



# MRI of ankle sprain: the association between joint effusion and structural injury severity in a large cohort of athletes

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Received: 24 November 2018 / Revised: 20 February 2019 / Accepted: 11 March 2019 / Published online: 1 April 2019  
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## Abstract

**Objective** To test the hypothesis if presence and amount of effusion in the tibiotalar and talocalcaneal joints are associated with an increased risk for severe structural injury in ankle sprains.

**Methods** A total of 261 athletes sustaining acute ankle sprains were assessed on MRI for the presence and the amount of joint effusion in the tibiotalar and talocalcaneal joints, as well as for ligamentous and osteochondral injury. Specific patterns of injury severity were defined based on lateral collateral ligament, syndesmotric, and talar osteochondral involvement. The presence and the amount effusion (grades 1 and 2) were considered as risk factors for severe injury, while physiological amount of fluid (grade 0) was considered as the referent. Conditional logistic regression was used to assess the risk for associated severe injuries (syndesmotric ligament rupture and talar osteochondral lesions) based on the presence and amount of tibiotalar and talocalcaneal effusions.

**Results** For ankles exhibiting large (grade 2) effusion in the tibiotalar joint (without concomitant grade 2 effusion in the talocalcaneal joint), the risk for partial or complete syndesmotric ligament rupture was increased more than eightfold (adjusted odds ratio 8.7 (95% confidence intervals 3.7–20.7);  $p < 0.001$ ). The presence of any degree of effusion in any of the joints was associated with an increased risk for severe talar osteochondral involvement (several odds ratio values reported;  $p < 0.001$ ), including large subchondral contusions and any acute osteochondral lesion.

**Conclusion** The presence of tibiotalar and talocalcaneal effusions is associated with an increased risk for severe concomitant structural injury in acute ankle sprains.

## Key Points

- For ankles exhibiting severe (grade 2) effusion in the tibiotalar joint after sprain, the risk for partial or complete syndesmotric ligament rupture increases more than eightfold.
- The presence of effusion in both tibiotalar and talocalcaneal joints is associated with an increased risk for severe ligament injury such as complete ATFL rupture as well as partial or complete syndesmotric ligament rupture.
- The presence of effusion in the tibiotalar or talocalcaneal joints after sprain is associated with an increased risk for severe talar osteochondral involvement.

**Keywords** Magnetic resonance imaging · Ankle injuries · Sprains and strains

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s00330-019-06156-1>) contains supplementary material, which is available to authorized users.

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## Abbreviations

ATFL	Anterior talofibular ligament
CFL	Calcaneofibular ligament
FOV	Field of view
MRI	Magnetic resonance imaging
NSMP	National Sports Medicine Program of the State of Qatar
PTFL	Posterior talofibular ligament
TE	Echo time
TR	Repetition time

## Introduction

Ankle sprain is one of the most frequent sports injuries among athletes. The inversion mechanism of sprain is by far the most common, frequently leading to lateral collateral ligament injury and potentially additional associated structural damage [1–6]. The reference standard for the diagnosis of ankle sprain is physical examination combined with radiographic assessment according to the Ottawa rules in order to exclude an associated fracture and to evaluate mortise alignment [6–8]. Concomitant structural injuries associated with lateral collateral ligament sprain are not rare and may have impact on the prognosis, such as syndesmotic injuries, or osteochondral lesions. A timely diagnosis is crucial as untreated structural damage may lead to chronic instability of the ankle joint, especially in cases of high-grade collateral ligament and/or syndesmotic injury [9, 10].

Ultrasound and magnetic resonance imaging (MRI) are able to assess ligamentous integrity after acute ankle sprains [11]. Compared with MRI, ultrasound is widely available and cost-efficient, allowing for dynamic assessment of ligamentous structures of the ankle, including the syndesmosis. However, MRI performs better than ultrasound for the detection of deep soft-tissue and osteochondral involvement potentially associated with ankle sprain [11]. Joint effusion in the tibiotalar and talocalcaneal joints is frequently detected in association with acute ankle sprain [12, 13] and may be easily detected and quantified using both ultrasound and MRI [13]. Assumingly, a larger amount of joint effusion would potentially reflect a more severe structural injury. However, there is no strong evidence that the presence and the amount of effusion detected after acute ankle sprain are associated with structural injury severity.

