Understanding Spinal Cord Injuries in Sports and Factors Affecting Recovery

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Abstract

Spinal cord injuries in sports are significant and often result from forces that exceed the ability of the spine to absorb impact. The cervical and lumbar regions are particularly vulnerable due to their mobility and exposure to high forces. This paper reviews the anatomy of the spinal cord and mechanisms of common spinal cord injuries associated with sports. It also investigates the treatment and methods for early diagnosis, including imaging, which is critical for improving recovery outcomes. Prevention strategies, including proper care, equipment, and technique are explored to reduce the risk of spinal injuries. Recovery from spinal cord injuries depends not only on the severity of the injury but also on the psychological and social factors, such as mental health and motivation. Understanding the complex interactions between the mechanisms of injury, spinal anatomy, and factors mediating recovery may facilitate injury prevention and improve treatment options for athletes at risk of a spinal cord injury.

Introduction

Spinal injuries are some of the most serious injuries occurring due to physical activity and sports [1]. The spine provides structure to the body and protects the spinal cord, which serves as the primary route of communication between the brain and the rest of the body. Athletes can experience high-impact forces, repetitive loading, and rapid movements that increase the risk of a spinal injury, particularly in contact sports such as football, rugby, and soccer, as well as in activities involving heavy lifting, diving, and collisions [2]. About 10%-15% of all athletes experience lower back pain [3]. Understanding how these injuries occur is crucial for the prevention, recognition, and effective management of spinal injuries.

The design of the spinal cord and vertebral column directly influences the risk and impact of spinal injuries. Although the vertebrae protect the spinal cord, intervertebral discs and nerve points are vulnerable to compression and trauma. The cervical and lumbar regions of the vertebrae are particularly vulnerable due to their greater mobility, exposure to high-impact forces, and frequent loading compared to the more structurally stable thoracic and sacral regions. Since different spinal regions connect to specific nerves in the body, the level of injury determines the functional outcomes in different parts of the body.

This paper examines sport-related spinal injuries through the lenses of anatomy and physiology, injury mechanisms, pathophysiology, and factors impacting recovery. It also highlights the importance of prevention, early assessment, imaging, and holistic recovery strategies.

