Surfer's myelopathy: A review of etiology, pathogenesis, evaluation, and management

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Abstract

Context: Surfer's myelopathy (SM) is an acute syndrome identified by nontraumatic paraparesis or paraplegia. Though traditionally tied to first-time surfers, the condition encompasses any activity involving hyperextension of the back such as gymnastics, yoga, and Pilates.

Methods: MEDLINE® and Google Scholar literature searches were gathered to identify relevant case reports for determining the etiology, pathogenesis, evaluation, and management of SM.

Results: While the rare nature of SM limits its full understanding, studies have pinpointed that hyperextension in the back leads to vasculature insufficiency secondary to dynamic compression of the artery of Adamkiewicz. In surfing, this hyperextension combined with the execution of the Valsalva maneuver while trying to stand up on the surfboard likely increases intraspinal pressure. Due to its nontraumatic origin, the presence of SM is not immediately clear. Moreover, its similarity in clinical and radiological presentations with other entities can further complicate diagnosis. Seemingly, idiopathic urological symptoms can be explained by the physician if they conduct a thorough history.

Conclusion: In an effort to raise awareness for the practicing physician, we presently review the etiology, diagnosis, treatment, and prolonged effects of SM. With the surging popularity of surfing as well as the advent of children participating in precarious sports and activities at an earlier age, we can expect a rising incidence of traumatic and nontraumatic spinal cord injuries. Neurologists, urologists, emergency medicine and sports medicine physicians alike can utilize this review to build a high index of suspicion for SM. The risk factors for SM should be conveyed to those participating in novices in surfing, yoga, gymnastics, ballet, and any activity enabling sustained or repeated spinal extension. Increased general awareness will facilitate increased symptom recognition in order to arrest aggravation of injury.

Keywords: Surfer's myelopathy, Nontraumatic spinal cord injury, Nontraumatic paraparesis, Sports injury, Artery of Adamkiewicz, Neurogenic bladder

Introduction

Surfer's myelopathy (SM) is a rare, nontraumatic spinal cord injury associated with hyperextension of the back. SM derives its nomenclature from cases in which young,

novice surfers experience back pain followed by progressive neurological deficits. Thompson et al. were the first to define this rare diagnosis.[1] Over 60 cases have been published to date with etiology and pathogenesis of the condition still under question. It has been estimated that the incidence of SM ranges from a minimum of 2.2 to a maximum of 6.6 injuries per 1000 h of surfing.[2,3] Despite the rarity of this injury, methods of diagnosis and treatment to recover from the neurological deficit have shown promise.

Myelopathy is generally defined as any neurological deficit related to spinal cord dysfunction. While SM cases have often involved first-time surfers, activities such as gymnastics, cheerleading, acrobatics, ballet, yoga, Pilates, or any sports where the back is hyperextended may cause SM. Currently, the youngest reported case of SM was documented in 2015 when a 7-year-old girl presented with back pain, urinary retention, and lower extremity weakness after performing a backbend during cheerleading practice. This case places greater importance in recognizing SM by emergency medicine physicians as more children become involved in competitive sports and experience possible trauma and consequent SM.[4] Golfers are also at risk of myelopathic syndromes such as neck-tongue syndrome and cervical arterial dissections. The injury is rare but may affect a diverse range of athletes in various sports and may occur in non-athletes such as demolition workers.[5,6]

Methods

A literature search using the MEDLINE® and Google Scholar databases was conducted using the term “spinal cord infarction” as well as a combination of the terms “surfer”, “sports”, and “nontraumatic” with “myelopathy.” The search results were restricted to case reports and review articles. There were no language restrictions. We selected papers that revealed artifacts for etiology, pathogenesis, evaluation, and management of SM.

