Athletes With Musculoskeletal Injuries Identified at the NFL Scouting Combine and Prediction of Outcomes in the NFL

A Systematic Review

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Background: Prior to the annual National Football League (NFL) Draft, the top college football prospects are evaluated by medical personnel from each team at the NFL Scouting Combine. On the basis of these evaluations, each athlete is assigned an orthopaedic grade from the medical staff of each club, which aims to predict the impact of an athlete's injury history on his ability to participate in the NFL.

Purpose: (1) To identify clinical predictors of signs, symptoms, and subsequent professional participation associated with football-related injuries identified at the NFL Combine and (2) to assess the methodological quality of the evidence currently published.

Study Design: Systematic review; Level of evidence, 3.

Methods: A systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. We reviewed all studies that examined musculoskeletal injuries identified among athletes at the NFL Combine and associated outcomes. Data on signs, symptoms, and subsequent NFL participation were collected, and the methodological quality of the studies was assessed.

Results: Overall, 32 studies, including 30 injury-specific studies, met the inclusion criteria. Twenty studies analyzed data collected at the NFL Combine from 2009 and later. When compared with matched controls, athletes with a history of a cervical or lumbar spine injury, rotator cuff repair, superior labrum anterior-posterior repair, anterior cruciate ligament reconstruction, full-thickness chondral lesions of the knee, or Lisfranc injury played in significantly fewer games early in their NFL careers. Additionally, athletes with a history of a cervical or lumbar spine injury, rotator cuff repair, and navicular injury had decreased career lengths versus controls. Defensive players and linemen were found to have decreased participation in the NFL for several injuries, including prior meniscectomy, anterior cruciate ligament reconstruction, and shoulder instability. Career length follow-up, measures of athletic participation, and matching criteria were highly variable among studies.

Conclusion: For medical professionals caring for professional football athletes, this information can help guide orthopaedic grading of prospects at the NFL Combine and counseling of athletes on the potential impact of prior injuries on their professional careers. For future studies, improvements in study methodology will provide greater insight into the efficacy of current treatments and areas that require further understanding.

Keywords: football; NFL; combine; injury; participation; career

Each offseason, the top college football prospects are invited to attend the National Football League (NFL) Scouting Combine. This weeklong event is held prior to the NFL Draft and allows the medical staff of each NFL club to collect medical histories, perform comprehensive physical examinations, and collect imaging modalities, including plain radiographs, magnetic resonance imaging (MRI), and computed tomography as indicated. Subsequently, the medical staff of each club assigns each player an orthopaedic grade, according to its own criteria, in an attempt to predict the impact of a given history on a player's physical durability, career longevity, and participation in the NFL.[5] This information often affects a player's draft status, and up to 6% of players may even receive failing medical grades.[4]

Since 1987, databases have been formed containing the medical information of all players evaluated at the NFL Combine.[4] Numerous retrospective studies based on these

The Orthopaedic Journal of Sports Medicine, 6(12), 2325967118813083
DOI: 10.1177/2325967118813083

data have been published.[1,4-6] In recent years, Provencher and colleagues have published several studies with NFL Combine data collected from 2009 to 2015, analyzing the association between specific prior injuries and outcomes in the NFL (draft position, games played, and games started during the first 2 NFL seasons).[1,8,9,22,25,28,31,32,38] These studies enable team management, scouts, coaches, physicians, and athletic trainers to better understand the impact of a given injury on a player's participation in the NFL. More important, even beyond the NFL, such information may (1) help athletes and medical professionals better understand the ability to return to sport at a high level, (2) guide treatment options, and (3) set appropriate expectations for both parties.[6]

The purpose of this systematic review was to critically evaluate the available literature on clinical predictors of outcomes relevant to musculoskeletal injuries reported or diagnosed at the NFL Scouting Combine. Specifically, we sought to (1) identify clinical predictors of signs, symptoms, and subsequent professional participation associated with football-related injuries identified at the NFL Combine and (2) assess the methodological quality of the currently published evidence.

METHODS

A systematic review was conducted in July 2018 according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[20] PubMed (Medline), Embase, and the Cochrane library were searched with the terms "National Football League," "NFL," "combine," "injury," and surgery." The search was limited to English-language articles. Titles and abstracts from these searches were independently reviewed by 2 authors (D.W., S.A.T), and full-text articles meeting the inclusion criteria were then obtained and reviewed. Additionally, the references of all included full-text articles were scanned for further eligible studies.

Inclusion criteria were established before data collection. Studies were included if they reported on musculoskeletal injuries identified among athletes at the NFL Combine and their association with clinical signs and symptoms and/or future participation in the NFL, including games played and career length. Studies were excluded if they (1) were case reports of 1 or only a few participants; (2) were epidemiologic studies that reported just the prevalence of specific injuries at the NFL Combine and did not evaluate for associations between injury and clinical signs, symptoms, or outcomes in the NFL; or (3) examined football-related injuries occurring after the NFL Combine. After elimination of duplicate articles among databases and screening of abstracts for relevance, 32 studies were analyzed (Figure 1). Thirty studies examined a cohort of athletes with a specific diagnosis or injury. All studies were retrospective, with the exception of 2 studies that prospectively collected data at the NFL Combine from a single year.[2,12]

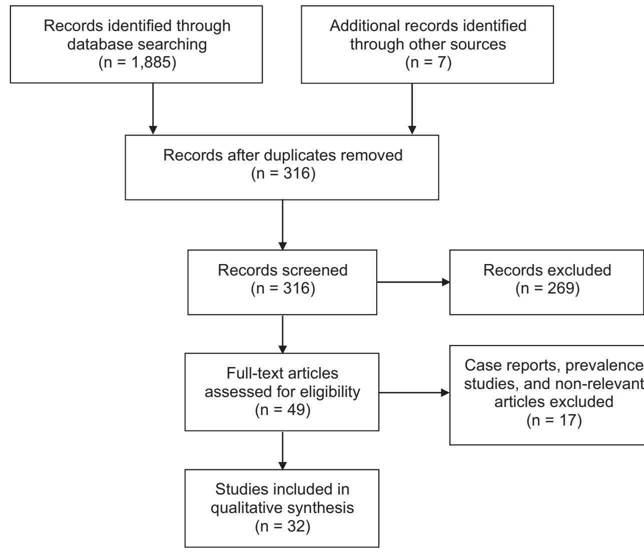

Figure 1. PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) flowchart of the literature search process.