In a large retrospective cohort of athletes having sustained an acute ankle sprain assessed on MRI, we aimed to evaluate the cross-sectional associations of the presence and amount of effusion in the tibiotalar and talocalcaneal joints with the severity of injuries including collateral ligament complex, syndesmotic, and bony injuries, as well as osteochondral lesions. We hypothesized that increasing amounts of joint

effusion are associated with more severe structural injury in athletes with acute ankle sprain.

## Methods

**Study population and design** Ethical approval was obtained from the local Institutional Review Board (Anti-Doping Lab Qatar, IRB No. EX2013000001), which waived informed consent due to the retrospective nature of the study. Participants were professional athletes registered in the National Sports Medicine Program (NSMP) of the State of Qatar, a centralized organization responsible for medical diagnoses and treatment of professional athletes from several sports competing in the highest national leagues who are registered in sports clubs in Qatar. Athletes in the NSMP may be clinically evaluated at the club level by a sports medicine physician or may be directly referred to a specialized secondary referral sports medicine center for injury assessment. Included in this study were all NSMP athletes referred for an ankle MRI after sustaining an acute ankle sprain during training or competition between 1 and 30 days before the MRI examination. The large majority of athletes included were football (soccer) players. Reasons for referral were not uniform, with the most common reasons for MRI being suspected lateral collateral ligament injury, syndesmotic injury, or acute osteochondral lesions.

For the period of January 1, 2009, until December 31, 2012, we retrospectively searched for ankle MRI examinations of athletes in the hospital picture archiving and communication system. The search yielded 697 MRI scans of the ankle. Further, referral forms were searched for the terms “acute ankle sprain,” “twisting injury,” “sprain,” “syndesmosis,” “lateral ligaments,” and “ligament tear.” We then identified 297 MRI scans of 261 athletes based on these criteria. If an athlete had more than one MRI scan, only the baseline scan was included, which left 261 MRI scans of the ankle joint finally included in our study. When the exact time interval from ankle sprain to MRI was not recorded, the occurrence of recent sprain was verified by the referral form, which had to include the terms “acute” or “recent” and “trauma” or “sprain.”

**MRI acquisition** All MRI scans were obtained with a 1.5-T large-bore MRI system (Espree, Siemens Healthineers), with a circumferential 8-channel extremity coil, using fat-suppressed, turbo spin echo, proton density-weighted sequences in the sagittal (repetition time [TR], 2330 ms; echo time [TE], 32 ms; 3-mm slice thickness; 0.6-mm interslice gap; 22 slices; 320 × 224-pixel matrix; 2 excitations [NEX]; 15.9-cm<sup>2</sup> field of view [FOV]; echo train length [ETL], 7), coronal (TR, 2860 ms; TE, 32 ms; 3-mm slice thickness; 0.8-mm interslice gap; 27 slices; 320 × 224-pixel matrix; 2 NEX; 14.0-cm<sup>2</sup> FOV; ETL, 7), and axial (TR, 2990 ms;

TE, 35 ms; 4-mm slice thickness; 0.8-mm interslice gap; 26 slices; 320 × 224-pixel matrix; 2 NEX; 14.0-cm<sup>2</sup> FOV; ETL, 7) planes. In addition, sagittal (TR, 493 ms; TE, 14 ms; 3-mm slice thickness; 0.6-mm interslice gap; 22 slices; 3,203, 224-pixel matrix; 1 NEX; 15.9-cm<sup>2</sup> FOV; ETL, 1) and axial (TR, 583 ms; TE, 14 ms; 4-mm slice thickness; 0.8-mm interslice gap; 26 slices; 320 × 224-pixel matrix; 1 NEX; 14.0-cm<sup>2</sup> FOV; ETL, 1) T1-weighted sequences were acquired.

**MRI interpretation** The MRI scans were read by a single musculoskeletal radiologist, with 15 years of experience in grading musculoskeletal MRI scans in a research context, on a high-resolution workstation using eFilm software (eFilm workstation v 3.4, Merge Healthcare). The MRI scans were read blinded for referral and clinical reports. Inter-observer and intra-observer reliability was assessed using 30 randomly chosen MRI scans. Inter-observer reliability readings were performed by a second experienced musculoskeletal radiologist with 22 years of experience in standardized semiquantitative MRI assessment. Intra-observer reliability was tested using the same 30 MRIs after an interval of 6 weeks to avoid recognition bias. Prior to the inter-observer reliability readings performed by the second radiologist, a 4-h calibration session between both readers was conducted using a different set of 20 MRI scans (not included in this cohort).

