The NFL Orthopaedic Surgery Outcomes Database (NO-SOD)

The Effect of Common Orthopaedic Procedures on Football Careers

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Background: Injuries are inherent to the sport of American football and often require operative management. Outcomes have been reported for certain surgical procedures in professional athletes in the National Football League (NFL), but there is little information comparing the career effect of these procedures.

Purpose: To catalog the postoperative outcomes of orthopaedic procedures in NFL athletes and to compare respective prognoses and effects on careers.

Study Design: Case series; Level of evidence, 4.

Methods: Athletes in the NFL undergoing procedures for anterior cruciate ligament (ACL) tears, Achilles tendon tears, patellar tendon tears, cervical disc herniation, lumbar disc herniation, sports hernia, knee articular cartilage repair (microfracture technique), forearm fractures, tibial shaft fractures, and ankle fractures were identified through team injury reports or other public records. Game and performance statistics during the regular season were collected before and after surgery. Statistical analysis was performed with significance accepted as $P < .05$.

Results: A total of 559 NFL athletes were included. Overall, 79.4% of NFL athletes returned to play after an orthopaedic procedure. Forearm open reduction and internal fixation (ORIF), sports hernia repair, and tibia intramedullary nailing (IMN) led to significantly higher return-to-play (RTP) rates (90.2%-96.3%), while patellar tendon repair led to a significantly lower rate (50%) ($P < .001$). Athletes undergoing ACL reconstruction (ACLR), Achilles tendon repair, patellar tendon repair, and ankle fracture ORIF had significant declines in games played at 1 year and recovered to baseline at 2 to 3 years after surgery. Athletes undergoing ACLR, Achilles tendon repair, patellar tendon repair, and tibia IMN had decreased performance in postoperative season 1. Athletes in the Achilles tendon repair and tibia IMN cohorts recovered to baseline performance, while those in the ACLR and patellar tendon repair cohorts demonstrated sustained decreases in performance.

Conclusion: ACLR, Achilles tendon repair, and patellar tendon repair have the greatest effect on NFL careers, with patellar tendon repair faring worst with respect to the RTP rate, career length after surgery, games played, and performance at 1 year and 2 to 3 years after surgery.

Keywords: football; surgery; NFL; ACL; Achilles tendon; patellar tendon

The inherent physical demands of the National Football League (NFL) subject athletes to a higher rate of injuries than any other sport.[2] Injuries that are severe enough to require operative management may have a significant effect on the subsequent performance and career longevity of these players. Brophy et al[4] demonstrated the negative predictive value of various procedures, such as anterior cruciate ligament (ACL) reconstruction (ACLR), knee meniscectomy, and shoulder stabilization, on an athlete's probability of making a roster in the NFL. This and other studies have highlighted potential negative perceptions for a player's ability to return to a high level of play after orthopaedic procedures.[3,6,12,13,20,24,25]

Because of the high turnover rate of an NFL roster, an athlete's career longevity is dependent on his ability to return to baseline performance postoperatively. Statistical performance after such interventions is much more applicable to this patient population than traditional legacy

measures for clinical outcomes such as visual analog scales, back pain scores, and the Oswestry Disability Index. Given that the NFL Players Association reports the average NFL career length to be 3.8 years,[5] the need for detailed postoperative outcome data is of particular interest to those involved in the care of these athletes.

The NFL Injury Surveillance System (ISS) is a prospective database maintained by team medical staff of significant injuries, defined as those causing at least 1 missed practice or game. While the database provides important information such as the procedures performed, mechanism of injury, playing conditions, and total days lost due to injury, the dearth of identifying information prevents the study of outcomes after an intervention. This significant limitation prevents league and medical personnel from identifying trends and improving outcomes after common orthopaedic procedures.

A number of studies have reported performance-based outcomes after individual orthopaedic surgeries in NFL athletes[2,6,12,13,20,24,25]; however, it is yet unknown what effect these injuries have in comparison with others. Furthermore, knowledge of incidence and injury rates may lead to alterations in training regimens for prevention and clinical improvement. This information would also be helpful in guiding short- and long-term postoperative expectations for athletes as well as allowing team physicians to provide evidence-based recommendations on effects on an athlete's career. In this study, we sought to compile a comprehensive injury database in NFL athletes to compare return-to-play (RTP) rates and performance-based outcomes after common orthopaedic surgical procedures.