Two authors (D.W., M.A.) extracted the data, which were then reviewed by the coauthors. Any disagreements in data were resolved by consensus or by arbitration of a third author (L.J.W.). The tabulated data included the injury or surgery, combine years studied, number of injuries and athletes, and level of evidence. Outcomes collected included draft status, game participation data, NFL career length, and clinical assessments derived from physical examination, imaging, and functional measures related to the specific injury.

The level of evidence of the selected studies was determined according to the criteria established by the Oxford Centre for Evidence-Based Medicine.[39] As no randomized clinical trials were identified among the included studies, the MINORS criteria (methodological index for nonrandomized studies) were used to assess the methodological quality of the studies.[36] This tool has 8 criteria to assess the

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One or more of the authors has declared the following potential conflict of interest or source of funding: D.W. has received educational support from Smith & Nephew. R.F.W. receives royalties from Zimmer Biomet and Arthrex and hospitality payments from Stryker. S.A.R. receives royalties from Zimmer Biomet, honoraria from Fidia Pharmaceuticals, and nonconsulting payments from Smith & Nephew. S.A.T. has received educational support from Arthrex and Smith & Nephew, is a consultant for DePuy, and has received hospitality payments from Encore Medical and Exactech. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Summary of Injury-Specific NFL Combine Level 3 Retrospective Studies[a]

First Author	Injury/Surgery	Years	Injuries (Athletes), n	Methods	Results
Cervical spine					
Schroeder[35]	Cervical spine diagnosis	2003-2011	143 (143)	Study on athletes with a history of a cervical spine diagnosis Control group matched by age, position, year drafted, and round drafted Outcomes: draft status, years played, games played and started, performance	Most common diagnoses: spondylosis, stenosis, cervical sprain/strain Athletes with cervical spine diagnosis were less likely to be drafted vs controls ($P = .001$) Athletes drafted who had a cervical spine diagnosis had decreased total games played ($P = .01$) but no significant differences in number of games started or performance score vs controls Athletes with cervical spine stenosis and those with prior cervical spine surgery demonstrated no difference in performance-based outcomes and no reports of neurological injury during their careers
Presciutti[30]	Chronic stinger syndrome	2005-2006	28 (28)	Study on athletes with cervical spine MRI Athletes with chronic stingers vs those without chronic stingers and age-matched nonathletes Outcomes: mean subaxial cervical space available for the cord (MSCSAC), mean subaxial cervical Torg ratio	Athletes with chronic stingers had lower MSCSAC (4.5) vs those without chronic stingers (5.8; $P < .01$) and controls (6.7; $P < .001$) A critical value of 5.0 mm for the MSCSAC produced a sensitivity of 80% and a negative likelihood ratio of 0.23 for predicting chronic stingers MSCSAC more accurate than the classic Torg ratio
Foot					
Carreira[7]	Jones fracture/ fifth metatarsal diaphyseal stress fracture	2004-2009	74 (68)	Study on athletes with a history of a Jones or proximal diaphyseal fifth metatarsal fracture Control group matched by draft status, player position, BMI, and medical grade Outcomes: games played and started, years played	Among all fractures, 61% were Jones, 20% were proximal diaphyseal, and 19% were of indeterminate location No significant differences in mean games played/started, total years, and likelihood of being drafted between fracture and control groups
Tu[37]	Jones fracture fixation	2012-2015	41 (40)	Study on athletes who had undergone fixation of Jones fracture Control group with no history of Jones fracture fixation Outcomes: draft status, games played and started	All fractures treated with intramedullary screw fixation with 92% complete union No athletes, including those with incomplete union, had any limitations in strength of ROM No significant differences between percentage drafted, games played, or games started between fracture and control groups
McHale[25]	Lisfranc injury	2009-2015	41 (41)	Study on athletes with a history of a Lisfranc injury Control group with no history of midfoot injury matched by position Outcomes: draft status and position, games played and started, NFL career length $\geq$2 y	63% of injuries treated operatively Athletes treated surgically were more likely to go undrafted ($P = .04$) and had a worse draft position ($P = .03$) vs those treated nonoperatively Athletes with Lisfranc injury had worse draft position ($P = .04$) and fewer games played ($P = .001$) and started ($P = .08$) vs controls Athletes with >2-mm residual displacement on radiograph had worse outcomes across all measurements vs those with $\leq$2-mm displacement
Vopat[38]	Navicular injury	2009-2015	15 (14)		11 overt navicular fractures, 3 stress reactions on MRI

(continued)

TABLE 1 (continued)

