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| **­­Table 1: Studies discussing return to play (RTP) in American football athletes with cervical spine injuries** |
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| **Stinger/Burner****Strain/Sprain****Author** | **TQ/Stenosis** | **CDH** | **Fracture** |  |  | **Objective** | **Methods** | **Results** | **Conclusions/****RTP discussion** |
| Bailes et al422005 |  |  | x |  |  | To discuss return to play (RTP) in athletes with transient spinal cord injury (TSCI) | * 10 athletes evaluated for TSCI, with 7 being football players
 | * Spinal stenosis of 8 to 13 mm in length at three or more levels was evident in all cases
* 4 patients returned to play without recurrent TSCI; six individuals retired
 | * Two groups of athletes experience TSCI: Those with 1) normal findings or 2) cervical stenosis
* Single episode of TSCI with normal MR or cervical stenosis may not increase risk of injury
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| Brigham et al62003 |  | X | X |  |  | To present an NFL player with history of neurapraxia and congenital stenosis who suffered spinal cord injury (SCI) | * Case report involving one 22 year-old NFL linebacker followed from 2 years pre-injury to two years post-injury
 | * Patient suffered axial load injury to neck with numbness in all four extremities and bilateral upper extremity dysesthesias
* Upper extremity dysesthesias persist 2 years later
 | * NFL athletes with congenital stenosis may be at increased risk of permanent SCI
* RTP decisions must be made on a case-by-case basis knowing that permanent SCI is possible
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| Brigham and Capo et132013 |  |  | X |  |  | To report outcomes for athletes who sustained cervical spinal cord contusion | * Case series of four professional athletes, including three NFL players, with cervical stenosis and contusions
* Follow up for minimum of 2 years
 | * All underwent ACDF at level of contusion
* Two athletes developed new contusions
* No correlation between MRI finding and symptoms
* Two NFL players RTP in 5 to 6 months after ACDF
 | * MRI for symptomatic athlete; acute CDH, fracture, fracture is contraindication to RTP
* Otherwise, can RTP when asymptomatic
* Stenosis increases risk of recurrent contusion
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| Cantu et al4 2005 |  |  | X |  |  | To provide a framework for RTP decisions after an episode of transient quadriplegia (TQ) | * Case series of 3 football players with history of transient quadriplegia
* Included 1 NFL player
 | * Relative contraindications: healed fracture, cervical disc herniation (CDH) or spondylosis without functional stenosis; Absolute contraindications: persistent symptoms, MRI with cord edema
 | * Athletes with history of neurapraxia, normal imaging and absence of symptoms may RTP
* Contraindications: bony or ligamentous injury, cord contusion, or functional stenosis.
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| Chung et al22019 | X | X | X | X | X | To describe the epidemiology of cervical spine injuries in NCAA football players | * NCAA-ISP database
* Rates of injury calculated as number of injuries divided by the total number of athlete-exposures (AEs)
 | * 7,496 cervical spine injuries were identified; rate of 2.91/10000 AEs with stingers/strains most common
* Most players returned to play within 24 hours of the injury (64.4%), while 2.8% remained out for > 21 days
 | * Rate of disabling cervical spine injuries is low in NCAA football, likely due new tackling rules, improved protective gear, and better rehab
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| Clancy et al311977 |  | x |  |  |  | To discuss the role of brachial plexus axonotmesis in football | * 13 cases with 10 documented by electromyography.
