

## [ Orthopaedic Surgery ]



# Knee Osteoarthritis Is Associated With Previous Meniscus and Anterior Cruciate Ligament Surgery Among Elite College American Football Athletes

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**Background:** Football puts athletes at risk for knee injuries such as meniscus and anterior cruciate ligament (ACL) tears, which are associated with the development of osteoarthritis (OA). Previous knee surgery, player position, and body mass index (BMI) may be associated with knee OA.

**Hypothesis:** In elite football players undergoing knee magnetic resonance imaging at the National Football League's Invitational Combine, the prevalence of knee OA is associated with previous knee surgery and BMI.

**Study Design:** Retrospective cohort.

**Level of Evidence:** Level 4.

**Methods:** A retrospective review was performed of all participants of the National Football League Combine from 2005 to 2009 who underwent magnetic resonance imaging of the knee because of prior knee injury, surgery, or knee-related symptoms or concerning examination findings. Imaging studies were reviewed for evidence of OA. History of previous knee surgery—including ACL reconstruction, meniscal procedures, and articular cartilage surgery—and position were recorded for each athlete. BMI was calculated based on height and weight.

**Results:** There was a higher prevalence of OA in knees with a history of previous knee surgery (23% vs 4.0%,  $P < 0.001$ ). The prevalence of knee OA was 4.0% in those without previous knee surgery, 11% in those with a history of meniscus repair, 24% of those with a history of ACL reconstruction, and 27% of those with a history of partial meniscectomy. Among knees with a previous ACL reconstruction, the rate of OA doubled in tibiofemoral compartments in which meniscal surgery was performed. BMI  $>30 \text{ kg/m}^2$  was also associated with a higher risk of OA ( $P = 0.007$ ) but player position was not associated with knee OA.

**Conclusions:** Previous knee surgery, particularly ACL reconstruction and partial meniscectomy, and elevated BMI are associated with knee OA in elite football players. Future research should investigate ways to minimize the risk of OA after knee surgery in these athletes.

**Clinical Relevance:** Treatment of knee injuries in football athletes should consider chondroprotection, including meniscal preservation and cartilage repair, when possible.

**Keywords:** knee osteoarthritis; football; ACL; meniscus

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Elite American football players are at a high risk of knee injury. Among players at the National Football League's (NFL) Invitational Combine, where collegiate players considered strong prospects for a career in professional football are evaluated for their potential to participate at the professional level, more than 50% reported a history of previous knee injury and more than 25% had undergone previous knee surgery.<sup>1,2</sup> Recent studies have reported the prevalence of full-thickness articular cartilage lesions among athletes at the NFL Combine,<sup>5,6</sup> but there are no data on the prevalence of osteoarthritis (OA) in these athletes. Risk factors for knee OA in this young population have not been well described or studied. The purpose of this study was to assess the relationship of previous knee surgery, particularly previous meniscal surgery and anterior cruciate ligament (ACL) reconstruction, body mass index (BMI), and player position with knee OA in elite American football athletes. Our hypothesis is that the prevalence of knee OA is higher in players with previous knee surgery and a higher BMI in elite football players undergoing knee magnetic resonance imaging (MRI) at the NFL Invitational Combine.

## METHODS

Institutional review board approval was obtained at the Washington University School of Medicine prior to conducting the investigation. The current study used identical methods to a previously published study looking at the prevalence of focal full-thickness cartilage defects in these athletes.<sup>6</sup> A retrospective review was performed of all NFL Combine participants undergoing knee imaging from 2005 to 2009. During this period, 594 players with 723 knees that had undergone radiographic imaging and an MRI were identified. This represented 35.9% (594/1654) of all players at the NFL Combine over this 5-year period.

