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Case Studies

# Spinal injury considerations in the competitive diver: a case report and review of the literature

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**Abstract**

**BACKGROUND CONTEXT:** Despite significant literature associated with spinal injuries and recreational diving, few articles exist regarding competitive diving injuries, with no reports pertaining specifically to spinal injuries. As a result, a case report of a collegiate diver with C5–C6 ligamentous instability requiring operative stabilization is currently presented in addition to a review of the literature.

**PURPOSE:** Present a case report of cervical C5–C6 ligamentous instability in a collegiate diver.

**STUDY DESIGN:** Case report and literature review.

**METHODS:** Not applicable.

**RESULTS:** Not applicable.

**CONCLUSIONS:** Diving injuries pertaining to competitive diving do occur but to a lesser extent than would be expected given the large forces the spine experiences. Training, experience and appropriate technique greatly minimize potential spinal hazards. Persistent complaints of neck pain after a competitive diving injury mandate aggressive evaluation and further workup. 

*Keywords:* Sports spine trauma; Diving injuries; Cervical spine injury

## Introduction

Although significant literature abounds regarding the serious paralyzing consequences of recreational diving, few articles exist in relation to competitive diving injuries, with none pertaining exclusively to spine-specific injuries [1–6]. In addition, to this author's knowledge, only one other report of cervical instability as a result of competitive diving has been reported with this being mentioned only briefly as part of a case example in a book chapter on general diving injuries [3]. As such, a case report of a female collegiate diver with C5–C6 ligamentous instability who underwent operative stabilization is currently presented with a review of the literature, description of the sport and analysis of spine-related injury.

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## Case report

A 19-year-old female collegiate diver presented for evaluation of neck and left upper extremity pain with associated paresthesias. The otherwise healthy athlete had 6 years of competitive diving experience and reported no previous cervical injury or similar episode of discomfort. The pain began approximately 9 weeks prior while performing a forward $2^1/2$ somersault in the pike position from the 3-meter springboard. After overrotating the dive, and in efforts to perform a "save," the patient entered the water with her neck in a flexed posture instead of a neutrally extended alignment. A popping sensation was appreciated on impact and an immediate pain localized to the posterior neck was noted. Because of concerns for a cervical strain, the patient abstained from diving for 2 weeks. Upon resumption of practice, the athlete noted persistence of the pain and subsequently developed intermittent numbness of her left thumb and index finger that prompted further medical evaluation. Radiographs at that time were interpreted as normal.

Upon presentation to the clinic, the patient reported musculoskeletal neck pain and radicular patterned left upper extremity discomfort. Her visual analog pain scale assessment was 6 of a possible 10 points. Tenderness about the posterior paraspinal cervical musculature was present, and her pain was exacerbated with axial loading. Spurlings testing was negative bilaterally (axial compression with lateral flexion to check for nerve root encroachment) [7]. Her neurological examination was normal with no evidence of myelopathy. Cervical radiographs, including flexion and extension imaging, revealed widening of the C5–C6 interspace (Fig. 1) that reduced in extension. Magnetic resonance imaging (MRI) showed no canal compromise or cord impingement.

Because of the evidence of posterior ligamentous instability and concern for neurological compromise, surgical intervention was advised. Three months after the injury, the patient underwent a posterior C5–C6 arthrodesis with interspinous wiring and iliac crest bone grafting (Fig. 2). She tolerated the procedure well and postoperatively was placed in a cervical collar that was gradually weaned after her first postoperative visit 4 weeks later. She collapsed the disc space over the next year (Fig. 3). Although she reported overall improvement of her symptoms postoperatively, the neck and left arm pain persisted but at a more tolerable level. Her MRI did not explain her arm pain (Fig. 4). A year later, she underwent an anterior cervical discectomy and fusion

Fig. 1. Lateral neutral radiograph showing increased space between spinous process of C5–C6 and narrowed disc space.