First Author	Injury/Surgery	Years	Injuries (Athletes), n	Methods	Results
				Study on athletes with a history of a navicular injury Control group matched by position and composed of players who missed <2 games in college and did not undergo previous surgery or have a documented injury Outcomes: draft status and position, games played and started, NFL career length ≥2 y	8 athletes with navicular fracture underwent surgery Evidence of ipsilateral talonavicular arthritis in 75% of those with fracture vs 60% in the uninjured foot ($P = .04$) 57% of athletes with navicular injury were undrafted vs 31% of the control group ($P = .001$) 29% of athletes with navicular injury played ≥2 y vs 70% of the control group ($P = .02$)
Hip/groin					
Knapik[14]	Athletic pubalgia repair	2012-2015	55 (55)	Study on athletes who had undergone surgical repair for athletic pubalgia Control group without history of athletic pubalgia repair Outcomes: draft status, current NFL status, games played and started, positive pathology (pubic plate injury, rectus abdominis injury, adductor aponeurosis injury, or combination thereof) on postsurgical MRI	No significant differences in games played/started, draft status, or current status between athletic pubalgia and control groups 53% of those with postsurgical MRI showed positive pelvic pathology No significant differences in games played/started, draft status, and current status between athletes with negative and positive MRI pathologies Offensive linemen ($P = .005$) and athletes who had surgery <1 y before NFL Combine ($P = .03$) were more likely to have positive pathology on MRI
Knapik[17]	Hip arthroscopic surgery	2012-2015	15 (14)	Study on athletes who had undergone hip arthroscopic surgery Control group with no history of hip arthroscopic surgery Outcomes: draft status, games played and started, current status	Acetabular labral tearing was treated with repair alone (73%), debridement alone (7%), or repair and debridement (13%) in 93% of hips undergoing arthroscopic surgery Decompression for FAI was performed in 33% of hips No significant differences in draft status, current status, games played, or games started between surgical and control groups
Knee					
Keller[13]	ACLR	2010-2014	NA (98)	Study on athletes with a history of ACLR Control group matched by age, size, and position Outcomes: 40-yd dash, vertical leap, broad jump, shuttle drill, 3-cone drill	No significant differences in 40-yd dash times, vertical leap, broad jump, shuttle drill times, and 3-cone drill times between ACLR and control groups
Provencher[31]	ACLR	2009-2015	NA (110)	Study on athletes with a history of ACLR Injury-free control group matched by position and draft class Outcomes: draft status, games played and started, snap percentage	Athletes with prior ACLR were drafted lower ($P = .019$), played and started fewer games ($P \leq .003$), and had lower snap percentage ($P < .001$) Defensive linemen, defensive backs, and linebackers were most affected positions
Provencher[32]	Chondral injury	2009-2015	124 (101)	Study on athletes with knee chondral injuries without	Patella (63%) and trochlea (34%) were most commonly affected

(continued)

TABLE 1 (continued)

First Author	Injury/Surgery	Years	Injuries (Athletes), n	Methods	Results
				history of prior knee surgery Injury-free drafted control group Outcomes: draft position, games played and started, snap percentage, position-specific performance metrics	Defensive linemen at highest risk for unrecognized injuries ($P = .015$) Athletes with untreated chondral injuries had lower draft position, played fewer games, and started fewer games than controls ($P < .001$) Subchondral bone edema and full-thickness cartilage injuries were associated with fewer games played ($P = .003$)
Chahla[8]	Meniscectomy and chondral injury	2009-2015	249 (247)	Study on athletes with chondral injury in the setting of prior meniscectomy Compared with injury-free control group matched by position Condition of the meniscus graded with modified ISAKOS scores Condition of the cartilage graded with ICRS scores Outcomes: draft position, games played and started, snap percentage	287 players had a prior meniscectomy (206 lateral, 81 medial) Poorer meniscal score was associated with worse chondral pathology, especially in the lateral compartment Controls had greater number of games played and started and higher snap percentage vs those with prior meniscectomy of at least 10% volume Athletes with severe chondral lesions (ICRS grade 4) had significantly worse performance metrics vs controls
Logan[22]	MCL injury	2009-2015	337 (301)	Study on athletes with a history of MCL injury Injury-free control group Outcomes: draft position, games played and started, snap percentage	55% had additional soft tissue injury (eg, meniscus, ACL, PCL) No significant differences in draft status/position, games played, or games started between athletes with MCL injury and controls Athletes with isolated MCL injury had better draft position ($P = .034$), proportion playing ≥2 NFL seasons ($P = .022$), games played ($P = .014$), and games started ($P = .020$) vs athletes with combined injuries
Chahla[9]	Posterolateral corner injury	2009-2015	23 (23)	Study on athletes with a history of posterolateral corner injury Inclusion criteria: positive clinical findings or previous surgery consistent with a posterolateral corner injury Compared with surgery-free control group matched by position Outcomes: varus stress physical examination, draft status, games played and started	70% of injuries treated surgically, 30% were diagnosed on clinical examination 57% were combined injuries (with ACL, MCL, or PCL), all treated surgically 87% of injuries treated surgically were stable on examination, whereas none of the injuries managed nonoperatively were stable No significant differences in draft status, games played, or games started between posterolateral corner injury and control groups; athletes with surgically managed posterolateral corner injuries started fewer games than controls ($P = .03$)
Lumbar spine					
Moorman[27]	Hyperconcavity of the lumbar vertebral end plates	1992-1993	88 (88)	Study on linemen with radiographic evidence of hyperconcavity of lumbar vertebral end plates Control group of nonathletes matched by age	Hyperconcavity present in 33% of linemen vs 8% in controls ($P < .0001$) Trend toward lower incidence of lumbosacral spine symptoms for those with hyperconcavity ($P = .1839$) When hyperconcavity was present, all 5 lumbosacral disk spaces were commonly affected

(continued)

TABLE 1 (continued)