* All involved the upper trunk
 | * All significant or repeated cervical nerve pinch injuries should be reexamined at 2 weeks
* All but one patient recovered by 42-weeks
 | * Patients with a history of axonotmesis should not RTP unless physical exam is unremarkable and electromymyogram is within normal limits
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| France et al38 2016 |  |  | X | X | x | To offer analysis of expert opinion regarding RTP after SCI | * 10 scenarios presented to 25 spine surgeons including various cervical spine injuries
 | * Consensus reached regarding RTP without symptoms or stenosis, surgically repaired herniated discs, and non-operatively healed C1 or C2 fractures
* No consensus exists for pts with persistent symptoms
 | * Consensus exists for patients with normal imaging and no symptoms to RTP. RTP recommendations for patients with stenosis or persistent symptoms are controversial
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| Grant et al10 1976 |  |  | X |  |  | To describe a case of TQ in an NCAA football player | * Case of 18M linebacker who suffered episodes of TQ
 | * Cervical stenosis diagnosed using lateral xrays
* Patients counseled not to resume contact sports
 | * Authors recommend against RTP in cases of cervical stenosis.
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| Gray et al162013 |  |  |  | X |  | To assess incidence, location, and type of CDH in NFL athletes | * Retrospective review of NFL surveillance database 2000 to 2012
 | * 22% of disc herniations occur in the cervical spine
* CDH was associated with a median of 69 days lost from participation, 24 practices lost, 7 games lost
 | * Cervical CDH represent a significant injury burden in the NFL, although indications for RTP unclear
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| Herzog et al111991 |  |  | X |  |  | To establish normal morphometric values for the cervical spine in NFL players | * 80 veteran and rookie and NFL players on one team
* n= 80 underwent XR evaluation, n=16 CT/MPR, n=9 MRI
 | * Spinal canal diameters of NFL athletes were slightly larger than those of non-athletes subjects
* Of asymptomatic athletes, 49% had an abnormal Torg ratios (Ratio < 0.80)
 | * Torg ratio is sensitive in detecting significant cervical stenosis but has low predictive value
* If NFL athlete has small canal on XR (<12.5mm on sagittal view), order MRI; RTP criteria are unclear
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| Hsu et al182011 |  |  |  | X |  | To evaluate performance of NFL athletes with CDH. | * Retrospective comparing NFL performance before/after CDH
 | * 99 NFL athletes identified
* 72% RTP after surgery, 46% RTP without surgery
* Defensive back with poorer outcomes after surgery
* Performance and games started not significant
 | * Fusion for CDH is associated with higher RTP rates and longer careers
* Defensive backs have poorer prognosis after CDH diagnosis
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| Mai et al172016 |  |  |  | X |  | To assess the impact of CDH level on NFL performance | * Retrospective cohort study

NFL players divided into two groups, C2-C4 (upper) and C4-T1 (lower)* 40 players: 15 upper and 25 lower
 | * 66% RTP in upper CDH group compared to 72% RTP in lower CDH group, although not significant
* Differences in performance scores not significant
* 10% of ACDF patients needed reoperation for ASD
* 50% foraminotomy athletes later required fusion
 | * No statistical difference in RTP and performance between upper and lower level cervical spine surgery patients in NFL p=layers
 |
| Mai et al262017 |  |  |  | X |  | To compare outcomes after ACDF, posterior foraminotomy (PF), or total disc replacement (TDR) in NFL athletes | * Retrospective case series
* NFL, MLB, NHL, and NBA athletes with CDH managed operatively
* ACDF, PF, and TDR cohorts
 | * 101 athletes (86 ACDF, 13 PF, 2 TDR)
* PF with better RTP rate and shortest time to RTP
* Re-operative rate highest for PF v ACDF (42% v 6%)
* No difference in performance scores for all cohorts
 | * ACDF/PF are appropriate for professional athletes
* PF has quicker RTP but higher risk of re-operation.
