Return to Play and Performance After Primary ACL Reconstruction in American Football Players

A Systematic Review

Bailey J. Ross,* BA, Ian Savage-Elliott,[†] MD, Symone M. Brown,[†] MPH, and Mary K. Mulcahey,[†‡] MD
Investigation performed at Tulane University School of Medicine, New Orleans, Louisiana, USA

Background: Anterior cruciate ligament (ACL) injuries are among the most common sports-related injuries, and they can have a negative impact on players' ability to return to play (RTP). There is a paucity of literature focused on RTP after ACL reconstruction (ACLR) in collision sports.

Purpose: To characterize the impact that an ACL injury has on the ability to RTP and the post-ACLR performance level in American football players.

Study Design: Systematic review; Level of evidence, 4.

Methods: An electronic search was performed using the following databases: the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed, Embase, and the Cumulative Index to Nursing and Allied Health Literature. Included studies were written in English; were published since the year 2000; examined only American football players; and reported on RTP, performance, and/or career length after primary ACLR.

Results: The initial search yielded 442 unique studies. Of these, 427 were removed after screening, leaving 15 studies that met inclusion criteria. An additional 2 studies were identified in these studies' references, yielding a total of 17. The rate of RTP after ACLR for football players was 67.2% (1249/1859), and the mean time to return was 11.6 months (range, 35.8-55.8 weeks). Although considerable heterogeneity existed in the study design and outcomes measured, in general, a majority of football players experienced greater declines from their preinjury performance level than controls over the same time period.

Conclusion: An ACL injury negatively affected football players' ability to RTP and their post-ACLR performance. The degree of effect varied by several factors, including playing position, preinjury performance level, and National Football League Draft round. These results may be used by physicians and football players to develop reasonable expectations for returning to play and performance after an ACL injury.

Keywords: football; ACL; injury; return to sport

Anterior cruciate ligament (ACL) injuries are common in sports that require sudden changes in acceleration and quick jumping, cutting, and pivoting motions, such as American football (subsequently referred to as football).[1,10] As many as 8% of all participants at the National Football League (NFL) Scouting Combine have a history of ACL injuries.[5,8] Previous studies have shown that such injuries require prolonged time away from competition and extensive rehabilitation after primary ACL reconstruction (ACLR), which not only imparts the psychological burden

of the fear of reinjuries on players but also a financial burden, given the time missed.[1,27,34,36] Numerous studies have shown that an ACL injury in football is significantly correlated with negative outcomes compared with controls, from decreased on-field performance to shorter careers.[7,8,25,26,32] Given the popularity of football in the United States, it is imperative that a better understanding of how an ACL injury affects participation in football is attained.

A major goal for players after ACLR is to successfully return to play (RTP) at the same preinjury skill and competition level.[1,2,20] Previous literature has suggested that players' ability to RTP successfully is dependent on numerous factors, ranging from the type of sport to playing position.[12,13,15,26,36-38] The purpose of this study was to perform

a systematic review of the literature reporting RTP data and performance level after ACLR in football players.

METHODS

Study Identification and Selection

This study was conducted in accordance with the 2015 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[28] A systematic review of literature reporting RTP data after ACLR was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed, Embase, and the Cumulative Index to Nursing and Allied Health Literature. The search was performed on June 19, 2019. The search terms were as follows: "American football" AND "anterior cruciate ligament injuries" (Medical Subject Headings terms).

Studies were included if they met the following criteria: evaluated RTP, performance, career length, and/or injury data after primary ACLR with at least one 12-month follow-up; examined American football players; were written in the English language; and were published in the year 2000 or after. Exclusion criteria were as follows: studies that included nonathletes, examined any sport besides American football, or explicitly included only nonisolated ACL injuries; editorial studies; basic science studies; studies published before the year 2000; case reports; epidemiological studies (without RTP outcome data); non-English studies; systematic reviews; and meta-analyses.

Two investigators (B.J.R., I.S.-E.) independently reviewed the titles and/or abstracts of all identified studies. Subsequently, full texts were reviewed for a further assessment of inclusion and exclusion criteria. Studies that met inclusion criteria were aggregated, and the references from these studies were scanned to ensure that the systematic review encompassed all relevant studies concerning the topic.

Data Collection

Each included study was assigned a study type and corresponding level of evidence as specified by Wright et al.[39] If reported, the following data were collected from each study: player demographics, total number of players who underwent ACLR, number of players who returned to play, percentage of players who returned to play, pre- and post-ACLR performance metrics, games played, games started, and career length. When applicable, this data was recorded both for players who underwent ACLR and for controls who did not. If available, only data for isolated ACLR was recorded; however, some studies did not state explicitly if the patient underwent ACLR alone or in combination with other procedures or did not separate RTP data as such. For continuous variables (age, timing, outcome data, etc), the mean and range and/or standard deviation were recorded unless otherwise specified.

RESULTS

Search Results

The initial search yielded 614 studies (Figure 1). After the removal of 172 duplicates, 442 unique studies remained. Subsequently, 402 studies were removed based on exclusion criteria. The remaining 40 studies underwent a full-text review, and 25 more studies were excluded, yielding 15 studies for inclusion in the study. An additional 2 studies that met inclusion criteria were found in the references of the other 15 included studies. Thus, a total of 17 studies were included in this systematic review.

Football Data

The characteristics of the 17 included studies are listed in Table 1. One study[27] reported on high school and college players, 2 studies[14,38] reported exclusively on college players, 4 studies[6,7,8,22] reported on NFL and college players, and the remaining 10 studies[§] reported exclusively on NFL players. Moreover, 9 studies provided the mean age of players; the weighted mean age of players who were able to RTP in these studies was 26.0 years (range, 25.2-27.3 years).[‖] No studies found significant correlations between age and ability to RTP. The type of graft used for ACLR was reported in 3 studies; bone–patellar tendon–bone autografts were the most frequently used graft in each study, followed by hamstring tendon autografts.[14,27,35] However, only Daruwalla et al[14] found a significant difference in graft type versus RTP percentage, with autografts yielding a higher RTP percentage than allografts (*P* = .045). Two studies reported on reinjury rate, but no significant associations between the reinjury rate and RTP rate were found.[19,29]

The 17 studies included a total of 2195 ACLR procedures. Of these, 3 studies (18%) did not specify how many players returned to play after ACLR.[7,22,31] The remaining 14

