Sports Medicine and Rehabilitation: A Sport-Specific Approach

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Chapter 7

EVALUATION AND TREATMENT OF INJURIES IN COMPETITIVE DIVERS

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With few exceptions, the sport of competitive diving has received relatively little attention in the medical literature. Many of the reviews occur as subheadings under more general discussions of aquatic sports. The unique medical aspects of competitive diving are more difficult to appreciate when the sport is lumped together with skin diving, scuba diving, or swimming. Similarly, the assumption that diving is simply an aquatic version of gymnastics or dance can be misleading.

Much of the medical attention focused on diving has dealt with the recreational version of the sport. An unacceptably high number of serious head and neck injuries has plagued recreational diving. Despite the absence of similar injury patterns in organized diving, the safety issues of competitive and recreational diving are often inadvertently linked. As a result, the medical literature on diving may be arguably unfocused or inappropriately focused on an activity considered distinct from competitive diving.

This chapter provides a clearer medical perspective on the sport of competitive diving. Background information on the sport of springboard and platform diving is provided as well as a review of the physical demands of training and competition. In the discussion of common injuries, emphasis is placed on how the pathomechanics of injury serves as the basis for the diagnosis, treatment, and ultimate prevention of diving-related injuries.

BACKGROUND

The evolution of diving can be traced to the 17th century when gymnasts in Germany and Sweden were first observed to perform acrobatics over water in what was known as “fancy diving.” Springboard diving became an Olympic sport at the 1904 games in St. Louis. Platform diving became an Olympic event at the 1908 games in London. The United States has long been a dominant force in diving, but increasingly competitive programs from China and the former Soviet Union testify to the international growth and development of the sport.

The standard format for diving competitions involves a 1-m springboard, 3-m springboard, and 10-m platform event for both men and women. Olympic competition involves 3- and 10-m events only. A diver must perform from 8 to 11 dives, depending on the event. A dive must be selected from six types of dives (Fig. 1): forward, backward, reverse, inward, twisting, and handstand (for platform only). The dives are performed in a straight, pike, or tuck position (Fig. 2). Each dive is assigned a degree of difficulty that ranges from 1.2 to 3.5.

Approximately half the dives are voluntary and half are optional. The voluntary dives (formerly called “required” or “compulsory”) are chosen from a representative sample of the six different types of dives. The total degree of difficulty of the voluntary dives must not exceed a predetermined maximal number. The optional dives have no limit on
FIGURE 1. Basic diving positions: (1) **Forward group:** The diver faces the front of the board and rotates toward the water. Dives in this group vary from the simple front dive to the difficult forward 3½ somersault. (2) **Backward group:** Dives begin with the diver on the end of the board with back to the water. The direction of rotation is from the board. (3) **Reverse group:** Formerly called "gainers," these dives begin with the diver facing the front of the board (using a forward approach) and rotating toward the board. (4) **Inward group:** The diver stands on the end of the board with back to the water and rotates toward the board or opposite the backward group's movement. The earlier term for these dives was "cutaways." (5) **Twisting group:** Any dive with a twist is included in this group. There are four types: forward, backward, reverse and inward. Because of the many possible combinations, this group includes the most dives. (6) **Armstand group:** The diver assumes a handstand position on the edge of the platform before diving. (Adapted from Shatkowski D (ed): 1992 US Diving Media Guide Record Book. Indianapolis, US Diving, 1992.)
cumulative degree of difficulty. The list of voluntary and optional dives must be declared prior to competition. The divers structure their lists to feature individual strengths as well as to demonstrate proficiency in all types of dives.

The dives are scored by a panel of judges who analyze the approach, take-off, elevation, execution, and entry. Scores range from 0 to 10, with 10 the best possible score. The high and low scores are eliminated, and the total award is calculated by using the degree of difficulty as a multiplier.

Participant Profile

The exact number of participants in competitive diving is unknown, although approximately 10,000 athletes (5,500 women, 4,500 men) are registered with U.S. Diving, and many more are nonregistered participants in YMCA, club, and high-school programs. The typical age of a diver of world-championship caliber varies from 12 years to the late 20s. The average age for the US national diving team is 23.5 years for women and 25 years for men. Divers at the national team level have competed for an average of 11 years for women and 13 years for men. National team divers train an average of 4.5 hrs/day, 6 days/wk. Most national team members began diving between age 11 and 12 years. Many have prior competitive experience as gymnasts.