* TDR cohort too small to draw conclusions
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| Mall et al12012 | X | X |  | X | X | To review epidemiology of spinal and axial skeleton injuries in NFL athletes  | * 2208 spinal injuries, 2000 to 2011
* 44.7% occurred in the cervical spine
* Mean loss of 25.7 days per injury
 | * Cervical fracture associated with 120 days missed
* CDH associated with 85 days missed
* Defensive secondary suffered most cervical spine injuries, representing 17.8% of all cervical injuries
 | * Spinal and axial skeleton injuries may result in significant time missed
 |
| Maroon et al492007 |  | X | X |  |  | To determine RTP after cervical spine injuries in NFL athletes | * Case series of 4 NFL players and one collegiate athlete undergoing ACDF
 | * 5 players returned to play < 8 months after ACDF
* Two athletes had career ending CDH after ACDF (one above and one below fusion level)
* One required repeat decompression after CDH
 | * RTP is acceptable after one-level ACDF if exam within normal limits
* NFL athletes are at increased risk of repeated herniation above or below the fused level
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| Maroon et al202013 |  |  | X | X |  | To characterize RTP decisions for professional athletes with cervical spine injuries | * Retrospective review of professional athletes who were patients of one spine surgeon from 2003 to 2012
 | * 15 professional athletes, including 7 NFL players
* Cervical stenosis was diagnosed in 14 athletes
* 13 of 15 players returned to play in 2 to 12 months after ACDF with a mean of 6 months
 | * Athletes may return to play after RTP but may be at higher risk of adjacent segment disease (ASD)
* Cord signal may not preclude RTP in NFL athletes
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| McAnany et al192017 |  |  | X | X |  | To assess RTP after ACDF in professional athletes | * Systematic literature review and meta-analysis
 | * 5 articles, 48 athletes, including 31 NFL players, who underwent ACDF
* Pooled success rate for RTP was 74%
 | * Elite contact athletes return to play 74% of time after ACDF
 |
| Meredith et al482013 |  |  |  | X |  | To describe presentation of CDH in NFL athletes | * Retrospective review of one NFL team, including athletes diagnosed with CDH by MRI from 2000 to 2011
* Minimum of 1-year follow-up
 | * 16 athletes with symptoms; 3 underwent ACDF, and one returned to play; 3 underwent CSI with temporary relief; 5 managed conservatively with no RTP; 8 treated conservatively and returned to play
 | * Cord compression + signal change is indication for surgery; CDH abutting cord may be managed conservatively but no RTP until asymptomatic and MRI demonstrates no cord compression
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| Milles et al44 2014 |  |  | X |  |  | To describe a case of TQ in a NCAA football player | * Case report of 22-year-old man with episodes of TQ after hit
 | * MRI with no congenital narrowing of canal
* Syringomeylia C5 to C7 visible on post-injury MRI
* Decision to disqualify patient from contact sports given abnormal MRI and 48h neurologic symptoms
 | * Recommend against RTP for patients with episode of transient quadriparesis, prolonged duration of neurologic symptoms, and syrinx
 |
| Morganti et al82001 |  |  | X |  |  | To offer consensus analysis of expert opinion for unique case factors regarding RTP  | * 10 cervical injury scenarios presented to 25 spine surgeons from Level-1 trauma centers
 | * Consensus regarding RTP in contact sports for cases of cervical cord neurapraxia without symptoms or stenosis, repaired herniated disks, and non-op healed C1 ring or C2 hangman's fractures
 | * Patients with normal imaging and resolution of symptoms may RTP; however, patients with cervical stenosis or clinical symptoms are a challenge to manage
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| Petraglia et al28 2012 | X |  |  |  |  | To report the case of a collegiate football player presenting with sprain/strain and found to have bipartite C1 | * 19-year-old male collegiate football player with neck pain after hyperextension injury
 | * CT with congenital bipartite atlas, xrays normal
* MRI with increased edema in pre-vertebral tissue
* RTP after resolution of symptoms and normal MRI at 1.5 months post-injury
 | * Diagnosis of a bipartite atlas in an asymptomatic patient with no evidence of instability is not a contraindication to RTP.