Etiology and pathogenesis

SM is hypothesized to be caused by hyperextension of the spine thus leading to vascular damage and ischemia to the distal spinal cord segment.[1] As novice surfers generate excessive force by maneuvering the surf boards and surrounding waves, tension on both the spinal cord and its vasculature increases. While most studies suggest this acute hyperextension is a predictor of SM, a study by Freedman et al. has posited alternative etiologies.[7] The authors proposed that inferior vena cava compression or embolization within the spinal arteries, both secondary to prolonged hyperextension, are the root causes. This may explain why the lower spinal cord and conus medullaris may be vulnerable to arterial insufficiency.[6] An alternative explanation is that affected patients have a thin body habitus concomitant with weak musculature, dehydration, and long distance travel.[1]

While the exact pathogenic mechanism of SM has yet to be elucidated, hyperextension of the spinal cord causing arterial insufficiency has been the most common explanation. Hyperextension is presumed to cause vascular changes including dynamic compression, vasospasm, and thrombotic infarction of the artery of Adamkiewicz. Unlike cerebral vessels, spinal arteries lie on a mobile structure, which make them prone to mechanical damage by prolonged hyperextension.[8] Interestingly, Robles suggested that stretching of the segmental arteries may cause small tears in the arterial intima that lead to arterial

dissection and consequent spinal cord ischemia.[9] The anterior spinal cord in the lower thoracic region is most susceptible to an ischemic event because collateral vascular supply is inadequate in this region compared to the posterior spinal cord. As the anterior and posterior spinal arteries run along the surface of the thoracic spinal cord, the central cord becomes a watershed region. Notably, a recent case report by Nakamoto et al. demonstrated that in a series of 23 cases of SM, all patients suffered from T2 hyperintensities and spinal cord swelling from the midthoracic spine to the conus medullaris.[8] Flexion-extension of the spinal column due to repetitive mechanical stress also has a role in the pathogenesis of SM.[10] Other suggested mechanisms of aberration are avulsion of perforation vessels and fibrocartilaginous embolization, an acute myelopathy marked by sudden onset of back pain followed by rapid and progressive neurologic deficit.[6]

