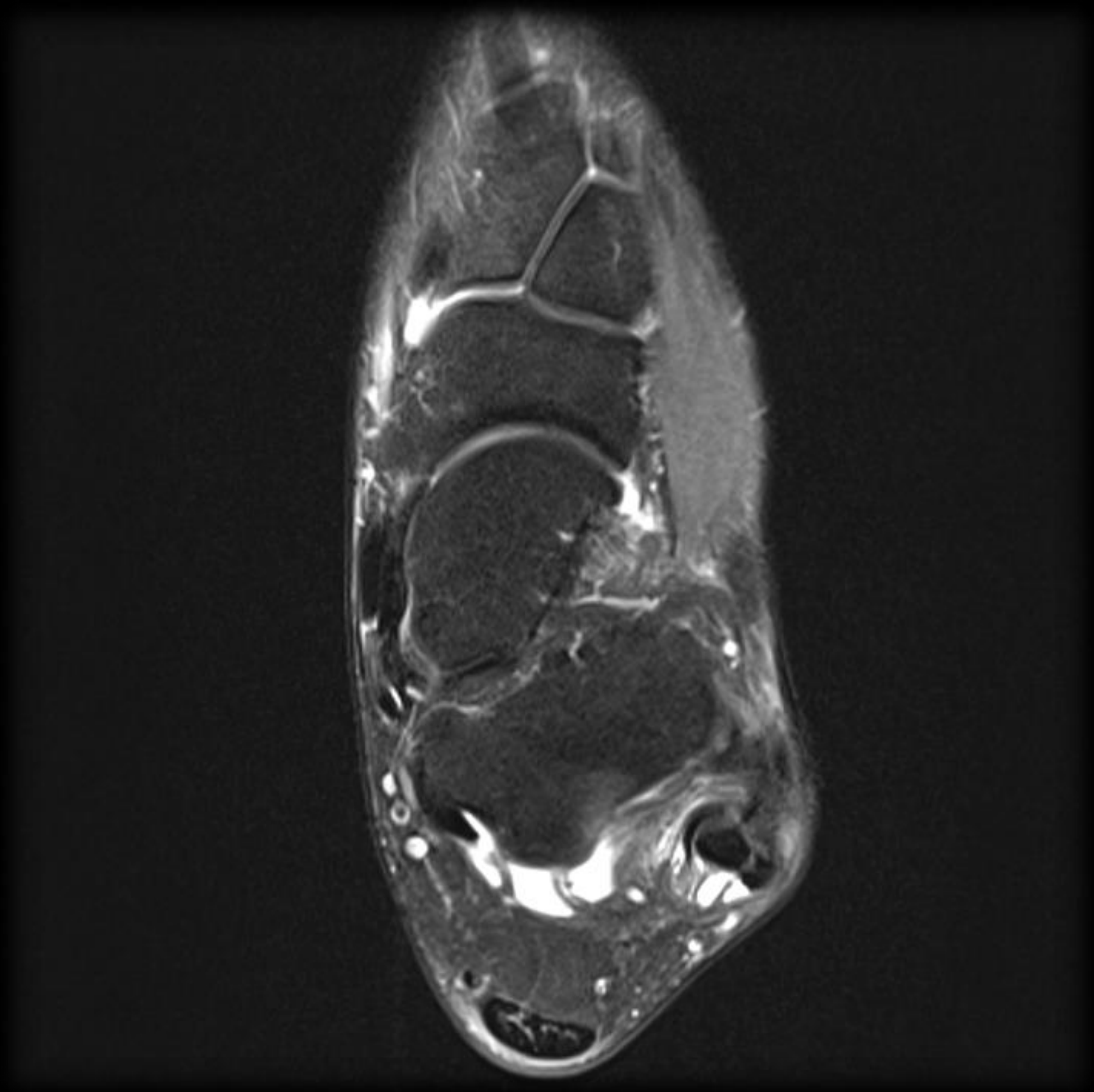
Skeletal MRI Features Associated with Peroneal Tendon Split Tears

2021

– A Comparative Retrospective Cohort Study



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Skeletal MRI Features Associated with Peroneal Tendon Split Tears – A Comparative Retrospective Cohort Study

(MR-skelettmanifestationer vid splitrupturer i peroneussenorna – En jämförande retrospektiv kohortstudie)

Degree Project in Medicine

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Abstract

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Title: *Skeletal MRI Features Associated with Peroneal Tendon Split Tears – A Comparative Retrospective Cohort*

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Background: Peroneal split tears are an underrated cause of ankle pain. While MRI (magnetic resonance imaging) evaluation is useful in diagnosis, the condition is among the most challenging to identify due to complex anatomy and artifacts. Several anatomical variants, soft tissue lesions and skeletal pathologies have been suspected to be associated with the condition. There is a lack of contemporary and comprehensive radiological research studying the relationship between peroneal split tears and other lesions seen on MRI.

Objectives: Investigate whether skeletal anatomical variants and pathologies of the ankle are associated with peroneal tendon split tears.

Methods: This retrospective cohort assessed existing MR images of the ankle in two groups: one with peroneus split tears (N=80) and one without (control group, N=115). Predetermined skeletal anatomical variants and pathologies were noted. The proportion of findings in each group were compared with Fishers exact test and analyzed with Pearson correlation.

Results: Moderate joint effusion, concave malleolar groove, bone marrow edema in the posterior fibula and in the lateral talus were significantly ($p<0.05$, confidence interval not including 0) more common in the split tear group than in the control group. No joint effusion and history of trauma were significantly less common. Distinct correlations in the split tear group were primarily found between bone marrow edema in the medial talus and no joint effusion.

Conclusion: Certain MRI features (i.e., moderate joint effusion, concave malleolar groove, bone marrow edema in the posterior fibula and in the lateral talus) were associated with peroneal split tears and these could potentially inform future research, guidelines and facilitate MRI evaluation.

Keywords: Tendon injuries; MRI; Ankle; Bone marrow; Edema; Anatomical variant.

Background

Ankle disorders are a common clinical problem. Injuries to the ankle constitute up to 10% of all visits to the emergency room (ER) [1] and about 25% of all injuries to the musculoskeletal system are inversion injuries to the ankle. In turn, roughly 50% of these are sport related. The ankle is reportedly the most prevalent injury location in 24 out of 70 sports [2]. While lateral sprains form a plurality of ankle injuries [1], an underestimated cause of ankle pain is split tears of the peroneal tendons. Often mistaken as lateral ligament injuries, only 60% of peroneal tendon ailments are correctly diagnosed on clinical examination [3, 4]. Estimations based on cadaveric dissections put the incidence of peroneus brevis (PB) tendon split tears between 11 and 37 % while split tears in the peroneus longus (PL) tendon are less common [5, 6]. The true incidence of split tears is unknown but most likely higher than reported in the literature due to frequent clinical misdiagnosis [7]. Injuries to the peroneus tendons can also occur in conjunction with lateral ligament injury, exacerbating confusion [2]. Magnetic resonance imaging (MRI) has been described as a useful tool in diagnosing the condition [8]. However, MRI assessment of the tendons can pose a challenge and it is unknown how many peroneus split tears are missed. This study investigated if surrounding MRI features may indicate a peroneal split tear. The background will give an overview of the anatomy of the peroneus tendons, the pathophysiology, symptoms, and treatment of peroneal tendon tears, and the role of MRI in diagnosis. Lastly, the aim of the study will be described.

Normal Anatomy

The peroneal tendons are located on the posterior aspect of the lateral malleolus. They are inferior extensions of two muscles, the PB and the PL. The PB muscle origin from the distal 2/3 of the fibular shaft and anterior intermuscular septum. The PB tendon passes through the fibula’s peroneal groove (syn. malleolar groove), continues down the lateral aspect of the calcaneus and inserts onto the lateral, proximal tuberosity of the 5th metatarsal bone [4].

The origin of the PL muscle is the fibular head, the superior two-thirds of the lateral fibular shaft, and the anterior and posterior crural intermuscular septa. The tendon changes direction while passing the lateral malleolus, and travels below the peroneal tubercle of the calcaneus. After passing through a fibro-osseous tunnel beneath the cuboid bone, the tendon inserts onto the proximal, medial side of the cuneiform and first metatarsal bone [9].

While passing through the malleolar groove, the PB tendon is typically situated anteromedial to the PL tendon. The superior peroneal retinaculum and the calcaneofibular ligament stabilize the tendons in this region [10]. The peroneal tendons are the primary evertors of the foot, dynamic stabilizers [11] and serve an essential role in ankle proprioception [5]. Figure 1 illustrates the anatomy on MRI.

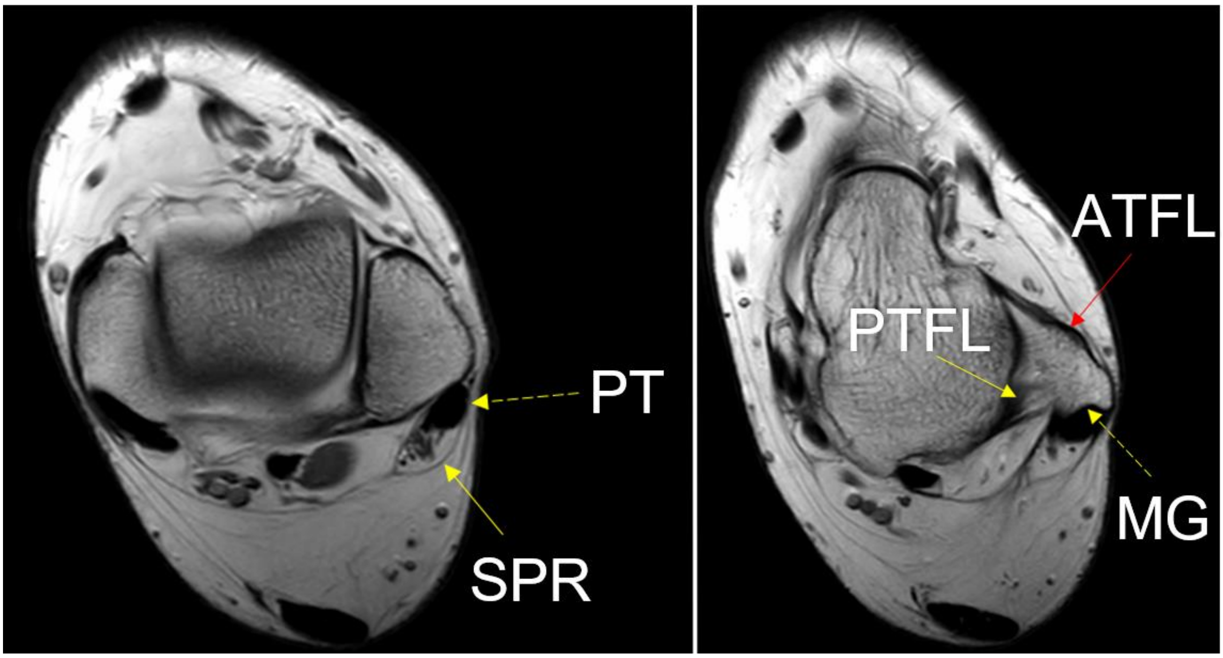

Figure 1: Structures on normal ankle MRI. PT=Peroneal tendons. Note how the brevis and longus are not discernable from each other. SPR=Superior peroneal retinaculum. ATFL=Anterior talofibular ligament. PTFL=Posterior talofibular ligament. MG=Malleolar groove. The shape is concave in this case.