First Author	Injury/Surgery	Years	Injuries (Athletes), n	Methods	Results
				Outcomes: incidence, association with lumbosacral spine symptoms	
Paxton[29]	Hyperconcavity of the lumbar vertebral end plates	1992-1993	93 (93)	Study on linemen with radiographic evidence of hyperconcavity of the lumbar vertebral end plates Control group matched by year and round drafted, surgery and injury history Outcomes: percentage who played at least 1 NFL game, career length, games played and started	No difference in likelihood of playing in NFL, years played, games played, or games started between athletes with lumbar spine hyperconcavity and controls No association between lumbar spine hyperconcavity and BMI
Schroeder[34]	Lumbar spine diagnosis	2003-2011	414 (414)	Study on athletes with a history of a lumbar spine diagnosis Control group matched by age, position, year and round drafted Outcomes: draft status, years played, games played and started, performance	Most common diagnoses: degenerative spondylosis, herniated disc, spondylolysis with/without spondylolisthesis, strain Athletes without lumbar spine diagnosis were more likely to be drafted than those with a diagnosis ($P < .001$) Drafted athletes with preexisting lumbar spine injuries had decreased number of years played ($P = .001$), games played ($P = .0001$), and games started ($P = .02$) but not performance score ($P = .013$) vs controls Spondylolysis was associated with decreased career longevity ($P < .05$)
Shoulder					
Knapik[16]	Bristow/Latarjet procedure	2012-2015	10 (10)	Study on athletes who had undergone Bristow or Latarjet surgery Control group with history of isolated shoulder soft tissue repair without bony augmentation or fracture fixation Outcomes: draft status, games played and started, status after the athletes' first NFL season	70% had deficits in shoulder motion; 40% had evidence of mild glenohumeral arthritis 40% of athletes were drafted into NFL No significant risk of diminished participation with regard to games played and started vs controls 60% remained on active NFL roster after their first season
Knapik[15]	Labral repair	2012-2015	146 (132)	Study on athletes with a history of labral repair and MRI of the operative shoulder Control group with no history of labral repair Outcomes: association between primary labral repair location and presence and location of recurrent tearing, concomitant shoulder pathology, arthritis, draft status, games played and started	32% of shoulders had recurrent labral tears on MRI Athletes with recurrent tears were more likely to have undergone bilateral labral repairs ($P = .048$) and possess concomitant shoulder pathology ($P < .001$) Recurrent labral tearing was more common in posterior labrum in the setting of prior posterior labral repair ($P = .032$) No significant differences in games played and games started between athletes who had undergone labral repair and controls No significant differences in chance of being drafted, games played, and games started between athletes with recurrent tearing and intact repairs

(continued)

TABLE 1 (continued)

First Author	Injury/Surgery	Years	Injuries (Athletes), n	Methods	Results
Murphy[28]	Anterior labral injury	2009-2015	226 (206)	Study on athletes with a history of an anterior labral injury Control group without history of surgery and >2 games missed in college Outcomes: draft status, games played and started, snap percentage	72% had surgical intervention, 38% were treated nonoperatively No significant differences in draft status, games played, games started, or snap percentage vs controls Concomitant injury (eg, SLAP tear, glenoid bone loss, Hill-Sachs lesion) was associated with lower draft position (P = .003)
Gibbs[11]	Rotator cuff tear	2003-2011	NA (49)	Study on athletes with a history of a rotator cuff tear Control group matched by age, position, year and round drafted Outcomes: draft status, years played, games played and started, performance score	45% underwent surgical intervention, 55% treated nonoperatively Athletes with rotator cuff tear were less likely to be drafted vs controls (P = .002) Athletes who were drafted started fewer games (P = .02) and played fewer years (P = .04) and fewer games (P = .04) vs controls
Chambers[10]	SLAP tears	2003-2011	NA (25)	Study on athletes reporting a history of a SLAP tear Control group with no documented shoulder pathology matched by position, age, and draft year and round Outcomes: draft success, games played and started	SLAP repairs most performed in offensive linemen (32%) Drafted athletes with SLAP tears played fewer games (P = .049) and had fewer game starts (P = .036) vs controls

[a]ACL, anterior cruciate ligament; ACLR, ACL reconstruction; BMI, body mass index; FAI, femoroacetabular impingement; ICRS, International Cartilage Repair Society; ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine; MCL, medial collateral ligament; MRI, magnetic resonance imaging; NA, not available; NFL, National Football League; PCL, posterior cruciate ligament; ROM, range of motion; SLAP, superior labrum anterior-posterior.

methodological quality of noncomparative studies and 4 additional criteria for assessing the methodological quality of comparative studies. Each criterion is scored 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate), with the global ideal score being 16 for noncomparative studies and 24 for comparative studies.

RESULTS

Data by Injury

Of the 32 studies, 30 were injury specific. There were 2 studies on cervical spine injuries,[30,35] 5 on foot injuries,[7,23,25,37,38] 1 on hand injuries,[26] 4 on hip/groin injuries,[14,17,18,33] 9 on knee injuries,[2,8,9,13,21,22,24,31,32] 3 on lumbar spine injuries,[27,29,34] and 6 on shoulder injuries.[10,11,15,16,19,28] No studies specifically examined injuries of the ankle, elbow, or long bones. Nineteen studies analyzed data collected at the NFL Combine from 2009 or later.[‖] There were 22 level 3 studies (Table 1) and 8 level 4 studies (Table 2). Based on the MINORS criteria, the mean score for methodological quality of the level 3 studies was 16.4 (range, 13-19) out of a possible 24 points. The mean score for methodological quality of the level 4 studies was 10.8 (range, 7-13) out of a possible 16 points.

Cervical and Lumbar Spine

Athletes with a cervical spine diagnosis (including spondylosis, stenosis, sprain/strain, herniated disc, and spine spasms) were less likely to be drafted, played fewer games (Table 3), and had decreased NFL career lengths (Table 4) as compared with controls. Those with a history of multiple stinger episodes were noted on MRI to have a lower mean subaxial cervical space available for the cord, with 5.0 mm reported as the critical value. Of note, players with a cervical sagittal canal diameter <10mm did not have any significant differences in games played or performance score compared with matched controls, and no neurological injury occurred during their careers.[35]

Athletes with a history of a lumbar spine diagnosis (including degenerative spondylosis, herniated disc, spondylolysis, and strain) were less likely to be drafted and had a decreased number of years played, games played, and games started. Radiographic evidence of hyperconcavity of the lumbar vertebral end plates (disk space expansion) in linemen was not