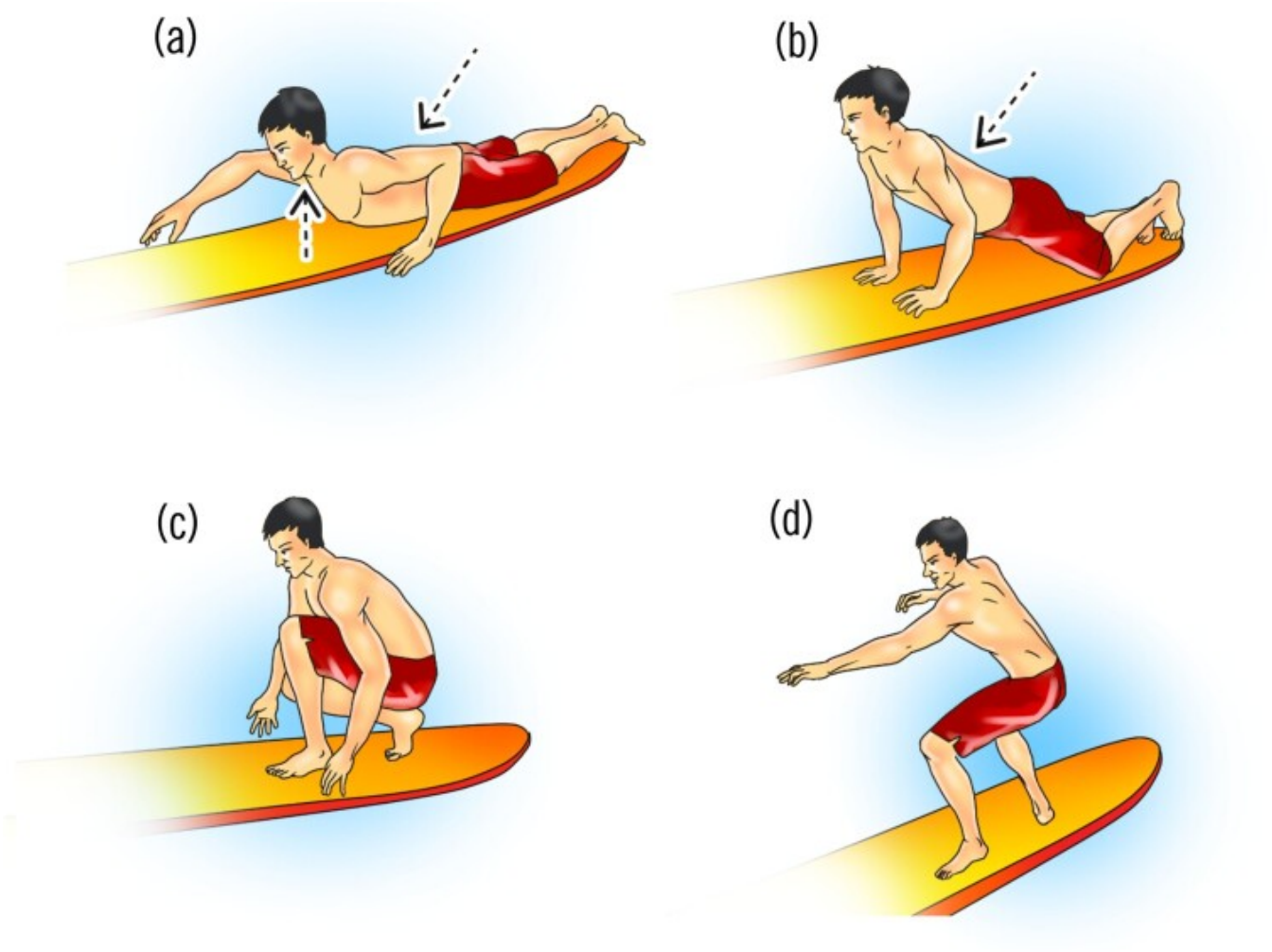
Applied anatomy of myelopathy

Correct prone paddling posture requires an extension of the lumbar and thoracic spine so as to raise the upper chest off the deck of the surfboard and allow for an ergonomic paddling stroke.[11] Cervical and lumbar musculature strains are relatively common, possibly due to sustained isometric contraction of those muscles while paddling.[11] For instance, surfing after prolonged periods of inactivity often leads to burning muscular pain in the trapezius and rhomboid muscles.[11] Similarly, hyperextension of the neck, to compensate for an inadequate lumbar extension during surfing, can exacerbate neck soreness.[11] Fortunately, most neck and back spasms caused by overuse resolve spontaneously, but physical therapy can also improve acute symptoms.[12] A proper warm-up before surfing (especially in cold water) and regular stretching of the low back, hamstrings, and hip flexors may help prevent this common problem.[13]

Actively engaging the core musculature while paddling creates a firm paddling platform, unloading the muscles of the low back. Therefore, land-based exercises aimed at improving core strength among surfers are essential.[11] Prior observation has suggested that while surfers have more powerful shoulder flexion and extension than other athletes, they often have weaker abdominal strength.[14] Unresolved neck pain upon conservative treatment can be explained by cervical disk injury, degenerative arthritis in older surfers, or thoracic outlet syndrome.[11] Symptoms are exacerbated by movements that forcefully extend the lower back such as duck diving under oncoming waves or popping up (moving from a supine to a standing position) on a surfboard. Stress fractures of the pars interarticularis generally heal with conservative therapy but often require 4-6 months of cessation from sports, though some may require spinal fusion later in life.[15]

Figure 1 depicts the typical progression of a surfer's posture as they rise from their boards. First-time surfers are more likely spend time in hyperlordosis compared to experienced surfers; the vulnerability of this posture combined with the time spent in it can greatly predispose them to developing SM from an event such as venous thrombosis. The persistent pressure of the surfboard on the surfer's trunk can impede flow of the inferior vena cava to worsen complications of weakened venous blood flow.[16] Suddenly shifting from a position of pronated hyperextension of the lumbar spine to squatting on the board and the associated Valsava maneuver can contribute to increased pressure and ischemia of the spine.

