Athletic Performance at the NFL Scouting Combine After Anterior Cruciate Ligament Reconstruction

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Background: Anterior cruciate ligament (ACL) injuries are common and potentially career ending in the National Football League (NFL). Although statistical performance has been demonstrated after ACL reconstruction, functional performance is not well defined.

Purpose/Hypothesis: The purpose of this study was to determine the functional performance of NFL combine participants after ACL reconstruction compared with an age-, size-, and position-matched control group. The hypothesis was that there would be no difference between players after ACL reconstruction as compared with controls in functional athletic performance.

Study Design: Cohort study; Level of evidence, 3.

Methods: A total of 98 NFL-caliber athletes who had undergone primary ACL reconstruction and participated in the NFL scouting combine between 2010 and 2014 were reviewed and compared with an age-, size-, and position-matched control group. Data recorded for each player included a 40-yard dash, vertical leap, broad jump, shuttle drill, and 3-cone drill.

Results: With regard to speed and acceleration, the mean 40-yard dash time for ACL-reconstructed players was 4.74 seconds (range, 4.33-5.55 seconds) compared with controls at 4.74 seconds (range, 4.34-5.38 seconds; *P* = .96). Jumping performance was also similar, with a mean vertical leap for ACL-reconstructed players of 33.35 inches (range, 23-43 inches) and broad jump of 113.9 inches (range, 96-136 inches) compared with respective values for the controls of 33.22 inches (range, 23.5-43.5 inches; *P* = .84) and 113.9 inches (range, 92-134 inches; *P* = .99). Agility and quickness testing measures also did not show a statistically significantly difference, with ACL-reconstructed players performing the shuttle drill in 4.37 seconds (range, 4.02-4.84 seconds) and the 3-cone drill in 7.16 seconds (range, 6.45-8.14 seconds), respectively, compared with respective times for the controls of 4.37 seconds (range, 3.96-5.00 seconds; *P* = .91) and 7.18 seconds (range, 6.64-8.24 seconds; *P* = .75).

Conclusion: This study suggests that after ACL reconstruction, high-caliber athletes can achieve equivalent levels of performance with no statistically significant differences compared with matched controls. This information is unique when advising high-level athletes on athletic performance after ACL reconstruction, suggesting that those who fully recover and return to play appear to have no decrement in athletic performance.

Keywords: ACL reconstruction; NFL players; football; athletic performance

Anterior cruciate ligament (ACL) tears are common sports-related injuries. ACL tears represent one of the most common injuries in sports, with an estimated incidence of 250,000 ACL injuries per year in the United States.[3] There is an inherent risk for ACL injuries in American football in particular. Previous studies have suggested that the incidence of

ACL tears is 0.11 per 1000 players in high school football and 0.7 per 1000 players in the National Football League (NFL).[23]

ACL tears are devastating injuries in high-level athletes. This injury necessitates surgical reconstruction, resulting in time away from sport, extensive rehabilitation, and player anxiety about future levels of performance after returning to play.[13,14,16,20,22] Several studies, however, have shown that reconstruction after an ACL injury is very successful. Previous studies in NFL players showed rates of return to sport as high as 92%, with most players returning to previous statistical in-game performance levels.[4,6,9,19,24] Although these studies provide insight to expected return to sport and on-field performance, to our knowledge, no study has specifically quantified athletic performance in terms of functional performance including running speed, jumping ability, and agility/quickness after ACL reconstruction.

The purpose of this study was to evaluate athletic performance at the NFL scouting combine of NFL-caliber athletes who had undergone ACL reconstruction compared with age-, size-, and position-matched controls. We hypothesized that players who previously underwent ACL reconstruction would have no difference in running speed, jumping ability, or agility and quickness when compared with matched controls.

METHODS

We conducted a retrospective case control study. Approval was obtained from our institutional review board.