Fig. 2. Lateral radiograph immediately after posterior arthrodesis showing restored disc height.

with allograft and plating (Fig. 5). Her arm and neck pain resolved.

## Evolution of competitive diving

Despite a paucity of historical data before its indoctrination as a competitive sport in England in 1880, the art of diving has inspired many cultures throughout the ages. The earliest documented evidence of diving as a spectator sport can be traced to the Etruscan wall painting from the sixth century BC entitled “Diving from a Rock” [8]. In this painting, a man is clearly depicted diving head first from a rocky cliff into the water below as three onlookers in canoes watch in admiration. Similar influences are also noted from ancestral civilizations of Italy as is exemplified by the “Tomb of the Diver” (Paestum, 480 BC) and the bronze statuette entitled “The Diver” (Perugia, 460 BC) The greatest and most recent evolutionary advancement of diving as a sport, however, is attributable to the seventeenth-century Swedish and German gymnasts who took their routine to the water, thus creating “fancy diving” in the process [1,9].


Fig. 3. Lateral radiograph showing C5–C6 disc space collapse.

Fig. 4. Lateral magnetic resonance image showing degenerative disc at C5–C6 with no herniation.

Today, in the United States alone, more than 10,000 athletes are registered with US Diving, and many more are involved in unregistered high school events and private athletic clubs [1]. Evidence of global growth is best demonstrated in China, where diving is second only to bicycle riding as sport most practiced [8]. In addition to popularity and number of participants, the sport has also advanced greatly in regard to complexity and difficulty. At the dawn of diving in the early 1900s, only 14 platform and 20 springboard dives existed with the most dangerous of dives considered the double somersault from the platform. Today, in sharp contrast, 63 dives on 1-meter, 67 on 3-meter and 85 on platform are listed for competition with divers routinely performing such feats as the reverse $3^1/_2$ or forward $4^1/_2$ somersault dives [9]. Given this growth and heightened level of complexity, the potential for injury, especially those pertaining to the spine, is a reality, as will be discussed further.

## Epidemiology and mechanism of spinal injury

Recreational diving injuries, in general, are catastrophic preventable injuries that are debilitating to the patient and society as a whole. Ranked fourth behind motor vehicle accidents, falls and gun shot wounds [10], recreational diving is associated with 10% to 20% [11–14] of hospital spinal cord admissions with over 800 new cases reported annually [15]. The typical patient profile and history elicit an athletically inclined, young white male (80% to 95%) [14–17] under the age of 25 years [12,13,16–18] who misjudged the depth of a shallow body of water and fractured his cervical spine after impacting with the bottom. Over 90% of these accidents result in quadriplegia, and over half are complete injuries [4,15,19]. Given a mean life expectancy of 30.2 years and the typical youth of the patient, the economic impact to society is quite extreme with conservative measures estimating $97 billion in medical costs and loss of productivity annually [15,20].

The most frequently cited mechanism of recreational diving injuries involves a flexion-compression force acting through the cervical spine that results in burst and/or compression type fractures [4,12,15,21–23]. A head velocity greater than 10 feet/second [15] is sufficient to cause injury, with most fractures occurring at the C5–C7 vertebral levels secondarily to the greater mobility noted at these

Fig. 5. Lateral radiograph 6 months after anterior discectomy and arthrodesis.

segments [12,16–19,22]. Besides negligence on the part of the patient, alcohol consumption is also an important risk factor, playing a role in 38% to 46% of injuries in reported series [15]. Ultimately, simple preventative measures designed to educate the public on the dangers of head-first diving, especially with alcohol involvement, can result in a drastic reduction in further spine morbidity.

In sharp contrast to recreational diving, competitive diving is a relatively safe sport that is rarely associated with catastrophic injury. In nearly 100 years of competition within the United States, no fatality has ever occurred. Similarly, worldwide, only two deaths have been reported, with both a result of the diver striking his head during a complex reverse somersaulting platform dive [3]. Much of this disparity can be attributed to the vast and meticulous training undertaken by the athlete, in addition to the careful supervision allotted by the coaches, to enhance performance and minimize injury.