The following structures were assessed using consensus definitions that were developed based on the existing literature and during calibration between the two readers as described above [12]:

All ligamentous structures were graded as normal (grade 0), as a low-grade sprain (grade 1 = periligamentous high signal/edema on fat-suppressed proton density-weighted sequences and no discontinuity of fibers), as partial disruption (grade 2 = partial discontinuity but preserved remnant fibers), as complete disruption (grade 3 = complete discontinuity), and as scar tissue (grade 4 = thinned or thickened ligament without discontinuity or periligamentous edema) [14, 15]. Ligaments assessed included the *lateral collateral ligament complex* (anterior talofibular (ATFL), calcaneofibular (CFL), and posterior talofibular (PTFL) ligaments assessed separately), the *syndesmotic ligaments* (anterior-inferior tibiofibular ligament, posterior-inferior tibiofibular ligament, transverse tibiofibular ligament, and interosseous membrane assessed separately), the *medial collateral (deltoid) ligament complex* (scored separately for superficial and deep portions), the spring ligament complex (scored separately for inferopltar longitudinal, mediopltar oblique, and superomedial), and the sinus tarsi ligaments (scored separately for the interosseous talocalcaneal and cervical ligaments).

Bone structures excluding the talus, that is, the fibula, tibia, calcaneus, navicular, and other, were assessed for injury using both T1-weighted and fat-suppressed proton density-weighted sequences as 0 = normal, 1 = contusion (bone edema without a fracture line), and 2 = fracture.

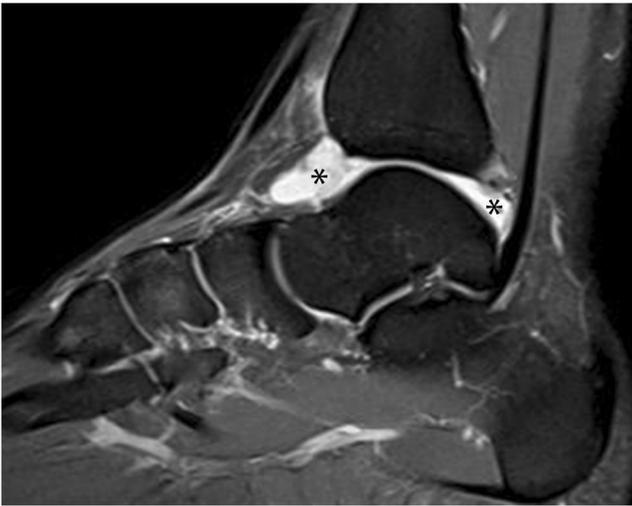
Talar osteochondral involvement was assessed mainly using coronal and sagittal fat-suppressed proton density-weighted sequences as 0 = normal, 1 = small subchondral edema only, 2 = large subchondral edema only, 3 = acute osteochondral lesion with intact cartilage, 4 = acute osteochondral lesion with cartilage injury, and 5 = chronic osteochondral lesion. Small talar contusions were defined as being restricted to only one part of the talus, that is, the body, neck, or head. Large talar contusions were defined as involving at least two regions of the talus. Both definitions excluded contusions of the talar dome adjacent to the subchondral plate, which were scored as an osteochondral lesion without surface damage (i.e., as grade 3 lesions and not as grade 1 or 2 lesions). Acute osteochondral talar lesions were defined as areas of diffuse hyperintensity of the lateral 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 [16].

Finally, the presence and amount of effusion in the tibiotalar and talocalcaneal joints were scored separately using sagittal fat-suppressed proton density-weighted, from 0 to 2, according to the amount of capsular distension: grade 0 = minimal physiological amounts of intra-articular fluid (normal); grade 1 = effusion with less than 50% of maximum capsular distension; grade 2 = effusion with ≥ 50% of maximum capsular distension (Figs. 1, 2, and 3).