METHODS

Inclusion Criteria

The NFL Orthopaedic Surgery Outcomes Database (NO-SOD) was compiled to optimize the capture rate, accuracy, and reliability of the reporting information. For this reason, entries were limited to athletes who underwent orthopaedic procedures during a 10-year time period (March 2003 to March 2013), selected for a 2-year minimum follow-up period after an intervention as well as the likelihood of public reporting of procedures from the use of media archives. The decision to limit the capture period was also made to reduce confounding factors such as advances in surgical techniques, changes in the active roster size, and standardization of postoperative protocols. Similar to previously published methodology,[14,20] multiple sources of public information

were utilized including player profiles, newspaper archives, press releases, and team injury reports.

Inclusion criteria included NFL athletes on an active roster or listed as an injured reserve at the time of injury and surgical procedure, with 2 independent sources confirming both occurrences. Search criteria unique to each particular injury and procedure were implemented (see Appendix A, available online at http://ajsm.sagepub.com/supplemental). Athletes who were injured and underwent procedures before participating in their first NFL regular season game were excluded. Demographic variables, including a player's age, height, weight, position, prior professional experience, and date of surgery, were collected.

Athletes with conflicting diagnoses or operative reports, revision procedures, and unclear injuries were excluded from the study. Furthermore, procedures with a sample size of less than 25 were excluded from analysis. Procedures excluded from the study for these reasons included shoulder stabilization, pectoral tear, Jones fracture, Lisfranc fracture, and hand/wrist fracture procedures. Surgeries with the potential for significant intraoperative variability affecting recovery, such as knee and ankle arthroscopic surgery, were also removed from data analysis. Because of limitations in publicly available information, it was not possible to determine if these arthroscopic procedures were diagnostic or if athletes underwent further reparative procedures such as meniscectomy or meniscus repair. Players who met inclusion and exclusion criteria were deidentified by removing all personal information, including name, date of birth, and team, from the database.

Performance-Based Outcome Measures

Game statistics from the regular NFL season, excluding preseason and playoff games, were compiled for players who met the inclusion criteria. Statistics were compiled on a preprocedure and postprocedure basis, including games played, games started, seasons played, and performance score. Successful RTP was defined as returning to the active roster for at least 1 regular season NFL game. An athlete's preoperative baseline performance was defined as the immediate season before the injury-shortened season. The immediate season after the procedure was considered postoperative season 1, and subsequent seasons were defined as postoperative seasons 2 and 3. For the purposes of this study, the beginning of each season was defined as March 1, a date after which the last postseason game was completed and before the beginning of organized team activities for the subsequent season.

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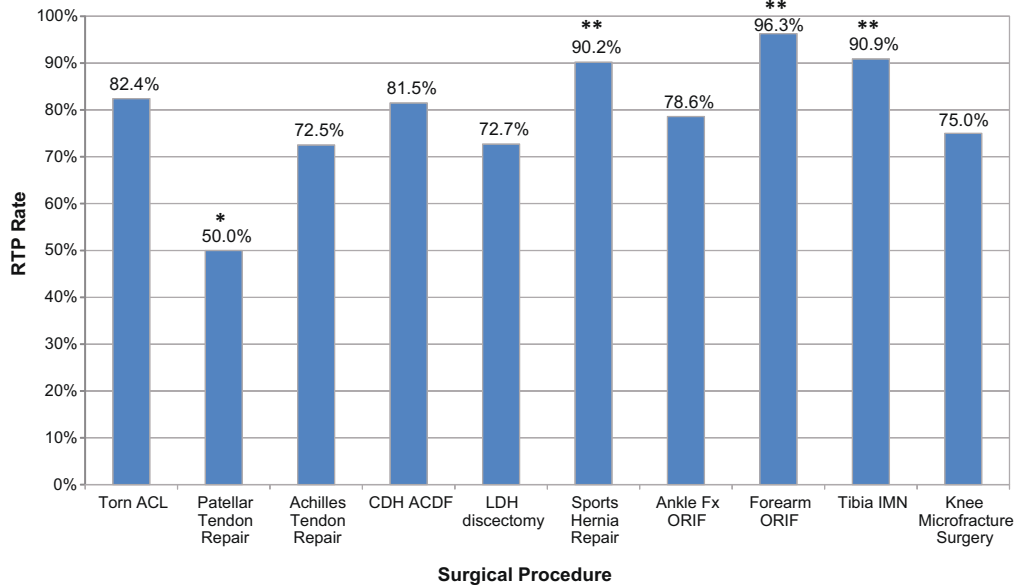
Figure 1. Comparison of return-to-play (RTP) rates after common orthopaedic procedures in National Football League athletes. Overall, 79.4% of athletes returned to play after an orthopaedic procedure. Patellar tendon repair had the lowest rate of RTP (50.0%; $P < .001$), while athletes in the forearm ORIF (96.3%; $P = .03$), tibia IMN (90.9%; $P = .03$), and sports hernia repair (90.2%; $P = .03$) cohorts had the highest rates of RTP compared with all other procedures. *Significantly lower than all other procedures ($P < .05$). **Significantly higher than all other procedures ($P < .05$). ACDF, anterior cervical discectomy and fusion; ACL, anterior cruciate ligament; CDH, cervical disc herniation; IMN, intramedullary nailing; LDH, lumbar disc herniation; ORIF, open reduction and internal fixation.