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§References 10, 12, 17, 19, 25, 29, 31, 32, 35, 40.
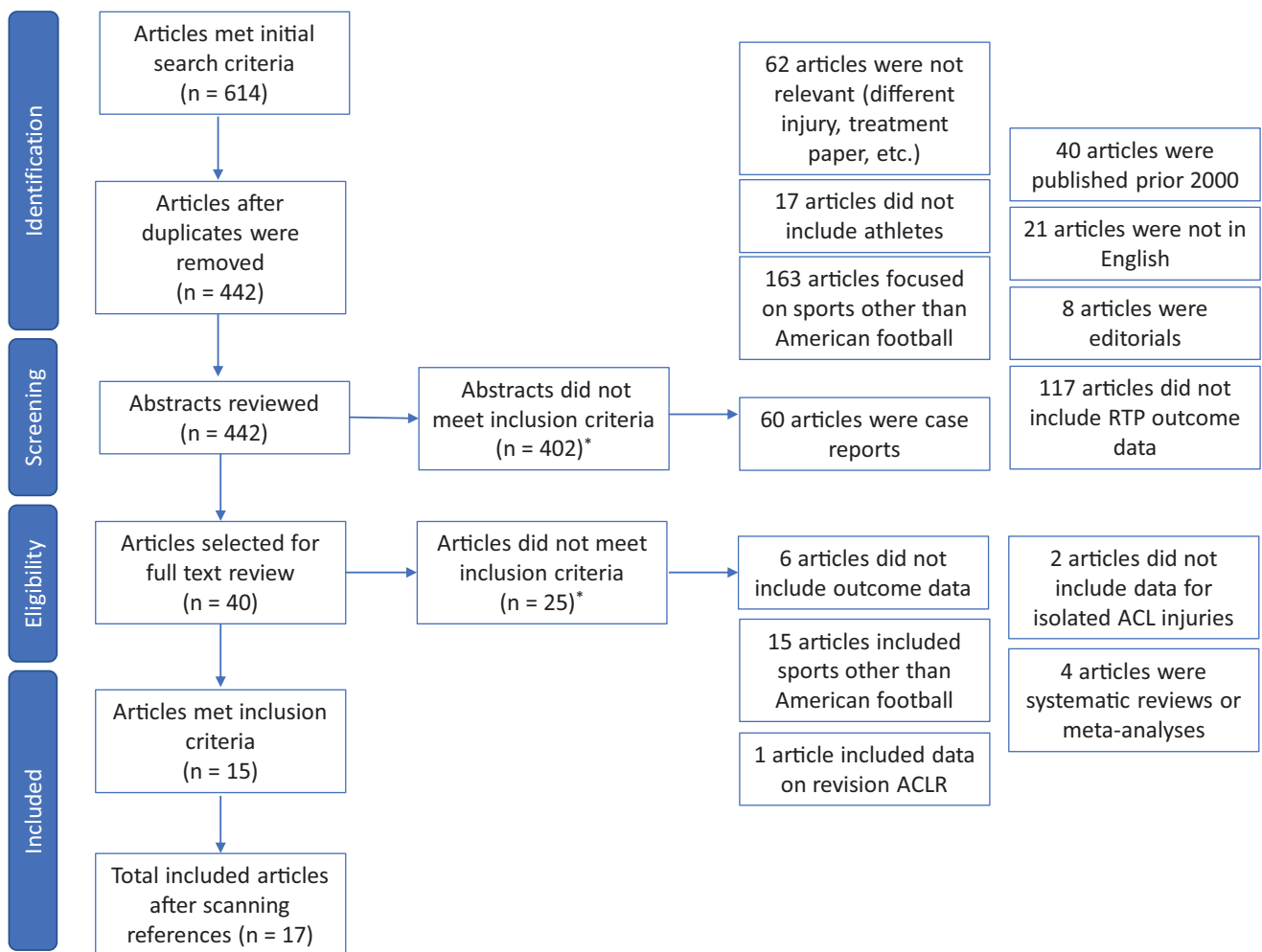‖References 10, 12, 17, 19, 25, 29, 32, 35, 40.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) flow diagram. ACL, anterior cruciate ligament; ACLR, ACL reconstruction; RTP, return to play. *Some articles were excluded for multiple reasons; therefore, the figures outlined in the exclusion explanations do not match the total articles excluded for each screening.

studies (82%) reported that 1249 players returned to play during the course of each study period (Appendix Table A1).¶ The mean RTP percentage across these remaining 14 studies was 67.2% (1249/1859). However, there was considerable variance in how each study defined successful RTP and how players were divided into groups (individual positions, "skilled" vs "unskilled" positions, etc) (Appendix Table A1). Brophy et al[6] reported the lowest overall RTP percentage at 45.9% (130/283) for players participating in the NFL Scouting Combine, while Erickson et al[19] reported the highest RTP percentage at 92.9% (13/14) for NFL quarterbacks. Additionally, 8 studies[10,12,14,19,25,29,32,35] explicitly reported the mean time to RTP (weighted mean, 11.6 months [range, 35.8[14] to 55.8[10] weeks]).

There were 7 studies that reported the number of games played by players after ACLR versus controls (Appendix Table A2).[7,8,10,12,19,22,31] Brophy et al[8] found that ACLR significantly reduced games played by NFL offensive

linemen compared with controls ($P = .003$), and Frank et al[22] concluded that players with a history of ACLR at the NFL Scouting Combine played in fewer games in their first 2 NFL seasons following ACLR than controls ($P < .05$). Additionally, 5 studies analyzed the number of games started (ie, first on the depth chart) for players who underwent ACLR versus controls either before or after the injury (Appendix Table A2).[7,12,22,31,32] Of these studies, 3 found significant differences. Frank et al[22] ($P < .01$) and Provencher et al[31] (season 1: $P = .005$; season 2: $P = .002$) found that players with a history of ACLR at the NFL Scouting Combine started fewer games in the following 2 seasons than controls. Read et al[32] concluded that NFL players who underwent ACLR had started a greater proportion of games before their injury than controls and experienced a greater decline in the proportion of games started after the injury than controls over the same time period ($P = .004$). Also, 4 studies reported on career length for players who underwent ACLR versus controls (Appendix Table A3).[7,12,19,32] Only Cinque et al[12] found significant differences,

¶References 6, 8, 10, 12, 14, 17, 19, 25, 27, 29, 32, 35, 38, 40.

