Chapter 6
Return to Play After Spinal Injury

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An estimated 9–15% of spine injuries and 8% of spinal cord injuries (SCI) in the United States are attributable to participation in sports [1–6]. Among elite or professional athletes involved in collision sports, studies suggest 7–10% of injuries in college-level or National Football League (NFL)-level athletes involve the spine, of which 35–49% affect the cervical spine [1, 3, 7–9]. While formal return-to-play (RTP) guidelines have been, or are currently being developed for, concussion, anterior cruciate ligament injury with reconstruction, and other musculoskeletal injuries, consensus protocols for RTP in elite athletes following a spinal injury remain lacking, due in part to anatomic complexity as well as heterogeneity of injury patterns [10–12]. A classification of spinal injuries relevant to athletes is discussed in Chap. 3, and the definitive management of associated SCI and peripheral nerve injuries is reviewed in Chaps. 4, 8, and 9. The aim of this chapter is therefore to provide a framework for decision making for RTP after common spinal injuries encountered in the care of the elite athlete.

In general, return to play following spinal injury requires an asymptomatic patient with an intact neurological examination, along with the radiologic absence of pathologic spinal segmental motion or ongoing spinal cord compression. The nuances of RTP decision making for cervical and brachial plexus injuries along with lumbar spinal injuries, following either operative or nonoperative management, are discussed herein.

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M. E. Oppenlander (ed.), *Neurosurgical Care of Athletes*,
https://doi.org/10.1007/978-3-030-88227-3_6

Cervical Spine and Brachial Plexus Injuries

Cervical Stingers

Traumatic upper trunk brachial plexopathy, also known as a cervical 'stinger' or 'burner', is characterized by transient burning pain down a unilateral upper extremity, often associated with paresthesias/numbness and/or motor deficits, after a significant contact injury to the neck or upper extremity [13, 14]. The pain typically resolves in seconds to minutes, with motor weakness lasting up to 24 h though in severe cases persisting up to 6 weeks [1, 15, 16]. While commonly thought to occur from traction injury to the brachial plexus following ipsilateral shoulder depression and contralateral lateral neck flexion, injury to the upper trunk is also possible via direct mechanical compression from contact to Erb's point, while cervical root compression may occur within the intervertebral foramina from ipsilateral lateral neck flexion coupled with hyperextension [13]. The severity of an acute injury, and therefore the natural history and prognosis for motor recovery, is categorized as per either the Seddon or Sunderland classification systems.

While athletes may be prone to underreporting stingers due to the transient nature of the injury, as well as the potential playing-time and career implications, it is nonetheless well known that the likelihood of sustaining a cervical stinger is considerably higher among rugby and American football players, though also among boxers, ice hockey players, and gymnasts [13, 17, 18]. At the collegiate level, a survey of National Collegiate Athletic Association (NCAA) football players revealed a cervical stinger rate of 1.87 per 10,000 athlete exposures [5], with a 50.3% lifetime prevalence among high-school-, collegiate-, and professional-level players [19], and an increased risk of recurrent stingers among those experiencing a single event [20, 21].

Algorithms for the sideline diagnosis and initial management of stingers, along with the role of subsequent imaging and/or electrodiagnostic studies, are discussed thoroughly in other chapters. In general, the vast majority of stingers are managed nonsurgically. Nonoperative management consists predominantly of rest and analgesia and, if persistent, physical therapy targeting postural correction and normalizing flexibility and strength imbalances in the cervicothoracic spine as well as scapular and core stabilizers [22, 23]. MRI is indicated if a stinger does not resolve within 24 h, or if the athlete has a history of repeated stingers.