Pathophysiology

The pathophysiology of peroneus tendon split tears is not entirely understood [12]. Injuries to these tendons may be caused by overuse, repetitive subluxation, acute trauma, and inflammation [7, 11]. Tears are more common in the PB than the PL. The most common location for PB tears is the malleolar groove region, while PL tears most commonly occur in the cuboid notch [5, 6]. A traditionally described injury pattern is forced dorsiflexion causing a split of the PB, followed by the PL inserting into the split, obstructing the halves to reconnect [13]. The opening is gradually expanded and if allowed to progress, a longitudinal split develops. Inflammation causes overloading in the malleolar groove, leading to further mechanical stress [7]. Indeed, peroneal tendon tear is often preceded by tendinopathy [4]. Athletes are more prone to injury than the general population due a higher mechanical load on the ankles [2]. Split tears are the most common type of peroneal tear and complete ruptures are rare [4, 13]. It has been hypothesized that peroneus split tears arise through two primary mechanisms: chronic overuse and acute injuries [14, 15].

Symptoms and treatment

Peroneus split tears may primarily cause intense pain in the lateral portion of the ankle [7], with or without a history of trauma. The pain can be ambiguous and may be accompanied by tenderness and warmth, typically in the malleolar groove [3]. Because of their proprioceptive role, another symptom is a feeling of instability, even if all ankle ligaments are intact [5]. Other symptoms are walking difficulties, swelling, pain on touch, and clicking. It can be difficult to distinguish from lateral ligament injury. During functional examination, weakness may be slight or even completely absent. All ages may be affected, but symptoms are more common in younger athletes than the elderly. In fact, half of patients are asymptomatic, and treatment is only used if symptoms are present [3, 16]. Physiotherapy and non-steroidal anti-inflammatory drugs (NSAIDs) are used initially, while surgery can be performed if symptoms persist [7, 10]. Surgical options range from tubularization to tenodesis depending on the tendon’s condition. Outcomes are generally good with a 70-80% success rate and complications are rare. If symptoms and loss of function are minimal, patients generally do well with non-invasive treatment [14]. However, patients may experience symptoms for long periods of time due to initial omittance and misdiagnosis. Difficult diagnosis in conjunction with good treatment outcomes highlight the need for an improved diagnostic process.

Diagnosis and Utilization of MRI

Peroneal tendon tears are usually identified using symptoms, clinical examination and/or imaging techniques [11]. Management relies on accurate diagnosis, particularly in athletes. Injury can render the elite athlete incapable of participating in both training and competition which in severe cases might be career-ending. Correct diagnostics are vital in initiating proper treatment and rehabilitation for the athlete to resume practice [17, 18].

History and clinical examination are essential for diagnosis [14], but clinical examination can be inaccurate in the acute situation due to pain provocation. While plain radiographs and CT can assist in evaluating skeletal ankle morphology and exclude fracture, – MRI can be used to obtain a comprehensive view of the ankle by surveying many structures including ligaments, tendons, and retinaculum. The modality is not limited to acute injury but can also be used in assessing chronic ankle conditions [1]. While axial and oblique images are the most useful in elucidating pathology in the tendons, all three orthogonal planes should be utilized. For dynamical evaluation in real-time, ultrasound imaging can be employed [10, 13, 14].

Although MRI is considered a valuable modality in regards to peroneal disorders [4], it has been stated that MRI alone is not yet sufficient in diagnosing peroneal split tears [12]. The ankle contains many anatomical structures in a relatively small area, making ankle MRI in general, a demanding endeavor [1]. Furthermore, peroneal injuries in turn are among the most challenging pathologies to identify on MRI [13]. The difficulty is in part due to the flattened appearance of the PB tendon and artifacts [4]. At the malleolar groove level, the PB typically flattens in shape as it conforms to the groove while the PL retains a globular contour [10]. On images portraying PB split tears, the tendon may resemble a boomerang or cashew-nut in shape as it wraps around the PL [4], but this is not always the case.

The magic angle phenomenon creates artifacts of increased signal in the peroneus tendons as they curve down the ankle. It occurs when collagen fibers are oriented at an angle of 55º in relation to the B0 main magnetic field and short time of echo (TE) is used (TE less than 32 ms; T1-weighted sequences, proton density sequences and gradient echo sequences). This artifact is most prominent in the subfibular region where a pseudo appearance of torn structures may visualize. The phenomenon can be reduced by positioning the foot at 20º plantarflexion during MRI scanning, allowing differentiation of the two tendons. Another artifact is incomplete fat suppression causing hyperintense signals in the bone marrow, generally seen in the lateral and medial malleolus [11, 19].

These factors impede the potential of MRI. The specificity of MRI in diagnosing tears in the PB and PL is 44 % and 55 % respectively while the sensitivity is 99 % and 96 % respectively [11]. False-positives and false-negatives are cited as complicating factors [5].

To facilitate MRI assessment of peroneal tendon tears, several skeletal MRI features have been identified as potential risk factors and associated landmarks. Some case studies and dissections have found anatomical variants that presumably predispose the peroneal tendons to split. These include prominent peroneal tubercle, os peroneum and variants of the malleolar groove (flat & convex) [11]. Coincidentally, these structures constitute the three points of osseous contact the PL tendon passes. In these locations, the tendon is typically modified with fibrocartilage, presumably to prevent tears due to mechanical stress. Despite reinforcement, PL tendon tear primarily occurs in these three locations [7].

In 40 % of individuals, the peroneal tubercle (also known as the peroneal trochlea) is present on the calcaneus' lateral outline. The size of the tubercle varies and based on cadaveric studies, the peroneal tubercle is prominent (hypertrophied) in 29% of cases [20]. As both the

PB and PL pass the protrusion, it may cause mechanical irritation. Subsequently tendonitis, stenosis and tear of the tendons can arise [5, 7, 10].

Os peroneum is an accessory, sesamoid bone situated within the PL tendon in the region of the cuboid bone. The prevalence is approximately 25% and in 20% of cases the bone is ossified [9]. On MRI, it appears as a an intratendinous osseous structure. When symptomatic, bone marrow edema or sclerosis is usually present [21]. If located more proximally, it may indicate a tear of the PL. Painful os peroneum syndrome (POPS) is a condition where patients experience pain in the area, e.g., due to fracture [10]. Correlations between POPS and peroneus longus tears have been found, indicating a potential mechanism [7, 22].

The malleolar groove is an indentation located at the posterolateral aspect of the lateral malleolus [4]. It can be divided into three morphological variations: concave, flat and convex. The prevalence is divided as 82 % concave, 11 % flat and 7 % convex. These numbers, however, are based on dissections performed in 1927 by Edwards [23] and there seems to be a lack of more recent investigations. It has been suggested that flat and convex grooves can predispose the peroneus tendons to tear through friction [9, 10]. Deepening of the groove (retromalleolar groove deepening) is an orthopedic procedure done in some patients with peroneal tendon luxation, a condition related to split tears [14].

Bone marrow edema is a skeletal pathology often associated with injury where fluid accumulates in the bone marrow resulting in increased MRI signal. In a study investigating the prevalence of ankle bone marrow edema in patients with foot and/or ankle pain, González-Martín et al. found a prevalence of 23 % [24]. The talus was the most affected bone. The significance of bone marrow edema has been appreciated in other anatomical regions. For example, the pattern of bone marrow edema on knee MRI is a recognized tool in diagnosing injuries to the anterior cruciate ligament (ACL). Research has also shown a correlation between bone marrow edema in patients with ACL injury and clinical recovery [25]. It has been suggested that some locations of bone marrow edema also could be linked to peroneal tendon disorders. One location is the lateral and posterolateral fibula. Another is isolated bone marrow edema in the calcaneus, especially the lateral portion, primarily caused by abnormalities in the peroneus longus [6, 26]. Other skeletal pathologies are ankle joint effusion and synovitis. Both are linked to inflammatory conditions, but joint effusion is also related to trauma [27].

The International Olympics Committee (IOC) has repeatedly emphasized the importance of preventing injuries. Because of the wide spectrum of sports injuries, modifying prevention measures for each sport’s injury profile is essential [17]. Understanding the anatomical risk factors and facilitating MRI assessment would aid in both aspects, i.e., prevention and diagnostics. This is not limited to athletes. For many years, certain skeletal MRI features have been suspected to be associated with peroneal split tears. Although some previous studies have investigated the relationship, sample sizes have generally been small, control groups have rarely been used, and results been mixed [9, 28]. From our understanding, no studies have been conducted to investigate the relationship between peroneus split tears, joint effusion, and synovitis.

Aim and Objectives

The aim of this study is to investigate whether there is an association between MRI features of the ankle (i.e., pathologies and anatomical variants) and peroneal tendon split tears. The objectives are two-fold. The first objective is descriptive and is intended to enable the second objective. It investigates the prevalence of bone marrow edema, joint effusion, synovitis, prominent peroneal tubercle, os peroneum, shape of the malleolar groove and history of trauma based on MRI of the ankle in a population with peroneus tendon tears and a control group. The second objective is comparative and investigates whether there are any statistically significant differences between the two groups and if there are any distinct correlations in the group with peroneal tendon split tears.