Figure 1



Position of the body during surfing. (a) prone position with raised head and hyperextension of lumbar part of spinal cord (paddling); (b) and (c) taking a squatting position (pop up/take-off); (d) straightening into position for surfing.

Evaluation

The revelation of telltale signs and symptoms, radiologic studies, and determination of a level of spinal cord dysfunction that can then be characterized by the formulation of an ASIA score are presently the optimal techniques to diagnose SM. Without these diagnostic tools, it is often difficult to ascertain whether cases of SM are atraumatic or traumatic. Specifically, it may not be clear whether a novice surfer hyperextended their spine lying on a board, in the water, jumping on a board, or while paddling. The American Spinal Injury Association (ASIA) developed the ASIA score for measurement of functional impairment from spinal cord injury. Noting such a score on patient admission and rechecking it for clinical improvement is useful to determine

prognosis.[8] Cerebrospinal fluid diagnostics can also be examined; findings may show elevated protein as well as, to a lesser extent, erythrocytes and leukocytes. However, these determinations can often be unremarkable.[5]

SM patients can have a tendency to go into spinal shock and subsequently into urinary retention. They may require a urinary catheter in early stages and develop neurogenic bladder from autonomic neuropathy later on. For such circumstances, urodynamic studies (UDS) are useful to determine the natural history of voiding as well as study the impact on sexual dysfunction as they are shared pathways. Instrumental UDS generates values for several parameters such as detrusor pressure, sphincter activity during filling and voiding phase, leak point pressure, and detrusor-sphincter dyssynergia which cannot be ascertained with clinical analysis.

Signs and symptoms

The most common symptoms of SM include back pain, urinary incontinence or retention, paraplegia or paraparesis, lower limb weakness, and sensory loss. As symptom presentation varies by case, Table 1 denotes frequencies from gathered case reports.

Table 1

Incidences of hallmark symptoms of surfer's myelopathy in the relevant literature.

Symptom	Frequency of finding (n = 14)
Back pain	Eight[4,26–32]
Paraplegia	Six[16–21]
Bladder control/urinary retention	Eleven[4,16,18,26,28–34]

Other signs include hypesthesia, hypoalgesia, and hyperesthesia. Between June 1998 and January 2003, nine cases of SM were reported, with an average patient age of 25, while exhibiting the aforementioned hallmark symptoms.[1] In a reported case series of three patients in 2013 (24–31 years old; two male, one female),[10] clinical manifestations also included bladder-bowel dysfunction with complete paraplegia (T9–12). Table 2 outlines the unique clinical presentation of gathered SM cases, a majority of which are due to surfing. Due to the likelihood of other conditions simulating SM, a proper differential diagnosis should be made while considering acute myelitis to broaden the spectrum (Table 3).[6]

Table 2

Clinical manifestations of published surfer's myelopathy cases to date.

Patient description	Cause of injury	Clinical manifestations
7-year-old female[4]	Cheerleading	• Back pain • Urinary retention

Patient description	Cause of injury	Clinical manifestations
8-year-old female[21]	First time surfing	• Lower extremity weakness • Back pain • Paraplegia • Urinary retention
13-year-old male[18]	Another child jumped on patient's back while patient was on knees	• Paraplegia • Urinary retention
15-year-old female[22]	First time surfing	• Weakness in both legs • Progression to paraparesis • Bladder and rectal disturbance
16-year-old female[18]	Gymnastics	• Back pain • Urinary retention; decreased rectal tone • Weakness/numbness distal to umbilicus • Paraplegia
16-year-old female[23]	Gymnastics	• Progressively worsening midthoracic back pain • Evolving paraplegia • Hypesthesia of lower extremities • Urinary retention • Diminished rectal tone
19-year-old male[24]	First time surfing	• Lower back pain • Profound bilateral lower limb paraparesis • Abnormally high serum creatine kinase
19-year-old male[25]	First time surfing	• Lower back pain • Lower extremity weakness • Progression to paraplegia with sensory loss below umbilical region • Urinary retention
23-year-old female[19]	First time surfing	• Acute and rapidly progressive bilateral lower extremity paraplegia, paresthesia,