Player performance was calculated using a previously published, standardized scoring system based on metrics important to an individual player's respective position (see Appendix B, available online).[6,13] For example, this score focuses on yards gained and touchdowns for offensive-position athletes, while defensive athletes are scored based on sacks, tackles, interceptions, and touchdowns. Offensive linemen and special teams athletes were excluded from the performance evaluation but were included in all other outcome measures in this study. Performance scores were evaluated on an individual game basis both before and after undergoing a surgical procedure.

Statistical Analysis

All descriptive and comparative analyses were performed using SPSS version 22 (IBM Corp). A Fisher exact test was used to analyze categorical data. The continuous variables of each cohort were compared using analysis of variance. Each player served as his own control, and a 2-tailed paired t test was used to evaluate postoperative performance changes. A Kaplan-Meier survivorship curve with "retirement" as the endpoint was constructed. Median survival (50% survival) was also determined based on survivorship analysis. Binomial regression analysis was used to determine the effect of independent variables (age, experience, body mass index [BMI]) on RTP. Statistical significance was accepted with $P < .05$.

RESULTS

A total of 559 athletes met the inclusion criteria for the NO-SOD. Surgical procedures included ACLR (n = 165), Achilles tendon repair (n = 80), patellar tendon repair (n = 36), sports hernia repair (n = 51), anterior cervical discectomy and fusion (ACDF; n = 27), lumbar discectomy (n = 44), ankle fracture open reduction and internal fixation (ORIF; n = 42), radius or ulnar fracture ORIF (forearm ORIF; n = 27), tibia intramedullary nailing (IMN; n = 55), and knee microfracture surgery (n = 32) (see Appendix C, available online). Comparing preoperative demographics, the ACDF cohort was older and had significantly more game experience, games played, and games started than all other athletes ($P = .004$ to $<.001$). No other significant demographic differences were found between the surgical cohorts (see Appendix D, available online).

Injuries by Position

Defensive backs comprised the largest proportion of injuries in the NO-SOD (see Appendix E, available online). A significantly higher proportion of defensive linemen (ends and tackles) underwent Achilles tendon repair than other positions (30.3%; $P = .001$). A significantly higher proportion of defensive backs underwent forearm ORIF than other positions (44.4%; $P = .013$). The incidence of all other procedures was not significantly different based on position ($P = .16$-$.71$).

TABLE 1
Recovery Period, Games Played, and Career Length
After Common Orthopaedic Procedures in
National Football League Athletes[a]

| | Recovery Period, d | After Surgery | |
		Games Played, n	Career Length, y
Overall	339.4	35.8	2.1
ACLR	378.1[b]	34.6	1.6[c]
Achilles tendon repair	375.1[b]	27.3[c]	1.6
Patellar tendon repair	391.2[b]	29.1[c]	1.5[c]
Sports hernia repair	229.4[c]	38.7	2.5
CDH, ACDF	324.1	36.3	2.0
LDH, discectomy	300.5	38.7	2.5
Ankle fracture ORIF	350.2	33.2	2.1
Forearm ORIF	232.9[c]	41.8	2.5
Tibia IMN	358.9	47.1[b]	2.8[b]
Knee microfracture surgery	329.8	32.4	1.7

[a]ACDF, anterior cervical discectomy and fusion; ACLR, anterior cruciate ligament reconstruction; CDH, cervical disc herniation; IMN, intramedullary nailing; LDH, lumbar disc herniation; ORIF, open reduction and internal fixation.
[b]Significantly longer in relation/comparison to all other procedures ($P < .05$).
[c]Significantly shorter in relation/comparison to all other procedures ($P < .05$).