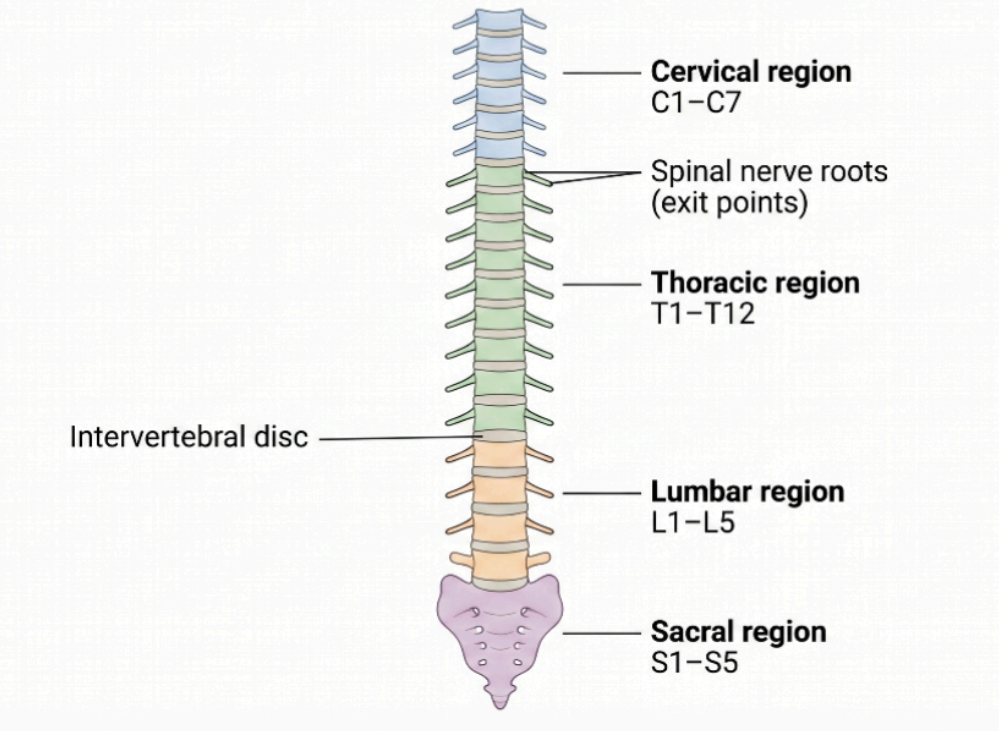
Anatomy and Physiology of the Spine

The anatomy and physiology of the spinal cord demonstrate how specific injuries can occur during physical activity. The vertebral column protects the spinal cord, which is part of the central nervous system. The spinal cord is a cylindrical structure that extends from the brain

caudally through the vertebral column [4]. The vertebrae protect the spinal cord while allowing flexibility. Between each pair of vertebrae are intervertebral discs and openings through which spinal nerves exit. As a result, forces that relate to the body moving beyond its limit (e.g., axial load, hyperflexion or hyperextension, and collisions) can pinch or compress these nerves, potentially damaging the spinal cord [3].

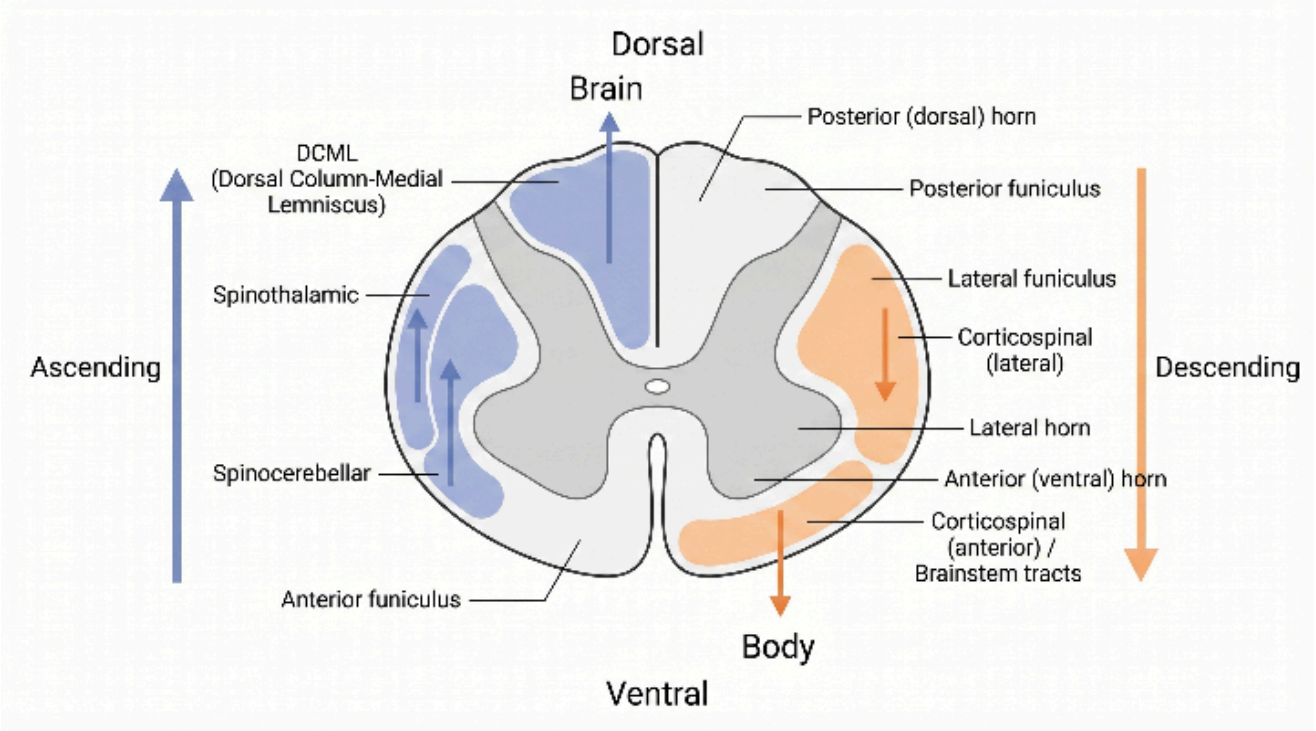
The vertebral column consists of four regions: cervical, thoracic, lumbar, and sacral (see **Figure 1**). The cervical region (C1-C8) is the most cranial portion of the cord, innervating the neck, diaphragm, arms, and hands. C5-C6 are the roots, which are often strained or compressed in neck injuries, causing numbness or weakness. The thoracic region (T1-T12) innervates the chest and abdominal muscles. These segments are relatively stable due to the ribcage, making spinal injuries less common, but they are still possible in the thoracic region. The lumbar region (L1-L5) occupies the lower back, hips, thighs, and parts of the lower legs. This region is prone to injury from heavy lifting and axial loading, which can lead to compression, a slipped disc, or lower back pain. The sacral region (S1-S5) forms the lowest segment of the cord and controls the pelvic organs and lower limbs. Injuries in this area can affect the bladder and the lower limb [5].

