MRI Findings Associated With Anterior Cruciate Ligament Tears in National Football League Athletes

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Background: Anterior cruciate ligament (ACL) tears are a high-frequency injury requiring a lengthy recovery in professional American football players. Concomitant pathology associated with ACL tears as identified on magnetic resonance imaging (MRI) is not well understood in these athletes.

Purpose: To describe the MRI findings of concomitant injuries associated with ACL tears among athletes in the National Football League (NFL).

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

Methods: Of 314 ACL injuries in NFL athletes from 2015 through 2019, 191 complete MRI scans from the time of primary ACL injury were identified and reviewed by 2 fellowship-trained musculoskeletal radiologists. Data were collected on ACL tear type and location, as well as presence and location of bone bruises, meniscal tears, articular cartilage pathology, and concomitant ligament pathology. Mechanism data from video review were linked with imaging data to assess association between injury mechanism (contact vs noncontact) and presence of concomitant pathology.

Results: Bone bruises were evident in 94.8% of ACL tears in this cohort, most often in the lateral tibial plateau (81%). Meniscal, additional ligamentous, and/or cartilage injury was present in 89% of these knees. Meniscal tears were present in 70% of knees, lateral (59%) more than medial (41%). Additional ligamentous injury was present in 71% of all MRI scans, more often a grade 1/2 sprain (67%) rather than a grade 3 tear (33%), and most often involving the medial collateral ligament (MCL) (57%) and least often the posterior cruciate ligament (10%). Chondral damage was evident in 49% of all MRI scans, with $\geq$1 full-thickness defect in 25% of all MRI scans, most often lateral. Most (79%) ACL tears did not involve direct contact to the injured lower extremity. Direct contact injuries (21%) were more likely to have a concomitant MCL tear and/or medial patellofemoral ligament injury and less likely to have a medial meniscal tear.

Conclusion: ACL tears were rarely isolated injuries in this cohort of professional American football athletes. Bone bruises were almost always present, and additional meniscal, ligamentous, and chondral injuries were also common. MRI findings varied by injury mechanism.

Keywords: ACL; American football; NFL; MRI; meniscal tear; cartilage injury

Anterior cruciate ligament (ACL) tears occur among American football athletes at the collegiate[1] and professional level, with a reported rate of 1.9% per season in the National Football League (NFL).[23] While a number of recent studies have looked at the mechanism of these injuries,[6,17] there is little known about the typical pattern of intra-articular damage resulting from ACL tears in NFL athletes. In a study from 2002 based on the NFL Injury Surveillance System, Bradley et al[3] reported that just over half (53.6%) of ACL tears among NFL players were isolated injuries with concomitant meniscal pathology in 22.5% and other ligamentous and chondral pathology in 23.9%; however, injury reporting and availability of clinical injury data has substantially improved since that time. In a previous study from the Norwegian Knee Ligament Registry and Kaiser Permanente ACLR Registry,[15] American football was associated with a higher risk for

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multiligament injuries than soccer but a lower risk for lateral meniscal and cartilage injuries than basketball. There are no comprehensive analyses of concomitant injuries associated with ACL tears in NFL athletes since implementation of the League-wide electronic health record (EHR) that facilitates more robust injury analysis.[10]

Previous studies in other cohorts have shown that ACL tears are associated with high rates of concomitant injury to the meniscus, articular cartilage, and other ligaments such as the medial collateral ligament (MCL) in the knee, as well as bone bruising.[22,26,27] Understanding concomitant intra-articular injury has potentially important implications in terms of the prevention, diagnosis, management, and expected outcomes of this injury for these elite athletes, particularly since concomitant meniscal and chondral injury at the time of ACL reconstruction (ACLR) is associated with worse clinical outcomes at 5 and 10 years after surgery compared with knees with isolated ACL tears.[2]

The purpose of this study was to describe the magnetic resonance imaging (MRI) findings of concomitant injuries associated with ACL tears among NFL athletes, including bone bruising and injury to the articular cartilage, menisci, and other ligaments. In addition, we explored whether mechanism of injury (contact vs noncontact) is associated with intra-articular findings, with the hypothesis that contact injuries will have more concomitant pathologies identified on MRI at the time of injury.