TABLE 1
Characteristics of Included Studies[a]

Author (Year)	Level of Play	Study Type	LOE	Data Collection Years	Type of Graft Used	Player Age,[b] y
Brophy[6] (2008)	NFL, NCAA	Cohort	3	1987-2001	N/A	N/A
Brophy[7] (2009)	NFL, NCAA	Case-control	3	1987-2000	N/A	N/A
Brophy[8] (2009)	NFL, NCAA	Cohort	3	1987-2000	N/A	N/A
Carey[10] (2006)	NFL	Cohort	2	1998-2002	N/A	27.1 ± 0.6
Cinque[12] (2017)	NFL	Cohort	3	1980-2015	N/A	OL: 26.3 ± 2.6; DL: 25.6 ± 3.1
Daruwalla[14] (2014)	NCAA	Case series	4	2004-2010	Auto (n = 155), allo (n = 27), unknown graft type (n = 2)	N/A
Eisenstein[17] (2016)	NFL	Case-control	3	2013-2015	N/A	25.96
Erickson[19] (2014)	NFL	Case-control	3	1988-2013	N/A	27.2 ± 2.39
Frank[22] (2017)	NFL, NCAA	Case-control	3	2009-2015	N/A	N/A
Mai[25] (2016)	NFL	Case series	4	2003-2013	N/A	26.4
McCullough[27] (2012)	NCAA, HS	Cohort	3	2002-2003	BPTB auto (n = 45), BPTB allo (n = 1), HT (n = 18), soft tissue allo (n = 7), unknown graft type (n = 21)	N/A
Okoroha[29] (2019)	NFL	Case-control	3	2009-2015	N/A	Revision needed (n = 23): 25.2 ± 3.5; no revision needed (n = 95): 25.4 ± 2.8
Provencher[31] (2018)	NFL	Case-control	3	2009-2015	N/A	N/A
Read[32] (2017)	NFL	Case-control and cohort	3	2006-2012	N/A	27.3 ± 3.1
Shah[35] (2010)	NFL	Case series	4	2001-2008	BPTB (n = 47), HT auto (n = 2)	RTP: 26.6 ± 2.7; no RTP: 25.6 ± 2.1
Wise[38] (2019)	NCAA	Descriptive epidemiology	3	2010-2015	N/A	N/A
Yang[40] (2017)	NFL	Case-control	3	2010-2013	N/A	RTP <18 mo: 25.2 (24.6-25.8); no RTP <18 mo: 25.4 (24.8-26.1)

[a]Allo, allograft; auto, autograft; BPTB, bone–patellar tendon–bone; DL, defensive linemen; HS, high school; HT, hamstring tendon; LOE, level of evidence; N/A, not available; NCAA, National Collegiate Athletic Association; NFL, National Football League; OL, offensive linemen; RTP, return to play.
[b]Values are presented as mean, mean ± SD, or mean (range).

concluding that ACLR reduced the total career length of NFL defensive linemen significantly versus control defensive linemen ($P = .020$).

Three studies compared the number of games played before and after ACLR for football players who returned to play (Appendix Table A2).[25,35,40] Of these, 2 studies found that the number of games played after the injury was significantly lower than the number played before the injury ($P = .001$[25] and $P < .001$[35]), whereas the third study concluded that players who were able to RTP less than 18 months after the ACL injury had played significantly more games before the injury than players who were not able to RTP within 18 months ($P = .018$).[40] Furthermore, 2 studies analyzed the number of games started among players who underwent ACLR and were able to RTP, and both reported significant results. Yang et al[40] found that players who were able to RTP in less than 18 months after an ACL injury had started significantly more games before the injury than players who were not able to RTP within 18 months ($P = .017$). Read et al[32] concluded that NFL defensive players who underwent ACLR started in significantly fewer games after their injury than they had before the

injury (all positions: $P < .001$; defensive backs: $P = .022$). Also, 3 studies analyzed career length for their respective ACLR cohorts (Appendix Table A3).[25,35,40] Of these, 2 studies found that players' postinjury career length was significantly shorter than their preinjury career length ($P = .01$[25] and $P < .001$[35]).

There were 10 studies that analyzed some degree of performance in players who were able to RTP after ACLR (Appendix Table A4).[#] The metrics used displayed a high degree of heterogeneity between studies. Furthermore, performance metrics measured typically varied by position (receiving yards by wide receivers, tackles by linebackers, etc). Of these, 5 studies found significant differences in performance metrics between players who returned to play after ACLR versus controls.[10,22,31,32,38] Carey et al[10] found that NFL running backs and wide receivers had higher average power ratings (an artificial statistic that combines yards gained and touchdowns) versus controls in the season before the injury ($P = .0008$) and lower average power ratings in the

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[#]References 10, 12, 19, 22, 25, 27, 31, 32, 35, 38.

season of the injury ($P < .0001$). Wise and Gallo[38] similarly found that after ACLR, college running backs averaged fewer carries per game ($P = .003$), yards per game ($P = .006$), and receptions per game ($P = .011$) than controls. Their study also found that wide receivers averaged fewer receptions per game ($P = .004$), yards per game ($P = .0009$), and touchdowns per game ($P = .004$) than controls after ACLR.[38] Frank et al[22] found that defensive backs with a history of ACLR had significantly fewer interceptions in their first 2 seasons than controls ($P < .05$) and that defensive linemen with prior ACLR had significantly fewer quarterback hits than controls ($P < .05$). Similarly, Wise and Gallo concluded that college linebackers averaged fewer tackles for loss ($P = .0003$) and sacks ($P = .026$) than controls after ACLR and that defensive backs also averaged fewer tackles for loss ($P = .002$) and sacks ($P = .043$) than controls after ACLR. Provencher et al[31] concluded that NFL players with prior ACLR participated in a lower percentage of plays in both the first ($P < .001$) and the second ($P < .001$) seasons after the NFL Scouting Combine compared with controls. Read et al[32] found that NFL defensive players had higher average solo tackles per game in the season before their ACL injury than controls ($P = .022$). Additionally, their study found linebackers averaged more interceptions per game before the injury than controls ($P = .039$).[32]

There were 3 studies that found significant differences between players who underwent ACLR and were able to RTP versus those who did not RTP (Appendix Tables A2-A4).[27,32,35] Shah et al[35] found that NFL players who were able to RTP after ACLR had played more games ($P = .04$) than players who were unable to RTP after ACLR. Read et al[32] similarly reported that NFL defensive players who were able to RTP started more games ($P = .014$) before the injury. Additionally, these players averaged higher combined tackles ($P = .002$), solo tackles ($P < .001$), forced fumbles ($P = .036$), passes defended ($P = .002$), interceptions ($P = .001$), and defensive touchdowns ($P = .046$) per game than players who were unable to RTP after ACLR. McCullough et al[27] found that at 2-year follow-up after ACLR, college football players who were able to RTP had significantly higher International Knee Documentation Committee ($P = .04$), Marx activity scale ($P < .01$), and Knee injury and Osteoarthritis Outcome Score (KOOS) Knee-Related Quality of Life ($P < .01$) scores than similar players who were unable to RTP.