Material and Methods

Study Design

This study has a retrospective cohort design where already existing MR images of the ankle were analyzed. The investigated parameters were compared using two groups: one consisting of patients with split tears and one control group without split tears. Additional inclusion and exclusion criteria were employed as described below.

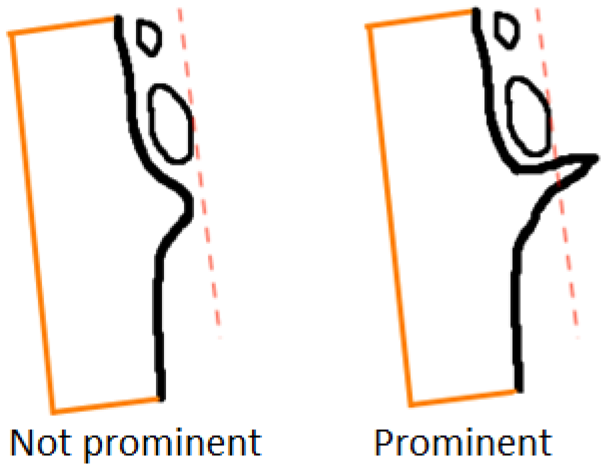

Figure 2: Schematic demonstration of the defined prominent peroneal tubercle, viewed in the axial plane. The protrusion is the peroneal tubercle, and the two round objects illustrate the peroneal tendons. By Pawel Szaro for use in crib sheet.

Anatomical variations were primarily chosen based on those mentioned in the previous literature. It was determined that all variations had to be in the distribution area of the peroneus tendons, for there to be a reasonable anatomical relationship. The anatomical variations chosen were os peroneum, prominent peroneal tubercle and malleolar groove shape. The presence of os peroneum was defined as a separate bone situated within the peroneus longus tendon, typically in the area inferior to the os cuboideum. If the length of the peroneal tubercle, measured from the lateral margin of the calcaneus, exceeded the width of each peroneal tendon it was defined as prominent (as demonstrated in *Figure 2*). Three malleolar groove shapes were included: concave, flat and convex. The shape was assessed at the level of where the posterior talofibular ligament (PTFL) attaches to the fibula. Using measurement tools in the Radiological information system/Picture archiving and communication system (RIS/PACS), a straight line could be drawn through the groove. If the groove curved towards the center of the fibula, away from the measurement line, the groove was considered concave. If the groove neither curved nor protruded from the measurement line it was considered flat. If the groove protruded beyond the measurement line it was considered convex.

To evaluate the occurrence and localization of bone marrow edema, the tibia, lateral malleolus, talus, and calcaneus were divided into sectors (see *Figure 3*). The tibia was divided into three parts: the lateral malleolus, the lateral portion, and the medial portion. The fibula was divided into an anterior and a posterior half. The talus was divided both in terms of superior/inferior and medial/lateral. The calcaneus was divided into a lateral and medial half.

Associated pathological findings were also included. Joint effusion in the talocrural joint was graded (see *Figure 9 in* Appendix p. 1 for illustrations). No gap between the talus and the adjacent fat pad in the anterior joint recess was defined as no effusion (grade 1). Fluid creating a gap between the talus and the adjacent fat pad in the anterior joint recess, as well as fluid expansion of the posterior recess, was defined as moderate effusion (grade 2). If fluid

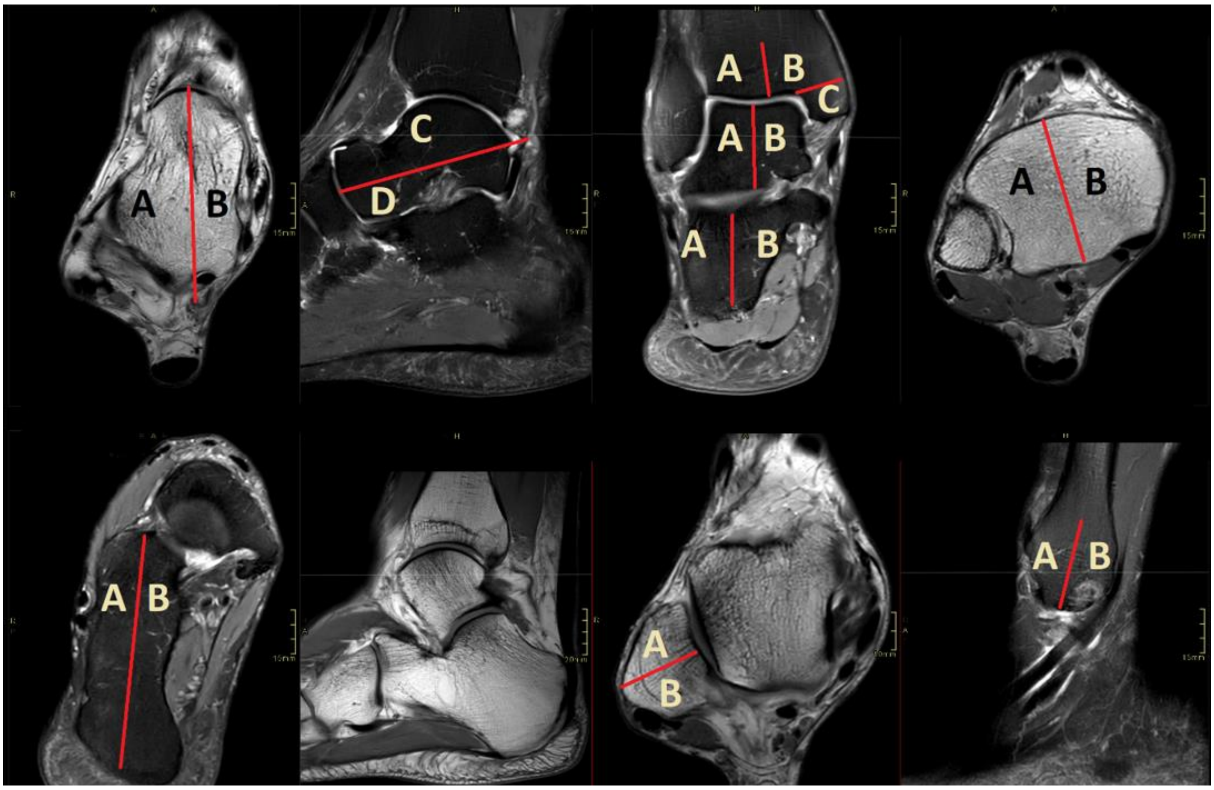

Figure 3: Illustrating the defined distribution areas of bone marrow edema. The fibula and calcaneus are divided into halves, the tibia into ternaries while the talus is divided into four quadrants. By Pawel Szaro for use in crib sheet.

also created a gap between the anterior tibia and adjacent fat pad it was defined as severe effusion (grade 3). Any synovitis in the talocrural joint was noted without grading.

Population and Data Collection

The population investigated was comprised of patients that had undergone MRI of the ankle due to clinical indications at the Sahlgrenska University Hospital (SU) in Gothenburg, Sweden. Patient age was ≥18 years. Exclusion criteria were recent fracture, neoplasm, sequences without angled axial projections, artifacts that obstruct evaluation (e.g., metal artifacts) and conditions which severely altered the appearance of the ankle. These criteria were chosen to include images that allowed for proper evaluation of the peroneus tendons and minimize interfering noise from other conditions and artifacts.

Only MRI-scans conducted after 2017 were included as sequence protocols conducted before that date did not reliably include angled axial projections (required to reduce magic angle phenomenon). Images logged up until 2021-02-10 were included. Protocols used: PD-weighted turbo spin echo (TSE): TE (the echo time) 45 ms, TR (the repetition time) 2800–5000 ms. T2-weighted (TSE) TE 60 ms, TR 3000–5000 ms. T1-weighted: TE 11.5 ms, TR 700–750 ms. Voxel 0.45 × 0.53 × 3.0 mm, slice thickness 3 mm, field of view (FOV) 14 cm. A dedicated ankle coil was used for MRI acquisition.

Two groups were assembled separately, the split tear group and the control group. The RIS/PACS of the hospital (AGFA©) was used to search for patients. Search criteria corresponded to the inclusion criteria (MRI ankle, age ≥18 years, date after 2017). Referrals with requests regarding neoplasms and recent fractures (<6 months) were excluded. A radiologist with 7 years' experience assessed the images of the remaining patients to assort those with peroneal split tears. Peroneal split tear was defined as a radiologically identifiable complete or partial, longitudinal tear of the peroneus brevis and/or peroneus longus tendon(s).

All patients that met the inclusion and exclusion criteria with radiologically confirmed split tears of the peroneus tendon(s), were included in the split tear group.

The control group was assembled in a similar way. Matching exclusion criteria were applied but in contrast, the image sequences were evaluated to *not* include any peroneus split tears or luxation. Using the same search criteria, patients were collected sequentially (starting from the most recent case) from the RIS/PACS by a medical student (10'th semester). Beforehand, the student had undergone a targeted teaching session in ankle MRI evaluation.

A predetermined template in Microsoft Excel© was used to examine the cases and register the data. The image findings included were bone marrow edema location, presence and degree of joint effusion, presence of synovitis, presence of os peroneum, presence of prominent peroneal tubercle and malleolar groove shape (concave, flat or convex). Presence of osteochondritis dissecans was noted in the control group. Simplified versions of bone marrow edema location and joint effusion were also registered. For example, if any bone marrow edema was found in the talus regardless of location, it was registered as simply "Bone marrow edema Talus". For joint effusion, degree 2 and 3 was registered as a positive finding of any "Joint effusion". Patient demographics (i.e., sex, age, and side) were registered. Additionally, if mentioned in the letter of referral, occurrence of trauma was noted. Data collection procedures were done separately by a radiologist and a medical student. The parameters were registered binarily for each patient onto Excel © sheets for documentation and statistical analysis. The final decision was made by consensus and two data sets were created accordingly, one for each group. Thus, all image material was reviewed by the radiologist at some stage.