Epidemiology of Injuries

Given the extraordinary training demands for serious divers, it is no surprise that injuries occur. Detailed epidemiologic studies of diving injuries are not available. Many of the reports on diving safety have centered on catastrophic injuries to the cervical spine. De-
spite the fact that such injuries have occurred exclusively in the recreational setting, competitive diving has been the unfortunate victim of guilt by association.

In an effort to determine the problems most relevant to the competitive diver, a survey was distributed to a limited number of elite divers in 1980. Of the 37 divers (16 men, 21 women) who responded, 34 (92%) reported an injury that interrupted training for at least 1 week. In this group, 61% reported back injuries, 61% reported upper-extremity injuries, and 40% reported neck problems. The respondents ranged in age from 11 to 26 years with a trend toward higher injury rate with increasing years in competition.

In 1991 a medical and injury history was distributed to all divers participating in a National Junior Olympics competition. The survey was administered as part of a talent identification battery that minimized any response bias based on injury status. For the most part, the divers were able to consult their parents regarding details of their health history. Medical personnel were available to clarify terminology and to answer medical questions. A total of 172 divers (78 boys, 94 girls) responded; 90% of the respondents were 18 years of age or younger. The subject profile and most common injuries are listed in Table 1. Fractures (48%), back pain (47%), and muscle strains (42%) were the most frequently mentioned problems. Shin splints, ligament sprains, and contusions were also common. Gender differences in the type or frequency of injury were not seen. A trend toward a higher injury rate in older, more experienced divers was again noted. Unfortunately, precise diagnoses could not be confirmed, nor could the relation of the injury to diving be established. Nonetheless, injuries are clearly present in abundance in young divers and appear to become an increasing burden with additional years of training and competition.

**INJURY PATHOMECHANICS**

**Rationale for a Pathomechanical Approach to Diagnosis and Treatment**

Understanding the cause of a diving injury is essential for administering proper treatment, determining readiness to return to participation, and planning preventive programs. Inherent in any physical activity are forces of compression or load, tension or traction, and friction. Any of these forces applied in excess can cause injury. Rapidly applied, maximal forces can result in tissue disruption and lead to acute musculoskeletal injuries such as fractures, dislocations, sprains, and strains. Repetitive, submaximal forces can result in overuse or overload injuries such as tendinitis, periarthritis, bursitis, traumatic arthritis, and stress fracture.

The likelihood of breakdown in response to maximal or submaximal forces is determined, in part, by the presence of extrinsic and intrinsic risk factors for injury. (Table 2). Extrinsic risk factors for diving injury may include the training regimen, coaching, facilities and/or equipment used for both water activities and land training. Intrinsic factors include physical characteristics such as age, maturation status, and general fitness level.

**TABLE 1. Injury History in Junior Olympic Divers (n = 172)**

<table>
<thead>
<tr>
<th>Injury †</th>
<th>No. (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken bone/fracture</td>
<td>83 (48)</td>
</tr>
<tr>
<td>Back pain/injury</td>
<td>80 (47)</td>
</tr>
<tr>
<td>Muscle pull/strain</td>
<td>72 (42)</td>
</tr>
<tr>
<td>Shin splints</td>
<td>53 (31)</td>
</tr>
<tr>
<td>Ligament sprain</td>
<td>47 (27)</td>
</tr>
<tr>
<td>Deep bruise</td>
<td>40 (23)</td>
</tr>
<tr>
<td>Neck pain/injury</td>
<td>37 (22)</td>
</tr>
<tr>
<td>Painful kneecap</td>
<td>31 (18)</td>
</tr>
</tbody>
</table>

†Subjects included 78 males and 94 females; ages = 13 yrs, 30 M/32 F; 14–15 yrs, 17 M/25 F; 16–18 yrs, 23 M/27 F; senior, 8 M/10 F.

‡Injury terminology is deliberately written for "lay"readership and is listed as it appeared on questionnaire. Data from US Diving, Ad Hoc Talent Identification Committee.

