In Brief: Rowing—whether on the water or with machines—is increasingly popular, and, as with any strenuous exercise, the potential for injury is high. Rowers may have common symptoms, such as low-back and knee pain, or more sport-specific problems such as rib stress fractures, nerve impingement, and blisters. Virtually all rowing injuries are due to overuse, and many can be traced to training errors or equipment problems. Understanding the mechanics of rowing, the equipment, and the training procedures is essential for the physician caring for injured rowers.

Rowing as a sport is growing at both the competitive and recreational levels. There is also growing enthusiasm for recreational and competitive use of rowing machines, which extend the rowing season and make rowing available to those who have never set a boat on the water. The popularity of rowing means that primary care physicians are increasingly likely to see rowing-related injuries.

Demographics

Rowers have been competing at the collegiate and club level for over 100 years. It was one of the first sports added to the modern Olympics and was a popular spectator sport, with significant wagering, in the late 1800s. Today, rowing continues at the club, elite, collegiate, and high school levels. Recent changes in Title IX enforcement, requiring equal opportunity for participation by women in collegiate sports, has spurred the rapid growth of collegiate rowing for women, with a trickle-down effect to the high school level. In the summer Olympics, rowing represents the second largest sport next to track-and-field in number of participants.

Equipment and Racing

Boat. The rowing boat, or shell, accommodates one to eight rowers, who may have either one oar (sweep rowing), or two oars (sculling). Each station has fixed shoes and a sliding seat (figure 1). Oars are held in riggers, and multiple individual adjustments are possible to vary the load per stroke, height of oarlocks, and position and angle of the shoes.
The rowing stroke begins as the oar enters the water, in a position called the "catch" (figure 2a). In this position, the legs and back are maximally flexed and the arms extended. During the power phase of the stroke, the "drive," the legs extend, followed by an opening of the back to a less flexed position, and finishing with flexion of the arms, the "finish" (figure 2b). The oar is removed from the water and the oar blade is turned parallel to the water by rotating the oar in the fixed oarlock, a maneuver called "feathering." In the "recovery" phase, the body returns to the catch position, preparing to take another stroke.

Races typically are contested over 1,000-m to 2,000-m courses in the spring and summer, and 3 miles in the autumn. The spring and summer races are run parallel for up to six boats at once, beginning from a stop, and are near-maximal aerobic efforts that begin with an anaerobic start and conclude with an anaerobic sprint. Times for the 2,000-m races vary depending on the boat size and weather conditions but are typically in the 5.5- to 8-minute range. Autumn races are from a running start against the clock and are virtually all aerobic effort, typically lasting from 15
to 20 minutes.

**Exercise machine.** The most commonly used rowing machine, or ergometer, has a flywheel for resistance connected to a handle by a chain, with a retractable stretch cord aiding the return of the handle to the starting position. The rower sits on a movable seat with fixed shoes and pulls the handle away from the flywheel. The ergometer is used for winter training, and winter "races" are held in which the times of each participant are compared. It is increasingly common to see people use the ergometer while training for another sport or for general conditioning.

**Training**

Rowing has both high strength and high aerobic demands, ranking among the most strenuous sports (1). Rowing athletes train virtually year-round, with emphasis on distance training in the fall, weights and distance in the winter, and increasing intensity and anaerobic work in the spring and summer racing seasons. Rowing athletes are highly fit, with recorded VO$_2$ max in the 65 to 70 mL/kg/min range for elite athletes (2). Rowing favors the tall athlete with a long reach, who can cover more distance per stroke.

Rowing is a repetitive-motion, nonimpact sport; thus, rowers are unlikely to suffer sudden and unexpected injury, but more likely to suffer overuse injuries. Like other athletes in repetitive sports, the cause of these overuse injuries can usually be traced to a training error in either volume or technique, or inappropriately sized or configured equipment.