**Statistical analysis** Conditional logistic regression analysis was performed to assess the risk for different patterns of ligament injury severity after ankle sprain in regard to the different grades of pathological effusion (grades 1 and 2) in the tibiotalar and talocalcaneal joints, using grade 0 (minimal



**Fig. 1** Sagittal fat-suppressed proton density-weighted MRI shows grade 1 effusion in the tibiotalar (arrow) and the talocalcaneal (arrowhead) joints



**Fig. 2** Sagittal proton density-weighted MRI shows grade 2 effusion in the tibiotalar joint (\*)

physiological effusion) as the reference. Three different ligament injury severity patterns were defined taking into account the scoring of grades as described in the “Methods” section: (C1) ankles with no acute injury (grades 0, 1, or 4, assuming functional stability of scar tissue/grade 4 lesions) or only low-grade acute injury (grade 2) involving lateral collateral ligaments and no syndesmotc injury; (C2) ankles with complete ATFL injuries (grade 3) but no syndesmotc injury; and (C3) ankles with any syndesmotc injury. Any syndesmotc injury was defined as partial (grade 2) or complete (grade 3) disruption of one of the four structures assessed. Furthermore, the same analysis was applied to specifically assess the risk for severe ligamentous and osteochondral injuries in regard to the different grades of pathological effusion.

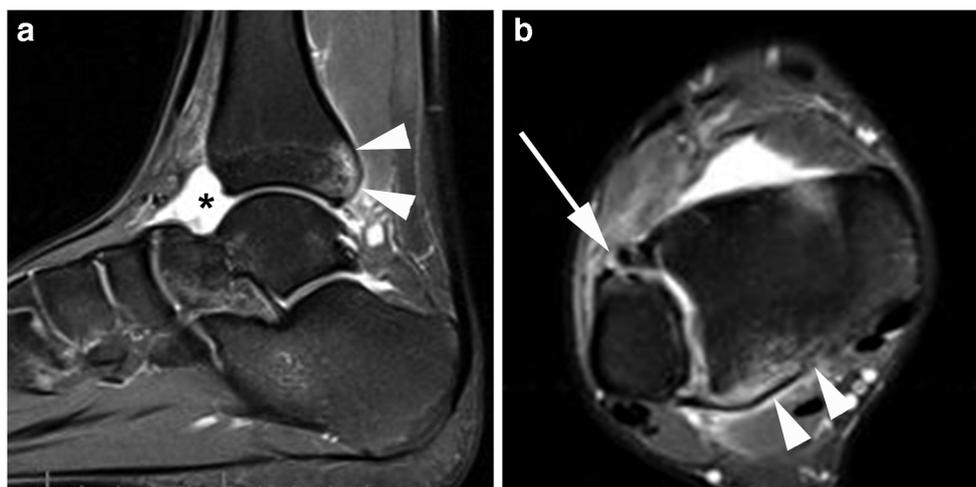
In addition to effusion severity considered for each joint (tibiotalar and talocalcaneal), four different patterns of effusion were evaluated as factors for injury severity: (P1) grade 0 or 1 effusion in both joints; (P2) grade 2 effusion in the tibiotalar joint only; (P3) grade 2 effusion in the talocalcaneal joint only; and (P4) grade 2 effusion in both tibiotalar and talocalcaneal joints. P1 was considered the reference standard when assessing the associations with ligament injury severity patterns. We additionally assessed the diagnostic performance of the presence of grade 2 effusion in both joints (P4) for the detection of ankles exhibiting syndesmotc ligament injury (C3), the highest ligament injury severity considered in this study.

Finally, we considered two groups of talar osteochondral involvement for the analyses: T1—mild, including grades 1 and 2 (normal or small subchondral edema only) and T2—severe, including grades 3 to 5 (large subchondral edema only or any acute osteochondral lesion).

Reliability was assessed using weighted kappa statistics and overall percentage agreement. The Fisher exact test was applied to assess differences in the injury severity patterns based on age and sex. All analyses were performed using SAS software (version 9.3 for Windows, SAS Institute). We considered a two-tailed  $p$  value  $< 0.05$  as statistically significant.

## Results

A total of 261 ankles of 261 patients were included. The athletes’ characteristics were previously described in detail [12]. Briefly, athletes included were on average  $22.5 \pm 4.9$  years old (range,



**Fig. 3** Acute syndesmotc injury after ankle sprain. **a** Sagittal fat-suppressed proton density-weighted image shows grade 2 effusion in the talocalcaneal joint (\*). Note the presence of traction bone marrow edema at the tibial insertion of the posterior-inferior tibiofibular

ligament (arrowheads). **b** Axial fat-suppressed proton density-weighted image shows complete rupture of the anterior-inferior tibiofibular ligament (arrow) associated with traction bone marrow edema at the tibial insertion of the posterior-inferior tibiofibular ligament (arrowheads)

14–39 years), 88.1% were male athletes ( $n = 230$ ) and 84.7% were registered with a football (soccer) club ( $n = 221$ ). The average time from injury to MRI was  $5.7 \pm 4.8$  days (range, 1–26 days) for 214 athletes. For the remaining 47 athletes, the exact interval from ankle sprain to MRI was not recorded. The distribution of the different injury patterns in regard to age and sex is detailed in Table 1. There were no significant differences in frequencies of the injury patterns for age or sex.