ACL-Reconstructed Players

A cohort of 98 football players with a history of ACL reconstrucion who participated in the NFL scouting combine between the years of 2010 and 2014 were identified. All players had undergone ACL reconstruction before the NFL combine. Players who underwent ACL reconstruction were identified with similar methods to those in previous studies.[6,7,9,12,15,17,18,21] Players with a history of ACL reconstruction were identified as such via team websites, press releases, personal websites, and college football statistical websites. In finding the cohort, ACL surgery was considered an acceptable reference.

Selection for participation in the combine is determined annually by a selection committee that is composed of scouts and player personnel departments from 25 different NFL teams. All eligible players are reviewed and voted on by committee members. Each player receiving the necessary votes, by position, is extended an invitation.

For each player, age, height, weight, and body mass index (BMI) were recorded as measured at the combine. Also recorded were the athlete's listed playing position, college attended, and years between ACL reconstruction and performance at the combine. Athletic performance data were obtained using combine performance statistics from nfl.com. Data that were recorded for each player included the 40-yard dash, vertical leap, broad jump, shuttle drill, and 3-cone drill. The 40-yard dash is intended to measure running speed and acceleration. The vertical leap and broad jump measure a player's jumping ability as well as power and explosion, while the 3-cone drill and shuttle drill are intended to measure quickness and agility.[2,10] The 3-cone drill is performed by a player maneuvering around 3 cones, with a distance of 4.6 m between each cone, placed in the shape of an *L*. The shuttle drill is performed by a player running 4.6 m in one direction, changing direction, running 9.1 m back in the opposite direction, and then changing direction again and returning 4.6 m in the opposite direction.

Control Players

A blinded age-, size-, and position-matched control group of NFL scouting combine participants was identified. The control group was identified for a comparison of players with a history of ACL reconstruction to a representative group of players at a similar level from the same NFL combine year. Our methods for selecting a control cohort were similar to those reported in previous literature.[6,7,12,17,18] Players with a known history of ACL reconstruction or "undisclosed knee injury" were excluded from the control cohort. No other exclusion criteria were used for the controls. Controls were selected by first removing players with a known history of ACL reconstructive surgery or "undisclosed knee injury." We then compiled a deidentified database of all remaining players who participated in the NFL scouting combine between 2010 and 2014. Players were then matched to the respective ACL-reconstructed athletes according to year of combine performance, listed position at the combine, age at the combine, height, and weight. For each control player, we recorded their listed playing position, college attended, age, height, weight, and BMI. Athletic performance data that were recorded for each player included the 40-yard dash, vertical leap, broad jump, shuttle drill, and 3-cone drill.

Statistical Analysis

The 2 groups were compared for differences in demographic information, year, and position played along with selected performance measures using 2-sample t tests for the continuous measures and χ^2 tests for the categorical measures. Pearson correlation coefficients were used to assess the relationship between age and the performance measures for all players separately. Also for the ACL-reconstructed players, correlation coefficients were computed for the years since surgery with the performance measures. Statistical significance was set at $P < .05$. Statistical analyses were conducted using SAS version 9.4 (SAS Institute).

RESULTS

A total of 98 players were identified who underwent ACL reconstruction before participating in the NFL combine. Table 1 shows the characteristics of the ACL-reconstructed and control players. There were no statistical differences between ACL-reconstructed players and controls, respectively, with regard to the following: age (mean, 22.42 years [range, 20-26 years] vs 22.27 years [range, 20-24 years]; $P = .23$), height (mean, 73.46 inches [range, 67-80 inches] vs 73.47 inches [range, 65-79 inches]; $P = .98$), weight (mean, 241.06 lb [range, 175-338 lb] vs 241.05 lb [range, 180-345 lb]; $P = .99$), or position played ($P > .99$). All ACL-reconstructed players and controls were from Division I or I-AA schools. Of the reconstructed group, 81 were from the following power conferences: 13 from the Pacific-12 Conference (Pac-12), 20 from the Atlantic Coast Conference (ACC), 12 from the Big 12 Conference (Big 12), 14 from the Big Ten Conference (Big Ten), and 22 from the Southeastern Conference (SEC). The controls consisted of 74 players (of 98) from the following power conferences: 16 from the Pac-12, 24 from the ACC, 9 from the Big 12, 12 from the Big Ten, and 13 from the SEC. The mean time between ACL