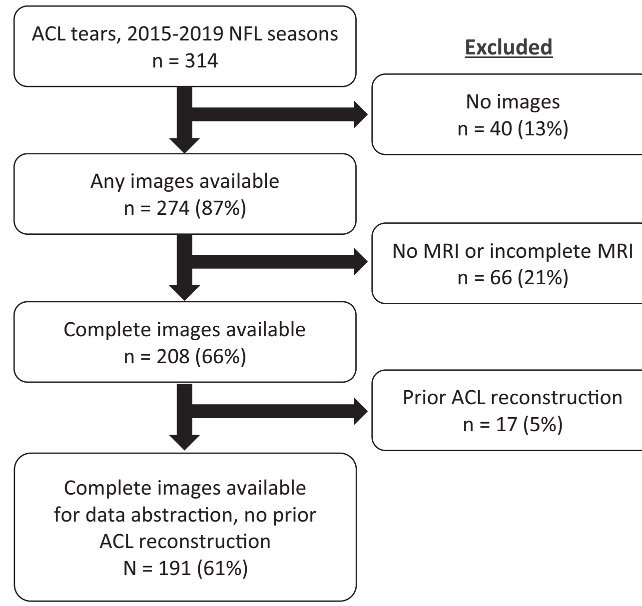

Figure 1. Flow diagram of participant inclusion and exclusion. ACL, anterior cruciate ligament; MRI, magnetic resonance imaging; NFL, National Football League.

METHODS

Approval for this study was obtained from an institutional review board and through the Player Scientific and Medical Research Approval Process of the NFL–NFL Players Association.[20] A total of 314 ACL tears occurring during the 2015 through 2019 NFL seasons were identified. Among these athletes, 294 (94%) had imaging uploaded to the League-wide imaging system (Infinitt), and 274 MRI scans (87%) from the time of injury were identified. The MRI examinations varied in scanner type and pulse sequences, and in order to be included, each imaging study needed to have proton-density, T1-weighted, and fat-suppressed, fluid-sensitive sequences suitable for the assessment of the knee menisci, ligaments, articular cartilage, and bone marrow. Postoperative MRI scans and images that lacked these requirements were excluded. Complete preoperative knee MRI scans relevant to the ACL tear were confirmed in 208 knees (66%). Reinjuries of previous ACLR were identified in 17 knees, and these were excluded from the analysis, resulting in a final study population of 191 MRI scans (Figure 1).

Two fellowship-trained musculoskeletal radiologists (J.C.B. and J.M.C.) with 11 and 20 years of experience, respectively, independently reviewed MRI scans. The anonymized examinations were evaluated in a blinded fashion using the League-wide imaging portal. No information regarding the injury history, subjective symptomology, or other patient characteristics was provided to the radiologists. At the start of the study, the authors met to align on definitions for data points collected, and then both radiologists reviewed 2 rounds of 15 of the same injuries, 20 of which had complete knee MRI scans per the above requirements where data were able to be abstracted, to compare interrater reliability. After each round of review, findings were compared across reviewers and the study team met to further refine definitions for data points collected. After the

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Ethical approval for this study was obtained from Mount Sinai School of Medicine (reference No. STUDY-17-NFL16-CR001).

second round of review, the remaining 208 images were divided between the radiologists for independent review (191 of which had complete knee MRI scans per the above requirements where data were able to be abstracted).

For each MRI, the injury date, study date, and side of the injured knee were noted. The presence, type (partial- or full-thickness), and location (proximal, proximal/mid, mid, mid/distal, or distal) of ACL tear or ACL graft tear were noted. The presence and location of bone bruise (defined as a focal reticular or confluent subchondral bone marrow signal abnormality hypointense to muscle on T1 and hyperintense on fluid-sensitive sequences) were recorded. For meniscal tears, the location (medial or lateral) and pattern (peripheral, complex, radial, bucket-handle, ramp, root, or other) of tear were determined. Articular cartilage was inspected for the presence and location of chondrosis, focal chondral defect, and/or associated loose body. The posterior cruciate ligament (PCL), MCL, lateral collateral ligament (LCL), posterolateral corner (PLC), and medial patellofemoral ligament (MPFL) were evaluated for the presence of sprain (defined as partial-thickness fiber disruption) or tear (full-thickness fiber disruption).