There were 2 studies that found significant declines in performance metrics in players who underwent ACLR and returned to play after the injury compared with before the injury (Appendix Table A4).[25,32] For all included players who returned to play, Read et al[32] found that NFL defensive players averaged fewer combined tackles ($P = .013$), solo tackles ($P < .001$), passes defended ($P < .05$), and interceptions ($P = .005$) per game than they had before the injury. By position, linebackers and defensive backs averaged fewer solo tackles per game after ACLR, and defensive backs also averaged fewer interceptions per game (all $P < .05$).[32] Using a unique game statistic–based performance score algorithm, Mai et al[25] found that NFL players performed at a lower level in both the first ($P < .001$) and second ($P = .0001$) seasons after the injury compared with their level of performance in the season before the injury.

DISCUSSION

RTP Rates

A primary goal of this review was to report on RTP after ACLR in football players; 82% (14/17) of included studies included adequate data (Figure 2). Our study demonstrated that football players had a mean RTP rate of 67.2% (1249/1859) across all studies that provided adequate RTP data, inclusive of all age groups and positions. As prior studies have reported, RTP rates varied significantly by player position.[3,4,16,40] For example, numerous studies reported that offensive linemen return to play at rates of ~60%,[8,12,17,35] whereas quarterbacks return to play at rates of >90%.[19,35,38] The risk of developing an ACL injury itself seems to display positional variance as well; previous literature suggests that running backs and linebackers are at the highest risk.[3,4,8,16] Other factors have been associated with the risk of ACL injuries and the ability to RTP, including higher levels of preinjury performance being predictive of future ACL injuries[10,32] and earlier draft round/position, more game experience before the injury, use of autografts, scholarship status (college players), and higher depth chart position for RTP after ACLR.[14,17,35,40] It must be noted, however, that these conclusions are based on the included data which is heavily biased toward NFL and National Collegiate Athletic Association (NCAA) Division I athletes (16/17 included studies). Given the exceptional skill required to participate at this level of competition, as well as the apparent correlation between skill and ability to RTP after ACLR, more research is needed to investigate RTP after ACLR in high school athletes and college athletes competing in lower NCAA divisions.

Time to RTP

The studies included in our review demonstrated that the weighted mean time to RTP after surgery for football players was 11.6 months, although considerable variance existed between included studies. It is unclear what factors underlie these differences in RTP rates and time to RTP, but they could be attributed to differences in the definition of successful RTP, time of injury during the season, time between injury and surgery, graft type, or rehabilitation protocol. Because the NFL/NCAA regular season is 4 months long (September-December), if successful RTP is defined by participation in games, an athlete who sustains an ACL injury at the beginning of the season may face a minimum of 12 months to RTP, while an athlete who is hurt in December may instead face a minimum of approximately 9 months to RTP. Most of the studies (15/17) included in this review explicitly defined successful RTP as participating in a game, which limits the ability to understand exactly how long it takes for elite football athletes to recover from an ACL injury from a clinical standpoint.

Despite this limitation, there are some data to suggest that lengthy times to RTP seem to be the norm in football, even when defined by a clinician. For example, a survey of NFL team orthopaedic doctors conducted by Schrock et al[33] found that only 14% (4/29) of physicians would allow a
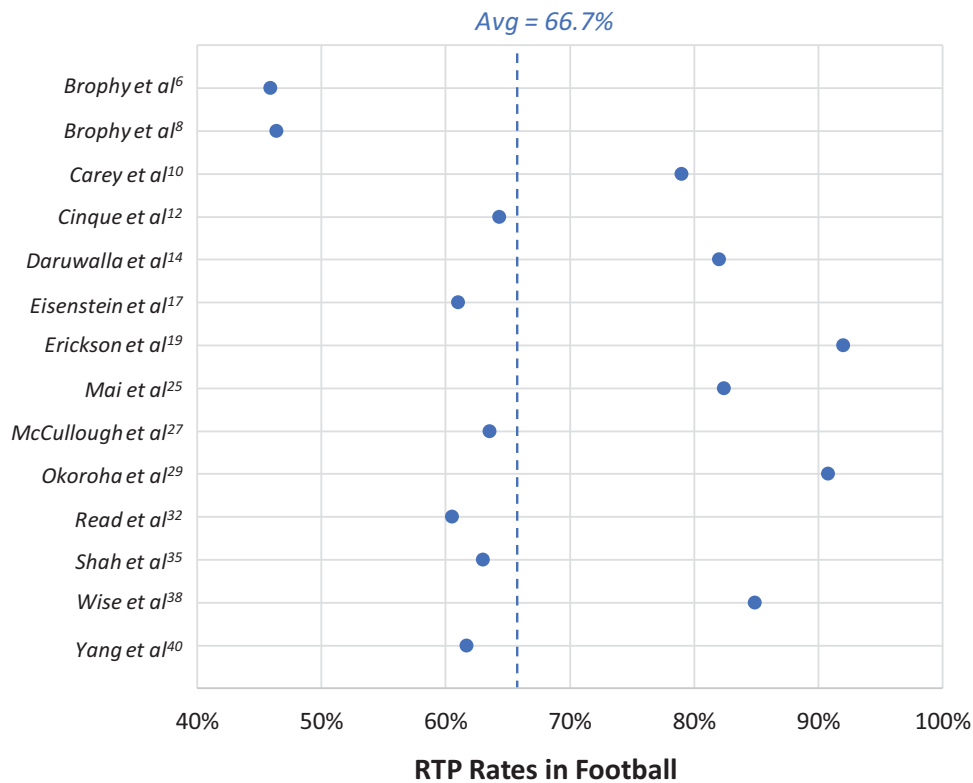
Figure 2. Return to play (RTP) rates in football players after anterior cruciate ligament reconstruction.

player to RTP at ≤6 months after ACLR. A similar study by Erickson et al[18] found only 56.2% (77/137) of NFL and NCAA physicians would clear a player to return at 6 months, and 12.4% (17/137) would not clear a player in less than 9 months. Further research is needed to investigate the factors that underlie the differences in time to RTP in football players and to elucidate rehabilitation protocols that minimize recovery time.