Patient description	Cause of injury	Clinical manifestations
24-year-old female[17]	First time surfing	and anesthesia • Lower back discomfort • Bowel and bladder dysfunction • Anterior spinal cord infarction • Paraplegia
25-year-old male[26]	First time surfing	• Lower back pain • Lower extremity weakness • Sensory changes • Urinary retention
29-year-old male[27]	First time surfing	• Lower extremity weakness • Sensory changes • Urinary retention
32-year-old male[28]	First time surfing	• Lower extremity weakness • Loss of bowel and bladder control
34-year-old male[20]	First time surfing	• Back pain radiating to lower limbs • Progression to complete paraplegia and total sensory loss in both legs • Absence of rectal tone; bladder distended
37-year-old male[16]	First time surfing	• Paraplegia • Neurogenic bladder with hypocontractile detrusor and no flow • Rectally, absent sensation and voluntary contraction with decreased sphincter tone • Absent bulbocavernosus reflex
55-year-old male[29]	Swimming	• Bilateral upper limb paresthesia followed by weakness and paralysis • Progression to complete paralysis of all limbs • Bowel and bladder dysfunction

Table 3

Differential diagnosis of surfer's myelopathy or acute myelopathy.

Cause	Example
Vascular lesions	Acute spinal cord infarct,[19] arteriovenous malformations, cavernomas
Longitudinal extensive transverse myelitis[19]	
Infectious myelitis[20]	Viral/postviral (e.g. enterovirus, HIV, HTLV-1, EBV, CMV, VZV, ADEM), bacterial, fungal, parasitic
Spinal stenosis	
Disc herniation	
Spondylolisthesis	
Fibrocartilaginous embolism	
Vasculitic or multisystem disease	Systemic lupus erythematosus, Behçet's disease, Sjögren's syndrome, granulomatosis with polyangiitis, sarcoidosis
Demyelinating disease	Multiple sclerosis, neuromyelitis optica
Paraneoplastic syndrome	
Electrical injury	
Toxic or metabolic condition	Heroin, epidural injection

Imaging

Magnetic resonance imaging (MRI) is an effective method of identifying early ischemic change through T2-weighted and diffusion-weighted imaging (DWI) imaging. DWI, in particular, renders early diagnosis more accurate.[30] Regardless of etiology, MRI reveals evidence of cytotoxic edema stemming from spinal cord infarction.[6] A 26-year-old male who became paraplegic after surfing presented with fusiform swelling of the spinal cord from T7–8 to the conus.[12] Fusiform enlargement was also observed in the case of a 37-year-old male following a 2-hour surfing lesson.[16] The combination of MRI and DWI aids in the recognition of ischemic lesion compatible with anterior spinal cord syndrome.[22] DWI can depict bright signal intensity consistent with acute spinal cord infarction. The use of MRI and DWI is highly sensitive in detecting acute cellular injury due to changes in water diffusion that is secondary to ischemia.[31] The use of gadolinium contrast has not found to be useful in ascertaining a SM diagnosis, but is helpful in ruling out differential diagnoses.[6] Though it is not a widely-adopted imaging modality for

diagnosing SM, spinal angiography may be useful for identifying vascular pathology and concurrent ischemic insult as a function of vessel patency.[7]

Management

An important element of SM treatment is first to follow preventative measures. Surfers, especially novices, should be well informed that SM is a serious risk. Surfers should be instructed about body positions and maneuvering techniques to prevent prolonged hyperextension. Those who plan to fly long distance are recommended to rest, rehydrate, and stretch before engaging in the activity.[17] Furthermore, the use of safety equipment designed specifically for surfers should be considered. While leg ropes are useful for maintaining close proximity to the surfboard, novice surfers should consider wearing protective headwear or using boards with built-in nose guards.[32] The Surfer's Myelopathy Foundation provides simple guidelines to moderating causative factors.