Figure 1. Anatomy of the vertebral column and the four regions showing intervertebral discs and spinal nerve points. This figure illustrates the anatomy of the vertebral column, highlighting the cervical, thoracic, lumbar, and sacral regions along with their corresponding spinal nerve roots. Created with BioRender.com



The spinal cord serves as the main pathway for communication between the brain and the rest of the body, transmitting sensory signals from the body to the brain and motor signals from the brain to the body [4]. The spinal cord has distinct functional regions that control different fibers; the cross-section of a spinal cord helps better understand those regions and their effects (see **Figure 2**). When viewed in a cross-section, it shows a central area of gray matter surrounded by white matter [6]. The gray matter consists of three horns. The posterior (dorsal) horn receives sensory information entering the spinal cord. If damaged, it can cause a loss of sensation, as a disc compression can affect sensory tracts first. The anterior (ventral) horn contains motor neurons that send signals from the cord to the muscles for movement. Damage can result in loss of motor function, such as an impact to the anterior spinal cord, which can cause paralysis below the injury level. The lateral horn contains sympathetic neurons that help control automatic body functions. The white matter outside of the gray matter divides into three columns. The posterior column carries sensory information, the anterior column mainly carries the motor signals, and the lateral column carries both sensory and motor signals. Injuries often affect multiple tracts, leading to a combination of motor and sensory loss [6].

Figure 2. Cross-section of the spinal cord illustrating gray and white matter and functional horns. This cross-sectional diagram of the spinal cord demonstrates the distribution of gray and white matter, including the anterior, posterior, and lateral horns. It also identifies major ascending and descending tracts to emphasize how signals travel between the brain and the body. Created with BioRender.com



When examining spinal injuries, it is also essential to consider the musculoskeletal system, which includes the muscles, bones, joints, and connective tissues such as tendons and ligaments that surround and support these structures. Together, these components form the body's framework [7]. Spinal injuries can lead to severe functional loss if not stabilized quickly. Lower back pain is common among athletes due to stress on the vertebrae, discs, and surrounding nerves, especially in sports that involve heavy weightlifting, contact collisions, or repetitive motion.

Because the spinal cord connects the brain to nearly every body system, spinal injuries can affect the bladder, bowel, respiratory, and autonomic functions [6]. Research shows that about 10%–15% of athletes experience lower back pain, and approximately 9% of all back injuries are related to sports participation [3]. Generally, the most common acute non-urgent injuries involve muscular strains and ligament sprains, while urgent injuries tend to include fractures, dislocations, and tendon ruptures.