Determinants of RTP

Returning to competition after an ACL injury is a difficult and complex process, and as such, the determinants of players' ability to RTP seem to be a range of variables that interact with each other. Although it is possible that differences in surgical care are driving the variance in RTP rates between studies, this possibility seems minimal. In the 3 studies that reported on graft type, bone–patellar tendon–bone autografts were most frequently used for ACLR.[14,27,35] This result aligns with 2 separate surveys of NFL and NCAA team orthopaedic surgeons regarding their preferred ACLR methodology.[11,18] Although this review found that autografts were most commonly used, there is a relative paucity of evidence in the literature connecting specific ACLR graft choices to superior clinical outcomes.[9,21,23,41] More research is needed to elucidate which graft choice is optimal for RTP in collision sports.

The limited ability to RTP after ACLR could reflect a bias against players with a history of ACL injuries in

professional football.[34] Three included studies found that a history of ACLR negatively affected players' NFL Draft position.[22,31,35] Several studies also reported that RTP rates varied significantly by player position.[3,4,16,40] Although the factors underlying these differences remain unclear, it is possible that a bias against players with prior ACLR may be more pervasive for certain playing positions and thus create a greater barrier to RTP. For example, because the quarterback position generally requires fewer cutting and pivoting movements and involves less physical contact, a history of ACLR may have less of an impact on the career of quarterbacks relative to other positions. This notion may be illustrated by the exceptionally high RTP rates for quarterbacks in this review, whereas an ACL injury was largely a significant derailment for athletes who played positions such as lineman, linebacker, and running back. Although our results suggest differences in RTP rates and time to RTP between studies and player positions, statistical analysis is needed to both validate and quantify these differences. Further studies are also needed to investigate the underlying factors driving the continued limitations in RTP after ACLR in football.

Athletic Performance After ACLR

After ACLR, most athletes seek to reach their preinjury level of performance. However, it is difficult to synthesize the results from the 10 studies that included post-ACLR performance data in this systematic review, given the high

degree of heterogeneity in how each study measured performance, the different athlete populations, and the scarce use of control groups (only 7 studies). These limitations make it difficult to draw concrete conclusions. In general, compared with control groups, players who underwent ACLR and returned to play subsequently played and started in fewer games and had shorter careers, although there was considerable positional variance.[8,12,22,31] These players also tended to start more games and were higher performing players compared with controls before their injury but experienced marked declines in performance after surgery.[10,22,25,31,32,38] This result may suggest that high-performing players are at a higher risk of ACL injuries because of increased opportunities for such an injury. Future studies should standardize the collection of performance data by position so that statistical analysis can be adequately powered to provide more accurate data points. A substantial amount of data is readily available to the public, especially for NFL and NCAA athletes. Defining a standardized set of position-based statistics (Table 2) that could be used for the purpose of academic analysis, although not inclusive of all tracked statistics, may strengthen the conclusions that can be drawn from the data in future studies.

Previous Work

Previous systematic reviews have analyzed outcome data in players after ACLR. Lai et al[24] performed a systematic review and meta-analysis of RTP and performance after ACLR across several sports, including collision sports such as football and rugby. The authors found that the average time to RTP for football players ranged from 8.2 to 13.0 months after ACLR. However, while Lai et al concluded that RTP rates did not depend on playing position, the present review suggests that positional variance does play a role. This difference may be attributed to the fact that this review includes more studies specific to football as well as more recently published literature. Thus, to our knowledge, this review is unique in its breadth of coverage, inclusion of recent literature, and targeted focus on football. Further research is warranted on numerous topics including position-specific RTP comparisons, collision sports–focused reviews, and further stratification based on graft type.

Limitations

There are several limitations to this study. As with any systematic review, variation limits the ability to draw conclusions from the data. The lack of standardization in RTP definitions, performance outcome measures and reporting methods, control groups, and reporting of polytrauma versus isolated injuries limited our ability to make cross-comparisons between studies. There was a broad time frame of data collection, with players from as early as 1987 and as late as 2015 being included. Advances in sporting techniques, surgical care, and rehabilitation protocols could skew the uniformity of the results; RTP rates have been, in fact, increasing steadily over time.[6] Additionally, the risk of bias was identified in several studies. A total of 3

TABLE 2
Recommended Position-Based In-Game Statistics
for Standardized Performance Analysis

Position and Game Statistics
Quarterback
Quarterback rating
Passing yards per game
Passing yards per attempt
Passing touchdowns
Interceptions
Sacks
Running back
Rushing yards per game
Rushing yards per carry
Rushing yards after contact
Touchdowns
Fumbles
Wide receiver and tight end
Receiving yards per game
Receiving yards per catch
Receiving yards after contact
Touchdowns
Fumbles
Offensive lineman
Successful blocks made
Missed assignments (eg, sacks allowed)
Defensive lineman
Tackles per game
Tackles for loss
Missed tackles
Sacks
Linebacker, cornerback, and safety
Tackles per game
Tackles for loss
Missed tackles
Sacks
Interceptions
Punter
Punt average length
Kicker
Field goal percentage (field goals made/field goal attempts)

studies only measured outcome data for players who successfully returned to play after ACLR, thus introducing selection bias by not including data for players who underwent ACLR but could not return to play. Therefore, the results of those studies cannot necessarily be applied to the average player. Only 1 included study collected data prospectively, introducing the risk of recall bias. Studies classified as level of evidence 3 or 4 (16/17 studies) may be affected by selection and/or performance bias because of the lack of randomization and prospective comparative control groups. Additionally, all 17 studies reported on only male players, and therefore, this analysis should not be extrapolated to female players who are known to be at a higher risk of ACL ruptures while participating in the same sports as male athletes.[30] Furthermore, given that 16 of 17 included studies reported exclusively on NFL or NCAA Division I athletes, the results of this study cannot necessarily be applied to younger athletes or athletes of lower skill levels.