Return to Play

Overall, 79.4% of NFL athletes returned to play after an orthopaedic procedure (range, 50.0%-96.3%). Athletes in the forearm ORIF, sports hernia repair, and tibia IMN cohorts had significantly higher RTP rates compared with all other procedures (96.3% [$P = .03$], 90.2% [$P = .03$], and 90.9% [$P = .03$], respectively). Players in the patellar tendon repair cohort had the worst RTP rate, which was significantly lower than other procedures (50.0%; $P < .001$) (Figure 1). The average recovery time after an orthopaedic procedure was 339 days (range, 229-391 days). The average recovery time after forearm ORIF and sports hernia repair was significantly shorter than for other procedures (233 ± 144 days [$P = .002$] and 229 ± 234 days [$P = .001$], respectively), while ACLR, Achilles tendon repair, and patellar tendon repair had significantly longer recovery times (378 ± 144 days [$P = .002$], 375 ± 130 days [$P = .004$], and 391 ± 157 days [$P < .001$], respectively) (Table 1). Binary logistic regression analysis demonstrated age and years of experience to be negative independent predictors of RTP ($r^2 = 0.81$, $P = .03$ and $r^2 = 0.84$, $P = .008$, respectively), while more preoperative games played was a positive independent predictor of RTP ($r^2 = 0.28$, $P < .001$). There was a 9.3% decrease in RTP with each increasing year of age and a 6.3% decrease in RTP with each increasing year of experience. BMI, starts, and preoperative performance were not significantly associated with an athlete's RTP rate ($P = .13-.48$).
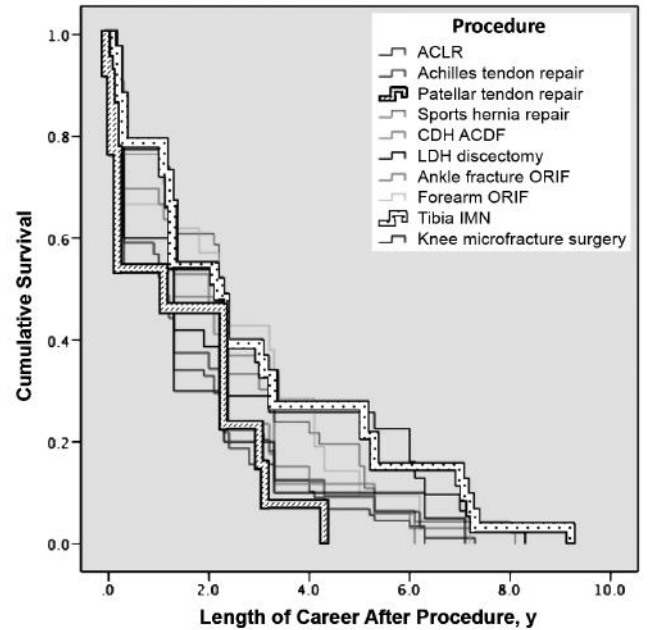

Figure 2. Kaplan-Meier survival analysis after common orthopaedic procedures, with ''retirement'' as the endpoint. The lowest median survival (50%) was seen after patellar tendon repair (1.1 years). The highest median survival was seen after tibia IMN (2.2 years). ACDF, anterior cervical discectomy and fusion; ACLR, anterior cruciate ligament reconstruction; CDH, cervical disc herniation; IMN, intramedullary nailing; LDH, lumbar disc herniation; ORIF, open reduction and internal fixation.

Career Length and Games Played After Surgery

The average career length for an NFL athlete in our database after an orthopaedic procedure was 2.1 ± 2.0 years. The average total career length for the players in the NO-SOD was 6.3 ± 3.6 years. ACLR and patellar tendon repair led to significantly shorter careers after surgery than other procedures (1.6 years [$P = .01$] and 1.5 years [$P = .03$], respectively). Athletes in the tibia IMN cohort experienced a significantly longer career after surgery (2.8 years; $P = .02$) (Table 1). Athletes played significantly more games postoperatively after tibia IMN (47 games; $P = .003$), while Achilles tendon repair and patellar tendon repair led to significantly fewer games (27 games [$P = .01$] and 29 games [$P = .03$], respectively). Kaplan-Meier survival analysis revealed significant differences in survival after orthopaedic procedures (log rank, $P = .037$), with the lowest median (50%) survival after patellar tendon repair (1.1 years) and the highest median survival after tibia IMN (2.2 years) (Figure 2).

