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The Athlete's Spine—Lumbar Herniated Nucleus Pulposus

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Lumbar herniated nucleus pulposus is common among athletes given the physical stresses placed upon the lumbar spine with various athletic activities. Although the natural course is generally favorable with conservative management, the reproducible success of lumbar discectomy provides itself as an alternative treatment option for the athlete. Both conservative and operative management are associated with quick recovery and return to play. This chapter reviews the natural history of lumbar herniated nucleus pulposus, various treatment modalities, and the athlete-specific metrics pertinent to the management of athletes.
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Lumbar herniated nucleus pulposus (HNP) is a common condition in the general population[1,2] and among athletes.[3-12] The incidence of lumbar HNP is estimated at 10 million people per year in the United States alone.[13] The typical manifestation includes low back pain (LBP) with lower extremity radicular symptoms, extending from the gluteal musculature and radiates distally down the leg in a dermatomal distribution. The severity of the radicular symptoms may vary from paresthesia and pain to sensory loss and motor weakness. Athletes carry a greater potential for developing a lumbar HNP by virtue of the musculoskeletal stresses placed upon the lumbar spine from various athletic activities.

The decision-making process related to the treatment of lumbar HNP among athletes can become quite intricate and challenging. Although the goal of any surgeon is to produce the best outcomes for the patient, one must consider the effect of each stakeholder. There are numerous parties involved that directly or indirectly influence the successful recovery of the athlete. As such, it is imperative for the surgeon to maintain focus on the athlete and limit any external conflicts of interest. Furthermore, understanding the unique nuances of the mechanics involved in an athlete's performance is paramount to providing the best treatment.

This article provides a comprehensive review of the pathophysiology, classification, and clinical evaluation of lumbar HNP. In addition, the conservative and operative management along with the clinical outcomes particularly among athletes is elucidated.

Anatomy and Pathophysiology

The intervertebral disc has 2 components, the annulus fibrosus that encircles the nucleus pulposus. The annulus is primarily composed of obliquely oriented type I collagen and is a fibrous ring that inserts onto the articular surfaces of the vertebral bodies. Because it is a multilayered structure composed of lamellae that are adhered together, the annulus helps contain the nucleus and enhances strength and flexibility to the disc. The nucleus is primarily composed of type II collagen, is rich in proteoglycan, and is gelatinous in nature. Compression across the disc space increases the pressure in the nucleus, resulting in flattening and the generation of tensile hoop stress. The circumferential fibers of the annulus are thus placed under tension. An HNP occurs when the annulus is disrupted and no longer functions to contain the nucleus. Because the posterior longitudinal ligament that runs along the posterior aspect of the vertebral bodies is concentrated at the midline and extends

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Table 1 Spine Pathology in Athletes

Reference	Finding
Hangai et al[4]	MRI findings of disc degeneration in university-level athletes competing in baseball and swimming
Maurer et al[41]	Overall, 40.9% of high-performance adolescent rowers demonstrated at least 1 abnormality in the lumbar spine on MRI compared with 9.1% in the control group
Walsh et al[9]	Weight lifting involving squats with 60% and 80% of maximum lift demonstrated significant increase in lumbar extension on motion analysis, predisposing to injury via increased pressure on the posterior annulus
Kaneoka et al[7]	Overall, 68% of elite swimmers demonstrated significantly higher MRI evidence of degenerative discs compared with 29% in recreational swimmers
Goldstein et al[42]	Spine abnormalities were increased based on level of competition in female gymnasts as follows: 9% in preelite gymnasts, 43% in elite, and 63% in Olympic-level competitors
Sward et al[5]	Overall, 75% prevalence of degenerative disc disease in elite gymnasts
Bartolozzi et al[8]	Overall, 44.4% incidence of disc pathology in volleyball players
Ong et al[6]	Total prevalence of disc displacement at one or more levels was 58% on MRI of Olympic athletes presenting with low back pain
Abla et al[35]	Amateur golfers experienced higher torque at L3-4 motion segments averaging 85.2 Nm compared with 56.8 Nm in professional golfers
Kraft et al[43]	Overall, 58% of elite horseback riders had statistically significant low back pain but no MRI evidence to suggest advanced spine pathology
Capel et al[44]	Competitive dancers did not demonstrate statistically significant MRI evidence of advanced spine pathology compared with matched control group

laterally and inferiorly, there is an inherent predisposition for a posterolateral herniation.