While there are no standardized RTP guidelines for stingers managed nonoperatively, athletes with a first-time stinger, in whom symptoms resolve completely within 1 h, with normal painless cervical range of motion and normal neurovascular examinations, may RTP within the same or subsequent games [13, 24]. In a modified-Delphi survey of spine surgeon members of the Cervical Spine Research Society (CSRS), Schroeder et al. found 84.5% agreement among members that athletes with stinger symptoms for <5 min should be allowed to RTP, with a case-by-case evaluation for anyone with symptoms lasting >5 min [25]. In general, first-time stingers with symptoms lasting >1 h, involving more than a unilateral upper extremity, associated with persistent neck pain, or recurrent stingers within the same game or season, mandate removal from competition and workup with cervical radiographs and magnetic resonance imaging [26]. Athletes with persistent symptoms beyond 1 week are often investigated with electrodiagnostic studies to assess the severity of nerve injury. While electromyographic (EMG) changes may persist after the resolution of clinical symptoms, and hence alone are not a reason to prohibit RTP, a plan for return to competition in athletes with electrodiagnostic evidence of denervation should commence only after the absence of spontaneous fibrillation potentials, and the emergence of polyphasic potentials indicative of larger motor unit recruitment as part of reinnervation [22]. In those athletes investigated with cervical radiographs or MRI, spinal cord parenchymal signal changes, or persistent root/cord compression in the presence of ongoing symptoms, are traditional contraindications to safe RTP. Bowles et al. have recently summarized the literature evidence on RTP recommendations after cervical stingers, encapsulated in Table 6.1 [13].

Table 6.1 Summary of RTP criteria following cervical stingers

	Clinical	Radiologic
Absolute contraindications	Second stinger in the same game	Cervical spine fracture
	Persistent neurological deficits	Ligamentous injury
	Bilateral or multiple extremity symptoms	Cervical spinal cord edema or intramedullary abnormality
	Persistent neck pain	Active neural element compression
	Diminished cervical range of motion	Evidence of spear-tackler's spine
		Multilevel fusion from Klippel–Feil syndrome
		Ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis
		Evidence of rheumatic arthritis
Relative contraindications	Persistent symptoms >1 h	
	Second stinger in the same season	
	Three or more prior stingers with full return to baseline neurological function and cervical range of motion	
No contraindications	First-time stinger, with symptoms <1 h, followed by complete resolution	Single-level Klippel–Feil anomaly, without involvement of C0–C1
	Second-time stinger not in the same game or season, with symptoms <1 h, followed by complete resolution	Spina bifida occulta
	Less than three prior stingers each lasting <24 h, with no neurological deficit or diminished cervical range of motion	Torg ratio <0.8 and asymptomatic

Cervical Nerve Root Injuries

Cervical nerve root avulsion injuries represent the most severe end of the spectrum of traumatic brachial plexopathy. These are extremely rare, in the context of the far more common transient neurapraxia or 'stinger', with only case series of functional root avulsion described in rugby and collegiate-level American football players [27, 28]. Following electrodiagnostic and/or magnetic resonance imaging (MRI) evidence of nerve functional transection (Seddon Grade 3), these severe injuries are often treated surgically with delayed nerve transfers and/or grafts primarily to restore stability of the shoulder girdle and re-animate shoulder abduction and elbow flexion, depending on the specific deficits. Injuries of this nature, with or without surgical reconstruction, are typically career-ending from competitive sport.

Congenital Cervical Stenosis

The incidence of osseous cervical canal stenosis has been estimated in cadaveric studies to be 4.9% of the adult North American population; when soft-tissue canal encroachment is accounted for on MRI, this number rises to as high as 24% in susceptible Asian populations [29, 30]. Cervical stenosis has historically been defined on plain radiographs by the segmental sagittal canal diameter (Fig. 6.1), with diameters of <14 mm at any level considered stenotic. On MRI, a sagittal canal diameter of <10 mm at any level has been considered as 'absolute' stenosis, with 'relative' stenosis defined as <13 mm [31–33]. To account for differences in XR magnification, Torg and Pavlov defined an eponymous ratio of the sagittal canal diameter to vertebral body diameter (Fig. 6.1), with a ratio of <0.8 portending an increased risk of cervical cord neurapraxia in the initial study, and reflecting the current literature definition of cervical stenosis [34]. Among athletes, a Torg ratio <0.8 in a retrospective study was 93% sensitive for those suffering a transient cervical neurapraxia, however with a positive predictive value of only 0.2 in predicting future injury [35]. This is due in part to the Torg ratio perhaps being not as accurate in elite athletes in high-impact sports, due to their larger vertebral bodies. Various measurements of functional reserve on MRI have therefore been proposed, reflecting the available cerebrospinal fluid (CSF) cushion around the cord (Fig. 6.2) [36–38].

