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Rowing Injuries

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Abstract

Participation in the sport of rowing has been steadily increasing in recent decades, yet few studies address the specific injuries incurred. This article reviews the most common injuries described in the literature, including musculoskeletal problems in the lower back, ribs, shoulder, wrist and knee. A review of basic rowing physiology and equipment is included, along with a description of the mechanics of the rowing stroke. This information is necessary in order to make an accurate diagnosis and treatment protocol for these injuries, which are mainly chronic in nature.

The most frequently injured region is the low back, mainly due to excessive hyperflexion and twisting, and can include specific injuries such as spondylolysis, sacroiliac joint dysfunction and disc herniation. Rib stress fractures account for the most time lost from on-water training and competition. Although theories abound for the mechanism of injury, the exact aetiology of rib stress fractures remains unknown. Other injuries discussed within, which are specific to ribs, include costochondritis, costovertebral joint subluxation and intercostal muscle strains. Shoulder pain is quite common in rowers and can be the result of overuse, poor technique, or tension in the upper body. Injuries concerning the forearm and wrist are also common, and can include exertional compartment syndrome, lateral epicondylitis, deQuervain's and intersection syndrome, and tenosynovitis of the wrist extensors. In the lower body, the major injuries reported include generalised patellofemoral pain due to abnormal patellar tracking, and iliotibial band friction syndrome. Lastly, dermatological issues, such as blisters and abrasions, and miscellaneous issues, such as environmental concerns and the female athlete triad, are also included in this article.

Pathophysiology, mechanism of injury, assessment and management strategies are outlined in the text for each injury, with special attention given to ways to correct biomechanical or equipment problems specific to rowing. By gaining an understanding of basic rowing biomechanics and training habits, the physician

and/or healthcare provider will be better equipped to treat and prevent injuries in the rowing population.

The sport of rowing has a rich history of competition, and has been increasing greatly in popularity in recent decades. Competitive rowing itself dates back several hundred years.[1] The first races occurred nearly 300 years ago in England on the Thames River.[2] At the collegiate and club levels, rowing races have existed for >100 years and it was one of the earliest sports to be added to the modern Olympics. Surprisingly, however, few studies address the specific injuries that may occur through participation in this activity. Most researchers maintain that rowing injuries occur primarily through overuse, and can often be traced back to an abrupt change in training level or alteration in technique or equipment.[1,3] Some believe they stem from inadequate lactate removal after hard training sessions or races, or improper recovery. Poor flexibility, strength deficiencies and muscle imbalances can also contribute. To add to the predicament, researchers reporting the incidence must be able to distinguish between rowing injuries and those sustained on stationary ergometers.[4] Therefore, it is important for the clinician or trainer to distinguish between the various mechanisms of injury, and to understand the underlying intricacies of the sport itself. This article attempts to elucidate the mechanisms, diagnosis and management of various sport-specific injuries encountered in this population.

1. Competition and Training

Rowing is divided into two categories: sweep rowing and sculling. Sweep rowing refers to the use of one oar per rower, which can be placed on starboard or port (left and right, respectively, from the perspective of the rower). The boat classes in sweep rowing are the pair, four and eight. The eight always employs a coxswain, although pairs and fours have separate classes for coxed or coxless (straight) events. Sculling refers to the use of two oars per person. Sculling boats are the single, double and quad. All sculling boats are coxless. Additionally, rowing competitions are divided into heavyweight and lightweight divisions.

Training comprises both aerobic and anaerobic components. The relative contribution of the anaerobic system is estimated at 10–30%, while the aerobic system supplies the remainder.[2,5] Because of the high amounts of lactic acid incurred during a 2000m race, rowing ranks among the most strenuous of sports. Maximum oxygen consumption ($\dot{V}O_{2max}$) values can reach 70 mL/kg/min for elite level rowers,[6] who are typically tall and lean. Long-term rowing is also beneficial for the cardiovascular system, as one study noted enlarged myocardial wall thickness, normal systolic function, and a high work capacity in the hearts of senior oarsmen.[7]

2. The Rowing Shell or Boat

Each rower is assigned to his or her ‘seat’ or spot in the rowing shell (figure 1), which comprises a seat that slides back and forth on tracks. The foot stretchers, or foot stops, normally have shoes attached to a plate that is positioned at various angles for effective leg drive. The oar is placed in an oarlock, which itself is a component of the rigger