Table 1 demonstrates the findings of several published studies regarding the effect of various sports on spine pathology. Certain sports inherently predispose athletes to lumbar spine pathology, whereas others are less harmful.

Clinical Evaluation

Athletes are typically better conditioned than the general population, which imparts a certain degree of protection from common back pain. However, they are more prone to sport-specific injuries from constant and high-demand stresses on the lumbar spine.[4,7] There are several risk factors for lumbar injury in athletes.[3,14-16] A previous lumbar injury carries 3 times the risk for recurrent injury compared with those without any previous complaint.[11] The lack of lumbar flexibility among athletes has also been commonly cited as a predictor of lumbar injury.

The anatomical level of disc herniation determines the symptomatology. The most common levels involved include L4-5 and L5-S1, which together account for up to 90% of symptomatic disc herniations. Patients with lumbar HNP typically present with LBP and radicular symptoms that worsen with flexion or Valsalva maneuver and improve in the supine position. A thorough history and physical examination is critical to assess the extent and severity of any spinal pathology. In particular, the sensory and motor function should be carefully evaluated. The straight-leg raise is one of the most sensitive provocative tests to evaluate an HNP. It is classically performed with the patient in the supine position. The heel of the leg is slowly elevated with the knee in extension while the hip is flexed. Reproduction of pain between 35° and 70° of elevation is considered a positive test. If the patient's presenting symptoms are reproduced by raising the contralateral or unaffected leg, it is highly suggestive of a lumbar HNP.[17]

Although plain film radiographs are not capable of demonstrating herniated discs, they can demonstrate degenerative changes, vertebral stability, and disc height. Magnetic resonance imaging (MRI) is the imaging modality of choice for the accurate assessment of the disc anatomy, pathology, and the surrounding ligamentous structures.

Classifications

In the sagittal plane, the spinal canal is divided into zones from medial to lateral including the central canal zone, subarticular zone, foraminal zone, and the extraforaminal zone. Herniations in the foraminal or extraforaminal zones typically involve the exiting nerve roots, whereas those in the central canal typically affect the traversing nerve roots (Figs. 1 and 2).

There are numerous published HNP classification systems but all are based upon the morphology and location of the herniation. Protrusions occur when there is an intact annulus with a bulge. Extrusion occurs when the nucleus violates the annular fibers but remains continuous. Sequestration occurs when the nucleus is no longer continuous and a fragment separates[18] (Fig. 3).

Natural History

Lumbar HNP typically resolves gradually with conservative management.[1,19,20] Saal and Saal[21] reported that 90% of patients with a documented lumbar HNP demonstrated favorable outcomes with conservative management. The period of time for symptom resolution is dependent upon several variables including the location and size of the lesion

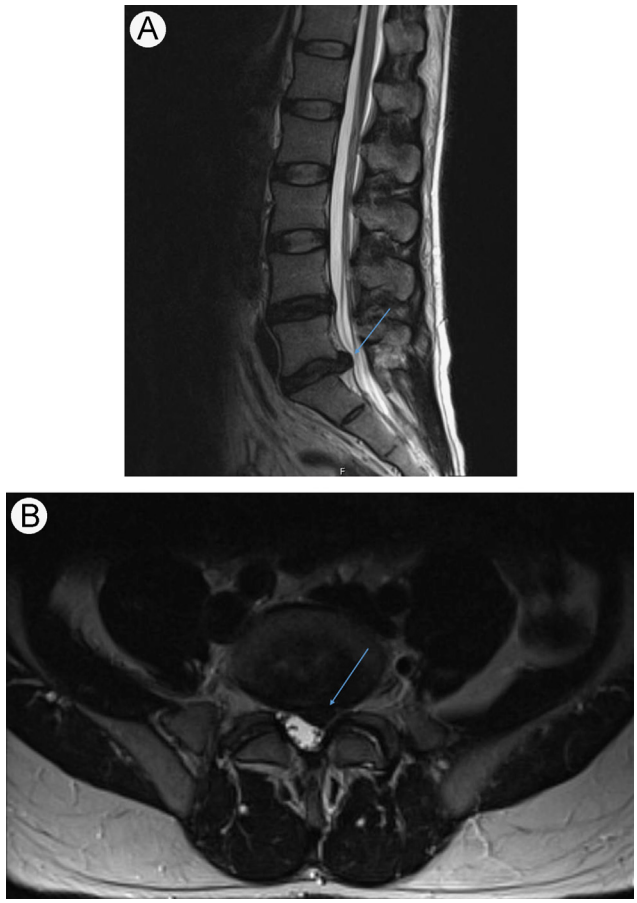

Figure 1 Classic left posterolateral herniation at L5-S1 demonstrated with (A) sagittal and (B) axial T2-weighted MRI.

