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REVIEW

Intervertebral disc herniation in elite athletes

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Abstract
Intervertebral disc herniations are a common cause of neck and back pain in athletes. It is thought to be more prevalent in athletes than in the general population due to the consistent pressure placed on the spine and concurrent microtraumas that are unable to heal. Prevention focuses on neck and trunk stability and flexibility, training on proper technique, and rule changes to minimize catastrophic injuries. The evaluation for athletes includes a full neurologic exam and imaging. The imaging modality of choice is MRI, but CT myelography can be a useful alternative. Standard management includes a six week trial of conservative treatment with hiatus from injurious activity and anti-inflammatory medication. If nonoperative management fails, operative treatment has been shown to lead to excellent clinical outcomes in this patient population. Special consideration to prevention needs to be further analyzed. Furthermore, more robust studies on alternative non-operative and operative treatment modalities for this patient population are also needed.

Keywords Herniations · Elite athletes · Return to play · Intervertebral disc · Lumbar spine · Cervical spine

Introduction

Neck and back pains are some of the most common reasons for missed playing time among high-performing athletes [1, 2]. Aetiologies vary according to age and injury type such as acute versus overuse injuries. Many of the injuries from minor impact are self-limiting and due to muscle strains [2, 3]. However, significant spinal pathology such as disc herniation, degenerative disc disease, and spondylolysis warrant prompt medical evaluation to ensure player safety and to minimize long-term impact on players' career [4].

The mechanisms, timing, and prevalence of neck and back pain are unique to each sport. In the general population, lifetime prevalence of degenerative changes on MRI in asymptomatic patients younger than 40 years old has been reported as 25% in the cervical spine [5] and 35–54% in the lumbar spine [6, 7]. Competitive athletic activity on a repetitive basis may predispose athletes to more risk for degenerative disc disease than in the general population [8]. In athletes, there are wide ranges of reported lifetime prevalence ranging from 33 to 84% [9, 10] in a variety of professional North American athletes and 47–90% in Olympians [11]. Collision sports such as American football players in the National Football League (NFL) and rugby may increase the risk of disc herniations; however, noncontact sports may be more protective against herniations by improved dynamic muscular support for the spine that decreases injurious forces on the discs [12]. The most common levels injured in the lumbar spine are L4–5 and L5–S1 which account for more than 90% of symptomatic lumbar disc herniations (LDH) [13]. Unique to the collision athlete with cervical disc herniations (CDH), C3–4 and C5–6 are the most commonly injured levels (23% each) followed by C4–5 (21%) [14]. The purpose of this review was to examine the current literature on CDH and LDH in professional athletes. Thoracic disc herniations have a low incidence rate and minimal amount of published data and thus, will not be discussed during this review.

Mechanism of injury

Symptomatic disc herniations develop from the rupture of the intervertebral disc and the gel-like nucleus pulposus extravagating through the injured annulus fibrosis and compressing a

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spinal nerve [2, 15, 16]. This degeneration occurs due to the relative avascularity of the discs, receiving its nutrients primarily through diffusion after adolescence. With age and abuse, the gel-like nucleus pulposus dehydrates, increasing the compressive force on the annulus. These forces cause micro-radial tears that lead to delamination and eventually result in rupture. After herniation, the nucleus pulposus can irritate or compress the adjacent nerve producing the radicular symptoms associated with disc herniations. Acute injury mechanisms of flexion and compression or rotational motion can cause the annulus to rupture [17, 18]. Overuse injuries are thought to occur from repeated microtrauma to the annulus that is unable to heal before it erodes. In a biomechanical study on porcine spines by Marshall and McGill, axial torque/twist motion plus repetitive flexion and extension led to radial delamination within the annulus [19]. Notably, repetitive flexion alone led to posterior nucleus tracking through the annulus while axial torque/twist alone was unable to initiate disc herniation. Therefore, the authors inferred that axial torque/twisting motion can exacerbate pre-existing disc damage.