ACLR, Achilles tendon repair, patellar tendon repair, and ankle fracture ORIF led to a significant decrease in games played 1 season after surgery compared with the preinjury season (-1.6 ± 0.6, -2.7 ± 0.9, -2.6 ± 1.7, and -2.3 ± 1.0, respectively; $P = .001-.026$) (Figure 3). For those athletes who were able to sustain careers in the NFL 2 or 3
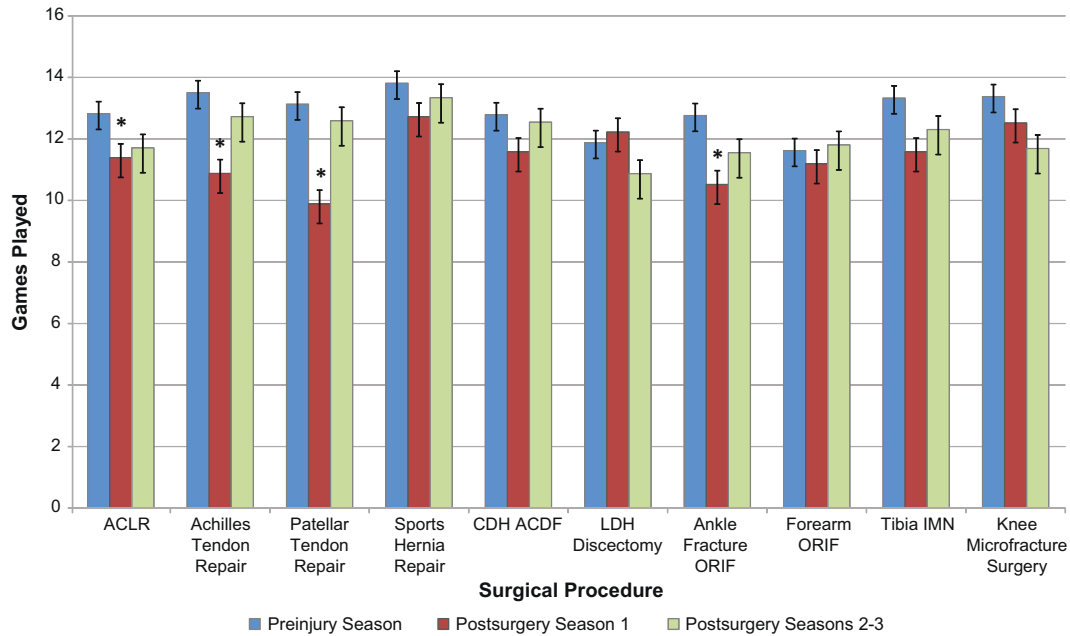
Figure 3. Comparison of games played in the seasons before and after surgery. ACLR, Achilles tendon repair, patellar tendon repair, and ankle fracture ORIF led to significant decreases in games played at postoperative season 1 (P = .001, .003, .015, and .026, respectively). For those athletes who were able to sustain careers in the National Football League 2 or 3 seasons after surgery (range, 53.8%-100.0%), game participation recovered to preoperative baseline levels (P = .06, .38, .55, and .62, respectively). *Significant decrease in games played compared with the preinjury season (P < .05). ACDF, anterior cervical discectomy and fusion; ACLR, anterior cruciate ligament reconstruction; CDH, cervical disc herniation; IMN, intramedullary nailing; LDH, lumbar disc herniation; ORIF, open reduction and internal fixation.