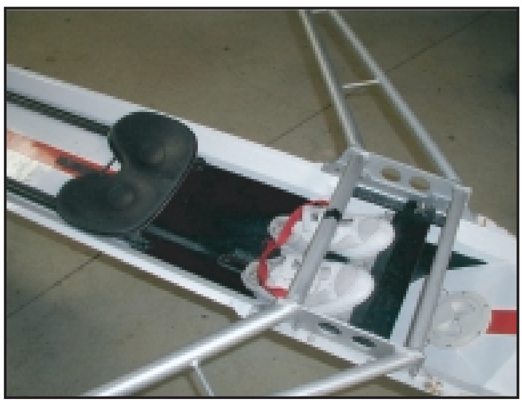

Fig. 1. The inside of a rowing shell. On the left side is the sliding seat on tracks, with the shoes attached to the foot stops on the right. Over the top is the aluminium rigger extending outward from the boat.

which extends outward from the boat. The oar comprises the blade (the part that enters the water), the shaft and the handle. Adjustments can be made on the oar or on the rigger to increase or decrease load, height and pitch; this is referred to as 'rigging'.

3. Phases of the Rowing Stroke

The rowing stroke includes the catch, drive, finish or release, and recovery (figure 2):

- Catch: the rower's legs and back are fully flexed and the arms are fully extended as the oar enters the water. The oar is in the squared position, which means that the blade is perpendicular to the water.
- Drive: the legs extend and the back begins to extend slightly. Novice rowers are taught to use their legs, back and arms in this sequence to avoid the common mistake of bending the arms too quickly to pull the oars. This is the power phase so it is important to use the legs first to contribute maximal strength. Once the back extends, the arms flex and continue to accelerate the blade of the oar through the water.
- Release: the elbows draw the blade through the water and the handle lightly brushes the abdomen, prompting the rower to tap the handle down slightly to remove the oar from the water. The blade is feathered, or turned so that it is parallel to the water, to become more aerodynamic and able to pass over waves more easily.
- Recovery: the drive sequence reverses as the hands carry the oar handle forward until the arms are extended, the back moves from an extended to flexed position, and the knees are brought up to the chest to prepare for the next catch.

a

b

c

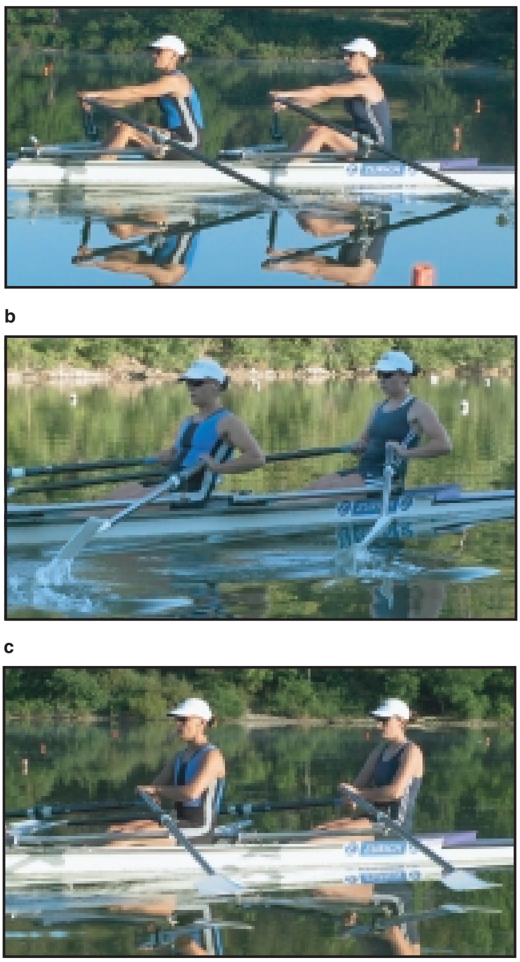

Fig. 2. Phases of the rowing stroke: (a) catch and early drive phase; (b) release phase; and (c) recovery phase.

4. Approach to Injury Evaluation

It is important to note that there are only three places of contact of the rower with the boat: (i) the feet to the footrest; (ii) the buttocks on the seat; and (iii) the hands on the handles. When evaluating the rower post-injury, it is important to assess the joints proximal and distal to the injured site, and to observe any muscle imbalances or strength deficiencies.[8] It is very possible that if an athlete is unable to move into the proper start position due to tight muscles, something else will compensate, and that may be the location of the resulting pain. For example, tight hamstrings prevent the necessary hip flexion in order to achieve the proper position at the catch. This may result in an increased kyphosis in the spine, likely at the thoracic level, as a compensatory mechanism.