**Musculoskeletal Injuries**

**Low-back pain.** The rowing stroke puts extraordinary pressures on the low back. The back begins the stroke flexed, and during the middle of the stroke the back opens up, but remains flexed, in a motion similar to an incomplete dead lift. Loading the back in flexion places large forces on both the back muscles and the disks. In one review (3), low-back and knee injuries were the two most common injuries found in collegiate rowers. In sweep rowing, the back is also twisted slightly during the stroke to achieve more reach in the catch position, which may increase the incidence of back pain (4), though this does not appear to be the case in my experience or that of several US national rowing team physicians.

Back injuries from rowing vary from low-back muscle or ligamentous strain to spondylolysis to lumbar disk herniation. Physicians evaluating rowers with back pain should maintain suspicion for disk herniation, the most serious of these problems. Rowers sometimes have disk herniation without the typical radiation of symptoms to the legs, perhaps because these herniations represent primarily central disk disease, which does not press on the spinal nerve roots.

Low-back pain in rowers usually has an insidious onset, typical for an overuse injury, but occasionally rowers may suffer acute disk herniations. A careful history will often reveal training errors, usually from increasing load or distance too rapidly, or attempting a high-load drill. The physical examination is frequently unrevealing because the rower may be only mildly symptomatic at rest, but a careful search for signs of radiculopathy is warranted. Low-back pain, especially with extension in a younger rower, is suggestive of spondylolysis, and the mechanism of this injury is likely the load to the pars interarticularis from the load to the back in rowing, rather than the repetitive hyperextension mechanism seen in other sports.

Diagnostic tests are not always indicated at the initial presentation of the rower with low-back pain, but the physician should suspect disk herniation and consider proceeding to lumbar magnetic resonance imaging (MRI) if conservative treatment is unsuccessful. Young people, particularly those with pain in extension, need plain x-rays with oblique views, followed by a bone scan if negative, to rule out spondylolysis.

Treatment for low-back pain in rowers is often frustrating, and many rowing careers have ended because of persistent low-back symptoms. A typical treatment program of low-back strengthening, range-of-motion exercise, rest as appropriate, and modalities such as ice and external stimulation for pain control is commonly used (5). Rowing equipment can be modified to decrease the load per stroke, and technique can be altered to keep the low back straighter. Having sweep rowers change rowing sides to lean and twist in the opposite direction, unfortunately, rarely improves symptoms. Athletes with disk herniations who do not respond to conservative treatment often have disk surgery, which also can end careers. Rowers are cautioned to protect their low backs by
not making errors in training, encouraged to modify rowing technique and volume, and reminded to seek care for persistent back symptoms.

**Knee pain.** The rowing stroke puts the knee through its full range of motion, with a significant load exerted to the fully flexed knee at the start of the stroke. There is, therefore, a fairly high incidence of patellofemoral knee pain in rowers. Like patellofemoral pain in other sports, this is more common in women, whose anatomy predisposes them to patellar tracking problems that are further exacerbated by the fixed position of the shoes in the rowing shell. If the shoes are spaced or twisted incorrectly for the individual's anatomy, knee pain may persist and worsen despite appropriate treatment. Knee pain may also be caused or exacerbated by other activities used for cross training, such as running and weight lifting.

Patellofemoral pain can be treated with specific strengthening of the vastus medialis muscle to improve patellar tracking, and by use of modalities, such as ice, in the acute phase. Bracing of the knee is difficult due to the range of motion required for the rowing stroke and thus is not recommended. Modifying the position of the shoes in the boat can have a significant impact by encouraging better positioning of the knee during the rowing stroke (figure 3).

![Figure 3: Courtesy of Kristine A. Karlson, MD](image)

**FIGURE 3.** To help alleviate knee pain, rowing shoes can be moved closer together or farther apart, up or down, or rotated.

Rowers may also complain of lateral knee pain, commonly due to friction of the iliotibial band passing over the lateral femoral condyle, that is exacerbated by the full knee compression required for the rowing stroke. Individuals with varus knees are at increased risk for this problem. Again, changing the position of the shoes in the boat can help alleviate symptoms. Other treatments consist of ice, stretching, and other modalities as appropriate. Gradual return to rowing is usually successful.