[‖]References 2, 8, 9, 13-17, 19, 21, 22, 25, 26, 28, 31-33, 37, 38

TABLE 2
Summary of Injury-Specific NFL Combine Level 4 Studies

First Author	Injury/ Surgery	Years	Injuries (Athletes), n	Methods	Results
Foot					
Low[23]	Jones fracture	1988-2002	86 (83)	Case series of athletes with a history of a Jones fracture Outcomes: radiographic union, complications	53% of fractures were treated surgically; of these, 89% healed without complication and 7% developed nonunion 20% of fractures treated nonoperatively developed nonunion
Hand					
Moatshe[26]	Scaphoid fracture	2009-2015	56 (56)	Case series of athletes with a history of a scaphoid fracture Outcomes: clinical outcomes (ROM, pain, stiffness, grip strength, pinch test), complications	76% treated with screw fixation, 4% treated with resection and fusion, 18% treated nonoperatively 72% had normal ROM of wrist, 93% reported no pain, 83% reported no stiffness; grip strength and pinch strength were 91% and 96% vs uninjured side 25% nonunion rate, 34% had degenerative changes, 15% had hardware complications
Hip/groin					
Larson[18]	Hip or groin pain	2009-2010	239 (125)	Case series of athletes with hip radiographs Outcomes: radiographic pathomorphology/abnormalities, radiographic predictors of athletic-related "hip" and "groin" symptoms	87% had ≥1 finding on radiograph suggestive of cam- or pincer-type FAI 75 hips in the symptomatic group, 164 hips in the asymptomatic group Although the symptomatic group had greater prevalence of cam-type FAI ($P = .009$), combined-type FAI ($P < .001$), and osteitis pubis ($P = .014$), increased α angle (larger cam deformity) was the only independent predictor of groin pain ($P = .01$) FAI not correlated to BMI or player position
Rebolledo[33]	Lower extremity and core muscle injuries	2015	107 (107)	Case series of athletes with low vitamin D levels Outcomes: association between vitamin D levels and lower extremity muscle strain (adductor/groin, hamstring, hip flexor, quadriceps) or core muscle injuries	59% of athletes with inadequate vitamin D levels, 10% with deficient levels Lower extremity or core muscle injury was present in 50% of athletes, which was associated with vitamin D levels ($P = .03$) African American race ($P < .001$) and positive injury history ($P < .001$) were associated with lower vitamin D levels No significant differences in age, BMI, or Functional Movement Screen scores among vitamin D groups
Knee					
Bedi[2]	ACLR	2012	34 (NA)	Case series of athletes measured for hip ROM Outcomes: association between reduction in hip ROM (internal rotation) and history of ACL injury	Reduction of left hip internal rotation was associated with increased odds of ACL injury in either knee ($P < .001$) 30° reduction of left hip internal rotation was associated with 4.1- and 5.3-times-greater odds of ACL in the ipsilateral and contralateral limbs, respectively
Mall[24]	ACLR	2005-2009	137 (125)	Case series of athletes with a history of ACLR and radiographs/MRI Outcomes: association between graft obliquity and knee laxity on Lachman physical examination	64% of knees had vertical grafts based on radiography and 35% based on MRI Knees with a sum score of ≤66 (sum of tibial and femoral tunnel positions on lateral radiograph), tibial tunnel ≤37% from anterior tibial plateau, and sagittal obliquity of ≤60° were less

(continued)

TABLE 2 (continued)

First Author	Injury/ Surgery	Years	Injuries (Athletes), n	Methods	Results
					likely to have increased translation on Lachman examination than knees with higher corresponding values ($P < .05$)
Logan[21]	PCL injury	2009-2015	69 (69)	Case series of athletes with a history of PCL injury Inclusion criteria: positive clinical findings or previous surgery consistent with PCL injury Outcomes: posterior drawer physical examination, concomitant injuries identified on MRI, draft status, collegiate games missed	Running back and offensive lineman were most common positions with PCL injuries (20% each) 16% treated surgically 52% of athletes had a grade II/III posterior drawer; athletes with grade III posterior drawer examination went undrafted Concomitant injuries: MCL (42%), ACL (12%), chondral (32%)
Shoulder					
LeBus[19]	Latarjet procedure	2009-2016	13 (13)	Case series of athletes who had undergone Latarjet procedure Outcomes: fixation type, hardware complications, bone block status, draft status, games played and started, total snaps, percentage of eligible snaps	61% had 2-screw fixation, 39% had 1 screw 46% demonstrated hardware complications All athletes had evidence of degenerative changes on radiographs (77% mild, 8% moderate, 15% severe) 54% drafted; of these, no player participated in more than half of the plays during rookie season

[a]ACL, anterior cruciate ligament; ACLR, ACL reconstruction; BMI, body mass index; FAI, femoroacetabular impingement; MCL, medial collateral ligament; MRI, magnetic resonance imaging; NA, not available; NFL, National Football League; PCL, posterior cruciate ligament; ROM, range of motion.

associated with a significant difference in career length, games played, or games started as compared with controls.

Shoulder

Two studies demonstrated that athletes with labral injuries or those who had undergone labral repair of the shoulder did not have any significant differences in draft status, games played, games started, or snap percentage when compared with controls.[15,28] Furthermore, athletes with evidence of recurrent labral tears on MRI did not have any significant differences in draft status, games played, or games started versus those with intact labral repairs. For athletes treated with bone block augmentation for shoulder instability, as many as 40% to 77% of athletes had evidence of glenohumeral arthritis on radiographs. Against controls, those who were drafted were not at significant risk for diminished participation with regard to games played or started in their first season in the NFL. In contrast, athletes with a history of a rotator cuff tear, of which 45% received operative treatment, were less likely to be drafted, played and started in fewer games, and played in fewer years versus controls. Finally, those treated with superior labrum anterior-posterior (SLAP) repair had no significant differences in draft status and performance scores as opposed to controls; however, they played and started in fewer games than healthy controls.

