

Posterior Cruciate Ligament Injuries of the Knee at the National Football League Combine: An Imaging and Epidemiology Study

Catherine A. Logan, M.D. M.B.A., M.S.P.T., Brendin R. Beaulieu-Jones, B.A., George Sanchez, B.S., Jorge Chahla, M.D., Ph.D., Nicholas I. Kennedy, M.D., Mark E. Cinque, M.S., B.S., Robert F. LaPrade, M.D., Ph.D., James M. Whalen, A.T.C., Bryan G. Vopat, M.D., Mark D. Price, M.D., Ph.D., and CAPT Matthew T. Provencher, M.D., M.C., U.S.N.R.

Purpose: To determine the epidemiology by player position, examination, imaging findings, and associated injuries of posterior cruciate ligament (PCL) injuries in players participating in the National Football League (NFL) Combine. **Methods:** All PCL injuries identified at the NFL Combine (2009-2015) were reviewed. Data were obtained from the database organized by the NFL medical personnel for the compilation of the medical and physical performance examination results of NFL Draftees participating in the NFL Combine from 2009 to 2015. Inclusion criteria were any player with clinical findings or a previous surgery consistent with a PCL injury who participated in the NFL Combine. **Results:** Of the 2,285 players who participated in the NFL Combine between 2009 and 2015, 69 (3%) had evidence of a PCL injury, of which 11 players (15.9%) were managed surgically. On physical examination, 35 players (52%) had a grade II or III posterior drawer. Concomitant injuries were present frequently and included medial collateral ligament (MCL; 42%), anterior cruciate ligament (ACL; 11.6%), and chondral injuries (31.8%), especially in the lateral tibiofemoral compartment. **Conclusions:** Three percent of the players at the NFL Combine presented with a PCL injury, with a significant amount being either running backs (14/69, 20.2%) or offensive linemen (14/69, 20.2%). Approximately half of the players with a PCL tear had a residual grade II or III posterior drawer after sustaining a PCL injury. Concomitant injuries were present frequently and included MCL (42%), ACL (11.6%), and chondral injuries (31.8%), especially in the lateral tibiofemoral compartment. For those players with clinical concern for PCL ligamentous laxity, there should be a complete comprehensive workup that includes plain and PCL stress view radiographs, and magnetic resonance imaging. **Level of Evidence:** Level IV, case series.

Isolated posterior cruciate ligament (PCL) tears comprise an uncommon cause of knee injury with a calculated annual incidence of 2 per 100,000 persons.¹ However, concurrent ligament injuries are commonly

associated with PCL injuries, increasing the prevalence of these lesions.² Moreover, the prevalence of PCL injuries in the National Football League (NFL) is likely to rise as a result of rule changes promoting tackling

From the Massachusetts General Hospital (M.D.P.), Boston, Massachusetts; Geisel School of Medicine at Dartmouth (B.R.B.-J., G.S.), Hanover, New Hampshire; Steadman Philippon Research Institute (J.C., N.I.K., M.E.C., R.F.L., M.T.P.), Vail, Colorado; New England Patriots (J.M.W., M.D.P.), Foxborough, Massachusetts; The Steadman Clinic (C.A.L., R.F.L., M.T.P.), Vail, Colorado; and University of Kansas Hospital (B.G.V.), Kansas City, Kansas, U.S.A.

The investigation was performed at Steadman Philippon Research Institute, Vail, Colorado, and Massachusetts General Hospital, Boston, Massachusetts, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: R.F.L. received institutional support from Arthrex, Ossur, Siemens, and Smith & Nephew; is a paid consultant for Arthrex, Smith & Nephew, and Ossur; receives 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. 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.); and receives publishing royalties from Arthrex and SLACK. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 16, 2017; accepted August 29, 2017.