along with patient compliance with conservative intervention. Weber et al. performed a randomized series of 126 patients with sciatica associated with lumbar HNP with a 10-year follow-up. In the nonsurgical cohort, 25% were symptom free and 36% demonstrated satisfactory improvement after 10 years.[20] Even patients with disc extrusion demonstrated radiographic improvement with conservative therapy.[22] The reduction in size of the extrusion and symptoms are typically greater the with larger disc herniations.

Despite the favorable prognosis associated with continued conservative management, one must consider the implications associated with "time-off" with regard to athletes. Prolonged conservative management and time away from the sport can lead to professionally deleterious consequences for the athlete. As such, surgical intervention is likely appropriate earlier with athletes when compared with the typical patient population.

Treatment

Athletes often require altered treatment regiments from traditional protocols. Hsu et al[23] emphasized the importance of understanding the particular culture of each sport and its effect on the recovery of a lumbar HNP. Equally important for the athlete is the nature of his or her contract, which may affect the decision for surgical intervention. For example, many contracts can be terminated when players are released from the team. Furthermore, the duration of each season and the number of games or matches carry paramount importance in the decision-making process. The time of year when the athlete develops an HNP is critical as well, and treatment decisions may vary accordingly.

Given the substantial amount of money invested in each player, diagnostic testing is routinely performed very early in athletes when compared with the general population. It is not uncommon for an athlete complaining of LBP to obtain an MRI within hours of symptom onset to rule out any significant pathology. This is especially true in full contact sports, such as football, where potential instability or significant HNP warrants immediate intervention.

Nonsurgical Treatment

Nonoperative treatment includes a very brief period of rest, physical therapy, education, and pharmacologic agents. Typically, the first step involves rest with oral anti-inflammatory medication. Periods of rest should be limited to 1 week followed by gradual mobilization.[19] If the patient experiences significant acute symptoms, an oral steroid taper may be warranted. Once symptoms begin to resolve, physical therapy is initiated. Physical therapy should be focused on core strengthening and improving flexibility. Another critical component to physical therapy involves education regarding proper posture and body position. When treating athletes, physical therapy and intensive rehabilitation programs are often substantially different from those performed on nonathletes. Athletes have access to advanced training facilities, routine utilization of multiple rehabilitation modalities, nutritional therapy, and sport-specific rehabilitation with athletic trainers and fitness coaches. Furthermore, athletes are typically in better physical condition at the time of injury, and therefore, strength and flexibility can be more focused and initiated at a higher baseline than nonathletes.

Pharmacologic intervention is also considered first line in the conservative management of lumbar HNP. Nonsteroidal anti-inflammatory medications alleviate the inflammatory component of the patient's symptoms. Other adjuvants include muscle relaxants and antispasmodic agents, which have less evidence and may not alleviate the symptoms. Lastly, for failed conservative management, epidural steroid injections (ESIs) may be considered as a final alternative before surgery.

Iwamoto et al[24] studied the short-term outcomes of 71 athletes presenting with symptomatic lumbar HNP treated conservatively. Overall, 78.9% of athletes returned to their original sporting activity level at an average of 4.7 months after the initiation of treatment. Subjective improvement in LBP, leg symptoms, and neurologic deficit were 63%, 78.4% and 69.6%, respectively.

