# Symptomatic Focal Knee Chondral Injuries in National Football League Combine Players Are Associated With Poorer Performance and Less Volume of Play

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**Purpose:** To (1) describe the magnetic resonance imaging (MRI) characteristics of knee chondral injuries identified at the National Football League (NFL) Combine and (2) assess in-game performance of prospective NFL players with previously untreated knee chondral injuries and compare it with matched controls. **Methods:** All players with knee chondral injuries identified at the NFL Combine (2009-2015) were retrospectively reviewed. Players with prior knee surgery were excluded. A knee MRI for each player was reviewed; location, modified International Cartilage Repair Society (ICRS) grade (I-IV), and associated compartment subchondral edema were documented. Position, respective NFL Draft pick selection number, games started, played, snap percentage, and position-specific performance metrics during the first 2 NFL seasons were recorded for the injury and injury-free control group composed of players with (1) no prior knee injury, (2) no significant missed time prior to the NFL ($\leq$2 total missed games in college), (3) no history of knee surgery, and (4) drafted in the respective NFL Draft following the NFL Combine. **Results:** Of the 2,285 players reviewed, 101 (4.4%) had an injury without prior knee surgery. The patella (63.4%) and trochlea (34%) were most commonly affected. Defensive linemen were at highest risk for unrecognized injuries (odds ratio 1.8, $P = .015$). Players with previously untreated injuries, compared with controls, were picked later (mean pick: 125.8) and played (mean: 23) and started (mean: 10.4) fewer games during the initial 2 NFL seasons ($P < .001$ for all). Particularly, subchondral bone edema and full-thickness cartilage injuries were associated with fewer games played ($P = .003$). **Conclusions:** The patellofemoral joint was most commonly affected in NFL Combine participants. Previously untreated knee articular injuries in players at the NFL Combine are associated with poorer early NFL performance in comparison to uninjured players. Subchondral bone edema and full-thickness cartilage injury on MRI were associated with fewer games played during the initial NFL career. **Level of Evidence:** Level III, case-control study.

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*The authors report the following potential conflicts of interest or sources of funding: M.T.P. is a paid consultant for Arthrex and JRF Ortho; has patents issued (one with The United States of America as Rep. by the Secretary of the Navy; three with Arthrex, Inc.); receives publishing royalties from Arthrex and SLACK; and the Steadman Philippon Research Institute receives research support from Smith & Nephew, Arthrex, DePuy Synthes, Siemens, Ossur, and Vail Valley Medical Center. R.F.L. reports that his institution is provided support by Arthrex, Ossur, Siemens, and Smith & Nephew; is a paid consultant for Arthrex, Smith & Nephew, and Ossur; receives institutional grants from Health East, Norway, and an NIH R-13 grant for biologics; has patents issued for Ossur and Smith & Nephew; and receives royalties from Arthrex, Ossur, and Smith & Nephew. Full ICMJE author disclosure forms are available for this article online, as supplementary material.*

*Received June 7, 2017; accepted August 29, 2017.*

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*0749-8063/17734/$36.00*

*https://doi.org/10.1016/j.arthro.2017.08.300*

The prevalence of knee chondral injuries identified on magnetic resonance imaging (MRI) among all players at the National Football League (NFL) Combine where collegiate players are evaluated for their potential to participate at the professional level has been reported to be 26%.[1] Specifically, full-thickness knee articular injuries have been reported to occur in 9%[1] to 20%[2] of Combine athletes. The lateral femoral condyle and the lateral tibial plateau have been reported to be at highest risk for full-thickness chondral injury in these players.[1] Previously reported risk factors for full-thickness chondral injury among players at the NFL Combine include body mass index greater than 30.5, weight greater than 222.5 pounds, and the following positions of play: linebacker,[2] tight end, defensive lineman, and wide receiver.[1] Furthermore, prior knee surgery has been reported to be directly associated with full-thickness knee chondral injury, particularly partial meniscectomy, loose body removal, and chondroplasty.[1,3]

Although the epidemiology and risk factors for knee chondral injuries among NFL Combine athletes has been previously reported, there is little information focused on NFL players without prior knee surgery who have knee cartilage pathology before entering the NFL. Furthermore, the effect of these previously untreated chondral injuries on players' early NFL career performance remains unclear and requires further elucidation. Therefore, the purposes of this study were to (1) describe the magnetic resonance imaging (MRI) characteristics of knee chondral injuries identified at the NFL Combine and (2) assess initial in-game performance of prospective NFL players with previously untreated knee chondral injuries and compare it to matched controls. It was hypothesized that players with previously untreated knee cartilage lesions would perform worse in game than the healthy control group.