Injuries typically associated with cervical stenosis include cervical cord neurapraxia, as well as cervical spinal cord injury (SCI), of which traumatic central cord syndrome is a subset. RTP recommendations after injuries associated with cervical stenosis are discussed in the subsequent sections. For athletes with an incidental discovery of radiographic cervical stenosis, 'functional' stenosis, defined as a complete obliteration of the CSF space or frank cord deformation on MRI, is typically considered a contraindication to RTP [24, 39]. It follows therefore that while

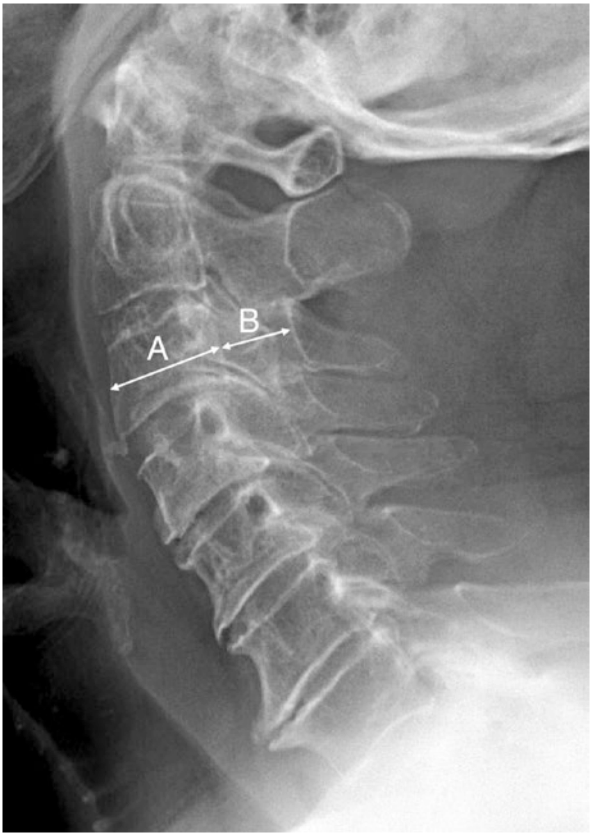

Fig. 6.1 Demonstration of calculation of Torg ratio on lateral cervical spine x-ray. *A*—vertebral body width. *B*—segmental sagittal canal diameter. Torg–Pavlov ratio = B/A. A Torg ratio <0.8 is indicative of congenital spinal stenosis and increased risk of a cervical neuropraxic event

incidental stenosis on radiographs or computed tomography (CT) imaging is not, in the absence of overt mechanical instability, an indication for surgical intervention, functional stenosis on MRI for an elite athlete in a collision sport may warrant consideration for surgical decompression in order to preserve the possibility of a playing career. This is borne out in the potentially increased risk for cervical SCI if the CSF space around the cord is obliterated, and the greater risk for symptom recurrence following cervical cord neurapraxia in the context of congenital stenosis rather than spondylosis [40, 41].

Cervical Cord Neurapraxia

Cervical cord neurapraxia is defined as a transient posttraumatic cervical neurologic deficit, occurring most frequently in professional American football and soccer players, with an estimated incidence of 1.3–6 per 10,000 exposures [42]. Cervical stenosis is a predominant risk factor, with up to 86–93% of cervical cord

Fig. 6.2 Measurement of spinal canal functional reserve on MRI, reflecting the available cerebrospinal fluid cushion around the spinal cord. Mid-sagittal T2-weighted cervical spine MRI. *A*—spinal cord diameter. *B*—Adjacent disc-level spinal canal diameter. "Space available for cord" (SAC) = (B-A). "Functional reserve" = A/B

neurapraxia cases associated with a Torg ratio <0.8 [35, 38], though with poor positive predictive value for future recurrence [43]. MRI measurements of functional reserve, or space available for cord (SAC) (Fig. 6.2), may have better predictive value for the future risk of developing cervical cord neurapraxia [44].