When applying kappa statistics, intra-reader reliability ranged from 0.67 (sinus tarsi) to 1.00 (retinacula, bone, and tendons), whereas inter-reader reliability ranged from 0.00 (retinacula) to 0.90 (syndesmosis). As some of the features were rare with regard to frequency, we also assessed overall percentage agreement, which ranged from 78.3% (effusion) to 100.0% (retinacula, bone, and tendons) for intra-reader reliability and from 68.3% (deltoid) to 98.9% (retinacula) for inter-reader reliability. Detailed intra- and inter-reader reliability for all MRI features assessed is presented in Appendix 1 in the Supplementary Materials.

Some athletes had spring ligament injuries (3.8%) and sinus tarsi ligament involvement (16.1%). Retinaculum and tendon injuries were rare (1.1% and 1.5%, respectively). Ninety-two (35.2%) ankles had either partial or complete disruption (grade 2 or 3) of the deep, superficial, or both parts of the deltoid ligament complex. Including low-grade (grade 1) injuries, 128 (49.0%) ankles had suffered a deltoid ligament injury.

**Patterns of joint effusion and ligament injury severity** The associations between the different patterns of joint effusion and injury severity are presented in Table 2. The presence of severe (grade 2) effusion in the tibiotalar joint only (without a concomitant grade 2 effusion in the talocalcaneal joint) was associated with an increased risk for exhibiting partial or complete syndesmotom injury (adjusted odds ratio (aOR) = 8.7 (95% confidence intervals [CI] 3.7, 20.7);  $p < 0.001$ ) regardless of the grade of concomitant lateral ligament injury. A grade 2 effusion in both joints was associated with an increased risk for exhibiting complete ATFL rupture without syndesmotom injury (aOR = 4.0;  $p < 0.001$ ; Table 2). Furthermore, a grade 2 effusion in the

talocalcaneal joint only (without a concomitant grade 2 effusion in the tibiotalar joint) was associated with an increased risk for exhibiting both complete ATFL rupture without syndesmotom injury (aOR = 4.1;  $p < 0.001$ ) and partial or complete syndesmotom injury (aOR = 2.7;  $p < 0.01$ ) (Table 2).

When considering each joint separately (tibiotalar and talocalcaneal), the associations of small (grade 1) and large (grade 2) effusions with injury severity patterns are presented in Table 3. Compared with the reference (grade 0 effusion), grade 1 and 2 effusions in each joint separately were significantly associated with an increased risk for exhibiting a complete ATFL rupture without syndesmotom injury as well as partial or complete syndesmotom injury, except for the relationship between grade 2 effusion in the talocalcaneal joint and partial or complete syndesmotom injury ( $p = 0.42$ ).

The detection of grade 2 effusion in both tibiotalar and talocalcaneal joints exhibited 9.1% (95% CI 3.4, 20.7) sensitivity, 87.4% (95% CI 81.9, 91.4) specificity, 16.1% (95% CI 6.1, 34.5) positive predictive value (PPV), and 78.3% (95% CI 72.3, 83.3) negative predictive value (NPV) in the detection of syndesmotom ligament injuries.

**Joint effusion and talar osteochondral involvement** The associations of grades of effusion (1 and 2) with severity of talar osteochondral involvement are presented in Table 4. The presence of grade 1 or 2 effusions in the tibiotalar joint was associated with an increased risk for exhibiting large subchondral talar contusions or any acute talar osteochondral lesion (aORs of 3.7 and 2.5, respectively;  $p < 0.001$ ). Also, the presence of grade 1 or 2 effusions in the talocalcaneal joint was associated with an increased risk for exhibiting large subchondral talar contusions or any acute talar osteochondral lesion (aORs of 3.5 and 3.9, respectively;  $p < 0.001$ ).