Pathophysiology of Spinal Injuries

Sports-related spinal injuries occur when external forces exceed the ability of the spine to absorb or distribute the load, leading to tissue damage at both the structural and cellular levels [4]. Without prompt recovery, the injury worsens, leading to damage to the vertebrae, intervertebral discs, spinal cord, or nerves. The most common injuries result from axial load, hyperflexion or hyperextension, rotation, or other shear forces [2]. Due to the force applied, axial loading occurs along the spine's vertical axis, such as during head collars, heavy weightlifting, or falls. This force is dangerous as it compresses the vertebrae and discs, causing them to collapse or bulge and irritates the cord or nerves. During tackles, collisions, or whiplash, intense forces push the spine past its normal limits, resulting in hyperflexion and hyperextension injuries. These forces can stretch or tear ligaments and damage discs. Chronic lumbar spine injuries and lower back pain are associated with repetitive flexion and extension in sports like soccer and weight training [3]. Rotation and shear forces occur when there is a twisting motion with high impact or load, which is common in sports that require agility and contact with other players. These forces increase stress on the discs and joints, leading to stress fractures, spondylolysis, and nerve pain. Certain regions of the spinal cord are more vulnerable to sports injuries due to their location, mobility, and exposure to forces.

The cervical and lumbar regions are the most commonly injured areas because of their mobility and susceptibility to force, making them vulnerable during high-impact sports like football [2]. The injuries occurring in this region can have many consequences, such as nerve irritation or severe outcomes like paralysis if the spinal cord has experienced significant damage. Cervical injuries can also affect respiratory function because of the nerves involved. Thoracic injuries are less frequent in sports because the rib cage provides protection, making the region more stable. If injuries do occur, they can result in instability, loss of sensation, or paralysis. The lumbar spinal cord (L1-L5) is frequently affected in sports due to heavy lifting, repetitive loading, and contact. While injuries in the lumbar region usually cause lower back pain, numbness, or weakness that can impact athletic performance or activities of daily living due to nerve compression, they do not cause complete paralysis, and the sacral region (S1-S5)

controls bowel, bladder, and other lower limb functions [4]. Injuries in this region can lead to significant complications such as loss of bladder control or sensory changes.

The outcome of spinal injuries depends on whether the damage is complete or incomplete, the level of the spinal cord that is affected, and how quickly the injury is recognized and treated. Incomplete injuries can undergo partial recovery, which may include the gradual return of some movement strength, improved sensations below the level of injury, or regained control over the bowel and bladder, whereas complete injuries often result in permanent motor and sensory deficits [4]. These injuries have two phases: the primary stage, caused by mechanical force, triggers the second stage, which leads to inflammation, swelling, and cell disorganization [8]. Beginning recovery as soon as possible is a must for sport-related spinal injuries, as spending more time without recovery can worsen the injury.

Treatment and Recovery

Recovery after a spinal injury is different for each person and depends on multiple physical, psychological, and social factors [9]. Prevention is essential for reducing spinal injuries and improving recovery, and it requires proper care, appropriate equipment, and correct technique [10]. Proper care would consist of sufficient physical preparation before the desired activity, such as stretching, warm-up exercises, and pre-game calisthenics, which help prepare muscles, joints, and the spine for loading and movement. Insufficient preparation, poor conditioning, and repetitive movements can place excessive stress on the vertebrae, discs, and surrounding tissues, increasing the risk of injury. Proper on-field treatment and management are necessary to prevent worsening of an injury suspected during physical activity. Healthcare professionals must follow appropriate protocols at the event to ensure quick, safe care. Assessment should initially start with a quick survey to evaluate airway, breathing, circulation, disability, and exposure [4]. Earlier recognition and treatment of injury lead to better outcomes and faster recovery for the person, with fewer complications. Limiting spinal movement during assessment and transport reduces the risk of further injury. CT scans and MRIs are commonly required to assess spinal cord and vertebral damage once in the hospital, and also take upright anteroposterior and lateral X-rays of the back [4]. The severity of the injury can be classified using the American Spinal Injury Association (ASIA) Impairment Scale (see **Figure 3**), which helps guide treatment decisions. ASIA Grade A refers to a complete injury. The treatment process includes preventing complications and maintaining joint and organ function, while incomplete injury (ASIA B-D) allows progressive rehabilitation tailored to preserve motor and sensory functions [4].

A medical professional who plays a significant role in recovery is the physical therapist. After initial stabilization and imaging, physical therapists help restore mobility, strength, and muscular control while protecting the injury. Using specific rehabilitation programs, they address muscle imbalances, core stability, posture, and movement [1]. Qualified healthcare professionals, safe transfer, immobilization, and surgery, when required, are crucial for preventing secondary injury and supporting maximum recovery.