TABLE 1
Descriptive Statistics for the Study Groups[a]

	ACL Reconstruction Group (n = 98)	Control Group (n = 98)	P Value
Age, mean ± SD (range), y	22.42 ± 1.00 (20-26)	22.27 ± 0.75 (20-24)	.23
Height, mean ± SD (range), inches	73.46 ± 2.89 (67-80)	73.47 ± 2.74 (65-79)	.98
Weight, mean ± SD (range), lb	241.06 ± 39.95 (175-338)	241.05 ± 40.02 (180-345)	.99
Year, n (%)			>.99
2010	19 (19)	19 (19)	
2011	14 (14)	14 (14)	
2012	24 (24)	24 (24)	
2013	19 (19)	19 (19)	
2014	22 (22)	22 (22)	
Position, n (%)			>.99
Quarterback	5 (5)	5 (5)	
Running back	19 (19)	18 (18)	
Wide receiver	10 (10)	11 (11)	
Tight end	5 (5)	5 (5)	
Full back	3 (3)	3 (3)	
Center	3 (3)	3 (3)	
Offensive guard	2 (2)	2 (2)	
Offensive tackle	5 (5)	5 (5)	
Free safety	3 (3)	3 (3)	
Strong safety	2 (2)	2 (2)	
Cornerback	7 (7)	7 (7)	
Outside linebacker	10 (10)	10 (10)	
Inside linebacker	8 (8)	8 (8)	
Defensive tackle	8 (8)	8 (8)	
Defensive end	8 (8)	8 (8)	

[a]ACL, anterior cruciate ligament.

TABLE 2
Comparison of Performance Measures[a]

Performance Measure	ACL Reconstruction Group (n = 98)	Control Group (n = 98)	P Value
40-yard dash, s	4.74 ± 0.26 (4.33-5.55)	4.74 ± 0.25 (4.34-5.38)	.96
Vertical leap, inches	33.35 ± 3.89 (23-43)	33.22 ± 4.18 (23.5-43.5)	.84
Broad jump, inches	113.90 ± 7.87 (96-136)	113.91 ± 8.35 (92-134)	.99
Shuttle drill, s	4.37 ± 0.21 (4.02-4.84)	4.37 ± 0.23 (3.96-5.00)	.91
3-cone drill, s	7.16 ± 0.34 (6.45-8.14)	7.18 ± 0.37 (6.64-8.24)	.75

[a]Results are reported as mean ± SD (range). ACL, anterior cruciate ligament.

reconstruction and combine performance was 2.93 years (range, 1-8 years).

In comparing the combine performance of ACL-reconstructed players to controls, results were almost identical, with no statistically significant differences in any physical performance measures (Table 2). With regard to speed and acceleration, the mean 40-yard dash time was 4.74 seconds (range, 4.33-5.55 seconds) for ACL-reconstructed players compared with 4.74 seconds (range, 4.34-5.38 seconds; P = .96) for the controls. Jumping performance was also similar, with a mean vertical leap of 33.35 inches (range, 23-43 inches) and broad jump of 113.9 inches (range, 96-136 inches) for reconstructed players compared with 33.22 inches (range, 23.5-43.5 inches; P = .84) and 113.9 inches (range, 92-134 inches; P = .99) for the controls, respectively. Agility and quickness testing measures also did not show a statistically significant difference, with reconstructed players performing the shuttle drill and 3-cone drill in 4.37

TABLE 3
Correlation of Years From Surgery to the
NFL Combine With Performance Measures
for the ACL Reconstruction Group[a]

Performance Measure	Correlation Coefficient	P Value
40-yard dash	0.173	.09
Vertical leap	−0.214	.07
Broad jump	−0.149	.21
Shuttle drill	0.147	.27
3-cone drill	0.183	.18