**TABLE 2. Extrinsic and Intrinsic Risk Factors in Diving Injuries**

<table>
<thead>
<tr>
<th>Extrinsic Factors</th>
<th>Intrinsic Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training ‡</td>
<td>Physical characteristics</td>
</tr>
<tr>
<td>Intensity, duration, frequency</td>
<td>Age</td>
</tr>
<tr>
<td>Coaching/supervision</td>
<td>Maturational status</td>
</tr>
<tr>
<td>Environment</td>
<td>Physical fitness</td>
</tr>
<tr>
<td>Facility design</td>
<td>Previous injury</td>
</tr>
<tr>
<td>Clearance from obstacles</td>
<td>Flexibility</td>
</tr>
<tr>
<td>Water surface visibility</td>
<td>Strength/power</td>
</tr>
<tr>
<td>Pool depth</td>
<td>Joint motion</td>
</tr>
<tr>
<td>Board/platform surface</td>
<td>Joint stability</td>
</tr>
<tr>
<td>Equipment</td>
<td>Malalignment</td>
</tr>
<tr>
<td>Tape, braces, splints</td>
<td>Spatial orientation, spotting ability</td>
</tr>
<tr>
<td>Spotting belts</td>
<td>Skills, technique</td>
</tr>
<tr>
<td>Dry land training equipment</td>
<td>Psychosocial characteristics</td>
</tr>
</tbody>
</table>
ter and dry land training. Intrinsic risk factors for injury include individual variables such as flexibility, joint laxity, strength, alignment, and skills and technique. When a diver presents with an injury, it is helpful to identify both the pathomechanic forces involved and the extrinsic and intrinsic factors that may be contributory. This approach encourages treatment programs that address the cause as well as the symptoms of the injury.

### Pathomechanics of Diving Injuries

For purposes of understanding the physical demands of executing a dive, it is useful to separate the dive into its three component parts—takeoff, flight, and entry.

The **takeoff** phase of the dive involves work on the springboard or platform. For a front dive, the takeoff includes an approach (minimum of 3 steps), a hurdle (the upward jump from one foot to the end of the board), and a press (depression of the board and upward acceleration of the body). For maximal height, divers must synchronize their descent from the hurdle with the descent of the board; this technique allows them to “ride” the board for a more efficient press. Working against the motion of the board has consequences for both performance and injury risk.

The takeoff for back or inward dives can be subdivided into the preparatory arm swing that sets the board in motion and the press. For platform dives, height is achieved by whatever spring the diver can generate from a fixed (nonflexible) surface.

The injury-producing forces during take off are related to jumping and deceleration, with the greatest physical demands and greatest injury potential placed on the extensor mechanism of the knee. The most common injuries related to this part of the dive are patellar tendinitis, quadriceps tendinitis, and patellofemoral compression syndrome. Eccentric overload to the Achilles tendon and impact to the leg from bouncing may result in injuries to these structures. Injuries to the lumbar spine may also occur during takeoff. If the diver is out of position while pressing the board or jumping, compensatory movements such as hyperextension of the back may lead to injury.

With handstand dives, takeoff must be initiated from a controlled, stable handstand position at the end of the platform. This position demands tremendous isometric strength and balance. The potential for injury in the handstand position stems from the use of the upper extremity for weight-bearing. The load-bearing demands on the wrist, elbow, and shoulder can be excessive—particularly when the necessary joint motion, joint stability, or muscular support is lacking.

The **flight** or mid-air maneuver phase of the dive begins when the diver leaves the board or platform and ends with initial water contact. During this phase, forces operate to allow the diver to spin forward, to spin backward, and/or to twist along the long axis of the body. To initiate a twisting motion, the diver throws one arm down and across the body and one arm up and away from the body (Fig. 2). Irritation of the long head of the biceps tendon on the abducted and externally rotated arm has resulted from this type of movement. The potential for torsional overload to the spine also exists. Strength and control in the trunk and extremities are necessary to maintain the pike, tuck, or straight-body position required for the dive. The rapid and forced flexion of the trunk with pike dives causes increased loading of the anterior segment (vertebral body and disc) and can be a factor in injury to these structures.