Address correspondence to CAPT Matthew T. Provencher, M.D., M.C., U.S.N.R., Steadman Philippon Research Institute, The Steadman Clinic, 181 West Meadow Drive, Suite 400, Vail, CO 81657, U.S.A. E-mail: mprovencher@thesteadmanclinic.com

© 2017 Published by Elsevier on behalf of the Arthroscopy Association of North America

0749-8063/17547/\$36.00

<https://doi.org/10.1016/j.arthro.2017.08.304>

low to avoid helmet-to-helmet contact. Importantly, there is also a high prevalence of concomitant chondral and meniscal injuries, which increases the risk of developing osteoarthritis almost 6-fold.^{1,3}

A key step in defining the treatment approach is to assess the status of the PCL and to address concurrent pathology through a comprehensive physical examination, radiographs including stress views, and magnetic resonance imaging. However, the latter can be misleading in cases of chronic tears because the signal and shape of the PCL can be restored in chronic healed PCL tears on magnetic resonance imaging (MRI), and therefore stress radiographs are advocated.⁴ With regard to the treatment, PCL reconstruction has been reported to yield more satisfactory and consistent stability when compared with a conservative treatment group in a recent systematic review.³

A recent study reported that there was significant early cartilage degeneration in asymptomatic athletes with an isolated PCL injury.⁵ In addition, Ahrend et al.⁶ reported that 4.8% of patients with isolated PCL injury and 7.6% of patients with a PCL injury associated with other concurrent pathology were not able to return to sport. This led the authors to suggest that only a minority of competitive athletes cannot return to sport.

To our knowledge, there is a limited body of literature investigating the prevalence of PCL injuries in elite professional American football players. There is also a paucity of literature regarding commonly associated concurrent pathology, and relative risks of PCL injury between different NFL positions. Thus, the purpose of this study was to determine the epidemiology by player position, examination, imaging findings, and other injuries associated with PCL injuries in players participating in the NFL Combine. We hypothesized that there would be a high prevalence of undiagnosed PCL injuries at the Combine, and that positions at risk of significant contact below the knee, such as running backs and linebackers, would be more prevalent.

Methods

Study Design

A retrospective database analysis of all PCL injuries identified at the NFL Combine from 2009 to 2015 was conducted. Data were obtained from the database organized by the NFL medical personnel for compilation of the medical and physical performance examination results of NFL Draftees participating in the NFL Combine from 2009 to 2015. Our institution's IRB and the NFL Physician Society Research Committee approved this study. Additionally, the NFL Players Association (NFLPA) and the NFL Physicians Society (NFLPS) Research Committee approved this study. Inclusion criteria consisted of any player who had a PCL injury based on their clinical examination, or had

known history of surgically managed PCL injury, and participated in medical and performance testing at the NFL Combine. Players were not excluded based on draft status; both drafted and undrafted players were included in study group.

Demographics and Physical Examination

Medical records, imaging, associated injuries, and treatments were reviewed, and surgeries of any kind, games missed, position played, and draft position of each player were recorded. The number of injuries (isolated vs combined), treatment method (surgical vs nonoperative), and recurrent injuries were also recorded. Physical examination findings were retrieved from the NFL Combine aggregate physician dictation note. At the NFL Combine, all musculoskeletal evaluations were performed by the medical staff of all 32 NFL teams, and one comprehensive orthopaedic note was dictated after all teams examined the athlete. These notes were reviewed and analyzed for involved structures, residual injury, and associated soft tissue and bony injuries. A PCL injury was identified if the clinical examination performed by any of the 32 team physicians found a PCL injury, which was diagnosed by an abnormal posterior drawer examination compared with their contralateral knee. Additionally, the epidemiology of PCL injuries was subsequently analyzed by position of play. Classification of PCL injury was determined clinically, by posterior subluxation of the tibia relative to the femoral condyles (anterior, even with, posterior to) with the knee flexed to 90°. Grade I, II, and III PCL injuries were categorized as subjective posterior tibial translation of 1 to 5 mm, 6 to 10 mm, and >10 mm, respectively. Recurrent injury status was determined by review of the medical record. All patients with clinical suspicion or clinical diagnosis of PCL injury underwent imaging evaluation.

Imaging

All available imaging, including radiographs and MRI (Fig 1), was reviewed by 2 board-certified orthopaedic surgeons for the purpose of this study (C.A.L., B.G.V.) to assess for PCL injury (PCL fibers disruption, posterior tibial translation), presence of bone bruises as well as associated soft tissue and/or full-thickness chondral injuries (Table 1). Disagreements were resolved by discussion between the 2 senior surgeons. Importantly, imaging was previously obtained at the Combine after determining a previous history or physical examination findings of a residual PCL injury, which was reviewed by a radiologist at the time of the Combine.