## Methods

### Study Design

The authors obtained approval to perform this study from their institutional review board (Protocol #2015P002224/MGH) and the NFL Physicians Society Research Committee. Following approval, a retrospective review of all NFL Combine participants from 2009 to 2015 was performed. Medical records and MRI reports were reviewed to identify all players with knee chondral injuries not previously surgically treated with surgery prior to the NFL Combine. MRIs were obtained at the NFL Combine in the presence of a prior knee injury or reported pain by the player, regardless of surgical history of the knee. Players who had undergone knee surgery of any kind, had a meniscal deficiency, or any associated ligamentous pathology were excluded. MRI scans in the coronal, sagittal, and axial planes, previously collected at the annual NFL Scouting Combine, were then independently reviewed by 2 orthopaedic surgeons (D.B.H., A.J.T., J.C.). In case of discrepancy, it was resolved through discussion. The MRIs were performed at the NFL Combine in the presence of a prior knee injury or knee pain, regardless of surgical history of the knee.

At the NFL Combine, the medical staff of each of the 32 NFL teams performed their respective musculoskeletal evaluation of each player and a comprehensive orthopaedic note was dictated following examination of the athlete. All injury data were collected through review of the injury data registry available to the medical and training staff of all NFL teams following the completion of the NFL Combine. These notes were reviewed and analyzed for involved structures, residual injury, and associated soft tissue and bony pathology of the knee.

### Articular Cartilage Evaluation

For each knee, articular cartilage injuries were characterized by the following anatomic locations: trochlea, patella, medial femoral condyle, medial tibial plateau, lateral femoral condyle, and lateral tibial plateau. Chondral injury dimensions were measured and the lesion area was calculated (in square millimeters). Chondral lesion measurements were taken in orthogonal planes using the provided Combine database MRI software (InteleViewer, Intelerad, Montreal, Canada). Additionally, each chondral defect was graded according to the modified International Cartilage Repair Society (ICRS) scale: grade 0, normal articular cartilage; grade I, superficial fissuring; grade II, less than 50% thickness chondral injury; grade III, greater than 50% thickness but not full thickness; grade IV, full-thickness chondral injury.[4-7] Each chondral injury on MRI was also evaluated for the presence of corresponding subchondral bone edema and subchondral cysts.

Given that multiple players had articular cartilage injuries in multiple anatomic quadrants, the "primary lesion" in cases of multiple lesions was defined as the highest-grade lesion in accordance with the ICRS scale. If 2 lesions of the same ICRS scale grade were identified, the lesion with the greatest size (in square millimeters) was considered the "primary lesion" in the statistical analysis.

### Performance Evaluation

Player position and number of missed collegiate football games were obtained from the medical database organized during the NFL Combine and available to the medical staff of the 32 NFL teams. The NFL Draft is composed of 7 rounds, including 253 draft picks total. The respective NFL Draft pick selection number, number of games played and started, and in-game performance statistics for the initial 2 seasons of each player's

NFL career were collected through use of STATS.com (Northbrook, IL) and Pro-Football-Reference.com (Sports Reference, Philadelphia, PA), a web-based, publicly accessible comprehensive sports statistics database.