Type of sport and position play key roles in understanding the mechanism of injury. Categorizing competitive athletics as "contact vs noncontact" may not be specific enough to the implications of return to play (Table 1). Rotational sports, such as baseball and golf, require greater trunk axial torque/twisting motion which may have different considerations with recovery. Fleisig et al. quantified the trunk axial rotation in baseball pitchers and batters, two positions that have high levels of symptomatic LDH [20]. They found that the average maximum trunk axial rotation for both was around 50° (pitchers, 55 ± 6°; batters, 46 ± 9°). Since Major League Baseball (MLB) is a long season consisting of 162 games over 6 months, repetitive lumbar axial rotation may be one explanation for disc injury.

Collision sports including American football, rugby, and wrestling require repetitive high-impact contact. In football, linemen may be at highest risk to herniate a lumbar disc, likely from the combined effects of their body weight, weight training regimen, and repeated forcible lower spine hyperextension during blocking [14, 21]. Weistroffer and Hsu evaluated 66 NFL linemen treated for LDH and reported that six of seven recurrent LDH occurred in offensive linemen [22]. This position may have higher risk for LDH recurrence because of the typical position at the line of scrimmage that causes greater hyperextension on the lumbar spine, placing enormous force on the posterior annulus (Fig. 1). Additionally, the upright blocking position on passing plays by the offensive lineman is meant to absorb the defensive lineman drive on the quarterback and can cause hyperextension and rotation on the lumbar spine.

Table 1 Type of sport breakdown with examples under each category

Noncontact	Contact	Collision	Rotational
Running	Basketball	American football	Baseball
Track	Soccer	Hockey	Golf
Cycling	Handball	Rugby	Tennis
Volleyball	Martial arts		Field
Crew			Water polo
Fencing			Equestrian
Swimming			
Skiing			

Collision sports are more likely to place large axial loads on the athlete's spine, which is the proposed mechanism of injury for CDH [18, 23, 24]. Athletic activities that are most associated with CDH are tackling and blocking as seen in these collision sports [14, 25]. Positions that increase these types of activities such as defensive backs and linemen in American football or front row forwards in rugby are associated with higher incidence of CDH. Interestingly, collision athletes may be more at risk for upper-level CDH, specifically at C3–C4. Although rare in the general population, Mai et al. found a high rate of C3–C4 herniations (35%) in the NFL [26]. Nevertheless, the upper-level CDH injuries had similar return to play (RTP) rates, recovery times, career lengths, and performance scores after injury compared to lower-level injuries. In a case series of 25 traumatic C3–C4 injuries in young athletes, Torg et al. noted that C3–C4 injuries respond differently to axial loading compared to other cervical spine segments [27]. Four football players ranging from high school to professional level players suffered C3–C4 acute posterior intervertebral disk herniation, all due to axial loading. Three of the four experienced transient quadriplegia. All were treated surgically with successful single-level fusion and complete neurologic recovery.

Prevention

There is still no set standard for prevention of intervertebral disc herniation. Recognizing dangerous activity and implementing rule changes are important in minimizing traumatic spine injuries such as cervical quadriplegia (i.e., spear tackling) [24]. Advising athletes on proper technique and wearing protective equipment also helps to prevent injury.

Due to the mechanisms that often lead to disc herniation, stability and flexibility are two core components of prevention and rehabilitation. Often targeted as the main form of initial rehabilitation exercises, truncal stability and flexibility training prevent hyperextension and relieve some pressure on the posterior annulus. Neck stability and flexibility minimizes the forced axial loading when the player's neck is in hyperextension or hyperflexion.

Evaluation

Evaluation for symptomatic neck and back pain is the same for athletes as in the general population including full assessment of range of motion and neurologic exam [17, 28–30].