CONCLUSION

This systematic review demonstrated that after ACLR, the rate of RTP for football players was 67.2%, although rates varied considerably between studies and playing position. The majority of football players who returned to play experienced significant post-ACLR performance declines compared with controls and their own preinjury level of performance. While previous RTP literature has been more broadly focused, these data may be helpful in characterizing the burden of ACL injuries on the ability to RTP for players participating in football or other collision sports. With more focused data, physicians and players can develop more targeted and accurate expectations for collision sports participation and performance after ACLR. Further research in the form of prospective comparison trials or meta-analyses is warranted, as these injuries are common in football and other collision sports, and rates of RTP remain variable.

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APPENDIX

Additional Data From Included Studies

TABLE A1
RTP Data From Included Studies[a]

Author (Year)	RTP Definition	No. of ACLR Procedures	Successful RTP, n	Successful RTP, %	Time to Return[b]
Brophy[8] (2009)	Played at least 1 NFL game	280 (52 RB, 37 WR, 45 OL, 14 TE, 15 QB, 54 DL, 22 DB, 33 LB, 8 K)	130 (24 RB, 18 WR, 18 OL, 8 TE, 7 QB, 29 DL, 9 DB, 15 LB, 2 K)	46.4 (46.2 RB, 48.6 WR, 40.0 OL, 57.1 TE, 46.7 QB, 53.7 DL, 40.9 DB, 45.5 LB, 25.0 K)	N/A
Carey[10] (2006)	Playing in at least 1 play after injury	33	26	78.8	55.8 (40-187) wk
Cinque[12] (2017)	Played at least 1 NFL game	73 (32 OL, 41 DL)	47 (20 OL, 27 DL)	64.4 (62.5 OL, 65.9 DL)	OL: 10.7 ± 1.5 mo; DL: 11.3 ± 2.9 mo
Eisenstein[17] (2016)	Playing at least 1 regular-season play after injury during 2013-2015 regular seasons	75 (15 LB, 12 OL, 16 DL, 9 CB, 19 WR, 4 TE, 1 FB, 4 QB, 4 S, 8 RB)[d]	46 (8 LB, 7 OL, 11 DL, 5 CB, 13 WR, 1 TE, 0 FB, 4 QB, 4 S, 4 RB)[e]	61.3 (53.3 LB, 58.3 OL, 68.8 DL, 55.6 CB, 68.4 WR, 25.0 TE, 0.0 FB, 100.0 QB, 100.0 S, 50.0 RB)	All >1 season but none specified
Erickson[19] (2014)	Playing in any NFL game after surgery	14	13	92.9	13 ± 3.9 mo
Mai[25] (2016)	Returning to active roster for at least 1 game	165	136	82.4	378.1 ± 144 d
McCullough[27] (2012)	Answering "yes" on a questionnaire that asked if they returned to play after ACLR	96 (68 HS, 28 college)	61 (43 HS, 18 college)	64.3 (63.2 HS, 69 college)	Not specified but all follow-ups were 2.1-2.9 y after surgery
Okoroha[29] (2019)	Playing in a regular-season NFL game after ACLR	130	118	90.8	Revision needed (n = 23): 48.3 ± 12.2 wk; no revision needed (n = 95): 50.2 ± 10.1 wk
Read[32] (2017)	Returned to play at least 8 NFL games	38 (9 DL, 12 LB, 17 DB)	23 (3 DL, 8 LB, 12 DB)	60.5 (33.3 DL, 66.7 LB, 70.6 DB)	47.0 ± 16.2 wk
Shah[35] (2010)	Playing in a regular-season NFL game after surgery	49 (3 WR, 2 QB, 9 CB, 3 TE, 11 LB, 5 OL, 5 RB, 5 S, 4 DL, 2 FB)	31 (3 WR, 2 QB, 6 CB, 2 TE, 7 LB, 2 OL, 3 RB, 3 S, 2 DL, 1 FB)	63.3 (100.0 WR, 100.0 QB, 66.7 CB, 66.7 TE, 63.6 LB, 40.0 OL, 60.0 RB, 60.0 S, 50.0 DL, 50.0 FB)	10.8 mo
Wise[38] (2019)[c]	Recorded an in-game statistic after ACLR	285 (33 OL, 21 QB, 45 RB, 60 WR, 35 DL, 43 LB, 48 DB)	242 (21 OL, 19 QB, 37 RB, 53 WR, 32 DL, 39 LB, 41 DB)	84.9 (63.6 OL, 90.5 QB, 82.2 RB, 88.3 WR, 91.4 DL, 90.7 LB, 85.4 DB)	N/A

(continued)

TABLE A1 (continued)

Author (Year)	RTP Definition	No. of ACLR Procedures	Successful RTP, n	Successful RTP, %	Time to Return[b]
Yang[40] (2017)	Playing in at least 1 regular-season or postseason play after ACLR	154 (111 skilled, 39 unskilled, 4 special teams)	<18 mo: 86 (60 skilled, 23 unskilled, 3 special teams); >18 mo: 95 (67 skilled, 25 unskilled, 3 special teams)[f]	<18 mo: 55.8 (54.1 skilled, 59.0 unskilled, 75.0 special teams); >18 mo: 61.7 (60.4 skilled, 64.1 unskilled, 75.0 special teams)	<18 mo (n = 86); >18 mo (n = 9)
Brophy[6] (2008)	Playing in at least 1 NFL game after ACLR	283	130	45.9	N/A
Daruwalla[14] (2014)	Achieving full, unrestricted participation in a full-contact practice, scrimmage, or regular-season game at any time after ACLR	184 (69 starter, 57 utility player, 48 rarely played), unknown depth chart position, n = 10	151 (65 starter, 50 utility player, 35 rarely played)	82.1 (94.2 starter, 87.7 utility player, 72.9 rarely played)	251 d

[a]Only 14/17 studies reported the number of players that RTP as a percentage of the total amount of players that sustained an ACL injury (ie, therefore a true RTP rate). 3/17 studies only analyzed players that had an ACLR and did RTP, and therefore did not include a true RTP rate. ACLR, anterior cruciate ligament reconstruction; CB, cornerback; DB, defensive back; DL, defensive lineman; FB, fullback; HS, high school; K, kicker; LB, linebacker; N/A, not available; NFL, National Football League; OL, offensive lineman; QB, quarterback; RB, running back; RTP, return to play; S, safety; TE, tight end; WR, wide receiver.