After all images were reviewed, data were aggregated across reviewers. The data were cleaned by 2 independent analysts and the radiologists were queried to clarify any unclear, inconsistent, or missing data. In addition, discrepant findings from the images that were reviewed as part of the interrater reliability analysis were reviewed by the study team (J.C.B. and J.M.C.) and resolved to provide a single data point for the analysis. Data from a previously conducted video review analysis among the same cohort of injuries[4] were linked to the imaging data to assess the association between contact versus noncontact mechanism of injury and concomitant intra-articular MRI findings for injuries from 2018 and 2019. To summarize the video review methodology and descriptive findings from the previous study,[4] 2 academic orthopaedic sports medicine surgeons (R.H.B. and another) reviewed the video clips of each injury to determine whether the injury was noncontact, indirect contact (contact to another body part above or below the knee), or direct contact (contact to the knee). We were able to match each MRI with the video of the corresponding injury when available through the League-wide EHR.[10]

If injury mechanism was not available from this video review, then contact type was used from the EHR as reported by medical staff. Contact-type reporting in the EHR was enhanced before the 2018 season to include 4 contact-type options: noncontact, indirect contact (contact to another body part above or below the knee), direct contact (contact to the knee), and other or unknown. Because of the change in reporting, the analysis of contact type and imaging pathology was restricted to ACL tears in 2018 and 2019 since the EHR-reported definition aligned with the video review–reported definition.

Statistical Analysis

Kappa (κ) statistics were calculated to assess interrater reliability, where >0.90 indicated almost perfect agreement, 0.80 to 0.90 indicated strong agreement, 0.60 to 0.79 indicated moderate agreement, 0.40 to 0.59 indicated weak agreement, 0.21 to 0.39 indicated minimal agreement, and 0 to 0.20 indicated no agreement. The kappa statistics were averaged across all data points collected to determine overall agreement. Mechanism and imaging findings were compared using Fisher exact chi-square tests to test a difference in proportion of pathology by contact type. A confidence level of 95% was set a priori.

TABLE 1
Concomitant Bone Bruises on MRI (N = 191)[a]

Location	n (%)	κ
MFC		1.00
No	147 (77)	
Yes	44 (23)	
MTP		0.90
No	98 (51)	
Yes	93 (49)	
LFC		0.86
No	51 (27)	
Yes	140 (73)	
LTP		0.57
No	37 (19)	
Yes	154 (81)	
Patella		NA[b]
No	182 (95)	
Yes	9 (5)	

[a]LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MRI, magnetic resonance imaging; MTP, medial tibial plateau; NA, not applicable.
[b]Kappa statistics were not able to be calculated for patellar bone bruise because none of the images included in the interrater reliability analysis showed pathology.

RESULTS

A total of 191 MRI scans of primary ACL tears were reviewed. The overall kappa statistic was 0.72, indicating moderate agreement (measure-specific kappa values are presented in the tables). Most MRI scans (98%) were obtained within 1 day of injury, with 67 MRI scans (35%) obtained on the day of injury, 121 MRI scans (63%) obtained the day after injury, 2 MRI scans (1%) obtained 2 days after injury, and 1 (<1%) obtained approximately 3 weeks after injury.

Only 10 knees (5%) did not show evidence of bone bruise in the knee. Among these, bone bruises were most common in the lateral tibial plateau (81%) and lateral femoral condyle (73%) (Table 1). Almost two-thirds of knees had the classic bone bruise pattern[9] on the lateral femoral condyle and lateral tibial plateau (64%), while 40% had bone bruising in the medial compartment in addition to the classic bone bruise pattern laterally.

Additional ligamentous, chondral, or meniscal injury was present in 89% of knees. Meniscal tears were the