Fig. 1 Typical ready positions of offensive (**a**) and defensive (**b**) linemen. Offensive linemen prepare in a squatting position, causing more hyperextension of the lumbar spine, whereas defensive players typically prepare in a crouched 3-point stance [22]. Permission obtained from *American Journal of Sports Medicine*

Symptom presentation is variable by patient and typically includes a combination of extremity pain, generalized neck or back pain, numbness, and weakness. Severe neurological compression, such as the conus medullaris and cauda equina syndromes typically manifest with saddle anesthesia, autonomic instability, and loss of reflexes and strength. More specific signs for LDH include extremity pain in a myotomal distribution, sensory disturbances in a dermatomal pattern, reduced reflexes, and pain that increases with Valsalva maneuver [15]. Provocative tests, such as the ipsilateral straight leg test, are highly sensitive, but less specific for LDH [1, 28]. In contrast, the contralateral straight leg test is more specific. For cervical radiculopathy, Spurling's test is specific (93%), but not sensitive (30%) [31].

When evaluating elite athletes, there are several additional factors to consider compared to the general population such as type of sport, position, and timing of injury. As we mentioned above, the type of sport and position highlight the athletes more prone to disc herniations. However, timing of injury should be noted as well. The timing of the injury can be categorized as acute, chronic, trauma-related to athletic activity, or at rest. If players have pain without playing, there are different considerations.

Sideline physicians need to prepare for worst case scenarios of acute spinal cord injury leading to on-field evaluation and management [23, 32, 33]. Proper preparation prior to the game includes requisition of appropriate tools for cervical trauma (i.e., backboard, cervical collar, tools for removing athletic equipment, and advanced airway management), rehearsed protocols, and a relationship with a hospital with an available spine surgeon. Once spinal cord injury is suspected, on-field evaluation begins with the standard "ABCDE" trauma protocol, which involves immediate cervical spine stabilization in the neutral position (unless moving the head/neck increases symptoms) and placement of a cervical collar. To maintain an airway, jaw thrust is preferred to prevent airway obstruction prior to facemask removal and prevent additional injury. Facemasks should be removed, but helmets and other protective equipment should not be removed unless necessary. Traction should never be applied to the athlete's head. If a player is found in the prone position, the team should transition the athlete to supine for proper evaluation using the "prone log roll technique" [34]. To transfer an athlete to a backboard, use the preferred "lift and slide technique" [34]. Appropriate transportation to the hospital can occur via ambulance or helicopter and should be based on clinical and logistical factors that optimize care.

Imaging

As with the general population, in athletes with clinically diagnosed disc herniations, non-contrast MRI is the imaging modality of choice (Fig. 2) [35]. It provides the best resolution of the nerve roots and surrounding soft tissues with sensitivity and specificity as high as 97% and 96%, respectively [15]. However, caution should be applied to its interpretation since around 27% of patients have asymptomatic disc bulges and herniations [6, 36], which may be higher in the competitive athlete population. Radiography is not always necessary, but is recommended for disc herniations to evaluate for other underlying conditions. If MRI is contraindicated, CT myelography is an adequate alternative to assess the surrounding neural structures. For patients with cervical injury, there is a lower threshold for imaging compared to the lumbar spine given the presence of adjacent central neurovascular structures [37, 38]. Additionally, acute injury has an even lower threshold for imaging to evaluate for spinal cord injury, stenosis, and fractures [23].

Management

To return to play, each athlete should be evaluated on a case-by-case basis and consider the type of sport, player position, imaging characteristics, clinical symptoms, and physical examination. The combination of these measures will allow the

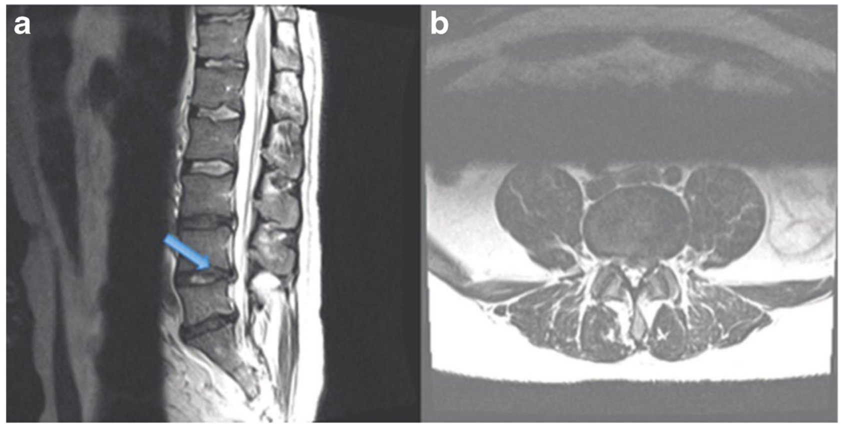

Fig. 2 Sagittal (**a**) and axial (**b**) T2-weighted MRI images for LDH (arrow) in a 33-year-old elite athlete [67]. Permission obtained from *Contemporary Spine Surgery*

team physician to recommend a decision that is best for that particular athlete.