Player performance was determined through calculation of position-specific performance scores, which were distinctively organized according to each position's individual metrics. Position-specific performance scores were not calculated for the offensive lineman or long snapper position. The analysis of position-specific performance was limited to players who participated in the NFL Combine between 2009 and 2013 because performance metrics corresponding to the first 2 seasons of NFL play were available up to the 2013 NFL Draft class at time of analysis. A complete summary of the scoring rubric associated with each position-specific performance score is shown in Table 1. Snap percentage—defined as the total number of plays a player participated in out of the total number of plays the player was eligible to participate in over the course of a season—during the first 2 NFL seasons was collected through use of profootballfocus.com (PFF Analysis, Luton, United Kingdom). To assess the performance of those athletes who were ultimately drafted, the following measures were analyzed during snap percentage per season, and position-specific performance score/game. These position-specific performance scores were calculated according to "Fantasy Score" grading rubrics by position as suggested by the Entertainment and Sports Programming Network, or ESPN.com, and NFL.com through the use of in-game statistics available on STATS.com and Pro-Football-Reference.com (Sports Reference).

**Table 1.** Breakdown of the Scoring Rubric Used to Calculate Position-Specific Performance Scores for All Players (Aside From Offensive Linemen and Long Snappers)

| Position | Scoring Rubric[8] |
|---|---|
| Quarterback | • Passing yards (1 point for every 25 passing yards)<br>• Passing touchdowns (4 points)<br>• Passing interceptions (−2 points)<br>• Rushing yards (1 point for every 10 rushing yards)<br>• Rushing touchdowns (6 points) |
| Running backs/wide receivers/tight ends | • Rushing yards (1 point for every 10 rushing yards)<br>• Rushing touchdowns (6 points)<br>• Receiving yards (1 point for every 10 receiving yards)<br>• Receiving touchdowns (6 points) |
| Offensive line/long snapper | No performance-specific score |
| Defensive linemen/ defensive backs/ linebackers | • Tackle (1 point)<br>• Assisted tackle (0.5 point)<br>• Sack (2 points)<br>• Interception (2 points)<br>• Forced fumble (2 points)<br>• Fumble recovery (2 points)<br>• Defensive touchdown (6 points)<br>• Pass defended (1 point) |
| Kicker | • Field goal made (3 points)<br>• Extra point made (1 point) |

NOTE. Each position is scored differently. Therefore, these scores are more useful for intraposition, not interposition comparisons.

The control group was built from players who participated in the NFL Combine from 2009 to 2015 based on the following set of criteria: (1) no prior knee injury, (2) no significant missed time prior to the NFL (≤2 total missed games in college), (3) no history of knee surgery prior to the NFL Combine, and (4) drafted in the respective NFL Draft following the NFL Combine. For both groups, players with a previously untreated chondral injury and players in the control group, the number of games missed during collegiate play, position of play, and draft position in the NFL Draft were collected. Undrafted players in the study group were assigned a draft round of 8 with a draft number of 254 as numerical values for analysis. The control group was developed to evaluate whether players without untreated chondral lesions were drafted in earlier draft rounds and had superior performance during the first 2 years of play than players with untreated chondral injuries.

### Statistical Analysis

Data were tested for normal distribution. For comparisons of normally distributed continuous variables between the study and control groups, an independent *t* test was used. For comparisons of nonnormally distributed continuous variables between the study and control groups, the Mann-Whitney *U* test was used. For pre- and postoperative comparisons of dependent variables, the paired samples *t* test was used for normally distributed data and the Wilcoxon signed rank test was used for non—normally distributed data. Comparisons of 2 categorical data were performed by use of $\chi$-square tests and Fisher exact tests. All *P* values were 2-tailed, and *P* values less than .05 were considered statistically significant. All statistical analyses were performed by use of SPSS (IBM Chicago, IL).

## Results

### Demographics

During the 7-year study period (2009-2015), 2,285 players participated in the NFL Scouting Combine. Of these, 545 (23.8%) players had a knee chondral injury on MRI. Knee chondral injuries without a known previous history or those with no previous knee surgery were identified in 101 (4.4%) athletes, thus meeting this study's inclusion criteria. Of these 101 players, 78 had unilateral knee chondral injuries, and 23 players had bilateral knee chondral injuries, yielding a total of 124 knees (Table 2).