Hip and Pelvis

Athletes who had undergone athletic pubalgia repair or hip arthroscopic surgery did not have any significant differences in draft status, games played, or games started as compared with controls. Although the prevalence of cam- or combined-type femoroacetabular impingement and osteitis pubis was higher among symptomatic athletes, an increased alpha angle was the only independent predictor of athletic-related groin pain.

Knee

When compared with controls, athletes who had undergone anterior cruciate ligament (ACL) reconstruction were more likely to be picked lower in the draft, and they played and started fewer games in their first 2 NFL seasons. Chondral injuries of the knee were noted in 4.4% of athletes at the NFL Combine who had knee MRI because they reported prior injury or reported knee pain but had no known history of surgery; the patellofemoral joint was the most affected compartment. Athletes with chondral injuries, in the setting of no prior knee surgery or prior meniscectomy, played and started in fewer games versus controls. Specifically, subchondral bone edema and full-thickness chondral lesions were associated with fewer games played. Athletes with a history of medial collateral ligament injury or

TABLE 3
NFL Games Played Data[a]

First Author	Injury/Surgery	Mean Games Played, n: Athletes With Injury	Mean Games Played, n: Controls	*P*
Schroeder[35]	Cervical spine diagnosis	42.1	55.6	**.01**
Schroeder[34]	Lumbar spine diagnosis	46.5	50.8	<**.01**
	Lumbar spondylosis	41	44.6	.11
	Lumbar herniated disc	45.3	50	.50
	Spondylolysis with or without slip	46.9	55.1	.11
Paxton[29]	Hyperconcavity of the lumbar vertebral end plates	86	76	.33
Knapik[15]	Shoulder labral repair	7.04[b]	2.8[b]	.38
Murphy[28]	Shoulder anterior labral injury	14.3[c]	15.3[c]	.39
Knapik[16]	Bristow/Latarjet procedure	6.2[b]	7.5[b]	.59
Gibbs[11]	Rotator cuff tear	47.1	68.4	**.04**
Chambers[10]	SLAP repair	33.7	48.3	.05
Knapik[14]	Athletic pubalgia repair	17.2	17.6	.87
Knapik[17]	Hip arthroscopic surgery	10.9[b]	11.0[b]	.96
Provencher[31]	ACL reconstruction	9.2[b]	7.4[b]	<**.01**
Provencher[32]	Knee chondral injury	23.0[c]	29.4[c]	<**.01**
Logan[22]	Knee MCL injury	16[c]	15[c]	.87
Chahla[9]	Posterolateral corner injury	24[c]	23.3[c]	.42
Carreira[7]	Jones fracture/fifth metatarsal diaphyseal stress fracture	16.9	24.9	.12
Tu[37]	Jones fracture fixation	8.8[b]	7.4[b]	.23
McHale[25]	Lisfranc injury	16.9[b]	23.3[b]	<**.01**
Vopat[38]	Navicular injury	15.0[c]	23.3[c]	.07

[a]Bolded *P* values indicate statistically significant difference between groups ($P < .05$). ACL, anterior cruciate ligament; MCL, medial collateral ligament; NFL, National Football League; SLAP, superior labrum anterior-posterior.
[b]In athletes' first NFL season after the combine only.
[c]In athletes' first 2 NFL seasons after the combine only.

TABLE 4
NFL Career Length Data[a]

First Author	Injury/Surgery	Mean Years Played, n: Athletes With Injury	Mean Years Played, n: Controls	*P*
Schroeder[35]	Cervical spine diagnosis	3.7	4.6	**.01**
Schroeder[34]	Lumbar spine diagnosis	4.0	4.3	<**.01**
	Lumbar spondylosis	3.6	3.8	.07
	Lumbar herniated disc	3.9	4.3	.27
	Spondylolysis with or without slip	4.1	4.4	.32
Paxton[29]	Hyperconcavity of the lumbar vertebral end plates	7.5	6.5	.11
Gibbs[11]	Rotator cuff tear	4.3	5.7	**.04**
Chambers[10]	SLAP repair	3.4	4.0	.06
Knapik[14]	Athletic pubalgia repair	1.5[b]	1.6[b]	.52

[a]Bolded *P* values indicate statistically significant difference between groups ($P < .05$). NFL, National Football League; SLAP, superior labrum anterior-posterior.
[b]Data collected from maximum of 4 NFL seasons after the combine.

posterolateral corner knee injury did not have any significant differences in draft status, games played, or games started as opposed to respective controls.

Foot

A history of proximal fifth metatarsal fractures, including Jones fractures, was not associated with a difference in draft likelihood, games played, or games started, as compared with controls. In contrast, a history of Lisfranc or navicular injury was associated with worse draft position and fewer games played and started during the first 2 NFL seasons. In addition, a prior navicular injury was associated with significantly decreased probability of playing ≥2 years in the NFL.

Data by Position

Two level 3 studies specifically examined injuries identified at the NFL Combine and their impact on NFL participation by player position.[1,6] Based on the MINORS criteria, the mean score for methodological quality of these studies was 17 (range, 16-18) out of a possible 24 points. NFL participation data by athlete position are summarized in Table 5. Game participation appears to be affected by injuries most in offensive and defensive linemen and defensive backs. Of note, spondylolisthesis was not significantly associated with a reduced percentage of athletes playing in the league or a shorter career length at any position.