[b]Values are presented as mean, mean ± SD, or mean (range).

[c]Only data from underclassmen were included in the analysis as senior athletes would be unable to return to college competition.

[d]Overall RTP numbers are specifically for isolated ACL injuries. However, RTP breakout by playing position also includes players with nonisolated ACL injuries; positional breakout for isolated ACL injuries was not reported.

[e]RTP breakout by playing position also includes players with nonisolated ACL injuries; positional breakout for isolated ACL injuries was not reported.

[f]Only the second number (n = 95) is included in the overall RTP calculation. The first number (n = 86) is included in the second number. This box shows the total amount of athletes that were able to RTP within 18 months and then the total amount that were able to RTP beyond 18 months, including those that did within 18 months.

TABLE A2
Studies Comparing Games Played/Started Data After ACLR Versus Before ACLR or Controls[a]

Author (Year)	Games Played			Games Started		
	ACLR	Control or Comparison	P Value	ACLR	Control or Comparison	P Value
Brophy[7] (2009)	64 ± 50	78 ± 62	.35	36 ± 60	46 ± 40	.46
Brophy[8] (2009)	∼50	∼100	.003[b,d]	N/A	N/A	N/A
Carey[10] (2006)[c]	Index −3: 13.5 ± 0.9; index −2: 13.7 ± 0.9; index −1: 14.3 ± 0.6; index year: 3.5 ± 0.8; index +1: 11.3 ± 1.3; index +2: 8.8 ± 1.4; index +3: 7.2 ± 1.5	Index −3: 13.7 ± 0.4; index −2: 13.8 ± 0.3; index −1: 13.9 ± 0.3; index year: 13.5 ± 0.3; index +1: 12.4 ± 0.5; index +2: 10.9 ± 0.5; index +3: 9.3 ± 0.6	Index −3: .8847; index −2: .8353; index −1: .5778; index year: <.0001[b]; index +1: .4120; index +2: .1352; index +3: .1800	N/A	N/A	N/A
Cinque[12] (2017)	OL: 39.2; DL: 37.1	OL: 56.7; DL: 59.3	OL: .370; DL: .835	OL: 33.0; DL: 25.3	OL: 49.8; DL: 49.4	OL: .305; DL: .833
Erickson[19] (2014)	39.9 ± 31.7	34.2 ± 32.9	.648	N/A	N/A	N/A
Frank[22] (2017)	21.3 ± 8.5	23.1 ± 8.1	<.05[b]	7.0 ± 8.7	10.8 ± 10.6	<.01[b]
Mai[25] (2016)	Total after surgery: 35.8; 1 y after surgery: ∼11; 2 y after surgery: ∼11.5	Total before surgery: 50.2; 1 y before surgery: ∼13	1 y before surgery vs 1 y after surgery: .001[b]; 1 y before surgery vs 2 y after surgery: .06	N/A	N/A	N/A

(continued)

TABLE A2 (continued)

Author (Year)	Games Played			Games Started		
	ACLR	Control or Comparison	P Value	ACLR	Control or Comparison	P Value
Provencher[31] (2018)	Season 1: 9.0; season 2: 8.9	Season 1: 11.9; season 2: 12.6	Season 1: .051; season 2: .094	Season 1: 2.1; season 2: 2.4	Season 1: 5.4; season 2: 7.4	Season 1: .005[b]; season 2: .002[b]
Read[32] (2017)	N/A	N/A	N/A	Preinjury ACLR group: 80.9 ± 28.5	Control (%): 60.5 ± 34.1 Post ACLR (%): 57.0 ± 33.0	Preinjury vs. control: 0.004[b] Pre- vs. post-ACLR: <0.001[b]
Shah[35] (2010)	Post-ACLR RTP: 24.3	Pre-ACLR RTP: 50.6	Pre-ACLR vs post-ACLR: <.001[b]	N/A	N/A	N/A
Yang[40] (2017)	RTP <18 mo, preinjury: 54.2 (3.8-4.2); skilled, early draft round postinjury: 76.8%	No RTP <18 mo, preinjury: 35.8 (27.0-47.2); skilled, early draft round preinjury: 86.8%	RTP <18 mo vs no RTP <18 mo: .018[b]; skilled, early draft round preinjury vs postinjury: <.0001[b]	RTP <18 mo, preinjury: 34.0 (25.8-44.9); unskilled UDFA postinjury: 58.8%	No RTP <18 mo, preinjury: 16.3 (9.5-27.9); unskilled UDFA preinjury: 20.5%	RTP <18 mo vs no RTP <18 mo: .017[b]; unskilled UDFA preinjury vs postinjury: .044[b]

[a]Values are presented as mean, mean ± SD, or mean (range) unless otherwise specified. ACLR, anterior cruciate ligament reconstruction; DL, defensive lineman; N/A, not available; OL, offensive lineman; RTP, return to play; UDFA, undrafted free agent.

[b]Significant at $p < 0.05$.

[c]Only players that maintained a total 7 season power rating of >200 were included in the performance analysis.

[d]Comparison includes only OL. Post-ACLR survival data was presented in graphical form. The number of games presented is an estimate from the graph of the amount of games that it took for 50% of each base cohort to cease participation in the NFL.

TABLE A3
Studies Comparing Career Length After ACLR Versus Before ACLR or Controls[a]

Author (Year)	ACLR, Seasons/Years	Control or Comparison, Seasons/Years	P Value
Brophy[7] (2009)	6.1 ± 3.1	6.4 ± 3.9	.77
Cinque[12] (2017)	OL: 7.7 ± 6.6; DL: 7.2 ± 3.0	OL: 8.2 ± 1.6; DL: 9.2 ± 3.0	OL: .442; DL: .020[b]
Erickson[19] (2014)	4.85 ± 2.70	3.85 ± 2.69	.354
Mai[25] (2016)	1.6	3.3	.01[b]
Read[32] (2017)	Shorter (~3)	Longer (~4.5)	.064[c]
Shah[35] (2010)	RTP: 6.8 ± 3.0; post-ACLR RTP: 2.3 ± 1.1	No RTP: 3.2 ± 2.0; pre-ACLR RTP: 4.5 ± 2.8	RTP vs no RTP: <.001[b]; pre- vs post-ACLR RTP: <.001[b]
Yang[40] (2017)	RTP <18 mo, preinjury: 2.81 (2.29-3.45)	No RTP <18 mo, preinjury: 2.36 (0.62-1.09)	RTP <18 mo vs no RTP <18 mo: .27

[a]Values are presented as mean, mean ± SD, or mean (range) unless otherwise specified. ACLR, anterior cruciate ligament reconstruction; DL, defensive lineman; OL, offensive lineman; RTP, return to play.