**Table 2.** NFL Combine Athletes Identified With Previously Untreated Knee Chondral Injuries by Year

| | Frequency of Knee Chondral Injuries, n (%) | |
|---|---|---|
| | Unilateral | Bilateral |
| Overall | 78 (3.4) | 23 (1.0) |
| 2009 | 2 (0.6) | 2 (0.6) |
| 2010 | 13 (4.0) | 4 (1.0) |
| 2011 | 4 (1.2) | 2 (0.6) |
| 2012 | 14 (4.3) | 4 (1.2) |
| 2013 | 15 (4.5) | 2 (0.6) |
| 2014 | 10 (3.0) | 4 (1.2) |
| 2015 | 20 (6.3) | 5 (1.6) |

NFL, National Football League.

Of the 101 patients included in the study, 8, 14, 18, and 22 had ICRS grade I, II, III, and IV, respectively. Thus, 22 had superficial lesions (grade I and II) and 40 had deep chondral lesions (grade IV). Deep chondral lesions were associated with shorter NFL career and fewer games played in the NFL. Thirty-nine (38.6%) had combined chondral injuries (Table 3). From the isolated chondral injury group, patellar chondral lesions were the most prevalent with 32 (31.7%), 10 (9.9%) had isolated trochlear, 3 (2.9%) had isolated lateral femoral condyle lesions, 7 (6.9%) had isolated medial femoral condyle lesions, 3 (2.9%) had isolated lateral tibial plateau lesions, and 7 (6.9%) had isolated medial tibial plateau (Table 3). Although 39 (38.6%) players had chondral lesions in more than 1 compartment, only the largest chondral lesion was used for performance analysis. The largest chondral lesions ($mm^2$) and the highest-grade chondral lesions were similarly distributed.

## Player Performance

Performance analysis was limited to players who participated in the NFL Combine between 2009 and 2013 and included 62 total players with newly identified or untreated knee chondral injuries with a total of 48 players with single knee injuries and 14 players with bilateral injuries. Players with previously untreated knee chondral injuries, on average, had a poorer overall draft pick ($P < .001$), played and started fewer games during the first 2 NFL seasons ($P < .001$ for both) when compared with matched controls (Table 4).

Players with their highest grade chondral lesion in the patella, trochlea or lateral femoral condyle had poorer overall draft pick numbers, played fewer years in the NFL, and played fewer games in the NFL when compared with matched controls ($P < .001$). Moreover, snap percentage was significantly decreased in the highest grade of all 4 cartilage lesions groups when compared with controls ($P = .02$). Players with their highest grade chondral lesions in the patella or trochlea also started fewer games in the NFL when compared with matched controls ($P < .001$, $P = .01$, respectively). Fewer players with the highest-grade chondral lesion in the medial femoral condyle were able to have an NFL career of at least 2 years when compared with controls ($P < .001$) (Table 5).

Subchondral edema on MRI with corresponding untreated knee chondral injury was associated with shorter career ($P = .04$) and playing fewer games in the NFL overall ($P = .003$) when compared with players with previously untreated knee chondral injuries without subchondral edema (Table 6). The presence of cystic changes was not correlated to games played in the NFL ($P = .06$).

Fantasy scores were significantly lower among defensive players with previously untreated knee chondral injuries when compared with position-matched controls ($P < .001$); specifically, defensive linemen ($P < .001$) and linebackers ($P < .05$) had lower fantasy scores than position-matched controls. Running

**Table 3.** Chondral Injury Location, Single or Both Knees Affected in NFL Combine Athletes for Previously Untreated Knee Chondral Injuries