Despite the unlikelihood of death resulting from competitive diving, noncatastrophic injury to the musculoskeletal system is a reality and should be expected, given the strenuous and physical nature of the sport. Although common areas of injury include the shoulder, elbow, wrist, hand and lower extremity [4,6], the focus of this discussion will be on injury pertaining to the spine. Based on collective data from two limited surveys conducted in 1980 and 1991 [1,5,24], the prevalence of neck and back injury was found to be 25% and 49%, respectively, in all respondents. No gender predilection was noted, and a greater incidence of injury was found with more advanced years of training.

The mechanism of injury, as previously described by Anderson, Lebwohl and Rubin [1,4,6] is best understood by breaking the dive down into its three interdependent components, which include the takeoff, flight and entry. The takeoff phase for forward and reverse dives includes the approach (steps taken to end of board), hurdle (one legged jump at end of board to initiate press), press (depression of board with resultant upward acceleration) and liftoff. In back and inward dives, the takeoff phase involves only the latter two plus an initial arm swing to initiate board motion. Spinal morbidity at this stage of the dive primarily occurs in the lumbar spine, with injury occurring as a result of the compressive loads generated during the deceleration of the press and with back hyperextension occurring with improper body mechanics at liftoff.

The second phase, which begins immediately after liftoff and involves the aerial acrobatics unique to each dive, is termed the flight stage. During this portion, damage to the soft tissues and intervertebral discs of the cervical, thoracic and lumbar spine may result from the torsional and compressive forces generated during the twisting and rapid flexion posturing necessitated for proper dive execution. In addition, “cheating” the dive at takeoff to enhance angular velocity or increase vertical height by means of improper technique (ie, leaning forward on inward dives, “pulling one’s head” during back or reverse dives or maintaining foot contact with the board too long) may produce inadequate horizontal distance, head impact with the board and resultant injury to the cervical spine. Fortunately, no cervical fracture from competitive diving has ever been reported in the United States, and with the advent of newer lightweight aluminum boards, the risk is further minimized [3].

The final and most injury-prone stage involves dive entry into the water. With entrance speeds averaging 18.75 miles/hour (1-meter springboard) to 31.25 miles/hour (10-meter platform) and a 53% reduction of initial dive velocity occurring within a fraction of a second, tremendous axial forces are generated upon impact, creating significant potential for spinal injury [6,25]. Employment of proper hand positioning at entry with arms extended and hands clenched, however, not only improves dive aesthetics by minimizing the splash, but also dissipates the forces and reduces axial loading. Failure to do so may result in cervical sprains and ligamentous instability. Lumbar injuries, also frequent with dive entry, generally are secondary to flawed technique at takeoff with resultant dive malrotation. In efforts to correct for underrotation common with back and reverse type dives, divers will often attempt a “save” by arching their backs at water entry to achieve a more vertical orientation. This hyperextended lumbar posturing induces significant strain at the osseous and ligamentous level, thereby predisposing to potential injury. Likewise, overrotation of forward and inward dives with the legs continuing past the torso after initial water submersion may also lead to back hyperextension with similar resultant injuries.

## Spine-specific injury

By the very nature of the sport, competitive diving places a high demand on the spinal column. With both flexion and extension posturing figuring prominently into most diving maneuvers, axial loading, shearing and torsional stresses repetitively act through multiple spinal segments, creating the potential for injury. In flexion, forces are dissipated at the intervertebral discs and posterior soft tissue structures, whereas in extension stresses act primarily on the posterior elements. As such, competitive diving injuries can be categorized into three subsets, including soft tissue injuries of the paraspinal musculature and ligamentous structures, discogenic problems encompassing protrusions and degeneration of the intervertebral discs and osseous injuries involving the posterior elements with the potential for facet joint arthopathy or stress fracture of the pars interarticularis.