Prognostication, and therefore RTP recommendations, following cervical cord neurapraxia in the current era is predicated on MRI measurements of the extent of cervical stenosis, as well as the presence of intramedullary T2 hyperintensity. While the literature on elite athletes with cervical cord neurapraxia consists entirely of case series, no athlete who returned to play following cervical cord neurapraxia without functional stenosis, that is, without complete obliteration of the CSF space around the cord, has been documented to have suffered from recurrent cord symptoms [34, 38, 40, 45–47]. Tempel et al. retrospectively reviewed the impact of intramedullary T2 hyperintensity in four National Football League players and one professional wrestler with cervical cord neurapraxia, of which four were ultimately cleared for RTP. In three of these four, RTP preceded complete resolution of MRI intramedullary T2 hyperintensity, with no subsequent neurologic symptoms in all, suggesting that functional canal reserve rather than intramedullary T2 hyperintensity is a predominant prognosticator for future injury [48]. This is captured in a recent Delphi survey of CSRS members, which provides strong consensus (71–94% agreement) for the following recommendations [25]:

1. Following an episode of transient paralysis, asymptomatic athletes with no T2 intramedullary signal change and no absolute cervical stenosis (canal diameter >10 mm on MRI) are allowed to RTP, but those with absolute stenosis (canal diameter <10 mm) should be evaluated on a case-by-case basis.
2. Following an episode of transient paralysis, asymptomatic athletes with resolved T2 intramedullary signal change and no relative cervical stenosis (canal diameter >13 mm on MRI) are allowed to RTP; those with a canal diameter 10–13 mm should be evaluated on a case-by-case basis; those with canal diameter <10 mm should not RTP.

This survey also provides weak consensus (60–70% agreement) for the following recommendation:

1. Following an episode of transient paralysis, asymptomatic athletes with continued T2 intramedullary signal change and no relative cervical stenosis (canal diameter >13 mm on MRI) should be evaluated on a case-by-case basis; those with canal diameter <13 mm should not RTP.

Cervical Disc Herniation

Asymptomatic cervical disc herniations are estimated to occur in approximately 25% of the general population under 40 years of age, unsurprisingly with a greater incidence in professional football players given prolonged exposures to repetitive axial loading [11, 49]. Asymptomatic cervical disc herniations, discovered incidentally, do not preclude RTP as long as the abovementioned criteria for preservation of CSF signal surrounding the cord on MRI are met [50, 51].

Symptomatic disc herniations, on the other hand, whether manifesting as radiculopathy and/or myelopathy, represent a consensus absolute contraindication to RTP due to the risk of worsening nerve root or cord injury with further impact [24, 52]. Surgery for an acute disc herniation is typically reserved for symptoms of myelopathy or progressive neurological deficits with ongoing radiographic cord compression or intramedullary T2 signal change on MRI. Conservative management is generally attempted as first-line for radicular-only symptoms, or for cord deficits with preserved surrounding CSF space on MRI [41].

Multiple authors have investigated RTP outcomes for elite athletes in the National Football League (NFL), Major League Baseball (MLB), and professional rugby, with generally >65% of athletes returning to play following cervical disc herniation treated either operatively or nonsurgically [53–57]. RTP rates in the literature have been equivalent among athletes treated operatively vs. conservatively [41], with the exception of one study by Hsu et al. suggesting increased RTP among surgically treated NFL players along with longer careers post treatment, perhaps reflective of athletes more advanced in their careers opting to retire rather than undergo surgery [54]. Sport-specific performance metrics in those NFL and MLB athletes who do RTP following cervical disc herniation have been equivalent among those treated operatively vs. conservatively [54, 56, 57].

Return-to-Play Recommendations Following Cervical Spine Surgery

The specific indications for surgical intervention following cervical spinal injuries have been discussed briefly here and more thoroughly in other chapters. Broadly, surgical options include anterior cervical discectomy with fusion (ACDF), cervical arthroplasty, posterior cervical decompression with fusion (PCDF), and posterior cervical foraminotomy +/− discectomy. RTP following operative cervical intervention has been most widely studied for ACDF; in studies of cervical injuries in athletes in the four major North American professional sporting leagues (NFL, MLB, NBA, NHL), 75–85% underwent ACDF, with 15–20% undergoing posterior cervical foraminotomy and a small minority cervical arthroplasty [41, 47, 48, 54–56, 58, 59].

Among elite athletes undergoing ACDF, RTP rates following a single-level ACDF range from 68% to 100% [53–55, 57–59]. To our knowledge, there are no literature reports to date of successful RTP in a professional athlete following 2+-level ACDF. In fact, in two studies by Maroon et al. evaluating ACDF in predominantly NFL players and professional wrestlers, 3 of 20 combined patients suffered adjacent-level disc herniation, with two requiring re-operation and none returning to play after their second injury [55, 58]. Similarly, in a series by Mai et al., four NFL athletes suffered adjacent segment disease after returning to play following single-level ACDF, with all undergoing reoperation and none returning to play thereafter [59]. Among those athletes returning successfully after single-level ACDF, RTP occurred within 6–12 months postsurgery [53, 55, 58–60]. The level of ACDF does not appear to impact the ability to RTP, with equivalent RTP rates and postsurgery career lengths in NFL players undergoing a 'high-cervical' (C2–4) ACDF vs. 'low-cervical' (C4–T1) [61].