Figure 4. Comparison of performance outcomes after orthopaedic procedures in National Football League athletes. *Significant decrease in performance compared with the preinjury season (P < .05). ACDF, anterior cervical discectomy and fusion; ACLR, anterior cruciate ligament reconstruction; CDH, cervical disc herniation; IMN, intramedullary nailing; LDH, lumbar disc herniation; ORIF, open reduction and internal fixation.
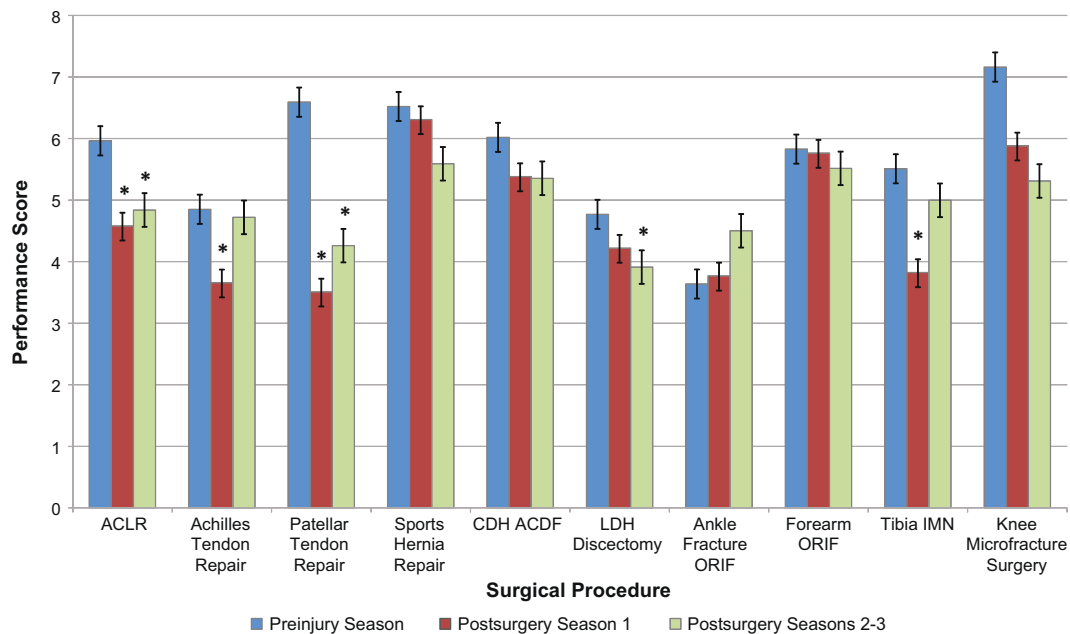
Figure 5. Comparison of the effect of orthopaedic procedures on performance in postoperative season 1. Patellar tendon repair led to the significantly greatest decrease in performance at postoperative season 1 (P = .02). *Significant difference in the magnitude of change in performance (P < .05). ACDF, anterior cervical discectomy and fusion; ACLR, anterior cruciate ligament reconstruction; CDH, cervical disc herniation; IMN, intramedullary nailing; LDH, lumbar disc herniation; ORIF, open reduction and internal fixation.
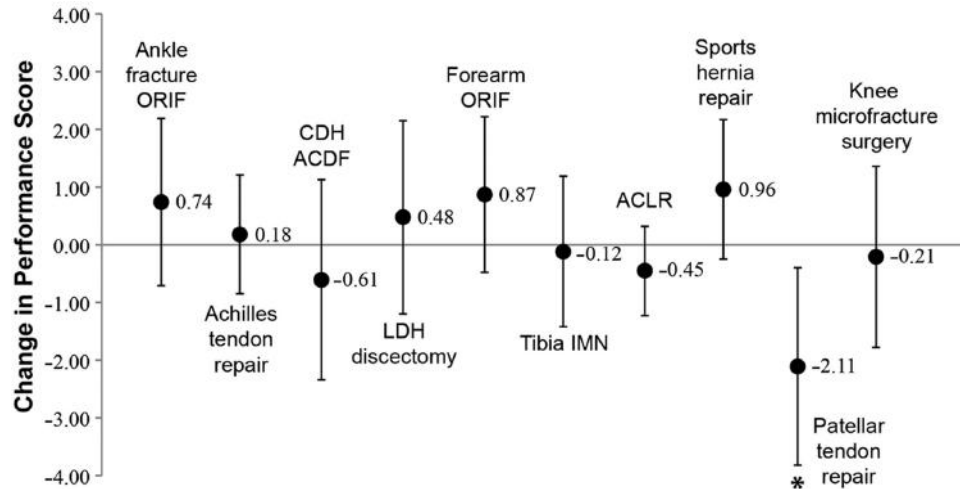
seasons after surgery (range, 53.8%-100.0%), game participation recovered to preoperative levels (P = .06-.62).

Performance Outcomes

Overall, 296 (53.0%) athletes in the NO-SOD met the inclusion criteria for performance analysis. Athletes who were excluded (n = 263) from performance analysis included those who did not return after surgery (n = 115; 20.6%), were offensive linemen (n = 89; 15.9%) or special teams players (n = 10; 1.8%), or did not have a full season before surgery (n = 49; 8.8%).