Krych et al[10] retrospectively reviewed records of all National Football League (NFL) players treated with ESIs for pain secondary to lumbar HNP. Seventeen players had 37 injections for 27 distinct lumbar HNP episodes from 2003-2010. The

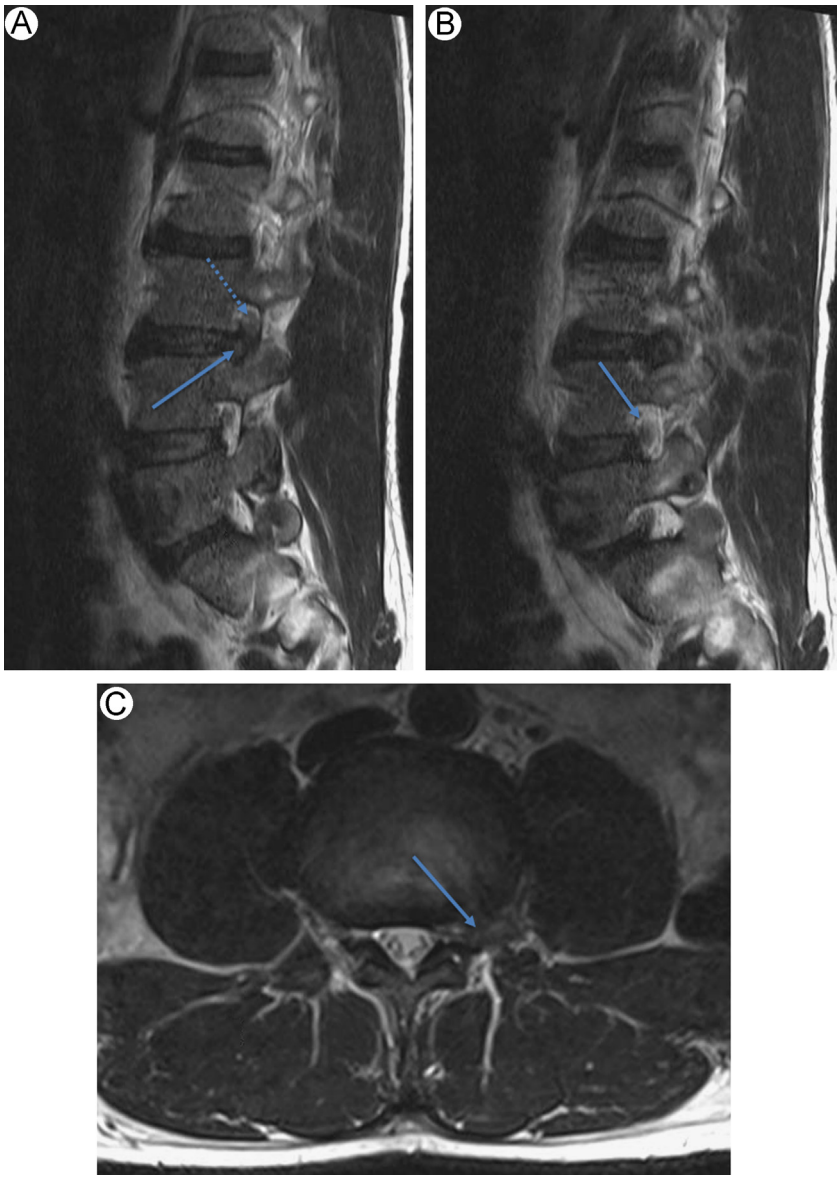

Figure 2 Left far lateral herniation at L3-4 on sagittal and axial T2-weighted MRI. (A) The left parasagittal image demonstrates the herniated disc (solid arrow) compressing the exiting L3 nerve (dashed arrow). (B) A more lateral left parasagittal images shows the L4 nerve root (arrow) in the L4-5 foramen completely free, whereas the L3-4 disc herniation is obliterating the foraminal space. (C) On this axial cut, the blue arrow demonstrates the left lateral herniation.

average time from injury to injection was 4 days. Overall, 89% returned to the field with an average loss of 2.8 practices and 0.6 games. After successful return, 13 athletes averaged 2.8 seasons in the NFL and 10 were actively playing at conclusion of the study. Three athletes ultimately required surgical intervention. The authors demonstrated that the risk factors for the failure of ESIs include the sequestration of disc herniation and weakness on physical examination.

In a prospective randomized trial, Buttermann[25] compared outcomes in 169 patients treated with ESIs or a surgical discectomy. Of the 50 patients in the ESI cohort, 42%-56% reported favorable outcomes whereas 31% demonstrated treatment failure. In a follow-up MRI study of the nonoperative cohort, Buttermann[26] did not demonstrate a significant regression of the disc herniation, but patients still reported progressive symptom improvement. It should be noted, however, that 92%-98% demonstrated significant improvement with surgical intervention.[25]

Surgical Treatment

Athlete or not, absolute indications for surgical intervention for lumbar HNP include progressive neurologic deficit or intolerable pain and cauda equine syndrome. For the athlete, a relative indication includes a prolonged inability to perform despite a course of conservative management.