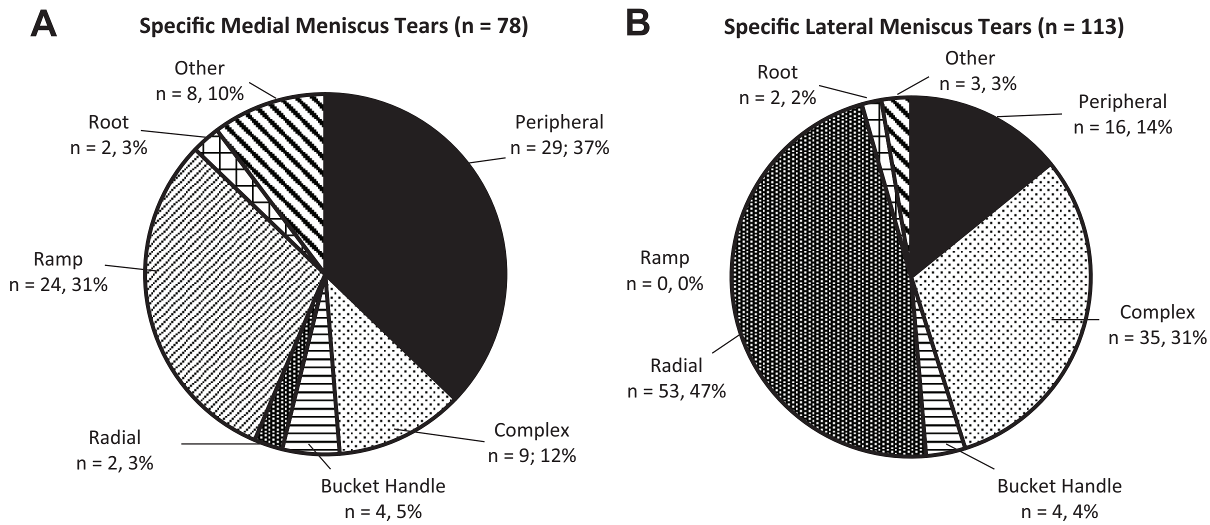

Figure 2. Concomitant (A) medial and (B) lateral meniscal pathology.

most common concomitant injury aside from a bone bruise, present in 70% of knees. Lateral meniscal tears were seen in 59% of the knee MRI scans, while medial meniscal tears were seen in 41% of knees, with evidence of medial and lateral meniscal tears in 30% of knees (Table 2).

The most common tear patterns of the medial meniscus were peripheral tears (37% of medial meniscal tears) and ramp lesions (31% of medial meniscal tears) (Figure 2A), whereas radial (47% of lateral meniscal tears) and complex tears (31% of lateral meniscal tears) were the most common injuries to the lateral meniscus (Figure 2B).

Concomitant ligament injuries of the MCL, LCL, PCL, PLC, and/or MPFL were common (Table 2), present in 135 knees (71%). The MCL was the most likely ligament to have a sprain or tear (57%), while the PCL was the least likely to have any evidence of concomitant injury (10%). MRI evidence of a grade 3 tear in another ligament was present in 23% of knees, most often to the MCL (17%) and MPFL (6%). When an additional ligament had evidence of injury (grades 1-3), the LCL and MCL were the most likely to appear torn on MRI (43% and 31% of injured ligaments, respectively), while the PLC and PCL were the least likely to appear torn on MRI (12% and 15% of injured ligaments, respectively).

Articular cartilage damage (Outerbridge grades 2-4) was present in just under half of the knees (49%), with ≥1 full-thickness cartilage defects (grade 4) in 25% of knees (Table 3). Chondral damage of any kind (grades 2-4) was most common in the lateral compartment, involving the lateral tibial plateau in 61 knees (32%) and the lateral femoral condyle in 27 knees (14%). Chondral defects (grade 4) were most common on the lateral tibial plateau (13%), followed by the lateral femoral condyle (7%) and trochlea (6%). Loose bodies were present in 6% of knees (Table 3).

TABLE 2
Concomitant Meniscal and Ligament Pathology on MRI (N = 191)[a]

	n (%)	κ
Meniscal tear		
No meniscal tear	57 (30)	
Lateral only	56 (29)	Lateral: 0.90
Medial only	21 (11)	Medial: 0.61
Both medial and lateral	57 (30)	
Concomitant ligament injury		
MCL		0.77
Normal	83 (43)	
Sprain	75 (39)	
Tear	33 (17)	
LCL		0.68
Normal	168 (88)	
Sprain	13 (7)	
Tear	10 (5)	
PCL		0.35
Normal	171 (90)	
Sprain	17 (9)	
Tear	3 (2)	
PLC		0.62
Normal	117 (61)	
Sprain	65 (34)	
Tear	9 (5)	
MPFL		0.73
Normal	137 (72)	
Sprain	43 (23)	
Tear	11 (6)	

[a]Sprain was defined as ligament grade 1 or 2; tear was defined as ligament grade 3. LCL, lateral collateral ligament; MCL, medial collateral ligament; MPFL, medial patellofemoral ligament; MRI, magnetic resonance imaging; PCL, posterior cruciate ligament; PLC, posterolateral corner.