DISCUSSION

When compared with matched controls, athletes with a history of a cervical or lumbar spine injury, rotator cuff repair, SLAP repair, ACL reconstruction, full-thickness chondral lesions of the knee, or Lisfranc injury played in significantly fewer games early in their NFL careers. Additionally, athletes with a history of a cervical or lumbar

TABLE 5
NFL Participation Data by Athlete Position[a]

Position	Injury: Participation
Offense	
Offensive lineman	Shoulder instability: decreased chance of playing in NFL
	Rotator cuff tear: shorter playing career and fewer games played
	ACLR: decreased chance of playing in NFL, shorter playing career, and lower snap percentage[b]
	Meniscectomy: fewer games played[b] and lower snap percentage[b]
	Ankle injury: fewer games played[b]
Quarterback	Shoulder injury: fewer games played[b]
Running back	Spondylolysis: decreased chance of playing in NFL
	Meniscectomy: fewer games played[b]
	Chondral injury (knee): decreased fantasy score[b]
Tight end	Shoulder injury: fewer games played[b]
	Hand injury: fewer games played[b]
Wide receiver	Shoulder instability: shorter playing career
	Meniscectomy: fewer games played[b]
	Chondral injury (knee): decreased fantasy score[b]
Defense	
Defensive back	Cervical spine diagnosis: shorter playing career and fewer games played
	Lumbar spine diagnosis: shorter playing career, fewer games played, and lower performance score
	Hand injury: fewer games played[b]
	ACLR: lower snap percentage[b]
	Meniscectomy: decreased chance of playing in NFL, shorter playing career, fewer games played,[b] and lower snap percentage[b]
Defensive lineman	Shoulder instability: decreased chance of playing in NFL and shorter playing career
	Rotator cuff tear: shorter playing career and fewer games played
	ACLR: decreased chance of playing in NFL, fewer games played,[b] and lower snap percentage[b]
	Meniscectomy: played fewer games[b] and lower snap percentage[b]
	Chondral injury (knee): decreased fantasy score[b]
	Ankle injury: fewer games played[b]
Linebacker	ACLR: decreased chance of playing in NFL, fewer games played,[b] and lower snap percentage[b]
	Meniscectomy: played fewer games[b] and lower snap percentage[b]
	Chondral injury (knee): decreased fantasy score[b]

[a]ACLR, anterior cruciate ligament reconstruction; NFL, National Football League.

[b]In first 2 NFL seasons after the combine only.

spine injury, rotator cuff repair, or navicular injury had decreased career length versus controls. The potential impact of these injuries seems to vary by player position as well, with defensive players and offensive and defensive linemen having decreased participation in the NFL for several injuries, including prior meniscectomy, ACL reconstruction, and shoulder instability (Figure 2). Nevertheless, the available literature remains highly variable with regard to length of follow-up, matching criteria, measures of participation outcomes, and overall methodological quality.

Using NFL Combine data collected by 1 team from 1987 to 2000, Brophy et al[5] examined the correlation between orthopaedic grade and career longevity in the NFL. Players with a high grade (no injury, minor injury, or successful surgical interventions) had a mean career of 42 games, as opposed to 34 games for players with a low grade (incomplete recovery and/or injury likely to recur) and 19 games for players with a failed grade. Thus, assigning orthopaedic grades to college football prospects based on their injury history has historically been a useful practice for predicting career longevity in the NFL. Of note, we found an increasing trend of likelihood of playing in the NFL for players treated with ACL reconstruction or shoulder stabilization over the study period, likely reflecting the improved understanding of these injuries and advancements in surgical technique and rehabilitation. As a result, over time, fewer players received failed grades at the combine.

Although recent NFL Combine studies have improved a medical professional's ability to predict the impact of a prior injury on a player's professional career, there is a dearth of studies examining athletes with a history of hand, elbow, long bone, and ankle injuries. Although hand and ankle injuries are among the most commonly identified injuries at the NFL Combine,[1,4] this review found only 1 study on hand injuries and no studies on ankle injuries. Furthermore, while the lone hand study examined the clinical and radiographic outcomes of scaphoid fracture, it did not assess NFL participation metrics.[26]

Moreover, future studies utilizing more rigorous methodology would allow medical professionals to provide more accurate predictions of a prior injury's impact on an athlete's NFL career. Currently available studies on injuries of the cervical spine or lumbar spine classify all spine diagnoses together in their analyses, resulting in heterogeneous cohorts. These aggregated diagnoses, which included stinger, spondylosis, stenosis, spondylolysis, and sprain/strain, are all unique pathologies that have different symptoms and prognoses. Although the studies by Schroeder et al[34,35] found that athletes with a cervical or lumbar spine diagnosis were less likely to be drafted and played in fewer games than controls, diagnoses of strain, scoliosis, and spasms were included in relatively fewer numbers when compared with the more severe diagnoses of spondylosis, spondylolysis, herniated disc, and stenosis. Future studies examining a more focused cohort of spine diagnoses are needed.

Additionally, measurement of draft status, games played and started, snap percentage, and game performance metrics are influenced by a multitude of factors (eg, player position, team needs, opponent game plan, depth chart), which can ultimately confound the results. Many currently available studies do not account for these factors. For instance, with regard to player position, drafted quarterbacks often do not play in any games during the first few years of their professional career, owing to their position on the depth chart, whereas kickers often go undrafted but are signed by teams and play during their rookie years. Several