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

seconds (range, 4.02-4.84 seconds) and 7.16 seconds (range, 6.45-8.14 seconds), respectively, compared with respective times for the controls of 4.37 seconds (range, 3.96-5.00

TABLE 4
Correlation of Age With Performance Measures for All Players, the ACL Reconstruction Group, and the Control Group[a]

	All Players		ACL Reconstruction Group		Control Group	
	Correlation Coefficient	P Value	Correlation Coefficient	P Value	Correlation Coefficient	P Value
40-yard dash	0.109	.13	0.098	.33	0.128	.21
Vertical leap	−0.025	.75	−0.087	.46	0.028	.79
Broad jump	−0.151	.06	−0.171	.16	−0.138	.19
Shuttle drill	−0.051	.55	−0.081	.54	−0.028	.80
3-cone drill	0.031	.72	0.052	.70	0.011	.92

[a]ACL, anterior cruciate ligament.

seconds; P = .91) and 7.18 seconds (range, 6.64-8.24 seconds; P = .75).

In evaluating for a correlation in the reconstructed players between the number of years from ACL reconstruction to the combine performance date compared with combine performance results, there were no correlations found in any performance markers. The years between ACL reconstruction and combine performance showed no correlation in the 40-yard dash (P = .09), vertical leap (P = .07), broad jump (P = .21), shuttle drill (P = .27), or 3-cone drill (P = .18) (Table 3). There were also no correlations between combine performance and age of the players (Table 4).

A post hoc power analysis demonstrated that with a sample size of 98 participants per group, a mean difference of 0.4 SDs could detect 80% power, assuming an α value of .05 and 2-sided testing. Using effect size and the SDs from Table 2, the detectable differences for performance measures would be 0.12 seconds for the 40-yard dash, 1.68 inches for the vertical leap, 3.32 inches for the broad jump, 0.08 seconds for the shuttle drill, and 0.16 seconds for the 3-cone drill. Thus, the current sample size of this cohort was found to be sufficient to find a meaningful difference.

DISCUSSION

To truly quantify the effect of ACL reconstruction on athletic performance, it is crucial to evaluate functional performance: speed, agility/quickness, and jumping ability. There have been no previous studies to our knowledge that have specifically evaluated the functional performance of high-level athletes who have undergone ACL reconstruction. Most current studies review return to sport or statistical performance in sports after reconstruction. Erickson et al[9] demonstrated that the in-game performance of 12 NFL quarterbacks returning to sport showed no significant difference compared with preinjury performance or controls. Busfield et al[5] evaluated the player efficiency rating (PER) in 27 National Basketball Association players after ACL reconstruction, demonstrating that 78% returned to sport, 15% had an increase in PER, 19% were within 1 point of their preinjury PER, and 44% had a greater than 1-point drop from their preinjury PER. Finally, Shah et al[24] showed that 63% of NFL players (31/49) who underwent ACL reconstruction at their institution returned to play at 10.8 months.

Although return to play and sport statistics after ACL reconstruction provide useful information, many athletes are concerned about how changes in their speed, agility/quickness, and jumping ability or power/explosiveness may be affected after ACL reconstruction. In brief, our study is unique in demonstrating that high-caliber athletes after ACL reconstruction can achieve equivalent levels of performance with no statistically significant differences compared with age-, size-, and position-matched controls. This information is unique when advising high-level athletes on athletic performance after ACL reconstruction and encouraging them that similar high-level athletic performance is not only possible but also probable.

Residual donor site weakness after autograft harvesting for ACL reconstruction is a concern for athletes and physicians as it may directly affect athletic performance. Studies have suggested both quadriceps and hamstring weakness with bone-tendon-bone and hamstring autografts, respectively. For example, Keays et al[11] compared reconstructed patients versus uninjured controls and found a 6% decrease in quadriceps strength after ACL reconstruction with a bone–patellar tendon–bone autograft. Ageberg and associates[1] also showed that lower hamstring and quadriceps muscle power might persist up to 3 years after autograft harvesting. This current study did not specifically evaluate donor site weakness; however, its results lend evidence that even if a minor strength deficit exists, there is no evidence of functional deficits in high-level athletes after ACL reconstruction.