Intrinsic factors such as body awareness, spatial orientation, and “spotting” ability are critical during the mid-air maneuver and, in part, determine whether or not the maneuvers results in injury. Many of the injuries that occur during flight occur as compensation for a flawed takeoff or as an attempt to save an entry. Injuries during flight may occur from striking the board. Such injuries are usually due to a mistake during takeoff on the board—not in the air.

Most diving injuries occur upon entry into the water. Even with a perfectly executed dive, the diver strikes the water surface with considerable impact. Additional forces occur underwater as the diver performs forceful maneuvers to facilitate a clean, splashless entry or “rip.” With multiple repetitions in practice and an inevitable number of less than perfect entries, the risk for entry-related injury becomes cumulative.

The approximate velocities of entrance from various springboard and platform heights are shown in Table 3. The average force of impact for a 10-m dive varies from 20 to 24Gs (1G = 9.8 m/s²). The challenge for the diver is to dissipate impact forces and to control deceleration in the water while still
TABLE 3. Approximate Entrance Velocities*

<table>
<thead>
<tr>
<th>Height</th>
<th>Springboard</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m</td>
<td>8.4 m/s</td>
<td>4.4 m/s</td>
</tr>
<tr>
<td></td>
<td>(18.75 mi/h)</td>
<td>(9.82 mi/h)</td>
</tr>
<tr>
<td>3 m</td>
<td>10.1 m/s</td>
<td>7.7 m/s</td>
</tr>
<tr>
<td></td>
<td>(22.54 mi/h)</td>
<td>(17.19 mi/h)</td>
</tr>
<tr>
<td>10 m</td>
<td>—</td>
<td>14.0 m/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(31.25 mi/h)</td>
</tr>
</tbody>
</table>


achieving a splashless entry. To dissipate impact initially and to protect the head and spine from axial loading, the diver enters with arms extended and hands in a clasped or overlapping configuration (Fig. 3). This position also serves to "punch a hole in the water" through which the body can presumably pass with minimal splash.

A proper entry requires enough strength to maintain a handstand position with the added demands created by deceleration forces on the water surface. The forces at impact initially act to cause dorsiflexion of the wrist and flexion or "buckling" of the elbow. The wrist flexors and elbow extensors must work to counteract these forces. Strains to the wrist flexors and tendinitis and/or strains to the triceps may result from overload of these supportive structures.

As impact forces are transmitted proximally, the shoulder must be prepared to absorb axial loading. Adequate scapular abduction is crucial to providing bony stability to the glenohumeral joint. Inadequate scapular abduction increases the demands on the soft-tissue structures of the shoulder to maintain support and to prevent glenohumeral instability (Fig. 4).

When a diver is short of a vertical entry at impact, he or she attempts to save the dive. The attempt involves hyperextension of the back and hyperflexion of the shoulders. This position of the shoulder markedly increases susceptibility to anterior glenohumeral subluxation. Save attempts are common in back and reverse dives—in part, because of the inherent difficulties with back-spinning dives. With back and reverse dives, the diver's vision is oriented opposite the direction of the somersault and away from the intended entry point. The diver has to initiate extension toward the water before seeing the entry point. If rotation is inadequate in a back-spinning dive, the diver has only a fraction of a second to recognize position and to make corrective maneuvers. To avoid a nonvertical entry, divers literally thrust themselves into the save position. The speed, force, and amplitude of this effort may contribute to injury. The effects of water impact on hyperextended shoulders and hyperextended spines exceed the already considerable impact forces associated with neutral alignment.

During the entry into the water, the diver must execute what is known as a "swim-out." As the arms and upper body enter the water, the diver forcibly pulls the arms forward or to the side in a swimming motion in an attempt to pull the hips and lower extremities into the water. The swim-out may also assist in an underwater save. The diver turns underwater in the same direction as the midair maneuver to maintain a smooth and continuous arc of motion. The timing of the underwater ma-
nevers and the adequacy of strength to support sudden changes in direction and velocity are factors in production of injury and should be factors in treatment of injury.