Non-operative

In the general population, > 90% of patients with LDH will recover within 6 weeks [39]. Hsu et al. demonstrated in the Professional Athlete Spine Initiative study of 342 professional basketball, American football, baseball, and hockey players that RTP rates were 82% after LDH with comparable rates between the operative and non-operative groups [39]. The initial trial of conservative therapy should include cessation of exacerbating activity, anti-inflammatory medications, muscle relaxants, and time. In particular, maintaining normal activity levels and minimizing bedrest are important for athletes to minimize muscular atrophy. These measures offer symptomatic relief while the injury heals.

Anti-inflammatory medications reduce the production of inflammatory cytokines and help relieve pain. While oral corticosteroids are commonly prescribed for acute symptoms, a recent randomized control trial demonstrated that there was a modest improvement in function, but no effect on pain [40]. In this study, the steroid group was more likely to have an adverse event compared to the placebo. In contrast, epidural steroid injections have been shown to be beneficial for athletes with LDH and can be used to reduce local inflammation and pain, allowing the player to return to play sooner than with conventional conservative treatment [41]. However, the evidence-based literature also suggests that these types of injections do not change the natural history of a LDH [41, 42]. Intralaminar epidural injections have not yet been studied in CDH for athletes, but there are promising results in the general population [43]. Strong analgesics should generally be avoided to prevent masking of pain allowing over-vigorous activity [44]. Short-term narcotics are useful in decreasing pain, but should be prescribed judiciously to patients who struggle through rehabilitation to minimize addiction and abuse. Psychological support should be provided due to the increased risk of depression, anxiety, and illicit substance abuse [45]. Counseling should establish the favorable prognosis of CDH and LDH, reaffirm the rehabilitation process, and set a realistic expectation for recovery. Regardless of treatment modality, athletes with CDH typically have a longer recovery period as compared to LDH [14, 21, 46].

Typically, physical therapy is included for the rehabilitation of disc herniations [47]. Most LDH rehabilitation regimens focus on core and back strengthening and flexibility [48]. As the athlete progresses, axial rotation and flexion are incorporated to minimize intradiscal pressure. Gradually, the athlete returns to sport-specific manoeuvres to regain full range of motion and build power. The Spine Patient Outcomes Research Trial (SPORT) demonstrated improvement in both non-operative therapy and open discectomy with 44% receiving active physical therapy and 67% having completed physical therapy prior to trial enrollment [49]. Additionally, other studies have shown that physical therapy is beneficial for patients but the exact methodology is still under debate [50]. A phased rehabilitation protocol that aligns with the healing process of LDH has been described [51]. There is little literature on CDH rehabilitation in athletes, but similarly focuses on the concepts of neck strengthening, flexibility, and gradual return to sport-specific manoeuvres [52].

Operative

Surgical management is often considered after failure of non-operative management and can be indicated for prolonged pain and/or muscle weakness. While surgical treatment for this condition is primarily discectomy, there are reports of professional athletes who have successfully returned after both cervical and lumbar fusion [26, 27, 38, 53, 54]. Treating physicians should understand that fusion of a spinal segment can lead to stiffness, adjacent disc disease, and altered spine mechanics [4, 36, 55]. Although these changes potentially alter the players' performance, physicians and athletes should consider the recovery time, estimated ability to return to high-level competition, career longevity, and quality of life after retirement.