| | Single Chondral Lesions, n (%) (n = 62) | All Athletes, n (%) (n = 101) |
|---|---|---|
| Patella | 32 (51.6)<br>Grade I: 6<br>Grade II: 9<br>Grade III: 7<br>Grade IV: 10 | 64 (63.4) |
| Trochlea | 10 (16.1)<br>Grade I: 0<br>Grade II: 3<br>Grade III: 3<br>Grade IV: 4 | 34 (32.7) |
| Medial femoral condyle | 7 (11.3)<br>Grade I: 1<br>Grade II: 2<br>Grade III: 1<br>Grade IV: 3 | 25 (24.8) |
| Lateral femoral condyle | 3 (4.8)<br>Grade I: 0<br>Grade II: 0<br>Grade III: 2<br>Grade IV: 1 | 28 (27.7) |
| Medial tibial plateau | 7 (11.3)<br>Grade I: 1<br>Grade II: 0<br>Grade III: 3<br>Grade IV: 3 | 2 (2.0) |
| Lateral tibial plateau | 3 (4.8)<br>Grade I: 0<br>Grade II: 0<br>Grade III: 2<br>Grade IV: 1 | 12 (11.9) |

NOTE. Percentages are of players with chondral injury at a given location out of the total number of players for the corresponding column. All percentage values correspond to total players, not knees, of the respective column. Therefore, of the total 101 players, 78 (77.2%) and 23 (22.8%) had a single and bilateral knee chondral injuries, respectively.

NFL, National Football League.

**Table 4.** Player Performance Outcomes, Limited to Draft Class 2009-2013

| | Overall Pick, Mean (SD) | ≥2 Years in the NFL, n (%) | Games Played, n (SD) | Games Started, n (SD) | Season 1 Snap Percentage (SD) | Season 2 Snap Percentage (SD) |
|---|---|---|---|---|---|---|
| All athletes (n = 62) | 125.8 (71.7) | 43 (69.4) | 23.0 (6.3) | 10.4 (9.9) | 30.4 (33) | 36.8 (36) |
| Single (n = 48) | 128.9 (73.5) | 36 (75.0) | 22.8 (6.6) | 9.5 (10.1) | 29.1 (33) | 35.8 (35) |
| Both knees (n = 14) | 110.6 (64.4) | 7 (50.0) | 23.9 (4.3) | 15 (8.0) | 38.6 (39) | 46.1 (40) |
| Controls (n = 182) | 78.6 (61.8) | 182 (100) | 29.4 (3.0) | 16.4 (10.8) | 53.2 (29) | 62.4 (28) |
| All vs control, *P* value | **<.001** | **<.001** | **<.001** | **<.001** | **<.001** | **<.001** |
| Single vs control, *P* value | **<.001** | **<.001** | **<.001** | **<.001** | **<.001** | **<.001** |
| Both vs control, *P* value | **.08** | **<.001** | **<.001** | **.37** | **<.001** | **<.001** |
| Single vs both, *P* value | .26 | **.04** | .35 | .09 | .39 | .37 |

NOTE. Boldface indicates statistical significance.
NFL, National Football League; SD, standard deviation.

backs ($P < .001$) and wide receivers ($P < .05$) with previously untreated knee chondral injuries were the only offensive players with significantly lower fantasy scores when compared with position-matched controls (Table 7).

## Discussion

The most important finding in this study was that players participating in the NFL Combine with previously untreated high-grade chondral injuries (ICRS IV) in the knee tended to play fewer games and had decreased eligible plays during the initial portion of their NFL career than players without a previous knee injury or surgery at the time of the NFL Combine. Furthermore, in a majority of positions, players with high-grade chondral injuries performed at a lower level than players without any previous injury. Taken together, the findings of this study provide valuable information to both the NFL team owners and prospective NFL players.

In the present study, an overall chondral injury prevalence of 23.8% was found, and 4.4% of the identified chondral lesions were in athletes with previous knee injury but no history of knee surgery. In this subset of players, the number of snaps played in season 1 and 2, and performance in a majority of positions, was lower than those Combine participants in the control group ($P < .001$). In contrast to previous studies evaluating chondral injuries in professional football players,[1,9-16] the present study focused on players who had not been diagnosed and had not undergone prior knee surgery. The prevalence of chondral lesions found in our sample is comparable to that reported in previous studies. Hirshorn et al. analyzed MRIs of 516 players (53% of Combine participants) at the NFL Combine from a 3-year period from 2005 through 2007. Of the 516 players who had MRIs, 197 (38.2%), or 20.1% of all Combine participants, were found to have evidence of chondral injury. The authors identified body mass index, body weight, and playing linebacker as independent risk factors associated with chondral injury.[2] Similarly, Nepple et al. examined chondral injuries of the knee in Combine athletes and reported an overall injury prevalence of 17.3%, with the highest prevalence being in the lateral compartment. The authors also noted that previous knee surgery, particularly meniscectomy, were highly associated with the presence of lateral compartment chondral damage.[1]