If possible, the clinician should attempt to observe ergometer and rowing technique, noting any asymmetries or improper biomechanics.[8] There will probably be a connection between what is assessed and what is observed on the water or on the ergometer. Rowers generally do not have an off-season, choosing instead to take their training indoors. Interestingly enough, one study mentions that 50% of injuries that occurred in elite rowers were due to land-based training, including ergometer training and weights.[9,10] Therefore, all activities should be investigated to determine the exact mechanism of injury.

The most common injuries sustained by rowers are discussed in the following sections. Hickey et al.[10] retrospectively analysed injuries to elite rowers over a 10-year period, and observed that chronic injuries made up the vast majority, with differences in the actual sites of injury found between males and females. The most common sites of injury for the male elite rowers were found to be the lumbar spine, the forearm/wrist and the knee. The most common sites of injury for the female elite rowers, however, were found to be the chest, the lumbar spine and the forearm/wrist. The majority of the current research reviewed is anecdotal, highlighting the need for future research to based upon well designed clinical studies in this specific population.

5. Musculoskeletal Rowing Injuries

5.1 Nonspecific Low Back Pain

Injuries to the spine account for 15–25% of all reported injuries in rowing,[10,11] making it the most frequently injured region. Of concern is the report that the prevalence of back pain, at the very least in intercollegiate rowers, is on the increase.[12] Although rowers who do not develop back pain during their collegiate years have lower subsequent incidences of back pain than the general population, those who experience back pain that causes one or more weeks of lost practice or competition over their collegiate career will likely have a recurrence.[13]

5.1.1 Pathophysiology

The majority of low back injuries are chronic in nature and occur from excessive hyperflexion and/or twisting force applied to the lumbar region.[14] Other suggested predisposing factors for back injury include: a low hamstring-to-quadriceps strength ratio;[15] strength asymmetries in the left and right erector spinae muscles during extension;[16] practice in the early morning hour;[17] increased respiratory demands;[18] and hip muscle imbalances, particularly in female athletes.[19]

5.1.2 Mechanism of Injury

Hyperflexion and twisting forces are exacerbated at the catch position, as the lower back muscles are relatively relaxed and then great loads are placed on the spine as the blade drives through the water. The compressive force generated at the lumbar spine has been estimated to be 4.6-fold the rower's body mass.[19] Fatigue, particularly when coupled with high-volume, high-intensity training, compounds this effect by impairing muscle fibre contractibility.[1,20] A recent study by Caldwell et al.[20] noted that muscle fatigue in the erector spinae muscles might cause excessive lumbar flexion, thereby increasing stress on the spinal structures. The researchers noted that throughout a maximal rowing trial on an ergometer, lumbar flexion of the subjects increased from 75% to 90% of their maximum range of motion, most likely due to muscle fatigue. Teitz et al.[12] studied 1632 college rowers for risk factors leading to back pain during college rowing. The observed risk factors include: increased training volume using multiple training methods; the use of a rowing ergometer for >30 minutes at one time; greater height and weight; and beginning the sport prior to the age of 16 years.

Howell[21] found a high positive correlation between hyperflexion of the lumbar spine and incidence of low back pain in elite lightweight oarswomen. This study also reported a high negative correlation between adherence to a stretching programme and occurrence of low back pain. 94% of the rowers tested were classified as hyperflexible in this area, prompting the author to suggest that excessive lumbar flexibility is necessary for elite level rowing. A proposed mechanism may be the increased range of motion available at the catch, generating a greater amount of power throughout the drive phase.[21] More research is warranted on this topic before conclusions can be drawn.

Reid and McNair[17] observed, through combining the findings of two earlier studies on swelling pressure of the disc[22] and stress on the lumbar spine,[23] that the time of day when practice occurs might play a role in development of injury.[17] Many rowers train during the early hours of the morning, when it is thought that due to overnight absorption of fluid from surrounding tissues, lumbar discs are more vulnerable to injury.[22] Greater loads and stresses on the spine are better suited for afternoon training when discs are more compressed[23] and therefore able to withstand the force generated by the rower.