"Dry land" training may also contribute to diving injuries. The acquisition of basic diving skills and the progression toward more complicated spinning and twisting dives may involve practice on a trampoline, a dry board with portable landing pit, or use of an overhead spotting belt. A thorough evaluation of an injured diver should include inquiries about dry land training and any risks that may result from the specific equipment and personnel involved.

**COMMON DIVING INJURIES**

The discussion of diving injuries is divided into those affecting the extremities and those affecting the spine. Most of the diagnoses in injured divers are also seen in nondiving settings. It is assumed that the reader has some baseline familiarity with these conditions; this discussion focuses on the aspects of diagnosis and treatment most germane to diving.

**Shoulder Injuries**

The most common shoulder problems affecting divers are rotator cuff impingement and glenohumeral instability. It is difficult to separate the discussion of pathogenesis of these problems because they may be interrelated. The shoulder is an inherently unstable joint. This creates added demands on supportive structures (rotator cuff, glenoid labrum, capsule) when external forces are applied. Inadequacy or weakness of supportive structures may lead to subacromial impingement of the supraspinatus tendon, biceps tendon, or subacromial bursa. Failure of supportive structures can cause labral disruption as well as glenohumeral subluxation or dislocation. Increased glenohumeral laxity may, in turn, lead to further problems with impingement. Ironically, a certain amount of increased glenohumeral laxity is required for divers to perform.

Shoulder injuries appear to be related to repetitive overhead use, saving short dives, and swimming entries. Because of the continuum of shoulder problems from impingement to instability, all divers with shoulder pain should be thoroughly evaluated for problems of both stability and strength. Anterolateral shoulder pain occurring after multiple dives may be the earliest sign of injury. Recognition and treatment of pathology at this stage usually lead to an earlier and more complete recovery than if the injury is allowed to progress. Shoulder pain at rest, pain that is present with simple reaching and extension, or shoulder pain that restricts movement and
function indicates a more advanced stage of disease. The presence of gross glenohumeral instability may be associated with reports of recurrent shoulder subluxations or dislocations. More subtle degrees of instability are not reliably detected by history but may be the cause of an athlete's report of popping, catching, or apprehension in positions of abduction and external rotation.

The physical examination of a diver with shoulder pain should include inspection, palpation, and assessment of range of motion, stability, and strength. The inspection should assess muscle bulk and definition, presence of scapular winging, and thoracic kyphosis. A kyphotic posture or an anteriorly tilted acromion limits forward flexion of the shoulder and results in increased risk of impingement. Systematic palpation should be carried out with particular attention to tenderness over the biceps tendon, the greater tubercle of the humerus, and the anterior glenohumeral joint line.

The assessment of shoulder range of motion can serve the dual purpose of detecting signs of impingement and signs of instability. Patients with symptomatic instability often have apprehension with passive abduction and external rotation of the humerus, whereas patients with symptomatic impingement may have pain in all directions except abduction-external rotation. Pain or restricted motion in all planes suggests a combined instability/impingement problem.

The goal of strength testing is to determine both the consequences as well as the contributing causes of injury. Isolated supraspinatus weakness usually indicates injury or disuse. Weakness of the external rotators of the humerus and the scapular stabilizers is more likely to be a risk factor for instability or impingement rather than an effect of the injury. Weakness of the deltoid, biceps, and/or triceps may indicate local injury or a referred problem from a cervical nerve root or brachial plexus injury.

The treatment for shoulder injuries should be based on specific pathomechanic changes in the injured diver. Some degree of rest is usually indicated. Relative rest may take the form of simply limiting dives from higher elevations and/or limiting back and reverse dives. With more severe symptoms, rest may require more global restrictions of activity. Inflammatory changes can be addressed with ice and nonsteroidal antiinflammatory medications. A selective strengthening regimen is essential to restore optimal strength to the downward stabilizers of the humerus and the scapular stabilizers. For patients who have impingement or instability refractory to conservative measures or evidence of significant lbral pathology, surgical intervention should be considered. Arthroscopic surgery has a role in both diagnosis and treatment of chronic impingement and labral pathology. The surgical treatment of instability is more controversial. The delicate balance between having "enough" and "too much" glenohumeral laxity must be respected in surgical decision-making.