**Table 5.** Effect of Primary Articular Cartilage Lesion Location on Outcome, Limited to Draft Class 2009-2013

| | n (%) | Overall Pick, Mean (SD) | ≥2 Years in the NFL, n (%) | Games Played, n (SD) | Games Started, n (SD) | Season 1 Snap Percentage (SD) | Season 2 Snap Percentage (SD) |
|---|---|---|---|---|---|---|---|
| Single injury (n = 48) | | | | | | | |
| Patella | 21 (43.8) | 130 (79.4) | 16 (76.2) | 22.7 (6.7) | 7.8 (9.9) | 30.6 (32) | 34.4 (33) |
| Trochlea | 9 (18.8) | 147.6 (72.2) | 8 (88.9) | 20.9 (6.1) | 6.9 (7.6) | 27.6 (29) | 34.9 (37) |
| Medial femoral condyle | 7 (14.6) | 84.5 (53.2) | 4 (57.1) | 27.8 (6.0) | 18.5 (14.2) | 30 (36) | 35.4 (39) |
| Lateral femoral condyle | 10 (20.8) | 134.2 (77.5) | 7 (70.0) | 21.6 (7.4) | 12.1 (10.0) | 33.0 (32) | 39.2 (36) |
| Lateral tibial condyle | 1 (2.1) | 178 (—) | 1 (100) | 29 (—) | 4 (—) | 34.2 (33) | 39.4 (36) |
| Patella vs control, *P* value | — | **<.001** | **<.001** | **<.001** | **<.001** | **<.001** | **<.001** |
| Trochlea vs control, *P* value | — | **.001** | **<.001** | **<.001** | **.01** | **<.001** | **<.001** |
| Medial femoral vs control, *P* value | — | .32 | **<.001** | .16 | .36 | **.02** | **.003** |
| Lateral femoral vs control, *P* value | — | **.01** | **<.001** | **<.001** | .25 | **<.001** | **<.001** |
| Lateral tibia vs control, *P* value | — | — | — | — | — | — | — |

NOTE. Boldface indicates statistical significance.
NFL, National Football League; SD, standard deviation.

**Table 6.** Effect of Subchondral Bone Edema at Primary Cartilage Injury Location on Outcomes

| | n | Overall Pick, Mean (SD) | ≥2 Years in the NFL, n (%) | Games Played, n (SD) | Games Started, n (SD) | Season 1 Snap Percentage (SD) | Season 2 Snap Percentage (SD) |
|---|---|---|---|---|---|---|---|
| Any injury (n = 62) | | | | | | | |
| Edema | 32 | 140.2 (63.8) | 19 (59.4) | 20.2 (4.8) | 8.5 (9.2) | 28.2 (33) | 32.9 (36) |
| No edema | 30 | 111.4 (77.5) | 24 (80) | 25.2 (6.5) | 11.9 (10.4) | 33.0 (33) | 41.6 (35) |
| *t* test, *P* value | — | .08 | **.04** | **.003** | .14 | .474 | .229 |

NOTE. Boldface indicates statistical significance.
NFL, National Football League; SD, standard deviation.

In this study, the patellofemoral joint was the most common location of chondral lesions; 63.4% of the players had lesions in the patella and 32.7 had lesions in the trochlea. These findings are comparable to those in the study by Hirshorn et al.,[2] which found patellofemoral chondral lesions to be the most prevalent. Nepple et al.[1] and Brophy et al.[12] on the other hand found femoral condyle lesions to be the most prevalent. Nepple specifically found lateral femoral condyle lesions to be the most prevalent at 39% of total chondral lesions.[1] However, these studies did not exclude prior surgery and found that previous lateral meniscectomy was significantly associated with lateral chondral lesions. Therefore, the exclusion criteria in this study may provide reasoning for the partiality toward patellofemoral lesions and relative lack of tibial plateau lesions.

