of strain compared with the CFL; consequently, the ATFL is more easily injured.[1,2] In the present study, among 58 CFL injuries, 56 (96.6%) were accompanied by an ATFL injury. Therefore, we considered the correlation between concomitant lesions and CFL injuries to be caused by the predominant occurrence of CFL tears after ATFL tears, with more severe injuries than isolated ATFL tears.

It is important to clinically apply this relationship between the location and pattern of ankle lateral ligament tears and associated injuries. Most patients with this injury do not undergo MRI, with ligamentous damage being usually assessed via a physical examination, which may be difficult to perform because of pain. Under these circumstances, an MRI assessment parallel to the lateral ligament axis can identify associated bone contusions and deltoid ligament injuries and infer the extent of damage to the lateral ligaments of the ankle. Patients with CFL injuries may have bone marrow edema with or without OLTs and concomitant deltoid ligament injuries; therefore, a careful assessment is required. Surgical repair could be recommended in cases of CFL tears that displace superficial to the peroneal tendon, even though this kind of injury pattern is rare. In terms of rehabilitation, we prescribe delayed weightbearing to about 2 or 3 weeks after the injury, in cases of both ATFL and CFL tears, compared to 10 days after the injury in cases of isolated ATFL tears.

Limitations

This study had several limitations. First, it was a retrospective study. Second, as MRI is performed in the acute stages of an injury, the assessment of ligamentous damage can be compromised by swelling, fluid collection, and hemarthrosis. For this reason, we performed MRI evaluations at least 1 week after the injury, and the mean interval between trauma and the MRI evaluation was 10.2 days. Third, in a population of athletes, the threshold for administering an MRI examination differs from that in the general population, and our cohort largely comprised athletes (the majority being soccer players), who had quick and easy access to MRI. Our data should be extrapolated to a nonathletic population with caution. Finally, systematic, longitudinal clinical follow-up was not available in this cohort; therefore, the relevance of MRI findings is unclear with regard to prognosis, including recovery times.

CONCLUSION

After an acute ankle ligament rupture, almost all athletes involved in this study injured their ATFL, and approximately 50% had a concomitant injury to the CFL. The rate of sleeve-type CFL injuries at the calcaneal insertion was high, and concomitant deltoid ligament injuries and OLTs were associated with this pattern of injury.

ACKNOWLEDGEMENT

We specially want to thank SJK, ISK, and SKJ for MRI interpretation.

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