Several researchers believe that breathing patterns may also play a role in the development or prevention of back injuries in rowing. Manning et al.[24] investigated the effects of inspiring versus expiring during the drive phase of rowing. They found that expiring during the drive results in an increased intra-abdominal pressure (IAP), which might help offset the high levels of shear force and compression observed in the lumbar spine during this phase. IAP may have a protective effect on the spine from the tremendous levels of shear and compression at mid-drive. The compressed position of the rower at the catch prevents maximal IAP by inspiration as contraction of the diaphragm is inhibited. Expiration during the drive allows the lungs to be full at the catch and the IAP to peak.

Inspiratory muscle training, in which respiratory muscles are specifically trained, shows great promise as it not only stabilises the thorax, therefore reducing incidence of low back pain, but also has been observed to improve rowing performance.[25] In this study by Voliantis et al.,[25] each subject inspired against a resistance equivalent to 50% peak inspiratory mouth pressure by using a muscle trainer for 30 repetitions, twice daily. The authors believe that respiratory muscle fatigue, altered respiratory sensation and altered ventilatory efficiency may contribute to a decrease in rowing performance, which can be lessened or alleviated by inspiratory muscle training. Loring and Mead[18] found that during times of increased respiratory demand, the central nervous system must prioritise respiratory drive over the other postural control functions of the respiratory muscles. Not only do the respiratory muscles help to control pressure in the thorax (for respiration) but, as mentioned in the paragraph above, they also aid in the stabilisation of the lumbar spine.

Therefore, cardiovascular training may not only be important for performance, but also for lumbar stability and injury prevention.

5.1.3 Assessment

Observation of the rower's technique is particularly helpful in this area. Rowers who adopt a slumped position at the catch or finish tend to have a higher incidence of back injuries. Some suggest that the back should be kept strong and straight as in weight lifting,[14] although tight hamstrings and an extended reach at the catch may hinder this position.[15] McGregor et al.[26] assessed intersegmental motion and pelvic tilt using magnetic resonance imaging (MRI) in 20 elite oarsmen, with interesting results. Rowers with current low back pain or those with a previous history presented with stiffness in the lower lumbar spine. To achieve the same length at the catch position as their healthy counterparts, they compensate at the pelvis or the upper lumbar or lower thoracic spine. During the drive, the sacrum would be upright as opposed to the preferred anterior tilt of healthy oarsmen, and along with the pelvis, would be rotated posteriorly at the finish position.

5.1.4 Management of Injury

Caldwell et al.[20] suggest an attempt for the rower to achieve more anterior rotation of the pelvis at the catch position. This can be achieved through the use of strong hip flexor muscles, particularly the psoas muscle, and having the appropriate length in the hamstrings to allow the anterior rotation of the pelvis. This anterior pelvic posture will help to reduce the amount of lumbar flexion and, therefore, the stress on the spinal structures. It is also crucial to train the endurance capabilities of the lumbar extensor muscles to help maintain healthy levels of flexion. Furthermore, these authors advocate an awareness of increased lumbar flexion and fatigue in the erector spinae muscles; however, Taimela et al.[27] have shown that awareness of excessive flexion is impaired when the muscles are fatigued.

Other preventative strategies include stretching, particularly of the hamstring and gluteal muscles, and core stability work.[26] Stretching of the hip flexors, due to their attachments to the spine, should also be incorporated in the programme as they also are liable to become very short and tightened. Of note is a study by Koutedakis et al.,[15] in which a hamstring strengthening programme in 22 female rowers resulted in reduced training time lost from back pain. Orlando[28] also maintains the importance of strengthening the deep abdominal stabilisers, preventing the compensatory muscles of erector spinae, hip flexors and quadratus lumborum from being overused. Work on core abdominal and back strength appears to help maintain and correct posture throughout the stroke cycle, preventing injuries to the low back. Maintenance of correct posture can be achieved through activation of the transversus abdominus, internal oblique abdominus, with co-contraction of the multifidus muscles.[29,30] Teitz et al.[13] further recommend that the ergometer be used for cardiovascular, as opposed to strength, training, with a lower load setting to simulate on-water rowing.

Rowers with back pain need not be discouraged from participating in the sport, however. O'Kane et al.[31] studied college rowers with pre-existing (before college) back pain and observed that these rowers were no more likely to miss training than their team-mates, and when practice was missed, it was for a shorter duration. These rowers were also less likely to have career-ending back pain. However, it should be noted that the definition of back pain in this article was limited to pain lasting a minimum of 1 week, and surveys were sent to former athletes, thus with the possibility of introducing recall bias.