Statistical Analysis

The number of findings for each parameter was calculated for both groups in Microsoft Excel ©. Additionally, the proportion and percentage of feature occurrence, compared to the total number of patients in each group was calculated (i.e., the probability of a feature occurring in each group). The remaining analyzes were made in the Statistical Package for the Social Sciences program (SPSS) ©. The analyzes are based on comparisons of the probability of feature occurrence in both groups. This supposition was made due to the relatively large size of the groups. In this case, the probability was determined by analyzing feature frequency in the study groups. Binominal proportion confidence intervals (CI, 95 %) were calculated using asymptotic normal approximation and Wilsons's test, to evaluate variance. The data was nominal, in sets of two unpaired groups. Hence, to determine the significance and magnitude of percentual differences, p-values, and CI (95%) were calculated using two-sided Fisher's exact test. Statistical significance was always defined as $p<0.05$.

To investigate bivariate correlations, Pearson correlation was used to analyze the direction, strength (Pearson's correlation coefficient, r) and significance of correlations. The analysis was done on the split tear and control groups separately, but also on both groups combined.

To evaluate the inter-rater reliability of the method, the results from the two parties were compared using Cohen's Kappa coefficient for each parameter using SPSS. Cohen's intervals were used for interpretation; no agreement (≤ 0), none to slight (0.01-0.2), fair (0.21-0.4), moderate (0.41-0.6), substantial (0.61-0.8) and almost perfect (0.81-1.0) [29]. In addition to Cohen's Kappa, crosstabulation of percentual agreement were calculated for each parameter. Cohen's kappa measured the degree of inter-rater reliability while the percentual agreement examined *what* differed in the evaluation. The disagreement proportion, i.e., the number of cases where the student and radiologist made different assessments ("1 0" or "0 1") divided by the total number of cases, were put into two tables: one for each group.

Ethics

The ethical considerations of this study were primarily the management of confidential patient material and the digital storage of said data. Patients were assigned pseudo encrypted codes through which deidentification was achieved. The Swedish Ethical Review Authority approved the study and waived the need for informed consent (number 2020-06-177). The study was performed in accordance with relevant named guidelines and regulations.

Results

Cases were assorted into two groups following the flow chart in *Figure 4*. Nine patients with, and 35 patients without split tears were excluded (to see reasons for exclusion, see *Table 5* in Appendix p. 1). Thereby a total of 80 and 115 cases respectively were found to meet the inclusion- and exclusion criteria. While not registered, almost all images were taken at SU. A few external cases found in the RIS/PACS (images taken at other sites for evaluation at SU) met the study criteria and were included.

*Table 1: Main demographics of the split tear group and control group rounded to the nearest integer, including trauma parameters. * As "history of trauma" could not be determined for all patients, in these calculations N=73 for the split tear group and N=102 for the control group.*

Table 1. Main Demographics of the Study Population

Characteristic	Patients with Peroneus Split tears (N = 80)	Control Subjects (N = 115)
Mean Age ± 1 SD - yrs	50 ± 13	40 ± 14
Male sex – % (no.)	50 (40)	50 (58)
Female sex – % (no.)	50 (40)	50 (57)
Right side – % (no.)	45 (36)	48 (55)
Left side – % (no.)	55 (44)	52 (60)
History of trauma – % (no.) *	40 (29)	63 (64)
Mean time since trauma ± 1 SD – yrs	2 ± 4	2 ± 2

The demographics of the study population are displayed in *Table 1*. The proportions of most demographic parameters were similar in both groups. History of trauma was considerably more common in the control group (63%) than in the split tear group (40%). History of trauma could not be discerned from the referral letter in some cases, meaning N=73 for the split tear group and N=102 for the control group in these calculations. Proportions of PB and PL tears were not registered, but it was observed that most cases had PB split tears.

The feature occurrence can be seen in *Table 2* and *Figure* 5. Most features are similar in occurrence, but some differ. Prevalence of osteochondritis dissecans was 11% in the control group (not displayed in *Table 2*). Group CI calculated with asymptotic normal approximation and Wilson's test were similar. In *Figure 5*, the group CI of three features (Fibula B, Effusion

Table 2: MRI features in the split tear group and control group rounded to the nearest integer. The features are detailed under "Material and Methods".

Table 2. Skeletal MRI Features		
Feature – % (no.)	**Patients with Peroneus Split tears (N = 80)**	**Control Subjects (N = 115)**
Bone marrow edema		
Fibula A	8 (6)	3 (4)
Fibula B	24 (19)	3 (3)
Fibula	24 (19)	4 (4)
Talus A	24 (19)	10 (12)
Talus B	14 (11)	19 (22)
Talus C	23 (18)	17 (20)
Talus D	23 (18)	16 (18)
Talus	33 (26)	25 (29)
Tibia A	13 (10)	4 (4)
Tibia B	10 (8)	7 (8)
Tibia C	15 (12)	10 (11)
Tibia	24 (19)	17 (15)
Calcaneus A	11 (9)	5 (6)
Calcaneus B	8 (6)	6 (7)
Calcaneus	15 (12)	9 (8)
Joint Effusion	50 (40)	38 (33)
1	46 (37)	67 (77)
2	40 (32)	23 (26)
3	13 (10)	10 (12)
Synovitis	15 (12)	17 (20)
Malleolar groove		
Concave	41 (33)	23 (26)
Flat	29 (23)	37 (42)
Convex	29 (23)	40 (46)
Os peroneum	14 (11)	7 (8)
Prominent peroneal tubercle	3 (2)	4 (5)

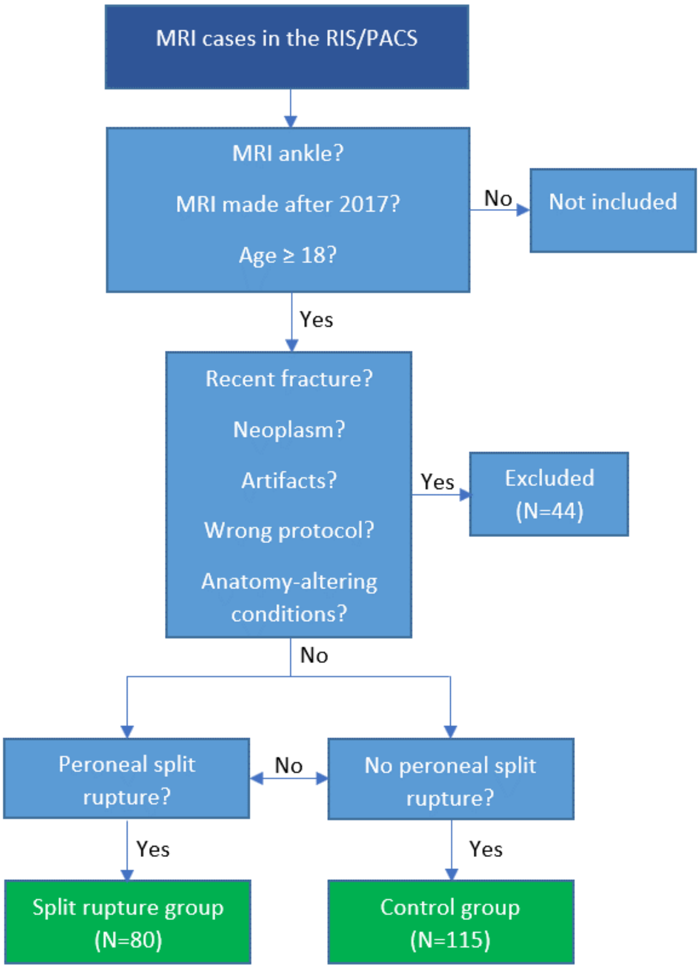

Figure 4: Flow chart demonstrating how MRI cases were collected.

1, Concave malleolar groove) do not overlap, which indicated statistical significance. However, this is not what the main comparisons are based on.

Distribution profiles for bone marrow edema, joint effusion, and malleolar groove shape can be seen in the form of radar plots in *Figure 6*. In the bone marrow edema profile, the control group is almost completely overlapping the split tear group, indicating a shared profile. The exception is the medial talus (Talus B) which was more common in the control group than in the split tear group. The split tear