Analysis of player position revealed that defensive linemen in the 101 players were at greatest risk for having chondral lesions without having a history of knee injury that required surgery. This differs from a study by Hirshorn et al.,[2] which reported that linebackers were at greatest risk. Although linebackers may be at greatest risk overall, they may also be more likely to have had prior knee surgery, thus excluding them from our study group. Interestingly, linebackers and defensive linemen both seem to be similarly affected by knee chondral injuries, as both positions had lower position-specific performance scores when compared with position-matched controls. In fact, defensive players in general were found to have poorer position-specific performance scores than their uninjured counterparts. Running backs and wide receivers were the only offensive players to have significantly lower position-specific performance than their matched controls. Evaluating athletes' performance by position is important because of the different demands on athletes in different positions. Therefore, the potential effect of chondral lesions should be seen in light of a player's position and location and the size of the lesion. Defensive players and skill positions in the offensive line put a lot of demands on the knees, and chondral lesions are found to affect their performance.

## Limitations

The primary limitations of this study include a retrospective design, the relatively small sample size comprising players with surgically untreated chondral injuries (101 players) and the use of the fantasy scores as a nonvalidated performance metric. The small sample size did not allow for advanced statistical analysis. In addition, MRIs at the NFL Combine were only performed in athletes with a positive history, or when physicians (a different physician from each team) had a high clinical suspicion for previous knee injury. This may have resulted in under-reporting of the incidence of chondral injuries. Several patients had multiple chondral lesions, and the largest or highest-grade lesion was defined as the "primary lesion" for the analysis; however, this might not correlate with the symptoms or performance. Moreover, it is also possible that players underwent surgical intervention to address the chondral injury or injuries immediately following the NFL Combine, which may have also affected their early NFL performance. Furthermore, although we tried to minimize variables, it is difficult to create a true control group while equalizing "talent" and "skill," which also partially determine productivity and objective outcomes of these prospective NFL players. Only the largest and highest-grade lesions were taken into account when correlating with performance; however, smaller lesions can also be symptomatic depending on the localization. The correlation between the number of lesions and performance was not performed. Validated

**Table 7.** Performance Score by Player Position, Limited to Draft Class 2009-2013

| Position | Any Cartilage Injury, n (%) | Fantasy Score, Mean (SD) | | *t* Test (*P* Value) |
|---|---|---|---|---|
| | | Cases | Controls | |
| Defense | 36 | 1.7 (1.8) | 3.1 (1.8) | **<.001** |
| DL | 19 | 1.1 (1.0) | 2.3 (1.3) | **<.001** |
| DB | 10 | 2.8 (2.1) | 3.3 (1.6) | .25 |
| LB | 7 | 2.1 (2.4) | 4.4 (2.5) | **.03** |
| Offense | 26 | — | — | — |
| QB | 2 | 11.0 (0.2) | 14.4 (2.7) | .08 |
| RB | 3 | 11.9 (3.0) | 3.8 (4.2) | **<.001** |
| WR | 11 | 1.7 (1.9) | 4.5 (1.9) | **.02** |
| TE | 2 | 1.9 (2.2) | 2.1 (2.0) | .45 |
| OL | 8 | — | — | — |

NOTE. Boldface indicates statistical significance.
DB, defensive back; DL, defensive lineman; LB, linebacker; NFL, National Football League; OL, offensive lineman; QB, quarter back; RB, running back; SD, standard deviation; TE, tight end; WR, wide receiver.

outcome scores in sports performance are still lacking, and some of the performance measures used in this study may not truly reflect performance. Because of the retrospective nature of the study, injury data after the NFL Combine was not available, and it is not known if the poor performance was caused by the chondral lesions or new injuries after the NFL Combine. Nevertheless, our analysis focuses on the comparison between injured and healthy players with considerable participation during the early portion of their careers. Therefore, we feel that the effect of these injuries is accurately and effectively shown.