5.2 Specific Low Back Injuries

Of the more severe low back injuries in the literature, spondylolysis,[32] sacroiliac joint dysfunction[33] and disc herniation[1] are most often described. Suggested treatment includes reduction of local spasm, rotational mobilisation and strengthening exercises with a rotational element for sweepers.[14] NSAIDs, rest and various pain control modalities can accompany this; in more severe cases surgery may be warranted.

5.2.1 Spondylolysis

Spondylolysis is considered to be the forward displacement of one vertebra relative to another. The severity of the slip is expressed in degrees ranging from a 25% slip (type I) to a complete displacement of the vertebrae (type IV). Type II and above typically involve a stress or acute fracture within the vertebrae.

Spondylolysis is relatively common in rowers.[32] The majority of injuries occur at the pars interarticularis. Risk of development of spondylolysis increases in sports with lumber hyperextension or extension and rotation.[32] Non-traumatic spondylolysis with a lesion in the pars interarticularis may be a significant cause of pain in a given individual, particularly in athletes involved in sports with repetitive spinal motions. The pars lesion likely represents a stress fracture of the bone caused by the cumulative effect of repetitive stress imposed by physical activity. However, Stallard[14] notes that weight training and not rowing induced all cases of spondylolysis observed in his group of rowers.

To care for these athletes, it is necessary to have a full understanding of spinal biomechanics and pathophysiology, the role of diagnostic imaging, and treatment options. CT scans can play a very important role in diagnosis, assessment of the defect, short- and long-term management decisions, and in determining prognosis. Often the stress fracture will not show up on plain x-ray films. Further imaging using nuclear medicine triple phase bone scans or CT scans is often necessary to pick up these vertebral fractures in the athlete complaining of low back pain.[34]

Conservative treatment is usually successful in controlling symptoms and restoring function; only a small percentage of patients require surgical intervention for pain or progressive spondylolisthesis.[35] Based on current evidence, treatment requires activity restriction (i.e. temporary discontinuation of the aggravating sport or activity, particularly extension) and may require bracing to achieve treatment goals, although healing, pain relief or both may occur without brace application.[36]

In a study by Sys et al.,[37] 89.3% of the athletes managed to return to their same level of competitive activity within an average of 5.5 months after the onset of treatment. It is also interesting to note the finding that non-union does not seem to compromise the overall outcome or sports resumption in the short term.

5.2.2 Sacroiliac Joint Dysfunction

Described as a chemical or mechanical irritation of the sacroiliac ligaments, sacroiliac joint dysfunction (SIJD) typically results in pain over the buttock, lateral thigh, anterior pelvis and groin. Pain is rarely referred below the knee.

Sacroiliac joint problems have been observed to occur for three main reasons: (i) a difference in leg length, causing the rower to push the legs down unevenly; (ii) presence of underlying hypermobility (usually from prior trauma); and (iii) the presence of a constant sudden balance problem.[3] The greatest demands placed on the sacroiliac joint occur at the transition point between the catch and the drive, and may also be exacerbated by the significant relative joint laxity and muscular imbalances observed in rowers.[33]

The prevalence of SIJD in rowers has not been extensively researched. In fact, data presently exist only on sweep rowers.[33] SIJD is discernible as pelvic obliquity, or asymmetry between the anatomical landmarks of the anterior superior iliac spine and posterior superior iliac spine.

Assessment and treatment of the sacroiliac joint, and of the amount of movement that this joint is capable of, remains controversial. To those who believe that the sacroiliac joint has substantial ability to move and subsequently cause dysfunction, assessment is based around the hemi pelvis position. The examiner must be aware of unilateral rotation and/or superior or inferior migration of the hemi pelvis compared with the sacrum. It is also important to look at the general muscle balance and flexibility around the pelvis, as this is a prime cause of pelvic dysfunction.

Treatment includes manipulation to increase mobility of the 'locked' or compressed side, and in the case of differing leg lengths, an extra insole in the shoe of the shorter leg will help.[3] Use of a stabilising belt may be beneficial, although in some rowers it tends to shift and be uncomfortable to use while the athlete is in the boat. A structured physiotherapy programme, including sacroiliac mobilisation, core muscle and general lower extremity strengthening, can be very effective in the resolution of sacroiliac dysfunction. One study, by Sasso et al.,[38] found 95% of patients treated with a structured physiotherapy programme rated their results as good to excellent 2 years after treatment.