Possibly one of the most common complaints of the competitive diver is backache resulting from muscle strain or ligamentous injury of the lumbar, thoracic or cervical spine. Injuries localized to the thoracic or lumbar spine are generally self-limited, benign processes resulting from the twisting and arching motions that occur during mid-flight and entry into the water. At these levels, symptoms usually consist of localized soreness and muscle spasm, with listing and decreased lumbar lordosis reserved for more severe cases. Treatment is focused on conservative measures, including rest, anti-inflammatories and gradual reconditioning with return to participation once all symptoms have subsided.

In comparison, cervical soft tissue injuries more frequently occur from the 3-meter springboard or 10-meter platform and, as a result, involve greater injury potential given the increased velocities and forces generated from these heights [3]. Most injuries are associated with dive malrotation or inappropriate positioning of the head between the arms with the resultant twisting of the neck upon entry into the water. Although the majority of injuries are minor, consisting of simple strains and complaints of neck stiffness, severe injuries, such as cervical instability with radicular or myelopathic symptoms, can occur as demonstrated in the case example. To this author's knowledge, only one other suggestion of cervical instability as a result of competitive diving has been documented in the literature [3]. However, it is thought that the actual incidence is more frequent and simply lacks adequate reporting. Depending on the severity of injury, treatment ranges from conservative approaches for simple strains, as noted for lumbar and thoracic problems, to surgical intervention with segmental stabilization for instability. Simple preventative measures, including "lineups" and exercises designed to improve the strength, endurance and flexibility of the spine, should be implemented early to minimize the risk of soft tissue injury at all spinal levels.

In addition to soft tissue insult, a second category of spinal injury resulting from competitive diving is discogenic problems primarily at the lumbar and cervical level. Changes in the lumbar discs occur as a natural component of the aging process but are rare in the adolescent or young adult under 25 years, with an incidence less than 1% to 2% [23,26–35]. Diving, however, potentiates this degenerative process by producing torsional shear forces and repetitive axial compressive loads that act to tear the annulus and predispose to disc protrusion [36–38]. The young diver, therefore, is rendered more susceptible to degenerative disc disease at an earlier age than the general population. This is made evident by comparative analysis of studies performed on gymnasts with similar spinal demands where an increased risk of disc degeneration and loss of disc height was noted, especially in those training more than 20 hours per week [38,39].

Symptomatic lumbar disc protrusion in divers and athletes in general typically does not present with the classic complaints of unilateral sciatica [40]. Physical findings, although varied, frequently include paraspinous muscle spasm, referred pain to the buttocks or hip, limited thoracolumbar motion with loss of lumbar lordosis and occasionally a trunk list. Neurologic deficits are unusual. The sitting straight-leg knee-extension test and contralateral supine straight leg-raising test are reliable tools that may assist in diagnosis [39]. Conservative measures, consisting of activity restriction, anti-inflammatory and analgesic medications, progressive mobilization and occasional bracing, are the mainstay of treatment, resulting in resolution of the symptoms within 1 to 2 months in more than 80% of the cases [41]. Approximately 40% of refractory patients may respond to a round of epidural cortisone injections [42]. Although reserved for the rare patient with cauda equine syndrome or progressive neurological deficits, surgery may be a reasonable option for those patients with no improvement after several weeks of conservative therapy [41,43].

Similar to lumbar disc disease, diving has also been implicated as a factor predisposing to cervical disc protrusion. In a study performed by Kelsey et al. [44] in 1984, frequent recreational diving was found to be the most important risk factor for cervical disc herniation with a higher association than even smoking and heavy lifting. Persons diving more than 10 times from a board in the 2 years before onset of symptoms were 2.3 times more likely to endure cervical disc disease compared with the nondiver; this risk was nearly tripled when the frequency of diving was more than 25 times in 2 years. By employing appropriate technique using extension of the arms above the head and the hands gripped tightly together upon dive entrance, many of the forces acting through the cervical spine can be significantly dissipated, thereby minimizing injury. Effectiveness of this technique was demonstrated in a classic study of six Acapulco cliff divers in whom those entering the water in this manner had minimal radiographic cervical spine abnormalities, whereas those impacting with their arms outstretched had severe notable deformity [44].