Cervical

In professional athletes, CDH is usually studied in collision sports due to the risk of associated severe spinal cord injury. In a systematic review of 80 reported surgeries for CDH in athletes by Joaquim et al., most of these players were able to RTP, with some studies demonstrating that patients undergoing surgery had a higher rate and longer career than their conservatively managed peers [38]. The vast majority of the procedures were single-level anterior cervical discectomy and fusion (ACDF) (85–95%), followed by posterior foraminotomy (PF) (3–13%) and cervical arthroplasty (1–2%) [38, 54]. The authors suggested that the anterior approach was preferred to avoid muscular and ligamentous injuries associated with posterior surgical approach. Recently, Mai et al. showed that for a single-level CDH, ACDF was associated with better long-term outcomes but lower RTP rates [54]. Posterior foraminotomy was associated with a greater RTP rate and shortest time to return after surgery but with an increased association of re-operation. Regardless, there was no significant difference in performance score after surgery for all cohorts, except baseball, which had a decrease in performance score after surgery. Additionally, a meta-analysis by McAnany et al. provided a pooled RTP rate of 73.5% for ACDF [56]. In rugby, ACDF demonstrated a RTP rate of 68.4% [25]. Evaluating CDH in the NFL, Hsu found a procedure distribution similar to Joaquim et al. (ACDF 60.4%, PF 5.7%, unknown 34%) and RTP rate (72%) in the operative group [4]. Furthermore, the operative patients compared to the non-operative group had a higher RTP rate (72% vs. 46%) and longer mean career length of (2.8 years vs. 1.5 years). Notably, there was no significant difference in performance scores or percentage of games started before or after treatment [4]. At the time, survey data showed that up to 50% of spine surgeons would not have cleared a player with ACDF to return to contact sports. Single- and 2-level fusions are cleared for RTP. However, more than 2-level fusions, myelopathy, and significant muscle weakness and/or pain should be considered absolute contraindications due to the risk for permanent neurologic damage or worsened injury.

Cervical stenosis also increases risk for severe, irreversible spinal cord injury in collision sports. Stenosis in the cervical spine increases the frequency of transient neuropraxia and can be present due to congenital formation, degenerative changes, or "functional" stenosis which refers to a lack of cerebrospinal fluid around the cord (Fig. 3) [8]. Any athlete with transient neuropraxia should be screened for cervical stenosis with an MRI. When cervical stenosis is found incidentally in an athlete, there is little evidence for RTP recommendations. Expert opinion suggests that congenital stenosis should not necessarily prevent an asymptomatic athlete from RTP to a contact sport [23, 37, 38]. Symptomatic patients found to have cervical stenosis should always be informed of the risks associated with RTP.