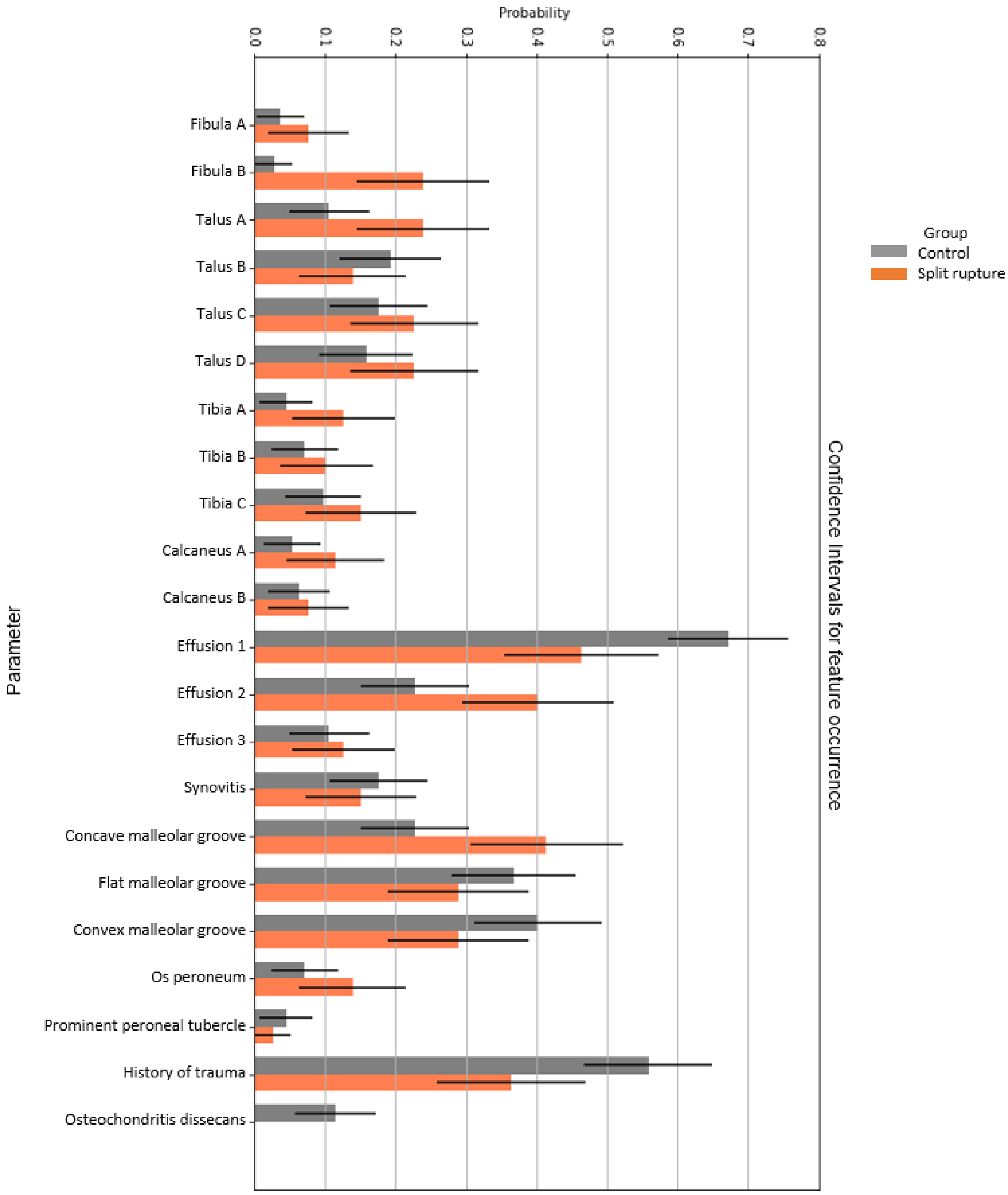

Figure 5: Bar graph visualizing the feature occurrence in both groups. "Fibula A" to "Calcaneus B" are locations of bone marrow edema. "Effusion 1-3" are degrees of joint effusion. Error bars denote 95% confidence intervals. Parameter definitions are described in further detail under Method/Materials.

profile, on the other hand, contain several areas of non-overlap. The most notable are the posterior fibula (Fibula B), lateral talus (Talus A) and lateral tibia (Tibia A). The Effusion profile illustrates how the control group leans more heavily towards no joint effusion (Effusion 1) and the split tear group towards moderate joint effusion (Effusion 2). There is still some overlap. Lastly, the malleolar groove profile demonstrates how the malleolar groove shape was more often concave in the split tear group while the other two shapes were

Figure 6: Radial plots visualizing the occurrence of bone marrow edema ("Bone Marrow Edema profile"), joint effusion ("Effusion profile") and malleolar groove shape ("Malleolar groove profile") in each group compared to the other. The axis unit is the proportion of feature occurrence in relation to the total number of cases in each group, expressed in decimal representation. Overlap indicates similarity.

slightly more common in the control group. Overall, the radial plots reflect the findings of statistical significance in *Table 3*.

Significant differences in percentual feature occurrence between the two groups can be seen in *Table 3*. In the split tear group, bone marrow edema in the posterior fibula and lateral talus, moderate joint effusion and concave malleolar groove were significantly more common.

Table 3: MRI features that were significantly more common in the split tear group than in the control group. P-values rounded to the nearest millesimal, CI to the nearest integer.

Table 3. Statistically significant differences in percentual feature occurrence (split tear group compared to control group)		
Feature	**p**	**95% CI – %**
Fibula B	<0.000	11, 31
Talus A	0.016	2, 24
Effusion 1	0.005	-35, -21
Effusion 2	0.011	4, 31
Concave malleolar groove	0.007	5, 32
History of trauma	0.009	-33, -5

Abbreviations: p=p-value, CI=confidence interval

No joint effusion and history of trauma were significantly less common. 95 % CI limits ranged from 2 to -35%. No other significant differences in percentual feature occurrence were found between the groups.

Several significant correlations were found (for details see *Table 7a-c* in Appendix p. 1). The strongest correlations in the split tear group were a positive correlation (r=0.4) between bone marrow edema in medial talus and no joint effusion, a positive correlation (r=0.32) between bone marrow edema in the anterior fibula and no joint effusion, a negative correlation (r=-0.27) between bone marrow edema in the central tibia and severe joint effusion. In the control group, other correlations were predominant with the strongest being a positive correlation (r=0.27) between bone marrow edema medial talus and severe joint effusion. A negative correlation (r=-0.22) was in fact found between medial talus bone marrow edema and no joint effusion; no correlation was found between bone marrow edema in the anterior fibula and no joint effusion. Neither was any correlation found between bone marrow edema in the central tibia and no joint effusion. Correlations in the control group were weaker than those in the split tear group; none reached r≥0.3. When the groups were combined, a negative correlation (r=-0.15) was still found between bone marrow edema in medial talus and no joint effusion. No correlation was found between bone marrow edema in the anterior fibula and joint effusion. The strongest correlation (0.31) was between medial talus and severe joint effusion. No other significant correlations were found.

Cohen's Kappa varied (for values, see *Table 8* in Appendix p. 2*)*. The Kappa value ranged between 0.03-0.6 in the split tear group and 0.2-0.4 in the control group. In the split tear group, the Kappa value was the lowest (0.03) for "convex malleolar groove" and the highest (0.6) for "Tibia C". The Kappa value was the lowest (0.2) for "flat malleolar groove" and the highest (0.6) for "Tibia C" in the control group. According to Cohen's interpretation intervals, the Kappa values of this study falls under none to slight (4), fair (20), moderate (14) and substantial (2). The relatively low Cohen's Kappa values for the malleolar groove shape is the reason why data was only used from one observer (the student) for this parameter, to improve interpreter consistency.

The disagreement proportion in MRI findings also varied (see *Table 9a-b* in Appendix p. 2). For the split tear group, the disagreement proportion where the student noted a finding while the radiologist did not, ranged between 3-31% and the mean was 15%. Conversely, the range was 0-45% and the mean 7%. Means of disagreement proportion excluding the malleolar groove shape was 15% and 5% respectively. For the control group the ranges were 1-28% and 0-22 % respectively; the means were 17% and 5% respectively. Means were 17% and 3% respectively when malleolar groove shape was excluded.

Discussion

This study set out to investigate the association between skeletal anatomical variants, pathologies of the ankle and peroneus split tears, using a retrospective, comparative cohort method to evaluate existing MRI-sequences. The study found that bone marrow edema in the posterior fibula, bone marrow edema in the lateral talus, moderate joint effusion and concave malleolar groove shape were significantly more common while absence of joint effusion and history of trauma were significantly less common in the split tear group than in the control group. Several statistically significant correlations were found, most notably a distinct correlation in the split tear group between bone marrow edema in the medial talus and no joint effusion.

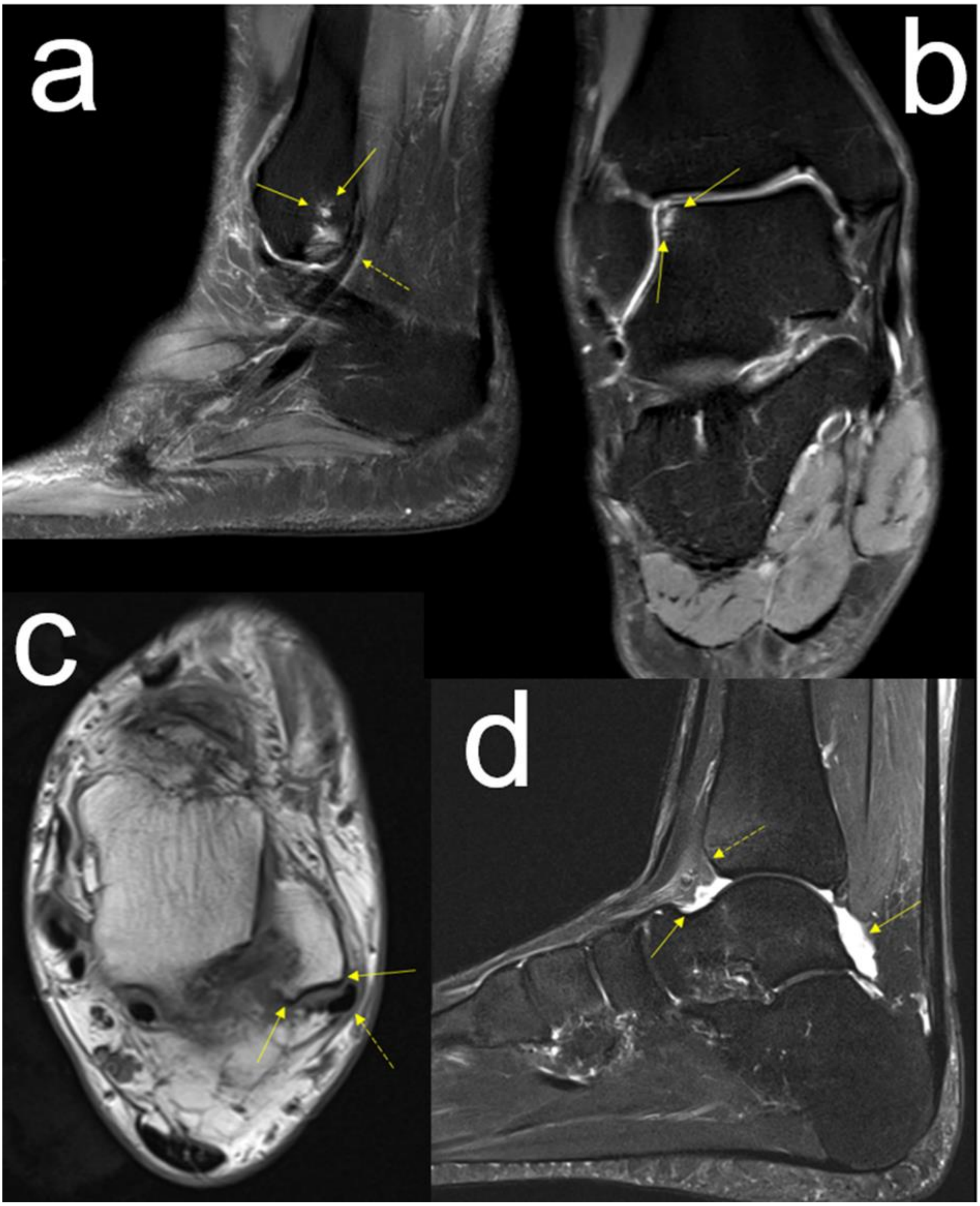

Figure 7: Collage of MR images exemplifying the features that were significantly more common in the split tear group. a) Bone marrow edema in the posterior fibula. Note how the peroneus tendons pass directly behind the fibula (dashed arrow). b) Bone marrow edema in the lateral talus. c) Concave malleolar groove. Dashed arrow pointing at peroneus tendons. d) Moderate joint effusion. Note the fluid expansion in both the anterior and posterior recess, but the anterior tibia is still in contact with the fat pad (dashed arrow) but not the talus (straight arrow).