In an acute SM case, several treatment options have helped to achieve complete or almost-compete recovery following diagnosis. Chronic cases may require physical rehabilitation support and subsequent urinary complication may require urological consultation. Strikingly, several treatment paradigms including methylprednisone dosing, lumbar drainage have not proven to be effective in management of this syndrome.[5] Acute and chronic management options of SM are outlined in Table 4.

Table 4

Acute and chronic management of surfer's myelopathy. As a disclaimer, this list represents elective treatments to consider.

Acute	• Bedrest • Emergent aortic spinal angiography • Superselective catheterization of tissue plasminogen activator or nimodipine to rule out underlying aortic disease • Intravenous tissue plasminogen activator infusion • Heparin and/or antiplatelet therapy • Lumbar drain sample while maintaining cerebrospinal fluid pressure <10–15 mmHg • Elevated mean arterial pressures >85 mmHg for at least 24 h through intravenous fluids, careful use of narcotic pain medications and vasopressors • Methylprednisolone use (24-h dose; 30 mg/kg loading dose; 5.4-mg/kg Hour infusion x23-h) or other steroid therapies
Chronic	• Comprehensive rehabilitation program • Urological consultation/urodynamic study

Prognosis

While SM poses serious neurological symptoms amongst new surfers and other at-risk individuals, appropriate treatment and follow-up therapy have been quintessential to complete or near-complete recovery. However, aggressive cases or complete paraplegia have also been reported.[1] In these unfortunate cases, patients have failed to see significant neurological recovery following treatment plans. As the majority of SM cases involve young individuals with no reports of spinal or vascular pathology, delayed (>24 h) presentation may significantly impact the overall outcomes.[6]

Conclusion

SM is a rare, nontraumatic spinal cord injury that usually affects young, novice surfers. Although most cases have been reported during first-time surfing incidents, sports or hyperextension activities such as gymnastics and yoga may also be a causative factor. Patients with preserved motor function have experienced an effective recovery process while those with a complete deficit have a poor neurological prognosis and recovery. Despite the rarity of this condition, preventative measures should be promoted to reduce the risks of SM and to identify early warning signs. Treatment options in both acute and chronic cases with surgical, drug, or rehabilitation therapy are appropriate options, as well.

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References

1. Thompson TP, Pearce J, Chang G, Madamba J.. Surfer's myelopathy. Spine (Phila Pa 1976). 2004;29(16):E353–6. doi: 10.1097/01.BRS.0000134689.84162.E7 [PubMed] [CrossRef] [Google Scholar]

2. Nathanson A, Bird S, Dao L, Tam-Sing K.. Competitive surfing injuries: a prospective study of surfing-related injuries among contest surfers. Am J Sports Med. 2007;35(1):113–7. doi: 10.1177/0363546506293702 [PubMed] [CrossRef] [Google Scholar]

3. Nathanson A, Haynes P, Galanis D.. Surfing injuries. Am J Emerg Med. 2002;20(3):155–60. doi: 10.1053/ajem.2002.32650 [PubMed] [CrossRef] [Google Scholar]

4. Wadia S, Padmanabhan P, Moeller K, Rominger A.. Pediatric surfer's myelopathy. J Emerg Med. 2015;49(5):e143–5. doi: 10.1016/j.jemermed.2015.06.065 [PubMed] [CrossRef] [Google Scholar]

5. Conidi F. Some unusual sports-related neurologic conditions. Continuum (Minneap Minn). 2014;20(6 Sports Neurology):1645–56. [PubMed] [Google Scholar]

6. Maharaj MM, Phan K, Hariswamy S, Rao PJ.. Surfer's myelopathy: a rare presentation in a non-surfing setting and review of the literature. J Spine Surg. 2016;2(3):222–6. doi: 10.21037/jss.2016.09.07 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