RTP following posterior cervical foraminotomy has been compared to ACDF in only one recent retrospective series by Mai et al., encompassing 101 professional athletes in one of the four major North American sporting leagues, with 86 undergoing ACDF, 13 foraminotomies, and 2 arthroplasties [59]. In this series, RTP following single-level posterior cervical foraminotomy (PCF) was 92.3%, compared with 70.9% for the ACDF cohort; these data are consistent with the >90% return-to-duty rate following PCF in a military cohort with presumably similar increased mechanical stresses as athletes [62]. While the time to return following PCF was markedly shorter than ACDF (238 vs. 367 d), the rate of reoperation was substantially higher (46.2% vs. 5.8%), with all reoperations following PCF occurring at the index level versus the majority following ACDF occurring at adjacent segments [59, 61].

Cervical arthroplasty, while studied extensively and with long-term follow-up in the general population, has been described infrequently in athletes, and at the professional level only in MLB players [57, 59]. All players were able to RTP in these series, with none of the two in the series by Mai et al. requiring reoperation at a follow-up of 6 years, with preserved or improved performance metrics postoperatively. To our knowledge, there have been no reports of elite athletes returning to play following posterior cervical decompression with fusion.

Sport-specific performance outcomes in those athletes returning to play after ACDF, foraminotomy and cervical arthroplasty have been evaluated by numerous authors. Among NFL players suffering a cervical disc herniation, there was no difference in position-specific performances scores among those treated operatively or nonoperatively, though with a slight decline in performance score among both groups [54]. In a retrospective review by Mai et al., of 101 professional athletes across the NFL, NBA, MLB, and NHL, only MLB players experienced a statistically -significant decline in performance after surgery (−14%) [59]. However, Roberts et al. found no change in performance metrics in MLB pitchers following ACDF, with respect to time-averaged metrics such as earned-run average (ERA) and walks + hits per inning pitched (WHIP), though with a significant decline in the number of innings pitched postsurgery and an increase in the rate of conversion of starting pitchers to relievers [57].

While formal RTP criteria have not been published or identified clearly in the majority of series of surgical intervention for cervical disease, in all cases the general rules of a neurologically intact patient with no neck pain and full painless cervical range of motion apply, along with the absence of radiographic spinal cord compression and pathologic vertebral motion. Following ACDF, Maroon et al. permitted the progressive return to full aerobic activity and 50% of weight-training capacity by 4 weeks postsurgery, with flexion-extension X-rays performed at 8 weeks. Return to full conditioning and subsequent contact was permitted if there was no motion on dynamic X-rays, therefore as early as 8 weeks postoperatively [55]. Formal radiographic criteria for RTP after posterior cervical foraminotomy or cervical arthroplasty have not yet been outlined in the literature.

The latest guidance for RTP after cervical surgery, from the CSRS survey by Schroeder et al., provide strong consensus for the following recommendations [25]:

1. Asymptomatic athletes with no T2-signal change after a solid 1-/2-level ACDF are allowed to RTP, but a 3-level ACDF should not RTP.
2. Asymptomatic athletes with continued T2-signal change after a solid 2-/3-level ACDF should not RTP, but a 1-level ACDF should be taken on a case-by-case basis.
3. Asymptomatic athletes with a solid fusion after a compression fracture, burst fracture, or facet fracture with no instability and no T2-signal change are allowed to RTP.
4. Following an episode of transient paralysis, asymptomatic athletes with no T2-signal change following a 1-/2-level ACDF are allowed to RTP, but following a corpectomy or posterior cervical surgery RTP should be taken on a case-by-case basis.

Lumbar Injuries

Lumbar Disc Herniation

The lifetime prevalence of radiographic lumbar degenerative disc disease has been reported to range from 33% to 84% in a variety of North American professional athletes, with increased rates in collision relative to noncontact sports [63–66]. Symptomatic lumbar herniations, as in the general population, occur most frequently at the L4/5 and L5/S1 levels [67].