## Discussion

In this large cohort of athletes sustaining an acute ankle sprain assessed on MRI, we demonstrated that the presence of

**Table 1** Distribution of patterns of ligament injury according to age and gender

Injury pattern	No. of ankles	Gender		Age range					
		Male	Female	N (%)					
C1	105	90 (85.7%)	15 (14.3%)	11 (10.5%)	25 (23.7%)	26 (24.8%)	28 (26.7%)	11 (10.5%)	4 (3.8%)
C2	103	90 (87.4%)	13 (12.6%)	8 (7.8%)	36 (34.9%)	26 (25.3%)	24 (23.3%)	7 (6.8%)	2 (1.9%)
C3	53	50 (94.3%)	3 (5.7%)	6 (11.3%)	17 (32.1%)	15 (28.3%)	8 (15.1%)	5 (9.4%)	2 (3.8%)
Total	261	230 (88.1%)	31 (11.9%)	25 (9.6%)	78 (29.9%)	67 (25.7%)	60 (23.0%)	23 (8.8%)	8 (3.1%)
$p$ value from Fisher's exact test		0.809		0.760					

(C1) ankles with no or only low-grade lateral ligament injuries and no syndesmotom damage; (C2) ankles with complete ATFL injuries but no syndesmotom involvement; and (C3) ankles with partial or complete syndesmotom disruption

**Table 2** Association of patterns of joint effusion in the tibiotalar and/or tibiocalcaneal joints with patterns of ligament injury

Joint effusion	No. of ankles <i>N</i> = 261 (100%)	Ligament injury pattern		
		C1	C2	C3
P1	137 (52.5%)	67 (25.7%)	47 (18%)	23 (8.8%)
OR		1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
P2	31 (11.9%)	10 (3.8%)	9 (3.5%)	12 (4.6%)
OR (95% CI)		1.4 (0.6, 3.2)	2.0 (0.9, 4.8)	8.7 (3.7, 20.7)
<i>p</i> value		0.45	0.10	0.00
P3	62 (23.8%)	18 (6.9%)	29 (11.1%)	15 (5.8%)
OR (95% CI)		1.2 (0.6, 2.2)	4.1 (2.2, 7.5)	2.7 (1.3, 5.4)
<i>p</i> value		0.67	0.00	0.01
P4	31 (11.9%)	9 (3.5%)	17 (6.5%)	5 (1.9%)
OR (95% CI)		1.1 (0.5, 2.5)	4.0 (1.9, 8.6)	1.3 (0.5, 3.6)
<i>p</i> value		0.87	0.00	0.62
Trend test	<i>Z</i>	2.94	− 2.41	− 0.65
	<i>P</i>	0.003	0.016	0.517

(C1) ankles with no or only low-grade lateral ligament injuries and no syndesmotc damage; (C2) ankles with complete ATFL injuries but no syndesmotc involvement; and (C3) ankles with partial or complete syndesmotc disruption. (P1) grade 0 or 1 effusion in both joints; (P2) grade 2 effusion in the tibiotalar joint only; (P3) grade 2 effusion in the talocalcaneal joint only; and (P4) grade 2 effusion in both tibiotalar and talocalcaneal joints. *OR*, odds ratio; *CI*, confidence intervals

Results in italics are statistically significant defined as *p* < 0.05

**Table 3** Association of pathological grades of joint effusion in the tibiotalar and tibiocalcaneal joints separately with patterns of ligament injury

	No. of ankles <i>N</i> = 261 (100%)	Ligament injury pattern		
		C1	C2	C3
<b>Tibiotalar effusion</b>				
Grade 0	53 (20.3%)	38 (14.6%)	6 (2.3%)	9 (3.5%)
OR		1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
Grade 1	107 (41%)	35 (13.4%)	53 (20.3%)	19 (7.3%)
OR (95% CI)		0.5 (0.3, 1.1)	20.6 (8.1, 52.6)	2.8 (1.1, 6.6)
<i>p</i> value		0.10	0.00	0.02
Grade 2	101 (38.7%)	31 (11.9%)	43 (16.5%)	27 (10.3%)
OR (95% CI)		0.8 (0.5, 1.3)	1.7 (1.0, 2.9)	2.4 (1.3, 4.5)
<i>p</i> value		0.36	0.04	0.00
Trend test	<i>Z</i>	4.43	− 3.10	− 1.60
	<i>P</i>	< 0.0001	0.002	0.109
<b>Talocalcaneal effusion</b>				
Grade 0	106 (40.6%)	56 (21.5%)	30 (11.5%)	20 (7.7%)
OR		1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
Grade 1	101 (38.7%)	33 (12.6%)	43 (16.5%)	25 (9.6%)
OR (95% CI)		1.1 (0.6, 2.0)	5.2 (2.9, 9.3)	3.9 (1.9, 7.6)
<i>p</i> value		0.67	0.00	0.00
Grade 2	54 (20.7%)	15 (5.8%)	29 (11.1%)	10 (3.8%)
OR (95% CI)		0.8 (0.4, 1.6)	3.8 (2.1, 7.1)	1.4 (0.6, 2.9)
<i>p</i> value		0.61	0.00	0.42
Trend test	<i>Z</i>	3.39	− 3.24	− 0.192
	<i>P</i>	0.001	0.001	0.848