Elbow Injuries

The maximal stress on the elbow for divers occurs during water entry. Repetitive impact and hyperextension forces may be seen, particularly with platform diving. Hyperextension may result in tensile overload to the medial collateral ligament. The resultant instability may interfere with the diver's ability to maintain a handstand position on the platform and to extend and lock out the elbows during entry. Medial elbow laxity may contribute to the development of ulnar nerve irritation as well.

Triceps injuries are also seen in response to the forces at entry. Triceps strength is required to maintain full elbow extension and to resist impact forces during entry. Failure to maintain full elbow extension results in an eccentric overload to the triceps. Strains to the triceps are most commonly seen at the distal musculotendinous junction but may also occur proximally.

The assessment of an elbow problem in a diver requires an evaluation of range of motion, stability, neurologic status, and strength. Lack of full elbow extension limits the diver aesthetically and functionally. A long line is visually desirable and facilitates a cleaner entry. Inability to lock the elbow into extension markedly increases demands on the triceps to hold the entry. The lack of full elbow extension warrants a radiologic evaluation of the elbow to rule out loose bodies, bony irregularities in the olecranon fossa, and deformity of the radiocapitellar joint. Restrictions of elbow flexion or pain and weakness associated with resisted elbow extension should raise concern about a triceps injury.

Stability of the elbow should be assessed with emphasis on the medial collateral ligament, which is susceptible to injury in divers due to the forces at entry.
ment. Medial instability can be checked by applying valgus stress to the elbow in a 30°-flexed position or with a stress radiograph at the same degree of flexion. Side-to-side comparison measurements should be obtained. The neurologic examination should include an assessment of irritability, instability, and/or dysfunction of the ulnar nerve. Strength testing should include not only the biceps and triceps but also the wrist flexors and extensors. Weakness or pain with resisted wrist flexion or pronation may be associated with medial elbow instability or secondary to overload of the wrist flexors from forces at entry.

The treatment of elbow injuries depends on the specific abnormalities and dysfunction present. The goals of treatment and criteria for return to activity should include restoration of full, pain-free motion, strength (especially in the triceps and wrist flexor groups), and adequate stability. Elbow taping and/or bracing may provide some protection for lax medial structures or weak dynamic stabilizers. However, taping and bracing tend to restrict motion and are generally not acceptable as a long-term solution. A simple test to determine readiness to return to full training after an elbow injury is to have the diver demonstrate the ability to maintain a handstand position.

Wrist and Thumb Injuries

Wrist injuries occur from repetitive impact and forced dorsiflexion at entry. Handstands and the act of pushing up to get from the water to the pool deck may also be contributory. Fractures may occur from the hand striking the board. Ulnar collateral ligament sprains of the thumb may occur at impact or as a result of missing a grab for the opposite hand prior to entry.

The assessment of wrist and thumb injuries in divers should include an evaluation of joint range of motion and stability. Palpation should be performed over the distal radius and ulna (including the epiphysis in skeletally immature divers), the proximal and distal carpal row, the ulnar snuff box (triangular fibrocartilage complex), the radial snuff box (scaphoid bone), and the first carpometacarpal and first metacarpophalangeal joint. Radiographs should be evaluated for evidence of fracture, stress fracture, carpal instability patterns, ulnar variance, epiphyseal widening, joint irregularity, or arthritis.

Some of the common causes of wrist pain that may have normal-appearing radiographs include the dorsal impaction syndrome (pain at radiocarpal joint secondary to forced wrist dorsiflexion), synovial ganglion (including occult ganglion cysts), flexor carpi ulnaris tendinitis, and milder sprains or capsulitis.

In the author’s experience, volar subluxation of the lunate may underlie much of the wrist pain seen in divers. This condition can be diagnosed by careful palpation of the wrist. Volar prominence of the lunate may be seen in association with wrist pain, whereas a nonprominent or reduced lunate may correlate with decreased pain.

Selected fractures and sprains with significant instability may require casting or even surgery. The remainder of wrist or thumb conditions may be treated conservatively with rest, anti-inflammatory medications, and protective taping or bracing. Many divers with injury, or even those attempting to prevent thumb and wrist injury, use a semirigid brace to provide added stability and protection against the forces of impact.