ACLR, Achilles tendon repair, patellar tendon repair, and tibia IMN led to significant decreases in performance in postoperative season 1 compared with preinjury values (P < .001, .039, .016, and .046, respectively) (Figure 4). Of these, decreased performance in seasons 2 and 3 continued for players in the ACLR and patellar tendon repair cohorts (P = .0001 and .009, respectively), while players in the Achilles tendon repair and tibia IMN groups recovered to preinjury performance. These data should be viewed in the context of the retirement rate. Athletes in the ACLR, Achilles tendon repair, and patellar tendon repair cohorts had the lowest rates of survival (high drop-out rates) at seasons 2 and 3 (53.8%-75.5%). Thus, these data demonstrate that of the small proportion of athletes able to remain in the NFL at postoperative seasons 2 and 3, they were able to return to baseline game participation levels. Of note, while lumbar discectomy did not lead to a decline in performance in postoperative season 1 (P = .27), there was a decrease in performance compared with baseline at seasons 2 and 3 (P = .04). Compared with all other procedures, athletes in the patellar tendon repair cohort experienced the largest magnitude of decline

in performance scores at postoperative season 1 (–2.11 points; P = .02) (Figure 5).

DISCUSSION

American football predisposes athletes to a variety of musculoskeletal injuries secondary to associated collision forces,[15,21] playing surfaces,[17,22] weather conditions,[18] time of year (preseason vs postseason),[9,17] and repetitive motions.[8,12] Injuries that require operative management can be career ending; however, this study demonstrates that overall, orthopaedic surgeries can lead to excellent outcomes. While previous studies have reported outcome measures after specific procedures in NFL athletes,[2,6,12,13,20,24,25] this is the first to compare outcomes from different musculoskeletal interventions.

The data in this study demonstrate that NFL athletes return to play at a high rate (79.4%) after common orthopaedic procedures. There were significant differences associated with different procedures; players of the forearm ORIF, tibia IMN, and sports hernia repair cohorts had significantly higher RTP rates, while patellar tendon repair led to a significantly lower rate. Consistent with previous studies,[14] athlete age and years of experience were negative predictors of RTP rates, while game experience was a positive predictor of RTP. While this finding may initially seem mutually exclusive, years of experience reflects how many years a player has been in the NFL, while game experience reflects the athlete's level of participation. Games played can be viewed as a proxy for the role of an athlete to a team; consequently, an athlete who participates in more games preoperatively may have a larger role on the team and would have more incentive to return. This similar situation has been reported in previous studies of NFL athletes.[2,24] Notably, the observed RTP rate

may be even higher as the design of this study may be subject to false negatives. For example, situations in which an athlete may have undergone a successful procedure but other nonmedical factors, such as a salary cap, league discipline, or personal reasons, precluded his RTP cannot be accounted for by this study design. Further, athletes who returned solely to preseason and postseason competitions were not credited with RTP, although these situations were extremely rare.

Of all procedures that met the inclusion criteria of the NO-SOD, patellar tendon repair appeared to have the most effect on the career of an athlete, leading to a significantly lower RTP rate than all other procedures (50.0%; $P < .001$). Athletes who did successfully return experienced a longer recovery period, fewer games played, shorter career length, and worse statistical performance after surgery. While a previously published study of this injury in 24 NFL athletes reported an RTP rate of 79%, the methodology utilized surveys of team physicians, which subject the results to recall bias and incomplete capture rates.[2] The data in our study reflect a larger sample size, more standardized capture methods, and more recent data than previous studies.

NFL athletes who require ACLR experienced significant declines in statistical performance even 3 seasons after the injury, which is consistent with previous literature.[6] These findings in both patellar tendon repair and ACLR highlight the potentially devastating nature of a tendon or ligament injury of the knee to these athletes because pivoting, jumping, and stopping movements are essential to high-level performance. Other factors in NFL athletes that may place further physical demands on the knee after surgery include high BMI, high-friction playing surfaces, and pre-existing osteoarthritis. This correlation may not apply to other knee injuries, as microfracture surgery did not result in significant decreases in performance-based outcomes.