This study does not differentiate between grafts, surgeons, or techniques. However, it can provide information with regard to the broad spectrum of athletes who undergo successful ACL reconstruction regardless of graft choice, surgical technique, or surgeon experience. Bradley and colleagues[4] demonstrated that 84% of NFL team physicians would use bone–patellar tendon autografts to reconstruct the ACLs of their athletes. A more recent study by Erickson and colleagues[8] assessed surgeon practice patterns in ACL reconstruction performed on National Collegiate Athletic Association (NCAA) and NFL athletes and concluded that 86% of NFL and NCAA surgeons use bone–patellar tendon–bone in their elite running backs and that 99% use single-bundle reconstruction. Thus, regardless of the possible variables in graft choice, surgical technique, and surgeon experience, it is likely that the majority of the

athletes whom we reviewed in the combine had similar ACL reconstruction techniques and graft choices.

The results of this study provide unique information that NFL-caliber athletes who are able to fully recover and play at the highest level do not have diminished functional athletic performance compared with a matched cohort after undergoing ACL reconstruction. However, this study has multiple limitations. This study was conducted as a retrospective review and would be more powerful if performed prospectively. The information in our study is based on public data, and although information was cross-checked with other sources including individual player media pages, there is the possibility of flaws in these data. There is also inherent selection bias with using this method for selecting our ACL cohort, as we did not use combine medical records or direct player contact to develop this group. We also acknowledge that there could have been athletes who were not included because of inaccuracies in reporting injuries. Intrinsic selection bias is also present, as this study did not evaluate players with previous ACL injuries who could not return to play or perform at a high enough level to be invited to the combine. There are also many variables that we are unable to control for such as concomitant ligamentous or meniscal injuries, graft types, surgical techniques, and previous other lower extremity injuries, which can directly affect outcomes. We also did not know how the ACL-reconstructed players would have performed before their ACL reconstruction. Future prospective studies would help to address these limitations.

In conclusion, this is the first study, to our knowledge, to truly evaluate the functional performance of high-level athletes compared with a group of age-, size-, and position-matched controls. This study suggests that after ACL reconstruction, high-caliber athletes can achieve equivalent levels of performance with no statistically significant differences compared with matched controls. This information is unique when advising high-level athletes on athletic performance after ACL reconstruction, suggesting that those who fully recover and return to play appear to have no decrement in athletic performance.