Several surgical approaches can be utilized to treat lumbar HNP. The standard approach involves an open discectomy with a partial or complete laminotomy, which can be

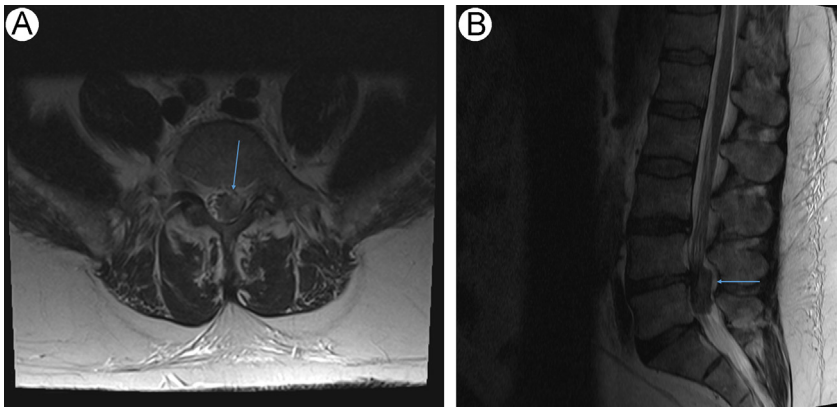

Figure 3 These sagittal and axial T2-weighted MR images illustrate a large sequestered fragment that ultimately caused cauda equina syndrome in the patient. (A) Axial image showing large free fragment (arrow) at L5. (B) Sagittal image demonstrating the same large free fragment (arrow) found posterior in the spinal canal.

performed with or without a microscope. Carragee et al[27] conducted a prospective study of 152 working patients with lumbar HNP who were treated with a limited open discectomy and no activity restrictions. Overall, 98% returned to the same occupation within 1.2 weeks, without an increased rate of complications. In another prospective analysis of 507 patients with sciatica secondary to lumbar HNP, Atlas et al[28] followed up with 85% of patients treated surgically and 82% of patients treated nonsurgically for 10 years. Overall, 69% of the surgical cohort reported symptom improvement compared with 61% managed conservatively. Of those treated surgically, 56% also reported that low back and leg symptoms improved significantly or completely resolved, compared with only 40% of nonsurgical patients. Weinstein et al[29] reported the Spine Patient Outcomes Research Trial results, which was conducted at 13 different sites and included 1244 participants with lumbar intervertebral disc herniation. Four years after surgery, the operative cohort reported greater overall improvement in all primary outcomes compared with those managed conservatively.

Minimally invasive spine surgery has gained a considerable momentum in recent years. The incorporation of microscopic discectomy as a surgical treatment option has been advocated to enhance visualization and minimize the size of the incision. Percutaneous techniques are also utilized as a less-invasive alternative. Sakou et al[30] and Matsunaga et al[31] demonstrated that athletes generally returned to sport 2 months after percutaneous discectomy. Regardless of the technique, for the athlete, minimizing paraspinal muscle injury may enable faster return to play (RTP), reduced postoperative complications, and quicker return to athletic baseline.

Complications of surgical intervention for HNP include reherniation and wound infection. Reherniation rates range from 0%-18%.[17]

Clinical Outcomes

Clinical outcomes can be assessed by a variety of metrics. Traditionally cessation of pain, improved functionality, and overall patient satisfaction are the ultimate end points for treatment. For the general population, other metrics such as return to work have been extensively reviewed. The goal of treatment for lumbar HNP in the athlete is to restore the preinjury athletic performance level. Achieving these goals is pivotal to the athlete's career and longevity in the sport. Furthermore, timing is paramount for the player, the team, the franchise, and the fans and has significant financial implications, particularly when considering post–regular season games and playoffs. There are several studies that have demonstrated successful RTP after lumbar discectomy (LD).[23,32-40]

Watkins et al[32] studied the average time for RTP for professional athletes undergoing microscopic LD (MLD). This retrospective review involved 171 professional athletes (85 athletes treated with MLD vs 86 athletes treated nonoperatively) with lumbar HNP between 1996 and 2010. Primary outcomes included rate of RTP and the average return time. The MLD cohort demonstrated an 89.3% return to sport rate within an average of 5.8 months. At 3, 6, 9, and 12 months, 50%, 72%, 77%, and 84% returned to play, respectively. This study involved only single-level discectomies and concluded that the disc level was unimportant. The specific sport did not statistically affect the RTP rate or the time.