Athletes who underwent Achilles tendon repair, another lower extremity tendon injury, fared slightly better than those with knee procedures. While they experienced longer recovery periods and decreases in games played and performance at postoperative season 1, they were able to recover to baseline levels during postoperative seasons 2 and 3. Thus, the data in this study demonstrate that procedures to repair tendinous and ligamentous injuries of the lower extremity may be more detrimental on the career of an NFL athlete than procedures to repair traumatic fractures. It is important to note that the NFL regular season spans only 5 months; thus, some recovery times may be artificially longer depending on the time point in the season that the athlete sustained the injury, although this effect is likely balanced by the large cohort.

NFL athletes undergoing ACLR, Achilles tendon repair, patellar tendon repair, and ankle fracture ORIF experienced a significant decrease in games played in postoperative season 1 but recovered to baseline game participation by postoperative seasons 2 and 3. Because these data are affected by the retirement rate, it is only a reflection of the players who recover well enough to return to the field.

Forearm ORIF, tibia IMN, and sports hernia repair were associated with excellent outcomes with greater than a 90%

RTP rate, with no significant changes in performance-based outcomes through 3 seasons after surgery. Notably, athletes who underwent tibia IMN did experience a decrease in performance scores in their initial return season but were able to recover to baseline performance by postoperative seasons 2 and 3 and had the highest survival rate of all injuries overall. Repair of bony injuries appears to portend better short- and long-term outcomes than soft tissue injuries of the joints above and below. The finding that defensive backs accounted for a significantly higher proportion of the forearm ORIF group is consistent with data from a previously published study of an official NFL injury database. Carlisle et al[7] found that defensive backs accounted for the highest proportion of reported injuries of the forearm, with the majority of these injuries categorized as traumatic fractures.

With the current protocols in place to care for NFL athletes, our methodology through the use of publicly available data[2,12,13,20] and/or single-surgeon case reports[1,24,25] represents the only way to compile such a database. To this end, these methods come with several well-published limitations.[12,14,20] First, with the use of public sources, the capture rate of these injuries comes into question. The NFL ISS represents the most accurate tracking of orthopaedic injuries in this patient population; however, only deidentified epidemiological data of the rate of a few of these injuries have been published.[3,7,10,11,16] Further, the rate at which NFL athletes undergo operative management for these injuries either has not been published or is not available. Second, while there are potential inaccuracies in reporting, such as in other published efforts, we attempted to control for this by limiting the study period to a recent decade in which more reliable and redundant reporting was possible. Furthermore, we attempted to exclude surgeries in which substantial variability of the exact procedures could be assumed without the aid of an operative report. For example, while arthroscopic surgery is a general term used to describe minimally invasive endoscopic repair, significant variability can exist in arthroscopic procedures, including the specific structures and extent of tissue repair within the joint. Therefore, players who had undergone shoulder, knee, and ankle arthroscopic surgery were excluded from this study because of the difficulty of normalizing and defining standard arthroscopic techniques for these operations in which a variety of interventions could affect the recovery period or outcomes. While not a true epidemiological study, we believe that the players who compose this database are representative of those who underwent each respective procedure. Notably, the career length of the players included in this study (the NO-SOD) appears to be longer than that of the reported average NFL player (6.3 vs 3.8 years, respectively). This finding may reflect that NFL athletes who undergo an orthopaedic procedure have more talent than average players, which may affect one's decision to undergo a season-ending procedure. Further, the oft-cited 3.8-year career average includes all athletes who make a preseason roster, while the reported average career length for athletes who make an opening day roster, which applies to most athletes in the NO-SOD, is 6.0 years (NFL, personal communication, 2011). Finally, the use of public data also limits the consideration of differences in injury severity and specific

repair techniques on the outcomes after surgery. For example, it is unknown which players received an autograft versus allograft for ACLR or underwent suprapatellar versus infrapatellar IMN for tibia fractures, as these differences in techniques have been associated with differences in outcomes.[19,23]

Careers in the NFL are relatively short, with success dependent on performance. Quantifying the effect of an orthopaedic procedure on an NFL athlete's career and performance is of particular interest to those who provide care. The data in this study demonstrate that procedures involving the lower extremity ligamentous and tendinous structures (ACLR, patellar tendon repair, and Achilles tendon repair) have the greatest effect on the careers of NFL athletes, while procedures for traumatic bony fractures and sports hernia lead to the best postoperative outcomes. To our knowledge, this study represents the largest database of active NFL athletes who have undergone orthopaedic procedures. The data presented herein will allow team physicians to provide evidence-based recommendations about expectations after common orthopaedic procedures.

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