The results suggest a significant overrepresentation of certain skeletal MRI features in patients with peroneal split tears. Examples of these are shown in *Figure 7*. We believe most of these associations are reasonable. Bone marrow edema in the posterior fibula correspond to tendon vicinity and results of previous research [10]. As can be seen in in *Figure* 7, the peroneus tendons pass directly behind the fibula. The lateral talus has no direct contact with the peroneus tendons but is located relatively close, hence the bone marrow edema could be related to split tears. A connection with osteochondritis dissecans is possible since that lesion is usually also found in the talus [30]. It is interesting that moderate, but not severe joint effusion was overrepresented in the split tear group. Because the amount of fluid is related to the degree of joint structure damage [27], the finding indicates a relationship between peroneus split tears and certain trauma types, but not severe trauma. The significant underrepresentation of no joint effusion was also reasonable as it mirrored the overrepresentation of moderate effusion. While trauma is considered one pathophysiological mechanism, significantly less history of trauma in the split tear group was not unexpected as non-traumatic split tears are known. A possible explanation could be a very high proportion of trauma in control group, giving the impression that trauma was uncommon in the split tear group. It is entirely possible that trauma was overrepresented in the split tear group in relation to the general population. Nevertheless, history of trauma seems to be less common among split tear patients than other patients undergoing ankle MRI.

Beyond the significant differences, it is worth noting that most features were similar in prevalence. This was generally expected, as most of the features had not been linked to peroneus split tears in previous research. Some features had been though (mainly os peroneum, prominent peroneal tubercle and lateral calcaneus bone marrow edema) [4] and finding no significant differences for these features was surprising.

The magnitude in differences between the groups can be interpreted by observing the confidence intervals. The clinical relevance of a 2% (lateral talus) difference is questionable, while -35% (no joint effusion) is a considerable difference. The upper CI limit for lateral talus edema was 24%, which would constitute a substantial difference. The trend of large CI was consistent for all significant results and pinpointing the true difference based on our study is thus difficult. Simultaneously, it does mean all differences have the potential to be substantial.

While several correlations were found, the strongest was found between medial talus bone marrow edema and no joint effusion and a negative correlation for the same feature was found in the control group. This was thus the most distinct correlation in the split tear group compared to the control group. It suggests that the occurrence of one feature is linked to the other; seeing both on MRI indicates a peroneus split tear. The pathophysiological relationship is unclear; however, it might suggest a multifactorial nature.

The distribution of malleolar shapes in neither group matched what was described by Edwards, 1928 (82 % concave, 11% flat, 7% convex) [23]. This was unexpected. Since they examined cases without any specific history of disease, we believe the control group is the most appropriate to compare with. The proportional order is reversed in our study with convex being the most common and concave the least. The prevalence is also less skewed towards either shape. It is difficult to assess which study better correspond to the normal population. The results of their study relied on cadaveric studies of the entire fibula which in theory could yield a more comprehensive appreciation of the peroneal shape, as opposed to MRI evaluation of only one level of the bone. On the other hand, the shape definitions are somewhat unclear, and the study is over 90 years old. While we can contradict the results of Edwards, because of methodological limitations (discussed below) we cannot confidently reject them. It does, however, raise a question on the ubiquitous use of Edward's study. Reasons for dissimilar results could be different methodology, study population as well as individual differences.

Thereby our results differ from the ruling theory that convex and flat grooves lead to peroneal split tears through overcrowding and mechanical stress [7]. From a pathophysiological perspective one could speculate why a concave malleolar groove would predispose the

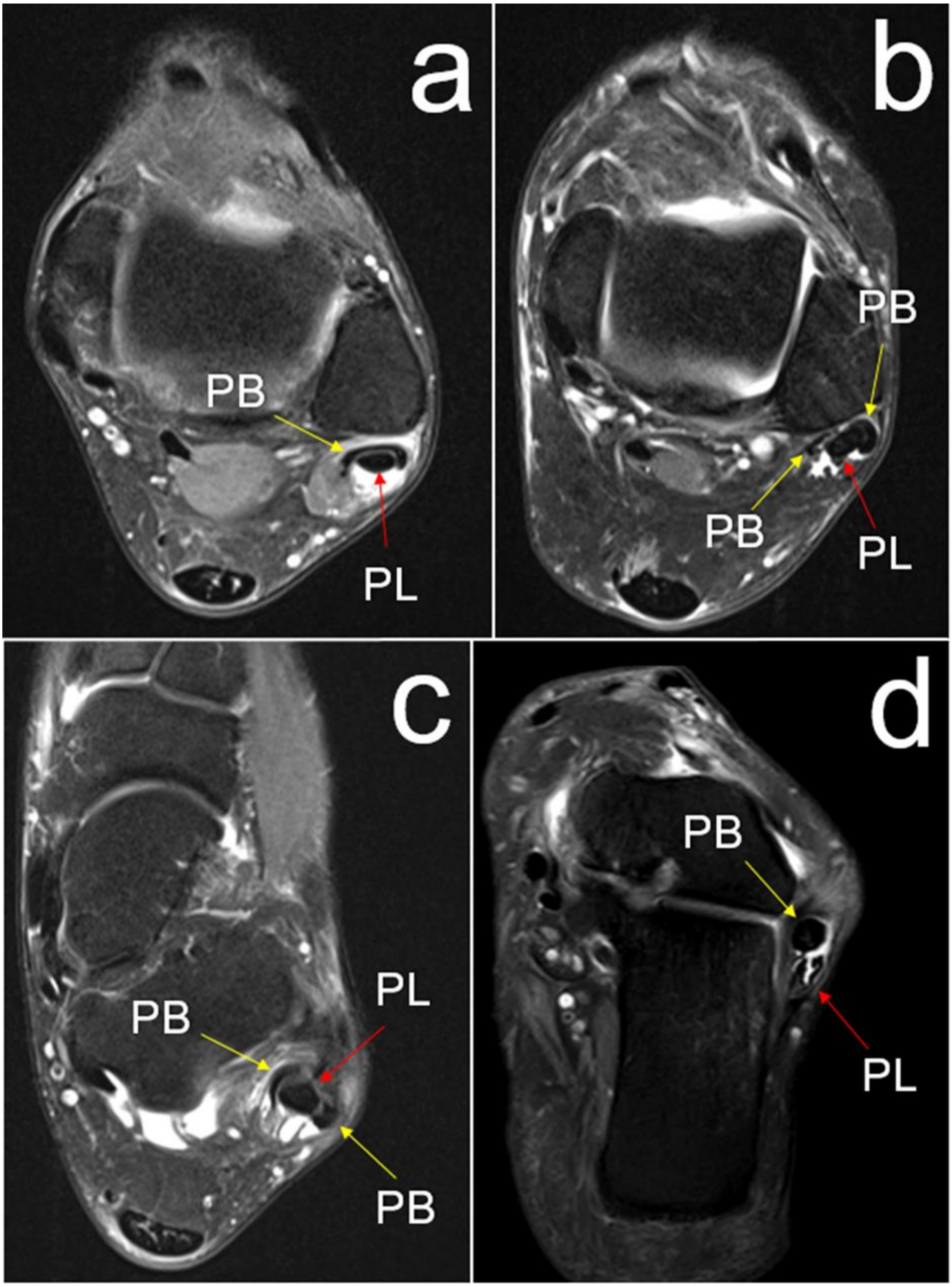

Figure 8: Collage of split rupture cases included in the study. PB=peroneus brevis tendon, PL=peroneus longus tendon. a) Boomerang shaped PB. The PL retains a globular shape and is pushed into the PB. A split was found just below. b) Peroneus brevis split rupture. The PL is inserted between the split halves. c) Different PB split rupture. d) Peroneus longus split rupture. The PL is situated inferior to the PB after passing the malleolar groove.

peroneus tendons to tear. One characteristic that distinguishes the concave malleolar groove from the flat and convex, is the protruding edges located on the outline of the groove. It is possible that some concave malleolar grooves contain sharp ridges, which in combination with repetitive subluxation or trauma could injure the peroneal tendons. Galli et.al. [11] found correlations between peroneal split tear, undulating malleolar groove and osteophytes in the groove, thus alluding to osseus protrusions playing a role in the pathophysiology of peroneus tendon split tears. They did not, however, find any correlation with concave malleolar groove specifically.

The results of the study should also be interpretated in relation to clinical relevance. Our study did not aim to examine patient symptoms. Because peroneus split tears most commonly do not cause symptoms [3], it is likely that some of the cases were asymptomatic. While all MRI-scans were performed on clinical indication, not all indications were related to peroneus split tears. MRI examinations may have been conducted for any indication related to the ankle. The sample was still inherently comprised of cases referred on clinical indication, which should entail a higher proportion of cases with peroneal symptoms (e.g., ankle pain, instability). In contrast, if patients were recruited from the general population, the proportion of completely asymptomatic patients would likely be higher. Maybe more importantly, it is unknown whether asymptomatic and symptomatic peroneus split tears share the same pathophysiological mechanisms or form distinct groups. Thus, we find it reasonable that all peroneus split tears were included, to not miss any potentially relevant cases.

Overall, the results lead us to believe the significant findings are plausible from an anatomical and pathophysiological perspective, and potentially sizable enough to carry clinical relevance. The findings have the potential to serve as “red flags” for peroneal tendon tears during MRI assessment, potentially leading to a quicker and more reliable diagnostic process. There is seemingly a lack of studies on the area, and we believe this study has laid some groundwork and could serve as a steppingstone for future research (discussed below).