TABLE 3
Concomitant Cartilage Pathology on MRI (N = 191)[a]

	n (%)	κ
Articular cartilage		
MFC		0.84
Normal	170 (89)	
Chondrosis	15 (8)	
Defect	6 (3)	
MTP		0.78
Normal	189 (99)	
Chondrosis	1 (<1)	
Defect	1 (<1)	
LFC		1.00
Normal	164 (86)	
Chondrosis	14 (7)	
Defect	13 (7)	
LTP		0.33
Normal	130 (68)	
Chondrosis	37 (19)	
Defect	24 (13)	
Patella		NA[b]
Normal	163 (85)	
Chondrosis	22 (12)	
Defect	6 (3)	
Trochlea		0.80
Normal	168 (88)	
Chondrosis	12 (6)	
Defect	11 (6)	
Loose body		1.00
No	179 (94)	
Yes	12 (6)	

[a]Cartilage damage was graded according to Outerbridge classification: chondrosis = grade 2 or 3, defect = grade 4. LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MRI, magnetic resonance imaging; MTP, medial tibial plateau; NA, not applicable.

[b]Kappa statistics were not able to be calculated for patellar articular cartilage pathology because all images included in the interrater reliability analysis had no pathology observed.

The majority of these ACL tears did not involve direct contact to the injured lower extremity (79%). ACL tears that involved direct contact were more likely to have a concomitant MCL tear and/or an MPFL sprain or tear and less likely to have any meniscal tear and less likely to have a combination of medial and lateral meniscal tears than noncontact and indirect contact injuries (Table 4). Noncontact injuries were more likely to have a concomitant MCL sprain (Table 4) and an associated medial tibial plateau (MTP) bone bruise (Table 5). There were no differences in cartilage injuries according to injury mechanism (Table 6).

DISCUSSION

In this study, very few of the athlete knees that we evaluated had isolated ACL tears; instead, the majority had concomitant ligament or meniscal injuries, and almost all knees had accompanying bone bruises. The MCL was the most common concomitant ligament injury, while the lateral meniscus was more likely to appear torn on MRI than the medial meniscus. Articular cartilage injury was also more likely to be identified in the lateral compartment. The MRI findings varied based on injury mechanism. While this descriptive study cannot determine if the high rate of concomitant intra-articular damage in these knees is due to the ACL tear or suggestive of preexisting pathology, the findings suggest a significant burden of knee pathology in NFL athletes who sustain an ACL tear and highlight concomitant pathology that may influence treatment and return to sport.

These results demonstrate a higher burden of concomitant injury with ACL tears in professional American football athletes than reported previously in the literature. Bradley et al[3] reported that over half of ACL tears in the NFL were isolated injuries, compared with 11% of our cohort. That study, published in 2002, was not based on medically reported injury data and had extremely limited information regarding additional injuries, simply stating that 53.6% of injuries were isolated ACL tears, 23.9% included other ligamentous or chondral pathology, and 22.5% had associated meniscal pathology. Obviously, the paper was not focused on concomitant injury. Other factors that may explain these discordant findings include different injury definition, reporting, and recognition, as well as changes in MRI over time. It is also possible that these differences represented true changes in concomitant pathology over time.

In a study of ACL registries from Norway and the United States (Kaiser),[15] 28% of ACL tears incurred while playing American football were isolated injuries. In that population, meniscal tears were also present in 63% of ACL tears in American football players, similar to the present finding of meniscal tears in 70% of these injuries. However, that cohort had a lower level of chondral injury (27%) than the current cohort (49%). That analysis demonstrated that American football players were 2.8 times more likely to have concomitant injury to the MCL than soccer players, even though the reported rate of MCL tear was much lower (2.8% vs 17%). One obvious possible reason for these differences is that the current cohort only includes professional athletes, which likely made up a small if not negligible portion of the other ACL registry.