Lower-Extremity Injuries

Lower-extremity injuries in divers are less common and have fewer unique implications for diagnosis and treatment than upper-extremity injuries. Lower-extremity injuries are generally related to jumping. Like other athletes in jumping sports, divers experience patellofemoral pain. The specific diagnoses include patellofemoral compression syndrome, patellar tendinitis, and quadriceps tendinitis.

The evaluation of knee pain in a diver should include an assessment of risk factors for patellofemoral pain, including malalignment, abnormal patellar tracking; poor flexibility in the hamstrings, quadriceps, or hip flexors; and strength imbalances between the hamstrings and the quadriceps. The risk factors should serve as the basis for treatment of patellofemoral dysfunction. Good eccentric quadriceps strength and adequate time for a functional training progression that includes jumping drills should precede a full return to training. McConnell patellar taping may be a useful adjunct for quadriceps reeducation and to facilitate pain-free return to activity.

Other jumping-related conditions include tibial periostitis ( shin splints) and tendinitis in the foot and ankle, including posterior tibialis tendinitis and Achilles tendinitis. Again, assessment for malalignment, flexibility prob-
lems, and strength imbalances serves as the basis for rehabilitation. Orthotics to compensate for malalignment are not a viable option for a diver during training. However, athletic taping and modification of training regimens to decrease jumping may allow an athlete to continue to train during rehabilitation.

**Cervical Spine Injuries**

Diving-related injuries to the cervical spine have drawn attention primarily because of the catastrophic problems seen in recreational diving. Recreational divers sustaining spinal cord injuries usually have no formal training in diving and are often injured in a setting with inadequate water depth and inadequate supervision. Often they are under the influence of alcohol. Fortunately, these risk factors can be and are addressed in organized diving. Catastrophic cervical spine injuries have not been reported in competitive diving or in a teaching or school environment.

Although catastrophic injuries may be preventable through implementation of safety measures (US Diving Safety Manual), the potential still exists for noncatastrophic injuries from repetitive impact-loading to the cervical spine. A frequently quoted study on the effects of recurrent spinal trauma in high diving was published by Schneider et al. in 1962. Histories, neurologic examinations, and cervical roentgenograms were obtained in 5 cliff divers from Acapulco. The divers averaged over 1,000 dives/year (5,000–26,000 over career) from diving points at 100 and 135 ft above water. None of the divers had cervical abnormalities by history or neurologic examination. The radiographic changes were felt to be minor, and no diver had received prior medical treatment for the changes that appeared in the cervical spines. The greatest bony changes of the cervical spine were in divers who had longer, less heavily muscled necks and who struck the water with hands apart. Fewer radiographic changes were seen in divers who locked thumbs or clasped hands to break the force of the dive. Despite the small numbers in the study, the theory that a strong neck, rigid arms, and locked hands protect the spine is widely accepted and practiced today.

A review of recent medical literature has failed to reveal a pattern of specific cervical injury or degenerative process that can be attributed directly to the sport of diving. Therefore, cervical spine problems in divers need to be considered individually with ongoing surveillance for patterns that may lead to further safety measures.

The clinical evaluation of a diver with cervical complaints should include an assessment of cervical range of motion. Pain or restriction of cervical extension should raise the possibility of a cervical facet injury or possible impingement of the interspinous ligament. Restricted cervical flexion or cervical pain associated with radicular findings should raise suspicion for a disc injury. Upper-extremity neurologic findings with a normal cervical spine examination may indicate brachial plexus injury ("stinger"). Part of the evaluation of a diver with neck pain should include radiographs to rule out instability, stenosis, and degenerative changes.

Criteria for determining a safe return to participation after cervical injury include restoration of pain-free, normal range of motion, absence of neurologic abnormalities, and restoration of normal cervical and upper extremity strength. Current investigation includes correlating cervical symptoms and physical findings with the presence of structural changes by radiographic and magnetic resonance imaging.