The sample was medium-sized, including 80 cases with and 115 cases without peroneal split tears. A larger sample size is preferable as it increases the probability of detecting statistically significant differences in feature occurrence, as well as narrowing the CIs. However, because peroneal split tears are not a common disease and there was a reliance on already existing good quality MRI sequence, the available study population was limited. Despite the limited amount, the study still detected statistically significant findings and relatively speaking, the sample size was substantial. The research to date has tended to only include case series (for example Sobel et.al. N=14 [6], Rademaker et.al. N=9 [9]) and have not dealt with statistical significance. Some studies have had larger sample sizes (for example Galli et.al. N=108 [11], Ersoz et.al. N=69 [28]) but have failed to include substantial numbers of peroneus split tears (N=4 and N=7, respectively). Bojanić et.al. [12] had the largest number of peroneal split tears (N=34), but their study used tendoscopy instead of MRI. We have not found any previous studies including a control group. Consequently, this study possibly includes the largest number of MRI cases with peroneus split tears to date.

In addition to sample size, the following section discusses the study's strengths. Using a control group gathered from the same study population enabled relating the findings in the split tear group to the appearance of other ankle MRIs. Since the control group was recruited from the same image data pool and the same time-period, we believe the material mostly mirror the actual image flow a radiologist would encounter when evaluating ankle MRIs. Images were controlled to be of high, consistent quality with minimal artifacts. Calculating Cohen's Kappa and disagreement proportion allowed for method evaluation, which otherwise would be difficult to assess. Even though no proper randomization was done, gathering patients sequentially for the control group likely reduced the risk of selection bias as compared to picking specific patients. The study is consequently of relatively high quality.

There are some limitations to the study, however. The significant findings possibly correspond to other ankle conditions that were not controlled for (e.g., ligament injury). That said, we have not found any such described in the literature. The inter-rater reliability of the method was variable, perhaps because MRI examinations were assessed by a student and an experienced musculoskeletal radiologist. The plurality of Cohen's Kappa was in the fair interval [29] while almost as many fell in the moderate interval. Cohen's kappa for the malleolar groove shape was the lowest in both the split tear and control group where it reached as low as 0.03. During the evaluation of the MR images, we noticed the shape of the malleolar groove changing dramatically in the longitudinal axis. Even when adhering to the defined level of where the PTFL attached, the shape could change from concave in the upper region to convex in the lower region. Future studies could use a stricter definition of groove level or, alternatively, use 3D-imaging for a more comprehensive view of the malleolar groove.

The main difference between the two examiners, according to the disagreement percentage, was a higher rate of positive findings on the student part. In 46/50 parameters (both groups, excluding malleolar groove shape), the student made more positive findings when the radiologist did not ("1 0"), than vice versa ("0 1"). This could be interpreted as either overdiagnosis on the student part or underdiagnosis on the radiologist part. The earlier was deemed as more likely during the consensus formulation. One could speculate using another musculoskeletal radiologist in place of the student, would increase assessment quality. In the case of malleolar groove shape, however, we believe the anatomical definition rather than observer experience was more impactful. Even though higher inter-rater reliability would have been preferable, when excluding the malleolar groove shape, we consider the result to be acceptable due to the subjective nature of radiological evaluation (e.g., as compared to lab tests). The ankle is one of the most challenging structures to evaluate on MRI and we believe our study reaffirms that notion. If some of the mentioned adjustments were made, we believe the challenge could be partially alleviated and higher inter-rater reliability could be achieved.

No differentiation between PB and PL tendon split tears was made which makes it difficult to comment on potential differences. This also applies to correlations. For example, as described by Wang et.al. [10], bone marrow edema of the lateral calcaneus is thought to be associated with PL tendon ailments specifically, but not necessarily with PB tendon conditions. It is possible that split tears of the peroneus tendons share similar MRI features, but that conclusion cannot be drawn solely based on this study. Instead, this study viewed the ankle in its entirety, including the interrelationships between the two tendons. While most cases had PB tears, the results should be interpreted in the context of peroneus split tears in general, without differentiation between the two tendons.

The demographic parameters noted in this study were sex, age, and history of trauma. Other demographic parameters were unknown due to the limited amount of data provided in the RIS/PACS. Significant associations were only found between peroneus split tear and no history of trauma. It is possible that other demographic parameters could influence the risk of acquiring split peroneus tears and accordingly, the MRI features. These could include smoking, weight, height, and BMI. Ethnicity was not registered or controlled for as a demographic parameter. We are not aware whether any geographic differences in morphology of the peroneus tendons and adjacent skeletal structures exist, but any extrapolation should take the study population into consideration. This also applies to adult age, absence of local recent fracture and neoplasms. If the registered age is accurate, it would suggest that most cases are older patients with chronic overuse injuries and not young athletes.

Because primarily age and history of trauma differed in the two groups, these demographic parameters could potentially be confounding factors. In theory, the findings in the split tear group could be associated higher age, rather than peroneus split tears. We believe the sequential collection of cases in part counteracted the confounding impact and it is thus entirely possible that the typical split tear patient is older and has experienced less trauma.

An environmental factor to consider is the MRI camera. We have no reason to believe that operative procedures and instruments at SU were used inconsistently. While the few cases sourced externally likely entailed different MRI cameras, we find discrepancies unlikely as rigorous measurements were in place to review all image material before inclusion. A technical limitation of the study is the slice thickness of 3 mm theoretically resulting in small lesions located outside the coverage being missed. From our understanding no studies have investigated the potential of 1 mm slice thickness or 3D sequences with isovolumetric voxels for diagnosing split tears and it is therefore difficult to comment on whether it would have an impact. Nevertheless, the 3 mm protocol reflected what was used in clinical practice at said hospital.

As is inherent to the retrospective cohort design, no causal relationships can be determined based on our study. Thus, we do not recommend employing the findings of this sole study in clinical practice yet. However, by taking the results of our study into account, prospective longitudinal studies can be planned. These could be used to inform clinical guidelines. In future research, it would be interesting to employ larger sample sizes and investigate other MRI features and variables. It would also be helpful to research potential differences between PB and PL split tears and the use of different slice thickness and other protocol parameters.

Conclusion

This retrospective cohort study investigated the association between skeletal MRI features and peroneal tendon split tears and found that certain MRI features (moderate joint effusion, bone marrow edema in the posterior fibula and lateral talus) and no history of trauma were significantly associated with the condition. A distinct correlation was found between bone marrow edema in the medial talus and no joint effusion. These could potentially facilitate MRI assessment, enabling faster and more accurate diagnosis for patients but prospective studies are required for causal corroboration. Beyond a shadow of a doubt this study suggests that certain MRI features are associated with peroneus tendon split tears.

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Populärvetenskaplig Sammanfattning

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Säkrare bedömning av skador i vadbenssenorna

Med hjälp av bilder tagna med magnetkamera kan man studera fotledens olika strukturer. Forskare vid Göteborgs Universitet har gjort en studie om hur man lättare ska upptäcka skador i en av fotledens strukturer: vadbenssenorna.

På utsidan av fotleden löper de två vadbenssenorna. Skador i dessa kan orsaka smärta och ostadighet och vid misstanke kan man undersöka med magnetkamera. Magnetkameran tar bilder av fotleden och gestaltar på så vis fotledens olika delar. Det finns dock flera svårigheter i att bedöma just skador i vadbenssenorna på magnetkamera-bilder och inte sällan går skadan oupptäckt under lång tid. Därför har forskare på Göteborgs Universitet försökt ringa in vad som är typiskt i utseendet för en skada i dessa senor.

- ”De här skadorna är svåra att upptäcka med magnetkamera. Vi hoppades på att hitta kopplade fynd i skelettet och på så vis underlätta bedömningen. Samma princip används redan vid korsbandsskador.” säger Michael Huuskonen, läkarstudent och författare till artikeln.

Sedan innan har forskare misstänkt att vissa fynd i skelettet skulle kunna vara kopplade till den här typen av skada. Det handlar bland annat om olika form på vissa av benen i fotleden. Man samlade in bilder från 80 patienter med och 115 patienter utan skada i vadbenssenorna. Därefter undersökte man 15 olika delar av fotledsutseendet i skelettet, i varje grupp och jämförde fynden. Man upptäckte att sju fynd särskilt skiljde grupperna åt. Några av fynden var vanligare hos patienter med skadan. Andra fynd var mindre vanliga. Men vad innebär detta och vad kan det användas till? Studien pekar på att vissa fynd utmärker skador i vadbenssenorna. I framtiden kan läkare förhoppningsvis använda de här fynden som stöd när de ska upptäcka skadorna vilket gör bedömningen säkrare. Patienter kan därför med större pricksäkerhet tidigare få veta vad de lider av och behandling kan påbörjas. Författaren är dock tydlig med att fler studier behövs innan fynden kan användas i praktiken.

Appendix – Skeletal MRI Features Associated with Peroneal Tendon Split Tears

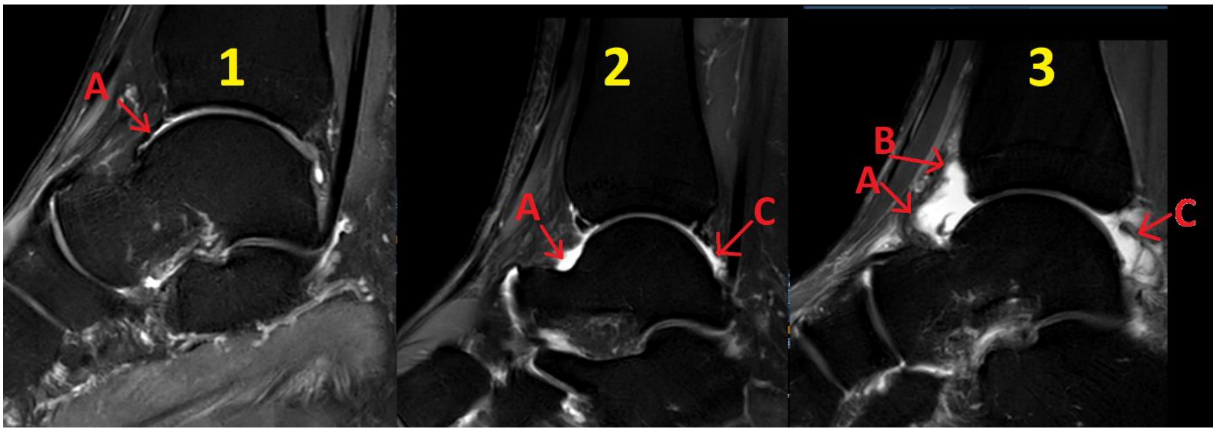

Figure 9: The defined grading of ankle joint effusion. 1) No joint effusion. 2) Moderate joint effusion. Note the fluid expansion in both the anterior (arrow A) and posterior (arrow C) compartment but maintained contact between the anterior tibia and fat tissue. 3) Severe joint effusion. Massive fluid expansion in both compartments. No contact between the anterior tibia and adjacent fat tissue (arrow B).