5.2.3 Disc Herniation

When the spine is flexed, vertebrae compress on the protective discs that separate each bone. This increases the pressure on the disc and causes it to protrude backwards or laterally. With excessive or repeated flexion, the outermost structures of the disc may weaken and allow the disc to bulge. This can result in compression of the nerve, causing numbness or tingling in the leg (known as sciatica).

In particular, an improperly supported back can lead to great forces being taken up on the lumbar spine.[28] When twisting and shear forces are added, such as those seen in sweeping, discs are more prone to injury than ever.[1]

Assessment of disc herniation includes a comprehensive examination of neurological function including sensation, strength, reflexes, and bowel and bladder function. Range of motion (ROM) is often limited due to muscle spasm. Some athletes experience more back and/or leg pain with flexion of the spine and relief with extension, while in others the opposite will be true. With pain on extension, spondylolysis or possibly facet problems should also be considered in the differential diagnosis. Radiographs may or may not be helpful – disc space narrowing may indicate the level of the pathology but a significant disc protrusion can be present with a normal x-ray. Additional imaging such as CT or

MRI scans may be required, particularly if symptoms are prolonged or severe.

If there is significant nerve damage or progressive pain and disability, surgery may be warranted. However, the first line of therapy should always be conservative if possible, including physiotherapy, anti-inflammatories and analgesic medications. If there are signs of a disc injury, it is best to take time out from the boat or off the ergometer. It is extremely difficult to eliminate if the athlete is still rowing, due to the seated position with the legs flexed in front.

5.3 Rib Stress Fractures

5.3.1 Pathophysiology

Rib stress fractures typically occur at the rib's weakest point (where it changes direction or has the smallest diameter), due to significant stress and/or overuse. Rib stress fractures are of particular concern to the rowing population, accounting for the most time lost from on-water training and competition.[30] Several studies report rates of occurrence of 6.1–22.6%,[10,39] with a higher rate of occurrence in female rowers.[10]

Theories abound as to the cause of rib stress fractures in rowers. It is important to note that the rib cage is loaded as a complete unit due to the closed system of thoracic vertebrae posteriorly, ribs, and the sternum anteriorly,[39] rather than each rib as an individual unit. Because of this, recent research[39] has focused on two known groups of factors: (i) those that affect rib loading (muscle, joint, technique, equipment, and weight training); and (ii) those that affect the response to rib loading (skeletal, training and sex).

Muscular factors include: weakness leading to the loss of shock absorption and increased stress at selected focal points of the rib; muscle pull across the bone exerting considerable repetitive forces, prompting a stress fracture; and muscular imbalance between serratus anterior and external oblique muscles. Muscles thought to be involved include serratus anterior, abdominals and the scapular retractors.[1,4,6,10,39-44]

Serratus anterior has long been implicated in the development of the rib stress fracture,[1,4,6,10,40,41,44,45] as it originates from ribs one to nine and attaches to the medial border of the scapula. However, Warden et al.[39] debate the ability of serratus anterior to generate enough tension to cause a rib stress fracture, as its principal activity occurs during the recovery, when resistance is low. One case study describes an avulsion injury of the serratus anterior in a rower,[44] although this is not a typical injury sustained in rowing or sport in general, and the authors were unable to pinpoint whether the avulsion occurred while training on the rowing ergometer or during a weight-training session earlier in the day. More likely is the theory of the protective effect of serratus anterior as it resists abdominal compressive forces on the rib at the finish of the stroke,[39] and with lessened protection as it fatigues. This compressive ability of the abdominal muscles has given rise to the theory that this group of muscles is the more likely culprit. As the abdominals contract, the rib cage is compressed and subsequently loaded. These muscles are predominantly active at the finish and during the recovery.[39]

Retractor muscles of the scapula may be implicated as mentioned earlier in this section, potentially due to the force generated during the drive with leg extension.[39] This force may be of sufficient magnitude to overcome the ability of the retractors to resist the motion.