The high prevalence of meniscal and chondral injury in NFL athletes may have significant implications for the treatment and outcomes of these injuries considering their impact on clinical outcomes.[2] A history of isolated ACLR at the NFL Combine was not shown to have any impact on the length of career in the NFL, whereas the combination of ACLR and partial meniscectomy was associated with a shorter career.[4] A study based on NFL athletes treated at a single institution also reported no difference in rates of return to sport after ACLR with concomitant procedures.[24] That study seems more aligned with the present data, as only 25% of surgeries were isolated ACLRs, although the overall findings may have been limited by the sample size of 49 and the fact that all ACL tears were treated at the same institution, whereas the present study included all-comer ACL injuries in the NFL. A previous study in NFL athletes based on publicly available

TABLE 4
Concomitant Meniscal and Ligament Pathology on MRI Stratified by ACL Injury Mechanism (n = 73)[a]

	ACL Injury Mechanism				
	Noncontact	Indirect Contact	Direct Contact	*P*	Other/NA
Meniscal tear				**.03**	
No meniscal tear (n = 25)	6 (18)	9 (39)	9 (60)		1 (100)
Lateral only (n = 20)	13 (38)	3 (13)	4 (27)		0 (0)
Medial only (n = 7)	4 (12)	2 (9)	1 (7)		0 (0)
Both medial and lateral (n = 21)	11 (32)	9 (39)	1 (7)		0 (0)
Concomitant ligament injury					
MCL				**<.01**	
Normal (n = 32)	14 (41)	13 (57)	4 (27)		1 (100)
Sprain (n = 34)	20 (59)	9 (39)	5 (33)		0 (0)
Tear (n = 7)	0 (0)	1 (4)	6 (40)		0 (0)
LCL				.87	
Normal (n = 60)	28 (82)	19 (83)	12 (80)		1 (100)
Sprain (n = 6)	3 (9)	1 (4)	2 (13)		0 (0)
Tear (n = 7)	3 (9)	3 (13)	1 (7)		0 (0)
PCL				.88	
Normal (n = 66)	31 (91)	21 (91)	13 (87)		1 (100)
Sprain (n = 7)	3 (9)	2 (9)	2 (13)		0 (0)
Tear (n = 0)	0 (0)	0 (0)	0 (0)		0 (0)
PLC				.87	
Normal (n = 45)	19 (56)	14 (61)	11 (73)		1 (100)
Sprain (n = 22)	12 (35)	7 (30)	3 (20)		0 (0)
Tear (n = 6)	3 (9)	2 (9)	1 (7)		0 (0)
MPFL				**<.01**	
Normal (n = 57)	28 (82)	21 (91)	7 (47)		1 (100)
Sprain (n = 13)	6 (18)	1 (4)	6 (40)		0 (0)
Tear (n = 3)	0 (0)	1 (4)	2 (13)		0 (0)

[a]Data are reported as n (%). Bolded *P* values indicate a statistically significant difference in injury mechanism ($P < .05$). ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; MPFL, medial patellofemoral ligament; MRI, magnetic resonance imaging; NA, not applicable; PCL, posterior cruciate ligament; PLC, posterolateral corner.

TABLE 5
Concomitant Bone Bruise on MRI Stratified by ACL Injury Mechanism (n = 73)[a]

	ACL Injury Mechanism				
	Noncontact	Indirect Contact	Direct Contact	*P*	Other/NA
MFC				.48	
No (n = 52)	22 (65)	18 (78)	12 (80)		0 (0)
Yes (n = 21)	12 (35)	5 (22)	3 (20)		1 (100)
MTP				**<.01**	
No (n = 33)	8 (24)	13 (57)	11 (73)		1 (100)
Yes (n = 40)	26 (76)	10 (43)	4 (27)		0 (0)
LFC				.82	
No (n = 17)	7 (21)	6 (26)	4 (27)		0 (0)
Yes (n = 56)	27 (79)	17 (74)	11 (73)		1 (100)
LTP				.83	
No (n = 11)	5 (15)	3 (13)	3 (20)		0 (0)
Yes (n = 62)	29 (85)	20 (87)	12 (80)		1 (100)
Patella				.50	
No (n = 67)	30 (88)	22 (96)	15 (100)		0 (0)
Yes (n = 6)	4 (12)	1 (4)	0 (0)		1 (100)

[a]Bolded *P* value indicates a statistically significant difference in injury mechanism ($P < .05$). ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MRI, magnetic resonance imaging; MTP, medial tibial plateau; NA, not applicable.