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REFERENCES

1. Ageberg E, Roos HP, Silbernagel KG, Thomeé R, Roos EM. Knee extension and flexion muscle power after anterior cruciate ligament reconstruction with patellar tendon graft or hamstring tendons graft: a cross-sectional comparison 3 years post surgery. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(2):162-169.
2. Barker M, Wyatt TJ, Johnson RL, et al. Performance factors, psychological assessment, physical characteristics and football playing ability. *J Strength Cond Res*. 1993;7:224-233.
3. Barrera Oro F, Sikka RS, Wolters B, et al. Autograft versus allograft: an economic cost comparison of anterior cruciate ligament reconstruction. *Arthroscopy*. 2011;27(9):1219-1225.
4. 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(5):502-509.
5. Busfield BT, Kharrazi FD, Starkey C, Lombardo SJ, Seegmiller J. Performance outcomes of anterior cruciate ligament reconstruction in the National Basketball Association. *Arthroscopy*. 2009;25(8):825-830.
6. Carey JL, Huffman GR, Parekh SG, Sennett BJ. Outcomes of anterior cruciate ligament injuries to running backs and wide receivers in the National Football League. *Am J Sports Med*. 2006;34(12):1911-1917.
7. Erickson BJ, Gupta AK, Harris JD, et al. Rate of return to pitching and performance after Tommy John surgery in Major League Baseball pitchers. *Am J Sports Med*. 2014;42(3):536-543.
8. Erickson BJ, Harris JD, Fillingham YA, et al. Anterior cruciate ligament reconstruction practice patterns by NFL and NCAA football team physicians. *Arthroscopy*. 2014;30(6):731-738.
9. Erickson BJ, Harris JD, Heninger JR, et al. Performance and return-to-sport after ACL reconstruction in NFL quarterbacks. *Orthopedics*. 2014;37(8):728-734.
10. Hoffman JR, Ratamess NA, Klatt M, Faigenbaum AD, Kang J. Do bilateral power deficits influence direction-specific movement patterns? *Res Sports Med*. 2007;15(2):125-132.
11. Keays SL, Bullock-Saxton JE, Keays AC, Newcombe PA, Bullock MI. A 6-year follow-up of the effect of graft site on strength, stability, range of motion, function, and joint degeneration after anterior cruciate ligament reconstruction: patellar tendon versus semitendinosus and gracilis tendon graft. *Am J Sports Med*. 2007;35(5):729-739.
12. Keller RA, Steffes MJ, Zhuo D, Bey MJ, Moutzouros V. The effects of medial ulnar collateral ligament reconstruction on Major League pitching performance. *J Shoulder Elbow Surg*. 2014;23(11):1591-1598.
13. Kvist J. Rehabilitation following anterior cruciate ligament injury: current recommendations for sports participation. *Sports Med*. 2004;34(4):269-280.
14. Kvist J, Ek A, Sporrstedt K, Good L. Fear of re-injury: a hindrance for returning to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2005;13(5):393-397.
15. Lansdown DA, Feeley BT. The effect of ulnar collateral ligament reconstruction on pitch velocity in Major League Baseball pitchers. *Orthop J Sports Med*. 2014;2(2):2325967114522592.
16. Lee DY, Karim SA, Chang HC. Return to sports after anterior cruciate ligament reconstruction: a review of patients with minimum 5-year follow-up. *Ann Acad Med Singapore*. 2008;37(4):273-278.
17. Makhni EC, Lee RW, Morrow ZS, Gualtieri AP, Gorroochurn P, Ahmad CS. Performance, return to competition, and reinjury after Tommy John surgery in Major League Baseball pitchers: a review of 147 cases. *Am J Sports Med*. 2014;42(6):1323-1332.
18. Marshall NE, Keller RA, Lynch JR, Bey MJ, Moutzouros V. Pitching performance and longevity after revision ulnar collateral ligament reconstruction in Major League Baseball pitchers. *Am J Sports Med*. 2015;43(5):1051-1056.
19. McCullough KA, Phelps KD, Spindler KP, et al; MOON Group. Return to high school- and college-level football after anterior cruciate ligament reconstruction: a Multicenter Orthopaedic Outcomes Network (MOON) cohort study. *Am J Sports Med*. 2012;40(11):2523-2539.
20. Morrey MA, Stuart MJ, Smith AM, Wiese-Bjornstal DM. A longitudinal examination of athletes' emotional and cognitive responses to anterior cruciate ligament injury. *Clin J Sport Med*. 1999;9(2):63-69.
21. Namdari S, Baldwin K, Anakwenze O, Park MJ, Huffman GR, Sennett BJ. Results and performance after microfracture in National Basketball Association athletes. *Am J Sports Med*. 2009;37:943-948.
22. Nebelung W, Wuschech H. Thirty-five years of follow-up of anterior cruciate ligament-deficient knees in high-level athletes. *Arthroscopy*. 2005;21(6):696-702.
23. Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy*. 2007;23(12):1320-1325.
24. Shah VM, Andrews JR, Fleisig GS, McMichael CS, Lemak LJ. Return to play after anterior cruciate ligament reconstruction in National Football League athletes. *Am J Sports Med*. 2010;38(11):2233-2239.