The management of lumbar disc herniations is fairly consistent between the general population and elite athletes, with perhaps a lower threshold for surgical intervention for subtle motor deficits that might be tolerable for the average individual, but have an appreciable impact on performance for an elite athlete [68]. As with the general population, >90% of athletes with symptomatic lumbar disc herniations will recover within 6 weeks [69]. In a large study of 342 professional players across the four major North American leagues, Hsu et al. demonstrated RTP rates of 82% after symptomatic lumbar disc herniation, comparable between those treated surgically vs. conservatively [69]. A noticeable drop in sport-specific performance scores, ranging from 64% to 104% of baseline, was seen in both operatively and nonoperatively treated patients, with no significant differences between groups [70, 71].

Surgical treatment for lumbar disc herniations typically consists of a laminotomy with discectomy, with 75%–100% of athletes returning successfully to play after this procedure at a mean of 2.8–8.7 months postoperatively [70]. Percutaneous discectomy may have slightly lower RTP rates (70%) relative to traditional microdiscectomy (85%) or conservative therapy (79%) [72]. Revision decompression for re-herniation has been reported to occur in approximately 13%, comparable to the general population, with similar RTP rates of 85% following a revision procedure [73]. RTP outcomes may differ between sports, with higher rates seen among MLB players (96%) and lower among NFL players (70%). RTP after posterolateral fusion in professional athletes has been described to date only for NHL players, with 8 of 8 returning to play after a single-level posterolateral fusion [74].

Lumbar Isthmic Spondylolisthesis

The incidence of isthmic spondylolisthesis with spondylolysis is estimated to be 15–47% in young athletes with low back pain, a significantly greater rate than in the general population [75]. Spondylolysis is seen most frequently in wrestlers, weightlifters, gymnasts, and divers, than athletes in other sports [76]. The initial management of symptomatic spondylolysis is nonsurgical, with sport activity cessation for up to 3–6 months, bracing with limitation of hyperextension, and subsequently targeted physical therapy [77]. RTP rates in a cohort of adolescent soccer players were shown to be significantly greater among those who ceased sport activity for 3 months relative to those who continued to play [78].

Surgical intervention is considered typically after failure of a trial of conservative therapy for at least 6 months, or with persistent neurological symptoms or progressive radiographic spondylolisthesis. For young patients with minimal spondylolisthesis, preserved disc height, and no neurological symptoms, direct pars repair through a variety of lag screw, pedicle screw-sublaminar hook or wiring constructs, may be performed. Direct pars repair in adolescent athletes has been reported in a number of studies to have excellent outcomes, with RTP rates from 80% to 100% to a variety of sports in amateur competition [79–91]. In patients with Grade 1–2 isthmic spondylolisthesis, surgical treatment generally involves an L5–S1 fusion with interbody grafting, with or without decompression. An anterior lumbar interbody fusion with percutaneous backup theoretically preserves lumbar paraspinal muscle integrity and provides a stronger foundation for rehabilitation and return to competition, though this has not been compared directly to traditional posterior approaches. While RTP after lumbar interbody fusion procedures is less well studied, they have been described for athletes returning to elite levels of competition, including Olympic equestrian [92].

RTP criteria following lumbar fusion are less well defined than in the cervical spine, owing in part to their relatively lower frequency. While RTP to elite competition in noncollision sports is documented, return to sports with greater axial loads remains a case-by-case determination. Literature surveys cite only 27–36% of surgeons permitting return to collision sports at 1 year post lumbar fusion, with half forbidding return to collision sports for low-grade spondylolisthesis, and 60% disallowing return for high-grade slips [93]. Among the four professional North American leagues, RTP after lumbar fusion has been described to date in only eight NHL players [74].

Conclusion

Return to play after spinal injuries remains a highly individualized discussion between the athlete and treatment team, taking into account sport-specific loads, pretreatment performance levels, and anticipated realistic career prospects and goals. RTP after cervical injuries, treated nonoperatively or with single-level procedures, is feasible with a high degree of safety given appropriate clinical and radiographic clearance. RTP after lumbar disc herniation is common and safe. Further study is needed to assess the safety of return to play after lumbar fusion and following emerging techniques, including cervical arthroplasty.

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