TABLE 6
Concomitant Cartilage Pathology on MRI Stratified by ACL Injury Mechanism (n = 73)[a]

	ACL Injury Mechanism				
	Noncontact	Indirect Contact	Direct Contact	*P*	Other/NA
MFC				.65	
Normal (n = 66)	30 (88)	22 (96)	13 (87)		1 (100)
Chondrosis (n = 5)	2 (6)	1 (4)	2 (13)		0 (0)
Defect (n = 2)	2 (6)	0 (0)	0 (0)		0 (0)
MTP				NA[b]	
Normal (n = 73)	34 (100)	23 (100)	15 (100)		1 (100)
Chondrosis (n = 0)	0 (0)	0 (0)	0 (0)		0 (0)
Defect (n = 0)	0 (0)	0 (0)	0 (0)		0 (0)
LFC				.52	
Normal (n = 65)	29 (85)	20 (87)	15 (100)		1 (100)
Chondrosis (n = 2)	2 (6)	0 (0)	0 (0)		0 (0)
Defect (n = 6)	3 (9)	3 (13)	0 (0)		0 (50)
LTP				.95	
Normal (n = 55)	26 (76)	16 (70)	12 (80)		1 (100)
Chondrosis (n = 10)	4 (12)	4 (17)	2 (13)		0 (0)
Defect (n = 8)	4 (12)	3 (13)	1 (7)		0 (0)
Patella				.86	
Normal (n = 65)	30 (88)	21 (91)	13 (87)		1 (100)
Chondrosis (n = 6)	3 (9)	1 (4)	2 (13)		0 (0)
Defect (n = 2)	1 (3)	1 (4)	0 (0)		0 (0)
Trochlea				.30	
Normal (n = 64)	32 (94)	18 (78)	13 (87)		1 (100)
Chondrosis (n = 3)	1 (3)	1 (4)	1 (7)		0 (0)
Defect (n = 6)	1 (3)	4 (17)	1 (7)		0 (0)

[a]Data are reported as n (%). ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MRI, magnetic resonance imaging; MTP, medial tibial plateau; NA, not applicable.
[b]All pathology was normal.

information reported no difference in rates of return to sport after ACLR if there was concomitant knee injury.[11] Publicly available injury data are heavily limited and may be biased,[16,19] however, and the study authors admitted a lower rate of concomitant knee injury than expected (18.5%), which appears inaccurate based on the current data. A recent study of athletes in the National Hockey League (NHL) reported that players with ACL injuries with a concomitant meniscal tear had a shorter career than controls or players with an isolated ACL tear.[25] In a study of professional basketball, players with an ACL tear and concomitant injury were 3.2 times less likely to return to sport than players with an isolated ACL tear.[7] More research is needed to determine how additional intra-articular injury relates to the treatment and outcome of ACL tears in American football athletes.

Interestingly, there is a high prevalence of bone bruising (95%) in this cohort compared with a more generally accepted prevalence of approximately 80%.[21] In a previous study comparing ice hockey with other sports, among which American football was the largest contributor at 43.5% of cases, lateral tibial plateau bone bruising was present in 93% of ACL tears from other sports,[18] which is actually higher than the prevalence of 81% in NFL athletes. A lateral femoral condylar bone bruise was present in 93% of ACL tears from other sports, also higher than the prevalence of 73% in professional American football players. They reported that lateral meniscal tears were present in 58.5% of knees injured during other sports, very close to the rate in this study of 59%. Similarly, they found that 37% of knees injured playing sports other than hockey had evidence of a medial meniscal tear, only slightly less than the 41% of knees in this cohort. MCL injuries were present in 31.2% of knees injured during other sports, which is similar to the 39% of knees with ACL tears in a cohort of primarily soccer and handball athletes.[12] While the prevalence of MCL injury (57%) in NFL athletes was higher than these reports, it was lower than a study of ACL injuries from the NHL Injury Surveillance System, which reported a 68% prevalence of concomitant MCL injury.[25] This NHL study also reported a 68% prevalence of concomitant meniscal injury, very close to the prevalence of 70% in the NFL.[25] Differences between the current study of NFL athletes and studies of professionals in other sports may reflect sport-specific activities and demands as well as differences in assessment of reporting of these injuries.

The findings of the current study are actually similar to those of a recent study of the general population out of Iceland.[22] In that study of 1365 MRI examinations of knees with ACL tears, only 13% had no other injury, almost as low as the 11% reported herein. Meniscal tears were present in 70% of knees, the same as the current finding of meniscal tears. Their distribution of meniscal tears was different, however, as medial meniscal tears (55% of knees) were more common than lateral meniscal tears (42% of knees), opposite the findings in NFL athletes with more lateral meniscal tears (59%) compared with medial meniscal tears (41%). The largest difference between studies was a much lower rate of bone bruising in the general population (57%) than in professional American football athletes (95%). This could have been the result of a number of factors, including the young age of the professional athletes in the current cohort as well as the very early timing of MRI scans relative to injury. Two important limitations of this study from Iceland include a complete lack of data regarding the time interval between injury and imaging and that the study relied on MRI reports rather than review of the images themselves.