Wang et al[40] studied 14 elite athletes from the National Collegiate Athletic Association who underwent LD for radiculopathy that was refractory to conservative treatment. The authors demonstrated that 90% of athletes returned to competition after a single-level MLD. All 14 patients reported pain relief and improvement in function. Anakwenze et al[33] attempted to quantify the athletic performance profiles after LD in National Basketball Association (NBA) players vs a control group of matched NBA players who did not undergo LD. The authors demonstrated an RTP rate of 75% for those treated with LD compared with 88% in controls. Iwamoto et al[39] performed a literature review between 1990 and 2009 regarding the outcomes of surgical vs conservative management of lumbar HNP in athletes. Overall, 78.9% of patients treated conservatively returned to play within an average of 4.7 months, whereas 85.1% of athletes treated operatively resumed participation, within an average of 5.2 months.

Savage and Hsu[37] performed a retrospective cohort study to determine whether NFL athletes with a lumbar HNP and subsequent discectomy can return to competitive play with no effects on performance. The primary outcomes included games played, yards gained, and touchdowns scored. Ultimately, 74% of players returned to play. The average length of career postoperation was 36 games over 4.1 years, with no significant change in performance. The average NFL career for all positions is 3.5 seasons. There was no difference in power ratio before and after the LD. There was also no difference in the percent of games started before and after surgery. Subanalysis of quarterbacks demonstrated the return for an average of 80 games over 6.1 years, with no difference in the performance rating. The reported recurrence rate was 2 of 23 (8.7%).

When treating professional athletes, one must also consider sport-specific metrics. Anakwenze et al[33] attempted to quantify the athletic performance profiles after LD among NBA players. The authors compared the number of games played, number of minutes/game, points per 40 minutes, rebounds per 40 minutes, assists per 40 minutes, steals per 40 minutes, blocks per 40 minutes, and shooting percentage. There was a declining trend in the number of games played compared with the control group. There was no statistical difference in the outcome measures with the exception of statistically improved rate of rebounds and blocked shots per game in the surgical cohort.

Hsu et al[23] demonstrated that the athlete's professional experience and the number of games played before an HNP was diagnosed were positive predictors of career length and RTP after surgery. Hsu[36] also reported that in the NFL, the positions of quarterback and punter were positive predictors for career length, although this may be high at baseline. Performance scores were stratified by position while excluding linemen. Age negatively affected longevity. Athletes >30 years of age demonstrated a 73% RTP rate in the operative group and 53% rate in nonoperative group, which was not statistically different. However, the older patients played fewer games than the younger patients after surgery.

Abla et al[35] assessed 523 surveys from the North American Spine Society members to determine the recommendations for the time to return to golf after surgery. Scenarios were based upon lumbar laminectomy, MLD, lumbar fusion, and anterior cervical discectomy and fusion (ACDF). Sex and age were not statistically significant but athletes were given less time before RTP than nonathletes. The most common RTP recommendation after L3-5 laminectomy was 4-8 weeks, L4-5 MLD was 4-8 weeks, and L4-5 laminectomy and fusion was 6 months. These findings suggest that, as reported in other studies, athletes respond well to surgical intervention and typically recover to preinjury performance with timely RTP.

Conclusion

Athletes who present with lumbar HNP present a unique treatment challenge. Firstly, the surgeon must have a clear understanding of the athlete's goals for treatment and their athletic needs. Although the natural history is favorable with conservative management, the reproducible success of LD may provide more timely and improved clinical outcomes including faster improvement of symptoms, RTP, and preinjury performance levels. The availability of resources for postoperative rehabilitation, including state-of-the-art facilities, physical therapy, and athletic training, provides an optimal environment for quick recovery. RTP rates vary depending upon the study but range from mid-70% to mid-80%. Although surgery carries a high success rate, there are always risks that should be discussed including the fact that surgical management does not guarantee RTP at the same level of performance.

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