7. Freedman BA, Malone DG, Rasmussen PA, Cage JM, Benzel EC.. Surfer's myelopathy: a rare form of spinal cord infarction in novice surfers: a systematic review. Neurosurgery. 2016;78(5):602–11. doi: 10.1227/NEU.0000000000001089 [PubMed] [CrossRef] [Google Scholar]

8. Nakamoto BK, Siu AM, Hashiba KA, Sinclair BT, Baker BJ, Gerber MS, et al. Surfer's myelopathy: a radiologic study of 23 cases. AJNR Am J Neuroradiol. 2013;34(12):2393–8. doi: 10.3174/ajnr.A3599 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

9. Robles LA. Letter: surfer's myelopathy: a rare form of spinal cord infarction in novice surfers: a systematic review. Neurosurgery. 2017;80(6):E266. doi: 10.1093/neuros/nyx044 [PubMed] [CrossRef] [Google Scholar]

10. Takakura T, Yokoyama O, Sakuma F, Itoh R, Romero RR.. Complete paraplegia resulting from surfer's myelopathy. Am J Phys Med Rehabil. 2013;92(9):833–7. doi: 10.1097/PHM.0b013e3182411f58 [PubMed] [CrossRef] [Google Scholar]

11. Nathanson AT. Surfing injuries. In: Mei-Dan O, Carmont MR, (eds.) Adventure and Extreme Sports Injuries: Epidemiology, Treatment, Rehabilitation and Prevention. London: Springer; 2013. p. 143–72. [Google Scholar]

12. Aoki M, Moriizumi S, Toki M, Murakami T, Ishiai S.. Rehabilitation and long-term course of nontraumatic myelopathy associated with surfing. Am J Phys Med Rehabil. 2013;92(9):828–32. doi: 10.1097/PHM.0b013e318238a1d0 [PubMed] [CrossRef] [Google Scholar]

13. Sunshine S. Surfing injuries. Curr Sports Med Rep. 2003;2(3):136–41. doi: 10.1249/00149619-200306000-00005 [PubMed] [CrossRef] [Google Scholar]

14. Renneker M. Surfing: the sport and the life-style. Phys Sportsmed. 1987;15(10):156–62. doi: 10.1080/00913847.1987.11702109 [CrossRef] [Google Scholar]

15. Moeller JL, Rifat SF.. Spondylolysis in active adolescents: expediting return to play. Phys Sportsmed. 2001;29(12):27–32. doi: 10.3810/psm.2001.12.1074 [PubMed] [CrossRef] [Google Scholar]

16. Aviles-Hernandez I, Garcia-Zozaya I, DeVillasante JM.. Nontraumatic myelopathy associated with surfing. J Spinal Cord Med. 2007;30(3):288–93. doi: 10.1080/10790268.2007.11753939 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

17. Chung HY, Sun SF, Wang JL, Lai PH, Hwang CW.. Non-traumatic anterior spinal cord infarction in a novice surfer: a case report. J Neurol Sci. 2011;302(1–2):118–20. doi: 10.1016/j.jns.2010.11.026 [PubMed] [CrossRef] [Google Scholar]

18. Albuja AC, Qaiser S, Lightner DD, Raslau FD, Zafar MS, Bernard PA, et al.. Surfer's myelopathy without surfing: a report of two pediatric patients. Spinal Cord Ser Cases. 2017;3:17008. doi: 10.1038/scsandc.2017.8 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

19. Teixeira S, Moser F, Kotton RH.. Imaging features and differentials in surfer's myelopathy: a case report. Emerg Radiol. 2016;23(1):89–92. doi: 10.1007/s10140-015-1346-1 [PubMed] [CrossRef] [Google Scholar]

20. Choi J, Seok HY, Kim Y, Kim BJ.. Surfer's myelopathy mimicking infectious myelitis. J Clin Neurol. 2017;13(2):207–8. doi: 10.3988/jcn.2017.13.2.207 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