**Rib stress fracture.** Stress fractures of the ribs were reported infrequently in rowing prior to the introduction of a more efficient oar design in 1992, which was rapidly and widely adopted (6,7). This new oar holds its position in the water with less slippage, and thus transmits greater forces to the muscles of the arm and chest wall. Since 1992, stress fractures of the ribs have been seen at all levels, are regarded by the rowing community as common, and have been reported more commonly in the literature (8-10).

During the rowing stroke, the serratus anterior muscle holds the scapula firmly against the chest wall while the scapula goes through its range of motion, from protraction when the stroke begins, to retraction when the blade exits the water. Researchers have proposed that overuse of the serratus anterior muscle leads to bending forces at the ribs, which can cause stress fracture, usually posterolaterally in ribs 5 through 9. There is also a case report (11) of a serratus anterior avulsion from rowing, attesting to the large forces exerted on and by this muscle.

The history of rib stress fracture is one of insidious onset of chest wall pain, often associated with training volume increases or training errors. Athletes often feel this initially as a strain of the intercostal muscles in the chest wall, but over time the pain begins to localize over a rib, where a palpable bony callus may develop. If a callus is not palpable, diagnosis may be made by plain x-ray, but, in most injuries, a bone scan is necessary for adequate and complete diagnosis.
Unfortunately, once the diagnosis of rib stress fracture is made, rest for 6 weeks is usually required for complete healing. There is little else that can be done in terms of physical therapy once the injury occurs; therefore, early recognition is necessary to save the rowing season for injured athletes. Modifying technique, to decrease stress on the serratus muscle, involves decreasing the reach at the beginning of the stroke and the follow-through at the end of the stroke (figure 4). It is also possible to modify the equipment to decrease the load per stroke. Specific protraction strengthening exercises for the serratus anterior may strengthen it enough to avoid rib stress fractures, but there is no documentation of the success of such a program.

![Figure 4](https://www.physportsmed.com/issues/2000/04_00/karlson.htm)

**Figure 4.** Standard (A) and altered (B) finish of the rowing stroke. This variation reduces the stress placed on the ribs by the serratus muscle.

**Forearm tendinitis.** Maintaining the tight hand grip required to hold on to the oar(s) for extended periods of time puts the forearms at risk for overuse injuries. Each rowing stroke also involves twisting the oar parallel to the water when feathering the oar in the recovery phase. This motion is carried out by extension at the wrist, further stressing the forearm.

Rowers with forearm tendinitis typically experience pain, tenderness, and even crepitus of the dorsal wrist in the region of crossover between the first and third dorsal wrist compartments (figure 5). On physical exam, affected athletes have pain and swelling in this region of the dorsal forearm. As with other overuse injuries, this problem is more common early in the outdoor rowing season when feathering the oar is still an unaccustomed activity. Feathering action at the wrist is not necessary to use a rowing ergometer.

![Figure 5](https://www.physportsmed.com/issues/2000/04_00/karlson.htm)

**Figure 5.** Forearm tendinitis among rowers commonly occurs at the intersection of the first and third dorsal wrist compartments.

Treatment of forearm tendinitis involves appropriate rest and technique modification. Affected
athletes can try to row with their wrists as flat as possible, which may or may not be possible, given their skill level. Looser grip on the oar(s) is also very important. Medical treatment involves ice, nonsteroidal anti-inflammatory drugs, and, occasionally, local steroid injection into the tendon sheath. Tendinitis usually resolves fairly quickly with appropriate management.

**Dermatologic Problems**

Hands of rowers are highly susceptible to blisters from friction with the oar handle. Most rowers are reluctant to wear gloves, thinking that this decreases the ability to feel the position of the oar in the water. Rowers in northern climates do not practice outdoors year-round, which can result in an increased incidence of hand problems when they return to the water each spring.