## Conclusions

The patellofemoral joint was most commonly affected in NFL Combine participants. Previously untreated knee articular injuries in players at the NFL Combine are associated with poorer early NFL performance in comparison with uninjured players. Subchondral bone edema and full-thickness cartilage injury on MRI were associated with fewer games played during the initial NFL career.

## References

1. Nepple JJ, Wright RW, Matava MJ, Brophy RH. Full-thickness knee articular cartilage defects in National Football League Combine athletes undergoing magnetic resonance imaging: Prevalence, location, and association with previous surgery. *Arthroscopy* 2012;28:798-806.
2. Hirshorn KC, Cates T, Gillogly S. Magnetic resonance imaging-documented chondral injuries about the knee in college football players: 3-year National Football League Combine data. *Arthroscopy* 2010;26:1237-1240.
3. Brophy RH, Wright RW, David TS, et al. Association between previous meniscal surgery and the incidence of chondral lesions at revision anterior cruciate ligament reconstruction. *Am J Sports Med* 2012;40:808-814.
4. von Engelhardt LV, Kraft CN, Pennekamp PH, Schild HH, Schmitz A, von Falkenhausen M. The evaluation of articular cartilage lesions of the knee with a 3-tesla magnet. *Arthroscopy* 2007;23:496-502.
5. von Engelhardt LV, Schmitz A, Burian B, et al. Three-tesla MRI vs. arthroscopy for diagnostics of degenerative knee cartilage diseases: Preliminary clinical results. *Orthopade* 2008;37:914, 916-922 [in German].
6. Bachmann G, Heinrichs C, Jürgensen I, Rominger M, Scheiter A, Rau WS. Comparison of different MRT techniques in the diagnosis of degenerative cartilage diseases. In vitro study of 50 joint specimens of the knee at T1.5. *Rofo* 1997;166:429-436 [in German].
7. Reed ME, Villacis DC, Hatch GF, et al. 3.0-Tesla MRI and arthroscopy for assessment of knee articular cartilage lesions. *Orthopedics* 2013;36:e1060-e1064.
8. Mai HT, Alvarez AP, Freshman RD, et al. The NFL Orthopaedic Surgery Outcomes Database (NO-SOD). *Am J Sports Med* 2016;44:2255-2262.
9. Scillia AJ, Aune KT, Andrachuk JS, et al. Return to play after chondroplasty of the knee in National Football League athletes. *Am J Sports Med* 2015;43:663-668.
10. Albright JP, Powell JW, Martindale A, et al. Injury patterns in big ten conference football. *Am J Sports Med* 2004;32:1394-1404.
11. Bradley J, Honkamp NJ, Jost P, West R, Norwig J, Kaplan LD. Incidence and variance of knee injuries in elite college football players. *Am J Orthop (Belle Mead NJ)* 2008;37:310-314.
12. Brophy RH, Rodeo SA, Barnes RP, Powell JW, Warren RF. Knee articular cartilage injuries in the National Football League: Epidemiology and treatment approach by team physicians. *J Knee Surg* 2009;22:331-338.
13. Campbell AB, Pineda M, Harris JD, Flanigan DC. Return to sport after articular cartilage repair in athletes' knees: a systematic review. *Arthroscopy* 2016;32:651-668.e651.
14. Flanigan DC, Harris JD, Trinh TQ, Siston RA, Brophy RH. Prevalence of chondral defects in athletes' knees: A systematic review. *Med Sci Sports Exerc* 2010;42:1795-1801.
15. Golightly YM, Marshall SW, Callahan LF, Guskiewicz K. Early-onset arthritis in retired National Football League players. *J Phys Act Health* 2009;6:638-643.
16. Steadman JR, Miller BS, Karas SG, Schlegel TF, Briggs KK, Hawkins RJ. The microfracture technique in the treatment of full-thickness chondral lesions of the knee in National Football League players. *J Knee Surg* 2003;16:83-86.