Statistical Analysis

Descriptive statistics were performed to characterize the nature of PCL injuries and their impact on draft status among all athletes. The epidemiology of PCL injuries was subsequently analyzed by position of play,



Fig 1. T1-weighted magnetic resonance image of a right knee demonstrating a midsubstance tear of the posterior cruciate ligament (yellow arrow).

as well as stratified by offensive versus defensive players. Additional descriptive statistics were obtained to describe the physical examination and imaging findings; this

information was stratified by management, specifically surgical or nonoperative. All statistical analyses were performed with SPSS (Version 24.0; IBM, Armonk, NY).

Results

Demographics

A total of 2,285 players participated in the NFL Combine between 2009 and 2015 (Table 2). Sixty-nine athletes (3%) were identified to have a PCL injury. Eleven (15.9%) had been treated surgically, although information regarding the exact surgical technique was not available. Running backs ($n = 14$, 5.9%) and offensive linemen ($n = 14$, 3.9%) were the most common positions with PCL injuries (Table 3), followed by defensive linemen ($n = 10$). Offensive players sustained more PCL injuries than defensive players (44 vs 25). The mean draft pick among athletes with known injury was 126.3 compared with 137.2 among athletes with unknown injury history.

Physical Examination Findings and Recurrence

Posterior drawer testing revealed 32 of 67 (47.7%) grade I, 33 of 67 (49.2%) grade II, and 2 of 67 (2.9%) grade III. Four of 9 surgically treated athletes had residual grade II laxity. Posterior drawer physical examination findings were unavailable for 2 (2.8%) of the surgically managed knees. The players with grade III posterior drawer examination went undrafted; however, there were no differences in the overall mean draft pick in PCL-injured players with grade I versus grade II posterior drawer. One athlete reported a PCL injury recurrence postoperatively, and the recurrence was

Table 1. MRI Findings of PCL-Injured Knees Managed Surgically and Nonoperatively

	PCL-Injured Knees Managed Surgically, n (%) (n = 11)	PCL-Injured Knees Managed Nonoperatively, n (%) (n = 58)
Available MRI	11 (100)	58 (100)
Concomitant soft tissue injury identified on MRI	9 (81.8)	34 (58.6)
ACL	6 (54.6)	2 (3.5)
After ACL reconstruction	6	2
MCL	7 (63.6)	22 (37.9)
MCL injury, nonoperative management	1	22
After medial knee reconstruction	6	5 (8.6)
PCL	2 (18.2)	3
After PCL reconstruction	2	2
Medial meniscus	4 (36.4)	5 (8.6)
Medial meniscus injury, nonoperative management	2	2
After medial meniscectomy	2	3
Lateral meniscus	3 (27.3)	4 (6.9)
Lateral meniscus injury, nonoperative management	2	4
After lateral meniscectomy	1	18 (31.0)
Chondral injuries identified on MRI	4 (36.4)	10
Medial femoral condyle	1	1
Lateral femoral condyle	3	3
Lateral tibial plateau	1	4
Trochlea	1	3

ACL, anterior cruciate ligament; MCL, medial collateral ligament; MRI, magnetic resonance imaging; PCL, posterior cruciate ligament.

Table 2. PCL Injuries at the NFL Combine (2009-2015)

	Any PCL Injury, n (%)	Known History of PCL Injury, n (%)		Unknown History of PCL Injury, n (%)	Missed Games, Mean (SD)		PCL-Injured Players		
		Isolated	Combined		Any Injury	PCL Injury	No Missed Games, n (%)	Undrafted, n (%)	Overall Pick, Mean (SD)
All athletes (n = 2,285)	69*	47	13	9	4.8 (6.1)	2.2 (3.9)	42 (60.8)	23 (33.3)	127.7 (77.2)
Offense (n = 1,175)	44	34	6	4	5.0 (6.6)	2.5 (4.5)	28 (63.6)	16 (36.4)	143.5 (71.1)
Defense (n = 1,028)	25	13	7	5	4.2 (5.1)	1.7 (2.5)	14 (56.0)	7 (28.0)	103.1 (81.8)

NFL, National Football League; PCL, posterior cruciate ligament; SD, standard deviation.