Figure 3. The American Spinal Injury Association (ASIA) impairment scale. This figure presents the ASIA Impairment Scale used to classify injury severity. It is a grading system that

ranges from complete loss of motor and sensory function to normal function, helping professionals determine the level of impairment and plan treatments. Reproduced from Ahsan, Md. K., Joshi, S. R., Khan, Md. S. I., Awwal, M. A., Mahmud, A. A., & Haque, Md. H. 2021 [11].

ASIA grading	Characteristics
A	Absent motor and sensory function
B	Sensory function present, motor function absent
C	Sensory function present, motor function present but not useful (MRC grade < 3/5)
D	Sensory function present, motor function useful (MRC grading > 3/5)
E	Normal function

In addition, sleep, nutrition, communication, and patient-centered care are vital components after a spinal injury. Adequate sleep is essential for tissue repair, immune function, and nervous system recovery. Poor sleep negatively affects healing, performance, and rehabilitation outcomes. Athletes and injured individuals often require more sleep than usual to support growth and regeneration [12]. In contrast, sleep deprivation combined with high stress levels can increase fatigue and delay the recovery process. Proper nutrition is equally important—sufficient energy intake supports muscle repair and overall recovery. If compromised, it can slow the healing process, increase injury risk, and reduce the effectiveness of treatment.

As in team sports such as soccer, where all team members need to cooperate during a match, all components of effective communication should be present and used [1]. Better motivation regulation may support better recovery, which in turn supports participation and performance [13]. Effective communication between healthcare providers, physical therapists, and patients is essential for a successful recovery [1]. This communication helps build trust and ensures that patients feel heard and supported throughout the recovery. Patient-centered care, which values the patient's perspective, goals, and preferences and addresses not only physical impairments but also psychological well-being, sleep habits, nutrition, and social support, makes recovery way more sustainable.

Social and psychological factors play a significant role in recovery from a spinal injury. A close and multifaceted relationship exists between mental health and physical performance. Good mental health leads to better recovery and vice versa [14]. Mental health has a critical role in the recovery process. Linking to both physical outcomes and the quality of life [10]. Individuals with spinal cord injuries often experience increased psychological distress, such as anxiety, depression, fear, and reduced life satisfaction, usually in the early stages after being injured [9]. These factors can influence how patients perceive pain, engage in rehabilitation, and adhere to treatment plans. While many individuals can adapt over time, recovery timelines vary depending on a person's mental strength, coping skills, and available support [9].

Psychological factors can act as either protective factors or risk factors for recovery. Protective aspects include strong motivation, self-efficacy, positive coping skills, social support, and effective communication with healthcare providers [15]. These factors are associated with more participation in rehabilitation, consistency in attending therapy, and better overall outcomes. In contrast, poor mental health can lead to worsening the injury, low motivation to recover, stress, and lack of support, which can delay recovery, reduce performance, and lead to poorer rehabilitation. Psychological barriers such as fear and lack of confidence have impacted recovery outcomes as strongly or even more than physical disability [1].

Conclusion

Spinal injuries in sports stem from specific interactions between anatomy, mechanics, and external forces. Of the four regions in the vertebral column, the cervical and lumbar areas are more vulnerable due to their mobility and exposure to axial loading, flexion, extension, and rotational forces. The severity of an injury depends on how complete the spinal cord involvement is and can range from temporary pain to permanent impairment.

Early recognition and management are essential for better outcomes and preventing the injury from progressing to a secondary stage. Stabilizing the individual, quickly imaging, and classifying the injury help reduce further damage. Physical rehabilitation is a vital part of recovery, but sleep, nutrition, communication, and psychological well-being are also crucial for a healthy and full recovery. Effective communication between healthcare providers, such as physicians and physical therapists, ensures coordinated care and supports optimal recovery outcomes.

Future research on spinal injuries should continue to focus on prevention strategies, optimized training, and recovery protocols that include physical and mental health interventions. There still isn't enough research dedicated to improving and addressing spinal injuries compared to other sports injuries. Current approaches to spinal injury management remain heavily focused on physical stabilization, often overlooking the measurable impact of psychological and social factors on recovery. A comprehensive, patient-centered approach remains necessary to enhance recovery and long-term quality of life after sport-related spinal injuries.