Training, equipment and technical factors include poor stroke mechanics,[6,45,46] equipment problems, a lack of flexibility and/or strength,[40] a sharp increase in training load, and the introduction of the hatchet blade, which has a much larger surface area to drive against a larger amount of water at one time.[41]

One study by McKenzie[45] suggests that the catch and finish segments of the stroke are not implicated in rib stress pathology, but points instead to the end of the drive phase and the recovery. The actions of scapular protraction (recovery phase) and retraction (end of drive phase), coupled with the contraction of the obliques (recovery phase), are thought to be involved in the pathogenesis of the rib stress fracture. Karlson[6] confirms this claim yet argues that the mechanism of injury occurs at the finish. According to this study, most of the damage occurs at the finish as the serratus anterior switches from a concentric contraction to eccentric, generating a significant amount of force. Additionally, the external oblique is at near maximal tension in this position. To minimise this contribution of scapular retraction and protraction to the development of rib stress fractures, Karlson has suggested that rowers lessen these movements during long-distance rowing sessions. However, it should be noted that this technique modification should not be assumed as a preventative method, in this author's opinion. One reason for long-distance rowing is to commit the motions to 'muscle memory'. If less protraction and retraction is utilised over long distances, this will be transferred over to race technique, which is inappropriate. Also, if these muscles are not being significantly used until a race situation, the rower may strain a muscle or cause further injury. The athlete instead should focus on strengthening any imbalances in serratus anterior[47] or external obliques. In the early return-to-sport phase this modification of technique may, however, prove beneficial.

Furthermore, costovertebral and costotransverse joint stiffness may prove to contribute to the onset of a stress fracture.[3,39] Stiffness decreases the ability of these joints to dissipate forces surrounding the rib cage.

Lastly, female sex steroid hormones are postulated to be involved in the pathogenesis of rib stress fractures. Amenorrhoeic rowers may have a higher incidence of stress fractures in this area because of decreased bone density.[40] Another potential reason is the relatively underdeveloped upper body strength as compared with male rowers.[10]

5.3.2 Assessment

Signs and symptoms range from generalised pain in the rib area, which persists with the activity and gradually becomes more specific,[48] a palpable bony callus with point tenderness, to a more severe presentation as the rower finds pain worse with deep breathing or rolling over in bed.[1] Fractures are located most often on the antero- to posterolateral aspects of ribs,[5-9] similar to those seen with stress fractures secondary to coughing.[6] Examination may uncover a positive rib spring,[6] and reproduction of pain during movements mimicking the rowing motion.[48] Bone scan is particularly helpful in diagnosis, as positive radiographic evidence may take 2–3 months.[1] Because of the complexity of the above factors, it is also advised that kinetic chain malfunctions or abnormalities distal to the site of injury should be evaluated when treating any thoracic injury.[49]

5.3.3 Management of Injury

Treatment is relative rest for 4–6 weeks. The athlete should be able to do anything he or she wants as long as the activity remains pain-free. This will often involve some time off the water, as avoidance of pain may eventually lead to a change in stroke mechanics. The mechanism of injury should be taken into consideration before prescribing a switch to an opposite side or from sweep to sculling. If an injury is sustained from extensive training on the ergometer, ideally the physician should ask the coach or observe the athlete to detect any aberrations in symmetrical pulling. This may repeat itself on the water in sculling or else aggravate present muscular imbalances. Stabilisation and core strength exercises should supplement the rower's training regimen as soon as they can be performed pain-free. Additionally, many authors recommend strengthening exercises for serratus anterior, which would theoretically lead to increased power and additional loading on the rib cage. In the case of costovertebral and costotransverse joint stiffness, treatment consists of passive mobilisation of the thoracic spine and costovertebral joints. For a more detailed explanation of manual therapy and evaluation, the reader is referred to an excellent review article by Davis and Finoff.[49]

5.4 Costochondritis

A poorly understood condition, costochondritis presents as pain and tenderness on the costochondral or chondrosternal joints without swelling.[48] This type of pathology is more likely to occur in sweep rowing due to the increased moment of rotation at the catch position.

Adduction of the arm on the affected side coupled with rotation of the head towards the affected side may reproduce pain. Inflammation in this area is most likely caused by an increase in pulling at this joint, possibly from adjoining muscles to the rib or a dysfunction at the costotransverse joints (the other attachment of the rib). The thoracic rib cage must be examined thoroughly to ensure adequate rotation segmentally.

Treatment consists of analgesics and reassurance.[48] Costochondritis will usually resolve itself and remains a relatively benign condition.