(C1) ankles with no or only low-grade lateral ligament injuries and no syndesmotc damage; (C2) ankles with complete ATFL injuries but no syndesmotc involvement; and (C3) ankles with partial or complete syndesmotc disruption. *OR*, odds ratio; *CI*, confidence intervals

Results in italics are statistically significant defined as *p* < 0.05

**Table 4** Association of pathological grades of joint effusion in the tibiotalar and talocalcaneal joints separately with severity of talar osteochondral involvement

	No. of joints N = 261 (100%)	Talar osteochondral involvement	
		T1	T2
<b>Tibiotalar effusion</b>			
Grade 0	53 (20.3%)	44 (16.9%)	9 (3.5%)
OR		1.0 (ref.)	1.0 (ref.)
Grade 1	107 (41%)	83 (31.8%)	24 (9.2%)
OR (95% CI)		2.0 (0.9, 4.7)	3.7 (1.6, 8.7)
<i>p</i> value		0.11	0.00
Grade 2	101 (38.7%)	70 (26.8%)	31 (11.9%)
OR (95% CI)		0.8 (0.4, 1.4)	2.5 (1.4, 4.5)
<i>p</i> value		0.36	0.00
Trend test	Z	1.97	-1.97
	P	0.048	0.048
<b>Talocalcaneal effusion</b>			
Grade 0	106 (40.6%)	86 (33%)	20 (7.7%)
OR		1.0 (ref.)	1.0 (ref.)
Grade 1	101 (38.7%)	77 (29.5%)	24 (9.2%)
OR (95% CI)		2.1 (1.1, 4.1)	3.5 (1.8, 6.9)
<i>p</i> value		0.03	0.00
Grade 2	54 (20.7%)	34 (13%)	20 (7.7%)
OR (95% CI)		0.7 (0.4, 1.3)	3.9 (2.0, 7.6)
<i>p</i> value		0.27	0.00
Trend test	Z	2.42	-2.42
	P	0.015	0.015

(T1) includes grades 0 and 1 of talar osteochondral involvement (normal or small subchondral edema only); (T2) includes grades 3 to 5 (large subchondral edema only or any acute osteochondral lesion). OR, odds ratio; CI, confidence intervals

Results in italics are statistically significant defined as  $p < 0.05$

effusion in both tibiotalar and talocalcaneal joints was associated with an increased risk for severe ligament injury such as complete ATFL rupture as well as partial or complete syndesmotic ligament rupture. We also found that large (grade 2) effusion in the tibiotalar joint only (without concomitant grade 2 effusion in the talocalcaneal joint) increased more than eightfold the risk for partial or complete syndesmotic ligament rupture. Furthermore, the presence of effusion in any of these joints was associated with an increased risk for severe talar osteochondral involvement, including large subchondral contusions and any acute osteochondral lesion.

The assessment of injury severity in acute ankle sprain is crucial for treatment planning and rehabilitation of athletes and may help in determining recovery times after injury [17–19]. For instance, the occurrence of syndesmotic injury in association with ankle sprains may impact treatment decision and increases the recovery times of athletes, as previously demonstrated in comparison with isolated lateral ankle injury [17, 19]. Accurate

assessment of structural injury severity after acute ankle sprains is limited using clinical examination only, especially when testing the syndesmosis, for which clinical tests demonstrate low sensitivity for the detection of injuries [20]. Furthermore, it was demonstrated that clinical examination in the acute phase of a first-time lateral ankle sprain shows limited predictive value for the development of chronic ankle instability [21]. The occurrence of talar osteochondral involvement associated with ankle sprains may also impact treatment decision and prognosis [22], the presence and severity of such involvement being extremely difficult to assess with clinical examination only.