Table 5: Number of patients excluded for each reason.

Table 5. Excluded cases

Reason for exclusion – no.	Cases with Peroneus Split Ruptures (N = 80)	Control Subjects (N = 115)
Metal artefacts	7	4
Fracture	2	7
Wrong protocol	–	6
Malignancy	–	2
Lim. conditions	–	13

Table 6: Pearson correlations between malleolar groove shape and prominent peroneal tubercle, in each group separately and combined. No significant correlations were found (p<0.05).

	Malleolar Groove Shape	r	p	group
0	concave	0.05	0.46	combined
6	convex	-0.09	0.24	combined
3	flat	0.04	0.59	combined
1	concave	-0.01	0.89	control
7	convex	-0.09	0.35	control
4	flat	0.10	0.27	control
2	concave	0.19	0.09	experimental
8	convex	-0.10	0.37	experimental
5	flat	-0.10	0.37	experimental

Abbreviations: r= Pearson's correlation coefficient, p=p-value.

Table 7a-c: Statistically significant correlations found in each group and the two groups combined. Parameter definitions described under Method/Materials.

Table 7a. Statistically significant correlations (p<0.05) in the split rupture group

Bone marrow edema	Effusion Grade	r	p
Calcaneus A	1	0.22	0.05
Fibula A	3	-0.23	0.04
Fibula A	1	0.32	<0.01
Talus B	3	-0.25	0.02
Talus B	1	0.40	<0.01
Talus D	1	0.25	0.03
Tibia B	3	-0.27	0.01
Tibia B	3	0.25	0.02
Tibia C	1	0.26	0.02

Table 7b. Statistically significant correlations (p<0.05) in the control group

Bone marrow edema	Effusion Grade	r	p
Calcaneus B	1	-0.21	0.03
Talus B	1	-0.22	0.02
Talus B	3	0.27	<0.01
Talus C	1	-0.26	<0.01
Talus C	2	0.19	0.04
Tibia D	1	-0.21	0.03
Talus D	3	0.24	0.01
Tibia B	1	-0.24	0.01

Table 7c. Statistically significant correlations (p<0.05) for both groups combined

Bone marrow edema	Effusion Grade	r	p
Calcaneus A	1	-0.19	0.01
Calcaneus A	3	0.20	<0.01
Talus B	1	-0.15	0.04
Talus B	3	0.31	<0.01
Talus C	1	-0.22	<0.01
Talus D	1	-0.16	0.02
Talus D	3	0.25	<0.01
Tibia B	3	0.19	0.01
Tibia C	1	-0.18	0.01
Tibia C	3	0.17	0.02

Abbreviations: r = Pearson's correlation coefficient, p = p-value

Table 8: Cohen's Kappa coefficient for each parameter in the study groups, rounded to the nearest centesimal.

Table 8. Inter-rater Reliability

Feature – Cohen's κ	**Cases with Peroneus Split Ruptures (N = 80)**	**Control Subjects (N = 115)**
Bone marrow edema		
Fibula A	0,4	0,3
Fibula B	0,5	0,2
Fibula	0,4	0,2
Talus A	0,5	0,2
Talus B	0,4	0,4
Talus C	0,4	0,4
Talus D	0,6	0,4
Talus	0,6	0,4
Tibia A	0,3	0,4
Tibia B	0,3	0,3
Tibia C	0,6	0,4
Tibia	0,6	0,4
Calcaneus A	0,3	0,2
Calcaneus B	0,1	0,3
Calcaneus	0,3	0,3
Joint Effusion	0,5	0,4
1	0,5	0,4
2	0,4	0,3
3	0,4	0,2
Synovitis	0,5	0,3
Peroneal groove		
Concave	0,3	0,4
Flat	0,1	0,2
Convex	0,03	0,3
Os peroneum	0,4	0,3
Prominent peroneal tubercle	0,3	0,4

Table 9a-b: Percentual disagreement proportions for each feature in each group when comparing the two evaluators, rounded to the nearest integer.

Table 9a. Difference in Inter-rating – Split Rupture Group

Feature – %	**Student Positive, Radiologist Negative**	**Radiologist Positive, Student Negative**
Bone marrow edema		
Fibula A	11	1
Fibula B	4	11
Fibula	10	10
Talus A	15	5
Talus B	23	0
Talus C	20	3
Talus D	11	4
Talus	20	3
Tibia A	13	5
Tibia B	21	1
Tibia C	6	4
Tibia	18	1
Calcaneus A	23	1
Calcaneus B	23	4
Calcaneus	31	3
Joint Effusion	13	14
1	14	11
2	18	14
3	3	8
Synovitis	6	6
Peroneal groove		
Concave	30	1
Flat	6	45
Convex	23	14
Os peroneum	18	1
Prominent peroneal tubercle	5	1
Aggregates		
Total mean	15	7
Mean Excluding Peroneal Groove	15	5

Table 9b. Difference in Inter-rating – Control Group

Feature – %	**Student positive, radiologist negative**	**Radiologist positive, student negative**
Bone marrow edema		
Fibula A	8	1
Fibula B	9	1
Fibula	12	1
Talus A	24	4
Talus B	24	1
Talus C	28	0
Talus D	17	3
Talus	33	0
Tibia A	9	1
Tibia B	20	3
Tibia C	12	2
Tibia	20	2
Calcaneus A	22	0
Calcaneus B	16	0
Calcaneus	27	0
Joint Effusion	20	7
1	7	20
2	28	6
3	1	9
Synovitis	4	12
Peroneal Groove		
Concave	13	4
Flat	17	22
Convex	18	17
Os Peroneum	21	0
Prominent Peroneal Tubercle	7	1
Aggregates		
Total mean	17	5
Mean Excluding Peroneal Groove	17	3

Features in each interval for Cohen's kappa

Split rupture group

Total inter-observer agreement

None to slight: 3

Fair: 7

Moderate: 8

Substantial: 2

Control group

Total inter-observer agreement

None to slight: 1

Fair: 13

Moderate: 6

Substantial: 0

Simplified Cohen's Kappa

Bone marrow edema described binary as occurring or not occurring. No sub-localization.

Joint effusion described as occurring or not occurring. No grading.

Split rupture group

Total inter-observer agreement

None to slight: 0

Fair: 1

Moderate: 4

Substantial: 0

Control group

Total inter-observer agreement

None to slight: 0

Fair: 3

Moderate: 2

Substantial: 0

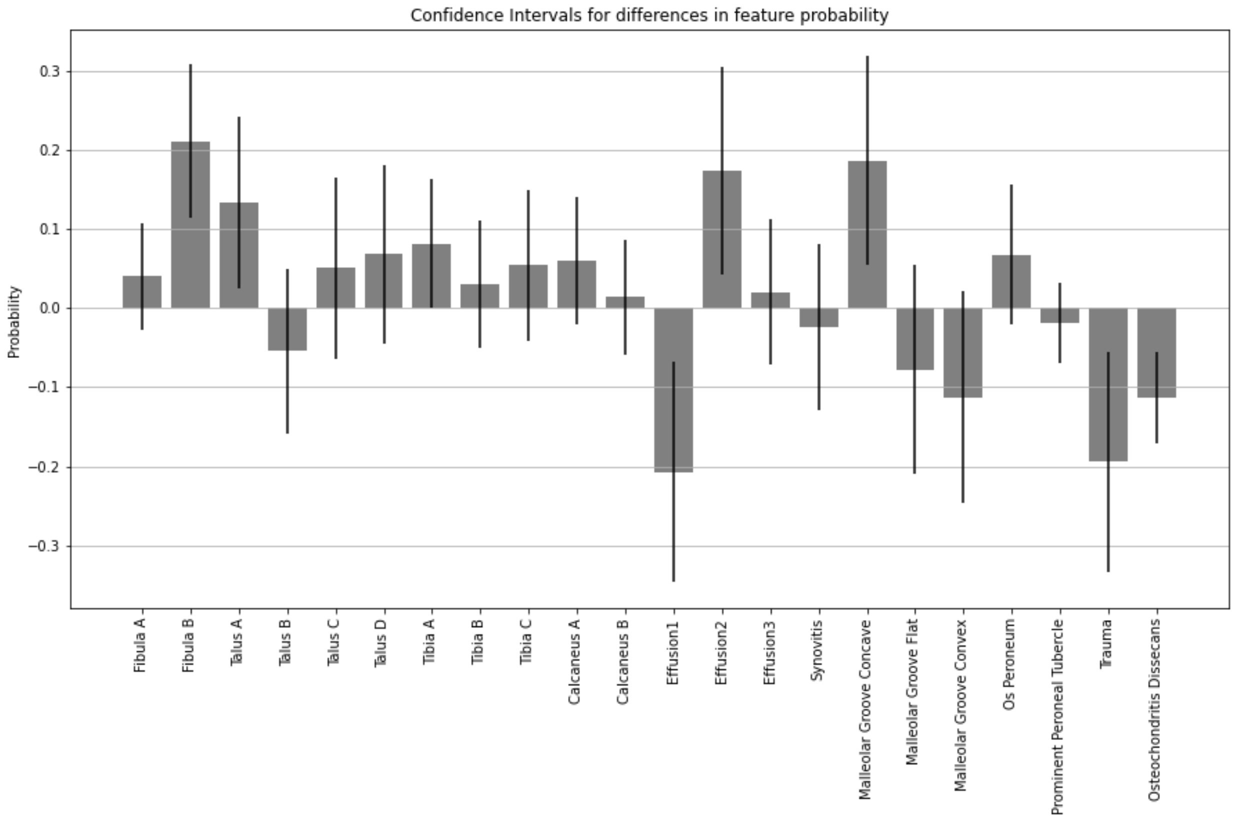

Figure 10: Bar graph illustrating the percentual differences in feature occurrence. Error bars denote 95 % confidence intervals (CI). Features are detailed in Methods/Material.