One of the interesting aspects of the current investigation that distinguishes it from previous studies is the very short interval between ACL injury and imaging. This is particularly relevant to the findings regarding bone bruising, which is generally thought to diminish over time, possibly as soon as 3 or 4 weeks after injury.[9,13,22,28] The authors are not aware of any prior study with such a short interval from injury to imaging, and this may explain why the prevalence of bone bruising is relatively high. Rapid imaging acquisition is also relevant to the prevalence of associated injury, as multiple studies have shown that time from injury to treatment is associated with the extent of meniscal and chondral injury at the time of ACLR.[8,14] With that in mind, the prevalence of additional injury appears higher than what might be expected so soon after an ACL tear.

The association of intra-articular findings with ACL injury mechanism is another notable finding. The association of direct contact with MCL tears and MPFL injuries likely reflects that at least some of these injuries likely include a valgus force on the knee, which could also contribute to a lower likelihood of medial meniscal tear. This may also explain the lower incidence of medial meniscal tears in direct contact injuries, as the distraction of the medial compartment from an external valgus force could reduce the stress on the medial meniscus, making it less likely to tear. Why noncontact injuries are more likely to have an MCL sprain and bone bruise in the MTP may not be as obvious. Indirectly, a higher incidence of MTP bone bruising could suggest a higher risk for ramp lesions, which are known to be associated with this finding.[5]

Limitations

This study has a number of limitations. MRI scans were not available in the League's centralized imaging system for all ACL injuries, and it is possible that those injuries without an MRI scan in the system were inherently different; however, the large sample size of 191 injuries included 61% of the ACL injuries in the League during this 5-year study. It is impossible to know why MRI scans were not available for all athletes as it is plausible that some athletes did not have an MRI, although it is more likely that the MRI was not uploaded to the centralized imaging system. NFL players are unique, as are the injuries they sustain, and results may not be generalizable to nonelite levels of American football or to other sports or nonathlete populations. The study did not evaluate player-specific variables such as position, draft status, or years in the NFL, as the focus of this study was to assess the global burden of additional intra-articular injuries accompanying ACL tears in these athletes. Intraoperative confirmation of the MRI findings is not available, with the potential discrepancy of over- and/or undercalling pathology. Treatment data were not available, so the study does not include follow-up data on the relationship between these findings with recovery and return to sport. Future research incorporating treatment strategies is necessary to fully understand how concomitant pathology may be related to return to play and time lost.

The heterogeneity in terms of location, MRI examination technique, and scanner is both a limitation and a strength in terms of the generalizability of the findings. While the heterogeneity may influence ability to observe concomitant pathology in certain cases, this heterogeneity is likely reflective of real-world variability in imaging equipment and protocols. There is also real-world variability in imaging reviews, and in this case, radiologists were blinded from some demographic and clinical patient information. Kappa statistics suggested moderate agreement overall between reviewers, which, while acceptable, suggests some differences of opinions. Given the large sample size, this is likely to have minimal impact on overall findings as discrepancies between reviewers tended to occur between grades/severity of a specific pathology (eg, chondrosis vs defect) as opposed to between the presence or absence of a concomitant pathology. However, it is important to point out that the radiologists met to review the definitions of various pathologies before viewing the images, which could have biased the study toward greater agreement than might have occurred otherwise.

CONCLUSION

The study findings showed that 61% of ACL tears in NFL athletes with MRI scans available are rarely isolated injuries, as ~90% present with damage to other structures in and around the knee. MRI findings are associated with mechanism of injury in this cohort. Almost all knees had bone bruising on MRI. Meniscal tears were the most common additional injury aside from bone bruising, involving the lateral meniscus more often than the medial meniscus. Ligamentous injury most often occurred on the medial side of the knee (MCL), while chondral injury, like meniscal injury, occurred more often in the lateral compartment. These findings may have important implications for the treatment, rehabilitation, and outcomes of these athletes.

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