The medical history was generated for each athlete at the NFL Combine from direct interview by both athletic trainers and physicians and from information provided by the college athletic training staff. The type of any previous knee surgery was recorded, including partial meniscectomy or meniscal repair, ligament reconstruction and treatment of articular cartilage lesions based on medical records and interview of the athlete. Operative reports were reviewed when available. Current symptoms and all physical examination abnormalities were documented based on medical records and history and physical examination performed at the Combine. Most athletes at the NFL Combine are asymptomatic and are performing at a high level.

A series of knee radiographs, including a posterior-anterior weightbearing image with the knee flexed to 40°, a nonweightbearing lateral radiograph at 30°, and a bilateral Merchant view of the patellofemoral joint, was performed on all athletes with a history of knee injury or surgery and any athlete with clinical symptoms or examination findings indicating potential knee injury. An MRI using standard protocols at 1.5 T without intra-articular gadolinium was obtained in players

considered to be at risk for intra-articular pathology of the knee based on their injury/surgery history, prior or current symptoms, and examination findings. Players with bilateral knee MRIs are included in the analysis twice (as 2 separate knees). All athletes with a history of any knee surgery, any current knee symptoms, or any abnormalities of the knee on physical examination underwent imaging.

Plain radiograph reports by musculoskeletal radiologists for all athletes were reviewed for any mention of joint space narrowing. The radiographs and MRIs for athletes with any mention of joint space narrowing in the radiologists' reports were reviewed. For the purposes of this analysis, OA was defined as either (1) the presence of moderate-to-severe nonfocal articular cartilage loss on MRI or (2) evidence of joint space narrowing on plain radiographs. The MRI findings of 19 players with a history of previous treatment of a focal full-thickness articular cartilage defect were excluded from statistical analysis. While these patients are at risk for developing OA, a focal articular cartilage lesion with no other changes on MRI does not qualify as OA. The posterior-anterior weightbearing radiographs and the Merchant views included the contralateral knee. Joint space narrowing of the affected knee was determined by comparing it with the same compartment in the contralateral knee. No attempt was made to quantify the degree of arthrosis as this was not a primary aim of the study and because there was a limited incidence of advanced degenerative disease in the cohort.

The association between potential risk factors and knee OA was analyzed using chi-square analysis. A *P* value <0.05 was considered significant. Statistical analysis was performed using SPSS software (IBM Corp).

## RESULTS

### Demographics

The mean age of players in this cohort was 22.8 years (range, 20-26 years) and the mean BMI was 31.8, with 59.3% of players having a BMI >30 kg/m<sup>2</sup>. Surgery had been performed on 423 of the 723 knees (58.5%). Meniscus surgery had been performed in 257 knees (35.5%), and 137 knees had undergone ACL reconstruction (18.9%), including 7 revisions (1.0%).

### Osteoarthritis

OA was present in 104 (14.8%) of the 704 knees based on MRI or plain radiographic evidence: 53 by MRI alone, 28 by plain radiographs alone, and 23 by both plain radiographs and MRI. Lateral compartment involvement was seen in 66 (63.5%) of the 104 knees with OA by MRI or plain radiographs. Twenty knees (19%) had evidence of involvement of more than 1 compartment.

### Factors Associated With Osteoarthritis

OA was significantly associated with any previous knee surgery (*P* < 0.001), surgery for a meniscal tear (*P* < 0.001), as well as a previous ACL reconstruction (*P* = 0.001) (Table 1). Lateral

Table 1. Association of previous knee surgery with osteoarthritis<sup>a</sup>

	(-) History	(+) History	P Value
Surgery	12/300 (4.0)	92/404 (23)	<0.001
Meniscus	39/454 (8.6)	65/250 (26)	<0.001
Partial meniscectomy		62/226 (27)	
Meniscal repair		2/18 (11)	
ACL reconstruction	72/570 (13)	32/134 (24)	0.001
Primary		29/127 (23)	
No meniscal surgery		15/75 (20)	
Meniscal surgery		14/52 (27)	
Revision		3/7 (43)	

ACL, anterior cruciate ligament.