The onset of cervical disc prolapse is usually heralded by an acute flexion injury with symptoms often including radiating neck pain into the upper extremities and sensory changes of the hands in a dermatomal distribution. Physical examination tools that may aid in diagnosis include the Spurling sign [7], as previously discussed, and the shoulder abduction test, which acts to relieve pain by elevating the arm above the head [45]. Similar to lumbar disc disease, initial treatment focuses on conservative measures, with surgery spared for those with intractable pain for extended periods or for those rare individuals with neurologic impairment.

The last class of spinal insult common in competitive diving is osseous injury to the posterior elements most commonly resulting in spondylolysis and lumbar facet syndrome. Defined as a break or discontinuity in the neural arch, spondylolysis in the diving athlete is a result of repetitive hyperextension of the lumbar spine leading to fracture of the pars interarticularis [1,4,46–48]. This process may be gradual with the development of a fatigue-type injury to the bone or, as suggested by Lebwohl, may represent an acute break within the pars [4,49]. By the very nature of the sport and the routine hyperextended posturing involved, diving has been shown to have an exceedingly high association with this anomaly [48]. In a radiographic analysis conducted by Rossi in 1978 of 1,430 competitive athletes aged 15 to 27 years, divers had the highest incidence of spondylolysis at 63% (compared with 16.7% overall incidence) with degenerative isthmic changes noted in 25 of 30 individual [48]. Persistent lumbar pain that is aching in nature, unilateral and exaggerated by hyperextension should alert the treating clinician to the possibility of this defect. Diagnosis is usually confirmed by a combination of radiographic analysis and physical examination, but occasionally a bone scan is indicated for more occult processes. Treatment of the injury is primarily focused on palliation of pain and prevention of spondylolisthesis seen with bilateral pars defects. As such, conservative measures, including temporary cessation of diving, occasional bracing and physical therapy for back strengthening, may be implemented for a 3 to 6 month period to allow potential healing of the fracture and resolution of the discomfort [47].

The second potential etiology of back injury stemming from an osseous source in the competitive diver is lumbar facet syndrome [1,50,51]. The synovial lining of the facet joint capsule is innervated by the posterior primary ramus. Therefore, irritation of this lining can result in back pain or sciaticlike symptoms. Although varied in cause, the syndrome in the competitive diver likely stems from repetitive motion at the facet joint level with subsequent development of an inflammatory synovitis, early arthritic changes and the resultant symptoms. Diagnosis of this disorder is often difficult secondary to the nonspecific nature of the pain in addition to the lack of an obvious radiographic abnormality. To assist in diagnosis, therefore, Mooney and Robertson correlated four clinical criteria characteristic of this disorder, including back pain associated with groin or thigh pain, localized paraspinal tenderness, radiographic evidence of facet joint changes and reproduction of symptoms with extension-rotation (compresses joint) and relief with flexion (separates joint surfaces) [51]. Subtle radiographic changes include joint space narrowing, surface irregularity and sclerosis, all of which are best appreciated by computed tomographic evaluation. Treatment of the syndrome begins with rest, anti-inflammatory drugs and physical therapy. Should symptoms persist longer than 2 months, facet joint injections may be used. However, the success rate for such modality is only 50% to 60% [51,52].

## Conclusion

Diving injuries occur but to a lesser extent than would be expected considering the large forces the spine experiences. As with other competitive athletes, divers tend to be stoic and do not necessarily report their symptoms. Aggressive evaluation of any persistent complaint after an injury, therefore, is warranted.

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