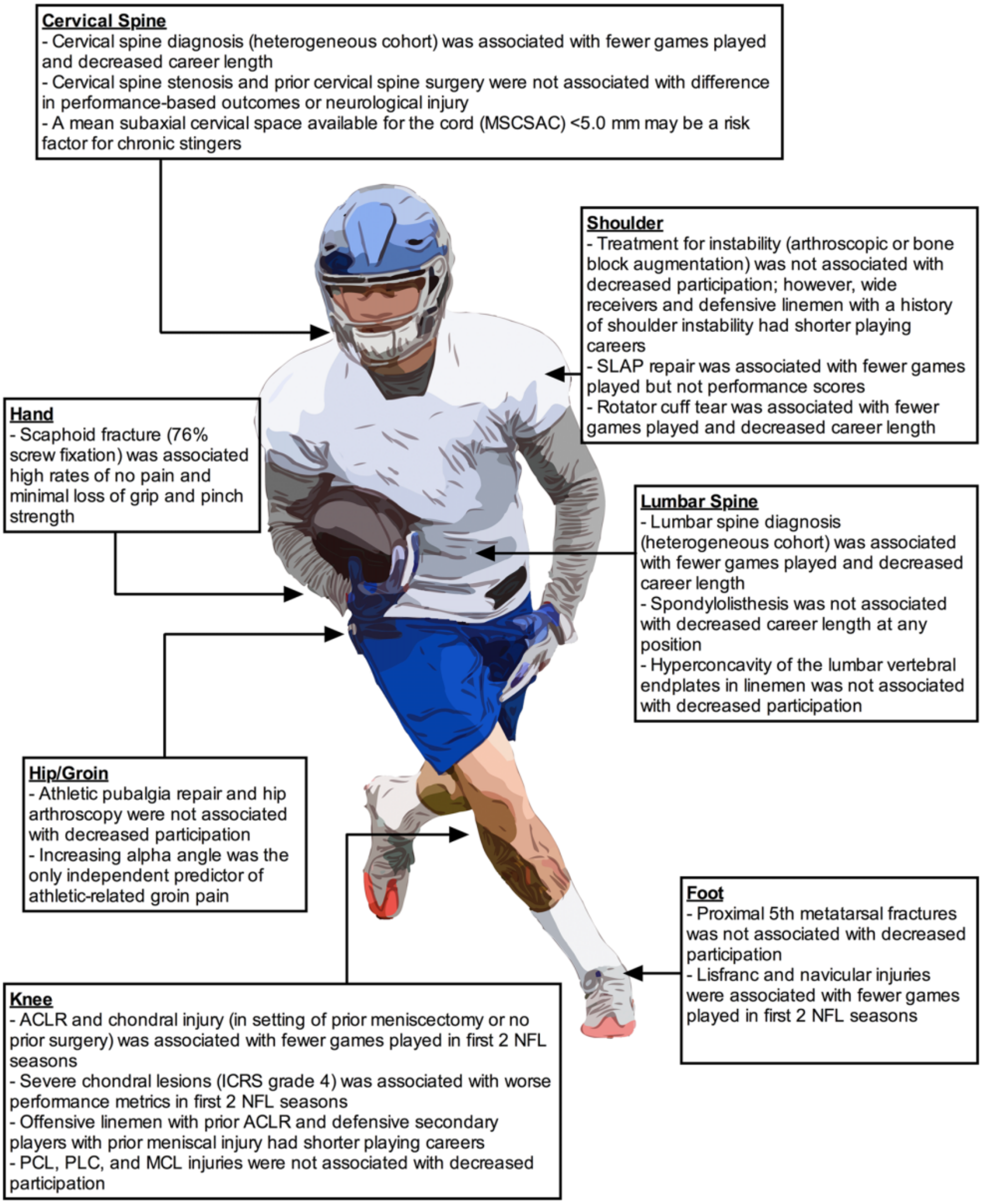

Figure 2. Summary of NFL participation data sorted by injury identified at the NFL Combine. ACLR, anterior cruciate ligament reconstruction; ICRS, International Cartilage Repair Society; MCL, medial collateral ligament; NFL, National Football League; PCL, posterior cruciate ligament; PLC, posterolateral corner; SLAP, superior labrum anterior-posterior.

studies utilizing a matched control group did not match per player position.[14,17,29,30,32,37] Some players are made inactive on game day despite being healthy and participating in practice. Therefore, measurement of games played or games started may not accurately represent the degree of professional athletic participation. Metrics such as athlete exposures, which accounts for practice participation, or days on the "physically unable to perform"–injured reserve list would better characterize athletic participation. Finally, missed time caused by reinjury to the previously injured anatomic area is more likely to be indicative of the impact of a specific prior injury on participation in the NFL.

Other limitations of this qualitative review are related to the level and availability of evidence reviewed. The majority of the studies reviewed were retrospective and used injury data that were self-reported or derived from scouting, introducing recall bias. Instead of using the NFL Injury Surveillance System, some studies used publicly accessible websites to collect participation and performance data, for which their accuracy or completeness cannot be verified. The majority of studies that measured participation or performance analyzed data within only the first 1 or 2 NFL years after the combine.[1,8,9,22,25,28,31,32,38] Analysis of outcomes within the first 4 to 5 years, which is the length of the typical rookie contract, may be more valuable from an administrative perspective. The impact of injuries within an anatomic region may not be mutually exclusive to the same region; for instance, limited hip rotation and femoroacetabular impingement have been linked to risk of ACL injury.[2,3] Finally, there is inherent selection bias in the analyzed studies, since athletes who were invited to the combine likely had successful outcomes after their injuries. These studies did not include athletes who were not invited to the combine but still made it to the professional level. Therefore, these findings cannot necessarily be extrapolated to the average collegiate football athlete, nor can they necessarily be extrapolated to high school or younger athletes, owing to the higher demands that are placed on the musculoskeletal system in the NFL.

CONCLUSION

NFL prospects with a history of a cervical or lumbar spine injury, rotator cuff repair, SLAP repair, ACL reconstruction, full-thickness chondral lesions of the knee, or Lisfranc injury played in significantly fewer games early in their NFL careers. Game participation was also dependent on player position, with defensive players and offensive and defensive linemen having decreased participation for several injuries. For medical professionals caring for professional football athletes, this information can help guide orthopaedic grading of prospects at the NFL Combine and counseling of athletes on the potential impact of prior injuries on their professional careers. For future studies, improvements in study methodology—including longer career follow-up, more accurate measures of athletic participation, more robust and consistent matching criteria, separate investigation of specific spine diagnoses, and prospective designs—will provide greater insight into the efficacy of current treatments and areas that require further understanding.

ACKNOWLEDGMENT

The authors thank Evan Pinkus for his assistance with Figure 2.

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