<sup>a</sup>Values in parentheses are percentages.Table 2. Association of previous knee surgery with osteoarthritis in the lateral compartment<sup>a</sup>

	Osteoarthritis		
	(-) History	(+) History	P Value
Meniscal surgery	22/523 (4.2)	44/179 (25)	<0.001
Partial meniscectomy		42/163 (26)	
Meniscal repair		2/14 (14)	
Failed meniscal repair		0/2 (0)	
ACL reconstruction	44/570 (8.0)	22/134 (16)	
No lateral meniscal sx.		12/96 (12.5)	
Lateral meniscal sx.		10/38 (26.3)	0.052

ACL, anterior cruciate ligament; sx, surgery.

<sup>a</sup>Values in parentheses are percentages.

meniscal tears were significantly associated with lateral compartment OA ( $P < 0.001$ ) (Table 2). Similarly, medial meniscal tears were significantly associated with medial compartment OA ( $P < 0.001$ ) (Table 3).

ACL reconstruction was significantly associated with both medial and lateral compartment OA ( $P = 0.002$  and  $P = 0.001$ , respectively). In both the medial and lateral compartment, the rate of OA approximately doubled if there was a history of ACL reconstruction and previous meniscal surgery compared with ACL reconstruction alone.

Athletes with a BMI  $>30$  kg/m<sup>2</sup> (18%) were more likely to have OA than athletes with a BMI  $<30$  kg/m<sup>2</sup> (10%) ( $P = 0.007$ ).

Player position was not associated with OA, although OA was seen in 20% of both defensive lineman and tight ends, and was least likely in running backs (7.0%).

## DISCUSSION

This study investigated characteristics of knee OA in a large group of primarily asymptomatic (ie, high-performance) college football players undergoing MRI at the NFL Combine. This setting offers a unique opportunity to investigate a large cohort of subjects with a similar athletic history, thorough history and physical examination, and uniform imaging studies. Fifteen

Table 3. Association of previous knee surgery with osteoarthritis in the medial compartment<sup>a</sup>

	Osteoarthritis		
	(-) History	(+) History	P Value
Meniscal surgery	18/617 (2.9)	19/85 (22)	<0.001
Partial meniscectomy		18/76 (24)	
Meniscal repair		0/6 (0)	
Failed meniscal repair		1/3 (33)	
ACL reconstruction	22/570 (3.9)	15/134 (11)	0.001
No medial meniscal sx.		6/104 (5.8)	
Medial meniscal sx.		9/30 (30)	0.001 <sup>b</sup>

ACL, anterior cruciate ligament; sx, surgery.

<sup>a</sup>Values in parentheses are percentages.

<sup>b</sup>Fischer's exact test.

percent of the elite athletes in this group who were imaged at the Combine had evidence of knee OA. Previous knee surgery, specifically previous meniscectomy and/or prior ACL reconstruction, and BMI >30 kg/m<sup>2</sup> were associated with a higher prevalence of knee OA. Player position was not associated with the prevalence of knee OA in this population.

These findings are similar to a previous analysis of these athletes focused on focal full-thickness cartilage defects.<sup>6</sup> However, in contrast to the current findings, a history of ACL reconstruction was not associated with focal full-thickness cartilage defects in the previous study. Furthermore, in another disparity, BMI was not associated with full-thickness cartilage defects. This study also differs from the previous report by assessing for more global changes in the joint consistent with a diffuse degenerative process in the joint. Focal cartilage defects certainly can progress to OA but they may also occur with focal trauma without associated global degeneration, and can be considered as related but distinctly different biological states. The findings support this approach as differences in the distribution of cartilage damage in this cohort compared with those in whom focal defects were identified. In the previous study of full-thickness cartilage defects, the lateral compartment appeared to be more vulnerable to partial meniscectomy as the rate of full-thickness articular cartilage lesions after partial meniscectomy in the lateral compartment (25%) was higher compared with the medial compartment (6.6%). In the current study, however, the rate of OA after partial meniscectomy was similar between the 2 compartments (26% lateral, 24% medial).