*One athlete with bilateral PCL injuries was excluded from study cohort.

managed nonoperatively (Table 4). A total of 4 (5.8%) athletes wore a brace on the PCL-injured knee, with 2 of the 4 (50%) having been managed operatively.

Imaging

The MRIs of all 69 players with PCL injury were available to review (Table 1). Concomitant soft tissue injury was identified on MRI in 9 (13.0%) of the surgically treated knees. Of these, an anterior cruciate ligament (ACL) tear was found in 8 (11.6%) of the PCL-injured knees, with all 8 players treated operatively with reconstruction. Medial collateral ligament (MCL) injury was identified in 29 players (42.0%), including 7 of 11 (63.6%) surgically managed PCL-injured knees. Six of these 7 (85.7%) MCL injuries were managed surgically with medial knee reconstruction. None of the MCL injuries were managed surgically in the PCL-injured knees managed nonoperatively. Chondral injuries were identified on 22 players' (31.8%) MRIs. The lateral tibiofemoral compartment sustained chondral injury most frequently (22/69).

Discussion

The main findings of this study revealed that although a small subgroup of patients participating in the NFL Combine had a diagnosed PCL injury, a slight majority,

52%, exhibited a residual grade II or III posterior drawer on physical examination. The players with grade III posterior drawer examination went undrafted; however, there were no difference in overall mean draft pick in PCL injured players with grade I versus grade II posterior drawer.

Knee injuries have been found to be present in 54% of athletes participating at the NFL Combine.⁷ Previous studies have investigated the types of knee injuries in elite college players entering the NFL Combine, and the most common knee injuries sustained were MCL tears.^{7,8} In our analysis, chondral injuries were identified on 31.8% of players. An epidemiologic study of 1,287 PCL injuries in Scandinavia reported that cartilage lesions occurred in 26.1% of PCL injuries and meniscal lesions in 21.0%.⁹ In a 2003 study⁹ of 25 active NFL players who underwent microfracture to treat full-thickness chondral injuries, 19 of the 25 (76%) returned to football the following season. However, 6 players retired for various reasons. Injuries to the PCL are not common and, in the elite football player, little is known regarding injury risk factors, such as position, preferred management technique, or impact on draft position.

In our analysis, running backs and offensive linemen were the most common positions with PCL injuries,

Table 3. PCL Injuries at the NFL Combine by Position (2009-2015)

	Any PCL Injury, n (%)	Known History of PCL Injury, n		Unknown History of PCL Injury, n
		Isolated	Combined	
Offense (n = 1,175)	44 (3.7)	34	6	4
Offensive line (n = 356)	14 (3.9)	10	1	3
Quarterback (n = 125)	5 (4.0)	2	3	0
Running back (n = 239)	14 (5.9)	12	2	0
Tight end (n = 133)	3 (2.3)	2	0	1
Wide receiver (n = 308)	8 (2.6)	8	0	0
Defense (n = 1,028)	25 (2.4)	13	7	5
Defensive back (n = 405)	8 (2.0)	5	1	2
Defensive line (n = 384)	10 (2.6)	5	3	2
Linebacker (n = 239)	7 (2.9)	3	3	1
All athletes (n = 2,285)	69 (3.0)	47	13	9

NFL, National Football League; PCL, posterior cruciate ligament.

Table 4. Clinical Management and Physical Findings of PCL Injuries (n = 69)

Clinical Management and Physical Examination	All Injuries, n (n = 69)	Surgical Management, n (n = 11)	Nonoperative Management, n (n = 58)
Recurrence	1	1*	0
Current brace	4	2	2
Time interval since original injury			
<1 year	20	3	17
1-3 years	24	6	18
3+ years	15	2	13
Posterior drawer test			
Grade 1	32	5	27
Grade 2	33	4	29
Grade 3	2	0	2
Examination unavailable	2	2	0

PCL, posterior cruciate ligament.

*PCL injury recurrence managed nonoperatively.

followed by defensive linemen, and offensive players sustained more PCL injuries than defensive players. Previous studies have reported an increased risk for ACL injury based on player position.^{7,10,11} Wide receivers, tight ends, and backs (linebackers, fullbacks, and halfbacks) had significantly greater injury risk than the rest of the NFL players.¹¹ Further, interior linemen (offensive guards, centers, and defensive tackles) had significantly greater injury risk compared with perimeter linemen.