MRI is the imaging method capable to assess all different structures around the ankle joint including ligament, bone, and osteochondral involvement associated with sprain, with detailed assessment of injury severity [11]. However, MRI is not routinely performed in all patients or athletes with acute ankle sprains as it is costly and thus not widely available. This is why we took advantage of this large cohort of athletes assessed on MRI after sustaining acute ankle sprain, so we could test if the presence and amount of joint effusion are associated with injury severity. As a potential translation to the clinical routine, joint effusion can be easily assessed using ultrasound, which is much more available on a worldwide level than MRI. If the presence of joint effusion were associated with structural injury severity in acute ankle sprain, an initial screening test using ultrasound could potentially be applied to patients and could be used to define which ones would benefit from further MRI assessment (i.e., those exhibiting joint effusion on ultrasound). We demonstrated that for ankles exhibiting severe (grade 2) effusion in the tibiotalar joint (without concomitant grade 2 effusion in the talocalcaneal joint), the risk for partial or complete syndesmotic ligament rupture increased more than eightfold. Most radiologists and sports medicine physicians will agree that one could easily and quickly evaluate the presence and the amount of effusion within the tibiotalar joint using ultrasound. Further, we demonstrated that the presence of effusion in the tibiotalar or talocalcaneal joints was associated with an increased risk for severe talar osteochondral involvement, reinforcing the potential usefulness of initial effusion assessment. Finally, the absence of high-grade effusion in both tibiotalar and talocalcaneal joints, which could be also verified on ultrasound, would likely indicate the absence of syndesmotic ligament injuries (considered in our study as the most severe ligament injury). We showed high specificity and relatively high NPV of grade 2 effusion present in both joints in the detection of syndesmotic ligament injuries.

A number of limitations need mentioning. Although we propose an initial screening of athletes and patients on ultrasound to detect joint effusion and then select which ones should be further explored on MRI, we never compared ultrasound and MRI data. In a population of athletes, the threshold for prescribing an MRI examination certainly differs from that

in the general population, and in our cohort, ultrasound was not performed prior to the MRI systematically. However, it is very likely that the assessment of joint effusion in both imaging techniques at the same moment would be equivalent [13]. Systematic longitudinal clinical follow-up was not available in this cohort, and for this reason, we do not know the relevance of the MRI findings in regard to prognosis, including recovery times. Our cohort consisted largely of male athletes (the majority being football players) who had quick and easy access to MRI, and extrapolating our data to a non-athletic population or athletes in other sports should be performed with caution. Reasons for referral for MRI were not defined in a standardized fashion, but most MRI scans were obtained to rule out or confirm lateral ligament and syndesmotic injuries based on injury mechanism, symptom presentation, and clinical examination.

## Conclusion

We demonstrated in a large cohort of athletes that ankles exhibiting MRI-detected effusion had a higher risk for exhibiting severe injuries such as complete ATFL rupture, partial or complete syndesmotic ligament rupture, and severe talar osteochondral involvement. Based on these findings, athletes or patients sustaining acute ankle sprains could potentially be screened by ultrasound to evaluate the presence and the amount of effusion in the ankle, which is more widely available and less expensive than MRI. If an effusion is present, especially large amounts of effusion in the tibiotalar joint, these ankles could then be further evaluated by MRI given the increased risk for exhibiting severe injuries, including syndesmotic and talar osteochondral injuries.

**Acknowledgments** We thank very much the staff from Aspetar Orthopaedic and Sports Medicine Hospital for their help.

**Funding** The authors state that this work has not received any funding.

## Compliance with ethical standards

**Guarantor** The scientific guarantor of this publication is Michel D. Crema, MD.

**Conflict of interest** Authors MDC, AG, and FWR are shareholders of Boston Imaging Core Lab (BICL), LLC. Author AG is a consultant with AstraZeneca, Genzyme, and Merck Serono. None of the other authors declare any conflict of interest.

**Statistics and biometry** Branislav Krivokapic (University of Belgrade) provided statistical advice for this manuscript.

**Informed consent** Written informed consent was waived by the Institutional Review Board.

**Ethical approval** Institutional Review Board approval was obtained.

## Methodology

- Retrospective
- Cross-sectional study
- Performed at one institution

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