The current findings are in line with most literature regarding OA. Multiple studies have demonstrated an increased incidence of OA associated with ACL reconstruction. In a systematic review, Oiestad et al<sup>7</sup> reported an incidence of OA of 0% to 13% at >10 years after ACL reconstruction. With additional meniscal

pathology, the incidence increased to 26% to 48%. Elevated BMI has also been shown to be associated with an elevated risk of knee OA. Englund and Lohmander<sup>4</sup> reported an increased risk of OA after meniscectomy in patients with a BMI >30 kg/m<sup>2</sup>. We also found meniscal tears to be significantly associated with knee OA.

The combination of ACL reconstruction and partial meniscectomy appeared to be particularly detrimental with regards to the development of knee OA. Previous meniscal surgery has been shown to be a risk factor for chondrosis at the time of revision ACL reconstruction.<sup>3</sup> These data are consistent with a number of long-term follow-up studies showing that radiographic OA after ACL reconstruction is common and higher with combined meniscus injury. Shelbourne and Gray<sup>10</sup> reported that 3% of knees without a meniscal tear had radiographic evidence of OA at 5- to 15-year follow-up, compared with 19% with a meniscal tear. Oiestad et al<sup>8</sup> and Risberg et al<sup>9</sup> demonstrated similar findings at 10- to 15-year and 20-year follow-up, respectively.

The current study has several limitations. Also, because only 36% of players had imaging studies performed at the NFL Combine, the study cannot determine a true overall prevalence of knee OA among these players, and admittedly likely overstates this value. Nevertheless, this limitation does not weaken the evidence associating knee OA with a history of prior knee surgery. Assuming that the athletes who did not undergo imaging at the Combine could be expected to have a lower rate of OA, a study including all athletes would likely only strengthen this conclusion. This is a cross-sectional study evaluating the prevalence of OA and the risk factors for the development of OA in elite American football players at the end of their collegiate careers. This information does not provide insight into the effects of a professional career on the future OA

risk. Other weaknesses of our study include its retrospective nature. Surgical details were limited to documentation from athletic trainers or player reporting. Although operative reports to confirm the surgical procedure were reviewed when available, time from surgery data were not consistently available. Athletes may not be completely forthcoming at the Combine with regard to present or past symptoms. MRI findings of meniscal blunting or absence of the meniscus were also used to confirm prior meniscus surgery. The lack of data on the status of the articular cartilage at the time of previous surgery is another confounding factor. The data are based on the report of musculoskeletal radiologists and there are no data on inter- or intrarater reliability. Plain films were not evaluated or graded with a highly sensitive rigorous methodology for evidence of joint space narrowing compared with the contralateral knee. As with any interpretation of imaging studies, there may be some subjective variability in interpreting the severity of disease but less variability in determining the presence or absence of the OA. Because the evaluators of the imaging studies are experienced musculoskeletal radiologists and orthopaedic sports medicine physicians with expertise in identifying OA on radiographs and MRI, the authors did not think a reliability study added much value to identifying the presence or absence of OA in these athletes. Also, data on the time from surgery for these athletes were not available. However, it is likely that most surgeries were performed during high school and/or college, suggesting the average follow-up time from surgery is likely to be 4 years or less, which is a relatively short time frame for the development of OA. Finally, the nature of retrospective data limits the ability to draw clear, definite conclusions but it does facilitate looking for associations that warrant further consideration. A multivariate analysis to assess for potential confounding factors such as elevated BMI in linemen compared with other positions was not possible.

## CONCLUSION

In conclusion, knee OA is a common finding among athletes undergoing knee imaging at the NFL Combine. Previous knee surgery, including partial meniscectomy and ACL reconstruction, and elevated BMI are significantly associated with knee OA. Future research should investigate the effect of knee OA on athletic performance and longevity, as well as optimal management strategies for this patient cohort.

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