References

1. Piussi, R., Ivarsson, A., Johnson, U., & Senorski, E. H. (2024). Psychological factors in sports injury rehabilitation: How can a sports rehabilitation practitioner facilitate communication? *JOSPT Open*., 2(1), 1–3. https://doi.org/10.2519/josptopen.2023.0007

2. Boden, B. P., & Jarvis, C. G. (2008). Spinal injuries in sports. *Neurologic Clinics*, 26(1), 63–78; viii. https://doi.org/10.1016/j.ncl.2007.12.005

3. Ball, J. R., Harris, C. B., Lee, J., & Vives, M. J. (2019). Lumbar Spine Injuries in Sports: Review of the Literature and Current Treatment Recommendations. *Sports Medicine - Open*, 5(1). https://doi.org/10.1186/s40798-019-0199-7

4. Margetis, K., Prabhu Emmady, & Das, J. (2025, June 2). Spinal Cord Injuries. *StatPearls*. https://www.statpearls.com/point-of-care/29326#Introduction

5. Nógrádi, A., & Vrbová, G. (2006). Anatomy and Physiology of the Spinal Cord. *Transplantation of Neural Tissue into the Spinal Cord*, 1–23. https://doi.org/10.1007/0-387-32633-2_1

6. Branco, F., Cardenas, D. D., & Svircev, J. N. (2007). Spinal cord injury: a comprehensive review. *Physical Medicine and Rehabilitation Clinics of North America*, 18(4), 651–679, v. https://doi.org/10.1016/j.pmr.2007.07.010

7. Vilella, R., & Anil. (2023, September 4). Musculoskeletal Examination. *StatPearls*. https://www.statpearls.com/point-of-care/31518

8. Anjum, A., Yazid, M. D., Fauzi Daud, M., Idris, J., Ng, A. M. H., Selvi Naicker, et al. (2020). Spinal Cord Injury: Pathophysiology, Multimolecular Interactions, and Underlying Recovery Mechanisms. *International Journal of Molecular Sciences*, 21(20), 7533. https://doi.org/10.3390/ijms21207533

9. Post, M. W. M., & van Leeuwen, C. M. C. (2012). Psychosocial issues in spinal cord injury: a review. *Spinal Cord*, 50(5), 382–389. https://doi.org/10.1038/sc.2011.182

10. Exercise Selection and Common Injuries in Fitness Centers: A Systematic Integrative Review and Practical Recommendations. (2022). *ProQuest*, 19(19), 12710. https://doi.org/10.3390/ijerph191912710

11. Ahsan, Md. K., Joshi, S. R., Khan, Md. S. I., Awwal, M. A., Mahmud, A. A., & Haque, Md. H. (2021, June 8). *Surgical Management of Primary Non-Hodgkin's Lymphoma of Spine - Clinical Surgery Journal* (ISSN 2767-0023). Clinical Surgery Journal. https://clinicalsurgeryjournal.com/article/1000093/surgical-management-of-primary-non-hodgkin-s-lymphoma-of-spine

12. Mason, L. R., Connolly, J., Devenney, L. E., K. Suzanne Lacey, O'Donovan, J., & Doherty, R. (2023). Sleep, Nutrition, and Injury Risk in Adolescent Athletes: A Narrative Review. *Nutrients*, 15(24), 5101–5101. https://doi.org/10.3390/nu15245101

13. Vista do Motivation and recovery in sports: *systematic review*. (n.d.). https://www.periodicos.rc.biblioteca.unesp.br/index.php/motriz/article/view/18433/13014

14. Fossati, C., Torre, G., Vasta, S., Giombini, A., Quaranta, F., Papalia, R., & Pigozzi, F. (2021). Physical Exercise and Mental Health: The Routes of a Reciprocal Relation. *International Journal of Environmental Research and Public Health*, 18(23), 12364.

15. Khomkham, P., & Kaewmanee, P. (2024). Patient motivation: A concept analysis. *Belitung Nursing Journal*, 10(5), 490–497. https://doi.org/10.33546/bnj.3529