21. Scatchard R, Alves Rosa J, Bowen P, Mortimer A, Sharples PM, Lux AL.. A case report: paediatric surfer's myelopathy. Eur J Paediatr Neurol. 2018;22(1):199–202. doi: 10.1016/j.ejpn.2017.09.011 [PubMed] [CrossRef] [Google Scholar]

22. Sugiyama N, Yokoyama JI, Ikegami M, Matsuda S, Miyashita Y.. A child case of surfer's myelopathy. No To Hattatsu. 2016;48(1):41–4. [PubMed] [Google Scholar]

23. Dillen WL, Hendricks BK, Mannas JP, Wheeler GR.. Surfer's myelopathy: a rare presentation in a teenage gymnast and review of the literature. J Clin Neurosci. 2018;50:157–60. doi: 10.1016/j.jocn.2018.01.039 [PubMed] [CrossRef] [Google Scholar]

24. Fessa CK, Lee BS.. An Australian case of surfer's myelopathy. Clin J Sport Med. 2012;22(3):281–3. doi: 10.1097/JSM.0b013e31824a5523 [PubMed] [CrossRef] [Google Scholar]

25. Lin CY, Fu JH, Li SC, Lai PH.. Surfer's myelopathy. QJM. 2012;105(4):373–4. doi: 10.1093/qjmed/hcr014 [PubMed] [CrossRef] [Google Scholar]

26. Karabegovic A, Strachan-Jackman S, Carr D.. Surfer's myelopathy: case report and review. CJEM. 2011;13(5):357–60. doi: 10.2310/8000.2011.110349 [PubMed] [CrossRef] [Google Scholar]

27. Dhaliwal PP, Cenic A, Eesa M, du Plessis S.. An unusual case of myelopathy: surfer's myelopathy. Can J Neurol Sci. 2011;38(2):354–6. doi: 10.1017/S0317167100011616 [PubMed] [CrossRef] [Google Scholar]

28. Bakhsheshian J, Chang KE, Strickland BA, Donoho DA, Christian EA.. Teaching neuroimages: acute neurologic deficits due to surfer's myelopathy. Neurology. 2016;87(17):e206–e7. doi: 10.1212/WNL.0000000000003261 [PubMed] [CrossRef] [Google Scholar]

29. Green E, Zishan US, Robertson N, Papanikitas J, Yanny S, Hughes R, et al.. Non-traumatic myelopathy associated with prolonged hyperextension during swimming: an unusual variation of surfer's myelopathy. Spinal Cord Ser Cases. 2018;4:22. [PMC free article] [PubMed] [Google Scholar]

30. Shuster A, Franchetto A.. Surfer's myelopathy – an unusual cause of acute spinal cord ischemia: a case report and review of the literature. Emerg Radiol. 2011;18(1):57–60. doi: 10.1007/s10140-010-0913-8 [PubMed] [CrossRef] [Google Scholar]

31. Lieske J, Cameron B, Drinkwine B, Goretzke S, Alemi L, Needham K, et al.. . Surfer's myelopathy-demonstrated by diffusion-weighted magnetic resonance imaging: a case report and literature review. J Comput Assist Tomogr. 2011;35(4):492–4. doi: 10.1097/RCT.0b013e31821e277b [PubMed] [CrossRef] [Google Scholar]

32. Dimmick S, Sheehan P, Brazier D, Anderson SE.. Injuries sustained while surfboard riding. Skeletal Radiol. 2013;42(4):463–5. doi: 10.1007/s00256-012-1536-9 [PubMed] [CrossRef] [Google Scholar]

33. Ruffion A, Castro-Diaz D, Patel H, Khalaf K, Onyenwenyi A, Globe D, et al.. . Systematic review of the epidemiology of urinary incontinence and detrusor overactivity among patients with neurogenic overactive bladder. Neuroepidemiology. 2013;41(3–4):146–55. doi: 10.1159/000353274 [PubMed] [CrossRef] [Google Scholar]

34. Madersbacher H. The various types of neurogenic bladder dysfunction: an update of current therapeutic concepts. Paraplegia. 1990;28(4):217–29. [PubMed] [Google Scholar]