Treatment and prevention of hand blisters is the object of much folklore and tradition in rowing, but not all interventions have proven benefits. Most rowers merely tolerate blisters as a necessary evil that will resolve as the skin adapts. A few may get secondary infections, which often require oral antibiotic treatment. More serious infection is rare. Rowers should be cautioned to watch for secondary infection and taught how to trim hand calluses to avoid the formation of new blisters under large, thick calluses.

Oars are usually shared among members of rowing teams. Open blisters and hand infections are therefore a potential source of blood or body-fluid exposure. Oar handles need to be cleaned regularly, especially after use by an athlete with hand wounds, to limit the spread of infection. One study (12) found an increased incidence of hand warts among members of a rowing team, suggesting that infection may spread even with intact hands.

Some rowers are particularly susceptible to blister, callus, and abrasion of the buttocks. This may be worsened by sitting on an improperly fitted rowing seat, which allows chafing or pinching of the buttocks, usually at the finish position of the stroke. Affected individuals are usually uncomfortable but rarely seek medical attention. This problem is usually improved by use of a different seat, a foam seat pad, and petroleum jelly or another dressing to the affected area. These abrasions can, though rarely, progress to serious infection, and awareness of this problem needs to be increased among rowers to decrease embarrassment in seeking appropriate care.

At the finish of the rowing stroke, the posterior lower leg contacts the metal track in which the seat rolls back and forth as the legs bend and extend. The extent of this contact is variable, depending on the width of the tracks and the height of the tracks with respect to the shoes. Athletes who tend to hyperextend their knees, whose shoes are considerably lower than the tracks, or whose knee alignment also aligns the calves with the seat tracks, can suffer a repetitive abrasion of the posterior legs, known to rowers as "track bites" (figure 6: not shown). These abrasions can be quite severe, frequently scarring and occasionally infecting. Rowers should be encouraged to wear protective long socks, cut-off portions of socks, or circumferential tape. Smaller dressings usually do not stay in place. If possible, the equipment can be altered to diminish contact of the legs with the tracks, but this is often difficult or impossible.

**Nerve Entrapment**

Various nerve entrapments are seen in rowing. They range from carpal tunnel syndrome caused by tight hand grip to numbness of the legs caused by pressure on the sciatic nerve from a poorly fitted seat. A ridge on the front of the seat can place direct pressure on the sciatic nerve. Leg numbness may also occur if the seat holes designed to fit the ischial tuberosities are improperly spaced for the individual, especially when women use seats designed for men that do not accommodate a wider pelvis.

Rowers with carpal tunnel syndrome often hold the handles too tightly and should modify their technique in addition to the usual treatments. Most other nerve entrapments are the result of poor equipment fit, exacerbated by long rowing sessions. Rowers with nerve entrapment should seek the assistance of an experienced rowing coach or trainer to aid them in making equipment modifications.

**Environmental Exposure**

Rowing is an outdoor sport; thus, rowers should be aware of exposure and safety issues, including
sun exposure augmented by reflection from the water and hypothermia augmented by wet clothing. Water exposure is not intentional, but splash when the oars enter the water frequently reaches rowers, making water quality a potential health problem as well.

Most rowing-associated deaths are preventable and due to drowning or exposure. Storms causing high waves and lightning are dangerous for any small boat and should be avoided. Collisions are possible, and strict attention must be paid to traffic patterns and use of lights in low light conditions. Rowing solo is not recommended. Rowers should be cautioned to dress appropriately in noncotton layers (depending on the anticipated weather conditions), avoid severe weather conditions that could be life threatening, and carry and use safety equipment such as lights, whistles, and personal flotation devices (PFDs). Coaches should ensure that their launches are equipped with safety gear including PFDs, paddles, lights, and a two-way radio or cellular phone.

Key Understanding

Rowing is a popular, strenuous sport with both unique and common injuries caused by overuse. Acute, sudden injury is rare. An understanding of the mechanics of the rowing stroke, the equipment, and the training practices is key to making appropriate changes to prevent and treat injuries.

References


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