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| Rodts et al27 2018 |  |  |  |  | X | To report the case of an NFL player treated surgically for an unstable Jefferson fracture | * 23-year-old NFL player with neck and occipital pain after suffering hit
* Neurologically intact
 | * CT with a widely displaced anterior arch and minimally displaced posterior arch of C1
* MRI with intact ligaments
* Underwent 2-stage transoral and posterior treatment
 | * ORIF of anteriorly displaced fracture required 2nd stage MIS posterior arthrodesis
* Patient has full ROM and no neck discomfort
* Patient decided not to RTP
 |
| Schroeder et al412014 |  |  | X | X |  | To determine the effect of cervical spine pathology on athletes entering the NFL | * Cohort study of NFL athletes 2003-2011 during combine
* Measured career statistics
 | * 143 NFL players with cervical spine diagnosis
* 10 with sagittal canal diameter <10mm and 7 with history of cervical spine surgery; both groups showed no difference in longevity or performance
 | * Cervical spine pathology is not associated with performance or games started
* Patients with cervical stenosis and those with previous surgery may not be at increased risk
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| Tempel et al12 2015 |  |  | X |  |  | To assess T2 hyperintensity in the cervical spinal cord in professional athletes | * Retrospective review o T2f hyperintensity on MRI, 2007-2014, in five professional athletes, including NFL players
 | * 4 underwent ACDF, one treated conservatively; 3 had no signal intensity at 9 months; 4 were released to return to play; clearance for RTP preceded complete resolution of hyperintensity on MRI in three of four athletes; 2 returned to play and have had no re-injury
 | * NFL players undergoing ACDF for CDH may return to play despite residual T2 hyperintensity if they are asymptomatic, neuro intact, and have no signs of instability on imaging
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| Torg et al371993 |  | X | X | X | X | To describe spear tackler's spine | * Review of 15 cases between 1987 to 1990 in football players
 | * 11 had complete neurologic recovery, 4 had permanent neurologic deficits: 2 quadriplegia, 1 incomplete hemiplegia, 1 residual long track signs
 | * Individuals with history of spear tackler's spine should not RTP to collision sports that put the cervical spine at risk
 |
| Torg et al351997 |  |  | X |  |  | To describe cervical cord neurapraxia (CCN) and RTP considerations | * Retrospective review
* 110 cases of CCN, 52 football players, most professional or collegiate
 | * 11% of all cases treated surgically
* Patients returning to football had higher recurrence than other sports
* For non-op patients, football participation and degree of stenosis increased risk of recurrence
 | * Routine MRI in all cases of CCN
* Patients without significant stenosis, instability, or persistent symptoms can return to sport after non-op treatment
* Significant of stenosis on RTP is controversial
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| Torg9 2009 | X | X | X | X | X | To assess contraindications to RTP after cervical spine injury in contact athletes | * Systematic review
* National Football Head and Neck Registry and anecdotal experience
 | * 1200 cervical spine injuries in NFL athletes
* Includes overview of relative and absolute contraindications for multiple cervical and lumbar spine injuries in NFL athletes
 | * Proposes four general principles for RTP
* After cervical spine injury, the athletes must be (1) asymptomatic, (2) pain-free, (3) neurologically intact, and have full strength and ROM of neck
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| Wakins et al212018  |  |  | X | X |  | To determine the rate and time of RTP among professional athletes after ACDF | * Prospective and retrospective review of athletes undergoing ACDF from 1982 to 2016
 | * 27 ACDF surgeries on 26 professional athletes, including 12 NFL players; 26 showed radiographic fusion; 20 of 27 athletes returned to play (80%)
 | * After single-level ACDF, 80% pro athletes able to RTP at approximately 9 months
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**Notes**: TQ, transient quadriplegia; RTP, return to play; ACDF, anterior cervical discectomy and fusion; NFL, National Football League; MLB, Major League Baseball; NHL, National Hockey League; NBA, National Basketball Association; CDH, cervical disc herniation; ROM, range of motion; CSI, corticosteroid injection; CCN, cervical cord neurapraxia; MRI, magnetic resonance imaging; CT/MPR, Multiplanar computed tomography; ASD, adjacent segment disease

**Source**: Results of PubMed, EMBASE literature search