**Lumbar Spine**

The sport of diving requires both mobility and stability in the lumbar spine. When the demands for motion or stability are exceeded, injury may occur. The anterior segments (vertebral body, vertebral endplate, and intervertebral disc) are particularly vulnerable to compressive forces or increased load. Increased disc-loading would be expected at takeoff and entry and with trunk flexion during the mid-air maneuver. A flexed or rotated spine during maximal loading (at takeoff or entry) combines the forces most likely to lead to disc injury.

An anterior segment injury typically presents with low back pain that lateralizes or radiates into the buttock or hamstring area. The pain may be worsened by sitting, bending, lifting, and/or straining and relieved by standing, walking, lying prone, and/or extending the spine. Radiographic evaluation should take place to rule out compression fracture, endplate irregularities, or disc-space narrowing. A normal radiograph does not rule out a disc protrusion or a degenerative
The treatment for spondylosis requires a period of rest with restriction of lumbar extension, followed by an exercise program aimed at decreasing hyperlordosis and increasing abdominal and trunk strength and a graded return to pain-free activity. Use of a semirigid antilordotic brace (i.e., Boston brace) may be required to control extension forces and to decrease pain. Skeletally immature adolescents with spondylosis need to be monitored during their growing years for progressive spondylolisthesis.

Lumbar facet arthropathy may also underlie a pattern of posterior element pain. The clinical findings of a facet syndrome are difficult to distinguish from spondylosis. Accordingly, the diagnosis of a facet syndrome should not be made until spondylosis has been ruled out.

Lumbar pain with extension may also be due to a midline disc protrusion or lateral recess stenosis. Back pain with extremes of motion in any plane may be related to segmental hypermobility. Sprains, strains, and other soft-tissue disorders may cause back pain. Such diagnoses, however, are less likely in an athlete whose symptoms have persisted for more than 2 weeks and are less valid until more specific diagnoses have been ruled out. Because treatment varies according to diagnosis, a favorable outcome depends on diagnostic precision.

SUMMARY

The preceding discussion of competitive springboard and platform diving has included a review of pertinent background information on the sport and its participants, an analysis of the pathomechanics of diving injury, and a review of the common musculoskeletal injuries. An appreciation of the physical demands of the sport is crucial to understanding the pathogenesis of injury as well as to planning treatment and prevention strategies and to determining safe return to participation after injury.

REFERENCES


disc. Therefore, magnetic resonance imaging may be indicated for more definitive evaluation of disc pathology.22

Conservative treatment of an anterior segment injury includes relative rest, antiinflammatory medication, and physical therapy to restore optimal flexibility, lumbar segmental motion, trunk strength, and body mechanics. Surgery should be considered for instability, progressive bony deformity, disabling discogenic pain, or neurologic compromise. The potential for loss of lumbar motion after surgery warrants careful consideration prior to surgical intervention.

Posterior element injury (facet joints, pars interarticularis) may be a more common cause of back pain in divers. The posterior elements are subjected to overload during maximal lumbar extension or extension combined with rotation. Settings in which overload can occur include the takeoff for a back dive, an entry for a back-spinning dive when the diver is "short," or a front-spinning dive when the diver overrotates.

The diver with posterior element pain typically presents with back pain at the level of the waist that is worse with standing, walking, running, jumping, and/or lumbar extension. The pain may be relieved by sitting, forward flexion, and/or lying supine. Physical findings may include hyperlordotic posture, restricted and painful lumbar motion, tender posterior elements, and, usually, a normal neurologic examination. Radiologic evaluation is aimed primarily at ruling out spondylosis and spondylolisthesis. Rossi16 found that spondylolytic lesions appear with increased frequency in divers with back pain compared with asymptomatic athletes in other sports (prevalence rates of 63% vs 17% respectively). Most authorities agree that diving is a sport where the rate of spondylolisthesis may be disproportionately high.25

The presence of a spondylolytic defect on the radiograph does not always mean that spondylolisthesis is the cause of back pain nor does a normal-appearing radiograph rule out a symptomatic spondylolysis. A bone scan and/or single photon emission computed tomography (SPECT) can help to reconcile differences between clinical and radiographic findings. A positive bone scan indicates that a spondylolysis is new and likely causing symptoms. A negative bone scan indicates that a spondylolytic defect on radiograph is old and suggests that other etiologies for back pain need to be pursued.