Numerous characteristics should be contemplated to yield optimal outcomes when treating a PCL injury.² This includes the presence of associated lesions, time elapsed since injury, severity of the lesion (grade), and time of the season. In this regard, isolated acute low-grade lesions are typically managed with a nonoperative approach, whereas grade III/combined/chronic symptomatic lesions are treated surgically. Ahn et al.³ performed a systematic review comparing the outcomes of nonoperative versus surgical reconstruction of PCL tears. The success rate of nonoperative treatment was 33%, and for surgical treatment, 90%. The authors concluded that there were more cases of satisfactory and consistent stability in the operative group.³

Limitations

The limitations of this study include the restraints associated with the retrospective nature of the study design. With regard to associated soft tissue injuries, such as an ACL tear, it is difficult to ascertain the true timeline of this additional injury. We also acknowledge the potential for inaccuracies in reporting injuries at the NFL Combine do exist and that there is variability in each of the physicians diagnosing these injuries. Further, PCL stress radiographs were not performed at the NFL Combine; thus, the true incidence and/or grade of PCL injury may be underrepresented. Despite these limitations, these findings may be used to assist team physicians as they counsel future players and determine optimal management of PCL-injured athletes. In

addition, we recognize that athletes with PCL injuries may be unable to compete at the NFL Combine and thus preselected to not participate.

Conclusions

Three percent of the players at the NFL Combine presented with a PCL injury, with a significant amount being either running backs (14/69, 20.2%) or offensive linemen (14/69, 20.2%). Approximately half of the players with a PCL tear had a residual grade II to III posterior drawer after sustaining a PCL injury. Concomitant injuries were present frequently and included MCL (42%), ACL (11.6%), and chondral injuries (31.8%), especially in the lateral tibiofemoral compartment. For those players with clinical concern for PCL ligamentous laxity, there should be a complete comprehensive workup that includes plain and PCL stress view radiographs, and MRI.

References

- Owesen C, Sandven-Thrane S, Lind M, Forssblad M, Granan LP, Aroen A. Epidemiology of surgically treated posterior cruciate ligament injuries in Scandinavia. *Knee Surg Sports Traumatol Arthrosc* 2017;25:2384-2391.
- Bedi A, Musahl V, Cowan JB. Management of posterior cruciate ligament injuries: An evidence-based review. *J Am Acad Orthop Surg* 2016;24:277-289.
- Ahn S, Lee YS, Song YD, Chang CB, Kang SB, Choi YS. Does surgical reconstruction produce better stability than conservative treatment in the isolated PCL injuries? *Arch Orthop Trauma Surg* 2016;136:811-819.
- LaPrade CM, Civitaresse DM, Rasmussen MT, LaPrade RF. Emerging updates on the posterior cruciate ligament: A review of the current literature. *Am J Sports Med* 2015;43:3077-3092.
- Okazaki K, Takayama Y, Osaki K, et al. Subclinical cartilage degeneration in young athletes with posterior cruciate ligament injuries detected with T1rho magnetic resonance imaging mapping. *Knee Surg Sports Traumatol Arthrosc* 2015;23:3094-3100.

6. Ahrend M, Ateschrang A, Dobeles S, et al. Return to sport after surgical treatment of a posterior cruciate ligament injury: A retrospective study of 60 patients. *Orthopade* 2016;45:1027-1038 [in German].
7. 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.
8. Brophy RH, Barnes R, Rodeo SA, Warren RF. Prevalence of musculoskeletal disorders at the NFL Combine—Trends from 1987 to 2000. *Med Sci Sports Exerc* 2007;39:22-27.
9. 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.
10. Bradley JP, Klimkiewicz JJ, Rytel MJ, Powell JW. Anterior cruciate ligament injuries in the National Football League: Epidemiology and current treatment trends among team physicians. *Arthroscopy* 2002;18:502-509.
11. Dodson CC, Secrist ES, Bhat SB, Woods DP, Deluca PF. Anterior cruciate ligament injuries in National Football League athletes from 2010 to 2013: A descriptive epidemiology study. *Orthop J Sports Med* 2016;4:2325967116631949.