[b]Significant at $p < 0.05$.

[c]Post-ACLR career length was presented in graphical form. Numbers provided are estimates from the graph of the amount of games that it took for 50% of each base cohort to cease participation in the NFL.

TABLE A4
Studies Comparing Performance Data After ACLR Versus Before ACLR or Controls[a]

Author (Year)	Performance Scale or Definition	ACLR	Control or Comparison	P Value
Carey[10] (2006)[c]	Power rating = (yards/10) + (6 * touchdowns)	Before injury: 138.3 ± 16.7; index year: 22.0 ± 5.1; after injury: 64.1 ± 13.2	Before injury: 92.9 ± 4.7; index year: 101.6 ± 6.2; after injury: 78.1 ± 6.2	Before injury: .0008[b]; index year: <.0001[b]; after injury: .7762
Cinque[12] (2017)[c]	Pro Bowl games	OL: 0.4; DL: 0.3	OL: 0.4; DL: 0.7	OL: .079; DL: .771
Erickson[19] (2014)[c,d]	QB rating	58.5 ± 25.2	53.5 ± 37.9	.698
Frank[22] (2017)[c]	Undrafted percentage	38.1%	29.3%	<.01[b]
	Draft position	125.7 ± 74.5	109.0 ± 68.8	<.01[b]
	DB interceptions in first 2 seasons	0.8 ± 1.1	2.1 ± 2.3	<.05[b]
	DL QB hits in first 2 seasons	5.9 ± 6.9	10.5 ± 11.5	<.05[b]
Mai[25] (2016)[e]	Standardized scoring system based on metrics important to an individual player's respective position	1 y after surgery: ~4.5; 2 y after surgery: ~4.75	1 y before injury: 6	1 y before injury vs 1 y after surgery: <.001[b]; 1 y before injury vs 2 y after surgery: .0001[b]
McCullough[27] (2012)[f]	IKDC	92	81	.04[b]
	Marx activity scale	16.0	10.0	<.01[b]
	KOOS Sports and Recreation	85	68	.10
	KOOS Knee-Related Quality of Life	94	72	<.01[b]
Provencher[31] (2018)[c]	Draft round, mean (range)	3.5 (1-7)	2.7 (1-8)	.019[b]
	Draft pick No., mean (range)	129.5 (1-254)	99.3 (1-254)	.002[b]
	Snap percentage for season 1	16.4%	44.1%	<.001[b]
	Snap percentage for season 2	22.2%	49.4%	<.001[b]
Read[32] (2017)[c,e]	Preinjury ACLR vs control: solo tackles/game	Preinjury ACLR: 3.44 ± 1.47	Control: 2.5 ± 1.16	Preinjury ACLR vs control: .022[b]
	Preinjury vs postinjury ACLR:	Postinjury ACLR:	Preinjury ACLR:	Preinjury vs postinjury ACLR:
	Combined tackles/game	3.17 ± 1.74	4.28 ± 1.99	.013[b]
	Solo tackles/game	2.38 ± 1.24	3.44 ± 1.47	<.001[b]
	Interceptions/game	0.047 ± 0.045	0.095 ± 0.086	.005[b]
Shah[35] (2010)[f]	RTP vs no RTP:	RTP:	No RTP:	RTP vs no RTP:
	Draft round	3.4	6.4	<.001[b]
	Games played before injury	50.7 ± 41.2	27.9 ± 25.1	.04[b]
	Seasons played before injury	4.5 ± 2.8	3.2 ± 2.0	.09
Wise[38] (2019)[c,g]	RB:	RB (n = 20):	RB (n = 54):	RB:
	Carries/game	9.10 ± 2.70	9.91 ± 1.54	.003[b]
	Yards/game	45.88 ± 15.45	47.75 ± 7.96	.006[b]
	Receptions/game	1.05 ± 0.40	1.12 ± 0.22	.011[b]
	WR:	WR (n = 28):	WR (n = 78):	WR:
	Receptions/game	2.29 ± 0.69	3.25 ± 0.45	.004[b]
	Yards/game	28.63 ± 9.38	44.23 ± 6.30	.0009[b]
	Touchdowns/game	0.25 ± 0.11	0.35 ± 0.07	.004[b]
	LB:	LB (n = 19):	LB (n = 54):	LB:
	TFLs/game	0.40 ± 0.60	0.68 ± 0.10	.0003[b]
	Sacks/game	0.10 ± 0.05	0.26 ± 0.06	.026[b]
	DB:	DB (n = 19):	DB (n = 54):	DB:
	TFLs/game	0.07 ± 0.04	0.22 ± 0.04	.002[b]
	Sacks/game	0.01 ± 0.01	0.44 ± 0.07	.043[b]

[a]Values are presented as mean, mean ± SD, or mean (range) unless otherwise specified. For studies that investigated a considerable amount of different performance metrics, only significant statistical results were reported. If no significant results were found, the most relevant performance metric(s) were reported. Additionally, in the event that performance metrics were not analyzed, notable outcomes that are not traditional in-game performance metrics were reported here. ACLR, anterior cruciate ligament reconstruction; DB, defensive back; DL, defensive lineman; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; RTP, return to play; TFL, tackles for loss; WR, wide receiver.

[b]Significant at $p < 0.05$.

[c]ACLR vs. controls.

[d]Many quarterback-specific performance metrics were assessed, but none were significantly different from controls. Of these, QBR was included as a general performance metric.

[e]Pre-ACLR vs. post-ACLR.

[f]RTP vs. no RTP.

[g]To be included in the performance comparison, an athlete had to play at least 4 games prior to the injury and at least 4 games for the same team after ACLR.