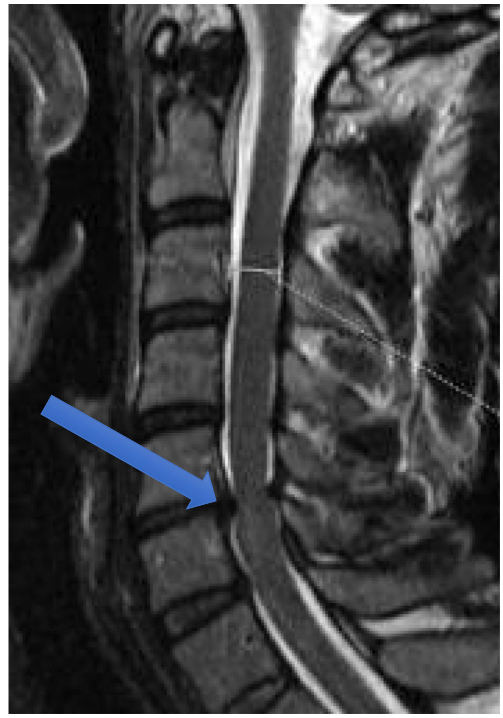

Fig. 3 Sagittal T2-weighted MRI depicting cervical stenosis

Lumbar

Laminotomy with discectomy is the surgical treatment of choice for LDH and is highly effective [15, 57–59]. In a systematic review, Nair et al. showed that after discectomy, 75–100% of athletes successfully RTP at an average of 2.8–8.7 months after surgery [60]. Player performance statistics ranged from 64 to 104% of baseline pre-operative statistics. A review by Iwamoto et al. showed that the treatment effect from microdiscectomy (RTP 85%) and conservative therapy (RTP 79%) was comparable, but percutaneous discectomy (RTP 70%) was lower [61, 62]. In data published from the Professional Athlete Spine Initiative, Hsu et al. noted 81% RTP rate for all athletes treated with lumbar discectomy with no difference between RTP rates between the non-operative and operative groups with average post-operative career length of 3.4 years [39]. Variables such as younger age and more game experience predicted longer career length. In the NFL, offensive skill position players (quarterbacks, tight ends, running backs, wide receivers) had an RTP rate of 74% and played at productive levels post-operatively [63]. Lumbar discectomy is effective even for positions at higher risk of LDH and recurrence. Weistroffer et al. found NFL linemen treated operatively had a higher RTP rate than the non-operative group (80.8% vs. 63.5%) [22]. In addition, 13.5% of the surgical cohort required revision decompression with 85.7% of these players successfully RTP.

Multiple studies have shown that the RTP rates are similar between operative and non-operative groups in other sports such as basketball [64], hockey [53], baseball [46, 65], and Olympic events [66]. However, outcomes after surgery differ by sport. Each of these sports has unique physical demands and stress on the lumbar spine. In the National Basketball Association (NBA), Minhas et al. described a high RTP rate of 78% and 79% for non-operatively and operatively treated players, respectively [64]. Basketball players had an initial decrease in performance statistics during the first season post-operatively, but these changes leveled in seasons 2 and 3 with no difference in post-operative career length [64]. Taller players and those who played center were more likely than not to RTP after LDH.

In hockey, skating may require smaller axial loads on the lumbar spine. Schroeder et al. had an RTP rate of 90% and 82% for non-operatively and operatively treated groups, respectively [53]. There was significant decrease in games played, points scored, and performance score, but no difference in performance measures between surgical and nonsurgical groups. They also showed that in a small cohort of patients treated with lumbar fusion in the NHL, 100% (8/8) RTP for an average of 203 games over a four year period has no significant difference in performance score or games played. Although the small sample size makes it difficult to make conclusions, this treatment group demonstrates that fusion does not preclude from RTP in contact sports. Further studies need to evaluate lumbar fusion rates and outcomes beyond the NHL.

In baseball, Earhart et al. and Roberts et al. showed a high RTP rate of 97–100% for both non-operatively and operatively treated players after LDH [46, 65]. However, when stratified by position, infielders treated operatively for LDH compared to non-operatively had a significantly longer mean time to RTP (11.4 months vs. 1.5 months, $p = 0.006$) [65]. In contrast, there was no difference between the timing to RTP for pitchers or outfielders treated operatively or non-operatively [65]. Both pitchers and batters showed decreased performance one year post-operatively with maintenance of differences at three years. Specifically, pitchers decreased the number of innings pitched per inning but there was no change to earned run average. These injuries are likely from the repeated high-torque hitting and pitching motions over a long six month season [20]. Unfortunately, when compared to the nonoperative group, MLB players who underwent lumbar discectomy had shorter careers (5.3 years vs. 4.1 years) [39].

Conclusion

Disc herniations in both the cervical and lumbar spine are common injuries that cause substantial missed playing time. These spine injuries are due to intense and repeated stresses of competing at an elite level. After evaluation, the management of the injury in athletes is multifaceted and should incorporate the player's respective age, sport, position, and time of injury in regard to the season. RTP rates for the major North American sports are comparable between non-operative and operative management. However, there is a lack of high-quality evidence for the optimal treatment and prevention strategies for these individuals to mitigate risk.

Statement of authorship All of the following authors contributed significantly to the development of this manuscript through data analysis, manuscript preparation, or analysis and editing of the final manuscript.

Compliance with ethical standards

Conflict of interest Author JTY has no conflicts of interest. Author WKH has received research grant from Wright Medical and IP royalties from Stryker; advisory board for the *Journal of Bone and Joint Surgery*; consulted for Stryker, Medtronic, Mirus, Allosource, Biovenus, Micromedicine, and Agnovos.

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