5.5 Costovertebral Joint Subluxation

Described as a partial or incomplete dislocation of the rib from its articulation with its two corresponding vertebral attachments, costovertebral joint subluxation is less common in rowers than rib stress fractures but can elicit similar symptoms acutely. Thomas[50] describes this injury in rowers as occurring during the recovery phase of the stroke. A rower may catch a buoy or wave unexpectedly and later complain of pain at the level of the sixth and seventh ribs, describing symptoms not unlike those of a rib stress fracture.

Palpation of the thoracic spine will reveal tenderness at the site of injury, and side flexion towards the affected side and rotation will increase pain. Suggested treatment is manipulation and stretching away from the painful side.[50] Taping or strapping along the line of the rib may also be of benefit upon resumption of training.[3]

5.6 Intercostal Muscle Strain

The overuse or stretching beyond the allowable limit of the muscles between the ribs, an intercostal muscle strain results in microtrauma and a corresponding inflammatory response along with pain in the affected tissue. Intercostal muscles are strained during unaccustomed or excessive muscular activity, such as that observed in athletes returning to heavy training after a period of rest or deconditioning.[48]

The rower will present with pain between the ribs, which worsens with motion, deep breathing or coughing, as well as tenderness on palpation. Treatment consists of NSAIDs and curtailing of activity. Myofascial work along with specific rib springing techniques are also indicated.

5.7 Nonspecific Shoulder Pain

5.7.1 Pathophysiology

Shoulder pain can be the result of many factors in rowers, but most typically occurs through overuse, poor technique, or tension in the upper body.

5.7.2 Mechanism of Injury

Significant forces are placed on the shoulder during the rowing stroke, as the scapula is retracted and the humerus is elevated to transfer the forces from the handle to the more powerful legs and back. This places the shoulder at significant risk for pathology. In the rower, the combination most often observed is an anteriorly placed glenohumeral head, a tight posterior shoulder capsule, tight latissimus dorsi and weak rotator cuff muscles.[29] This is exaggerated in the outside shoulder of the sweep rower. One study found that, interestingly enough, rowers are only slightly stronger in their trunk muscles than non-rowing controls.[16] Given the large difference between knee extensor strength of both groups, this comes as a surprise, and may be related to injuries in the thoracic region. Overuse problems or poor stroke mechanics can also lead to problems within the shoulder girdle, such as tendinitis of the rhomboid major and minor groups as well as levator scapulae. In sculling, a common mistake is to activate the upper fibres of the trapezius instead of engaging the mid-to-lower trapezius and latissimus dorsi, causing tightness and pain in those fibres which often radiates into a larger upper shoulder and arm area.

One case study[51] documented a lightweight rower who experienced a clavicular stress fracture, likely a fatigue fracture, due to a sudden resumption of hard training. The authors advise that clavicular stress fractures be included in the differential diagnosis of shoulder pain. Many shoulder problems begin with improper weight-training technique, which should not be overlooked as a possible causative factor.

5.7.3 Assessment

The shoulder actually comprises four distinct joints – the sternoclavicular, acromioclavicular, glenohumeral and scapulothoracic joints. Localisation of the pain and mechanism of injury will often help in diagnosis. In addition, the cervical spine must be thoroughly evaluated, as neck and shoulder problems often coexist. Previous traumatic injuries, such as acromioclavicular joint separation, clavicle fracture or shoulder dislocation can be contributory factors, as can generalised ligamentous laxity. Overuse and muscle imbalance and/or weakness are the most frequent causes of shoulder pain in the athlete. Routine x-ray examinations will demonstrate bony pathology and underlying osteoarthritis, while other tests such as diagnostic ultrasound and/or MRI scans may be necessary to further look at the soft tissues around the shoulder.

5.7.4 Management of Injury

Treatment consists of ice and other pain control modalities; however, long-term care should focus on strengthening imbalances, modifying technique, stabilising the surrounding musculature and stretching in particular the pectoral and latissimus dorsi muscles after activity. Commonly, the rotator cuff and scapular force couples are out of balance, which can lead to impingement and tendonopathies within the shoulder girdle when placed under stress. Rehabilitation should focus on the rebuilding and balancing of these muscles to ensure proper scapular and glenohumeral mechanics. Tight pectoral minor/major and latissimus dorsi can further compound the poor mechanics of the shoulder joint. One should maintain the proper length of these muscles through stretching to avoid the tendency for them to shorten.

Watson[52] recommends centralisation of the humeral head. This involves specific mobilising techniques involving stretching of the posterior capsule, which inevitably tightens due to the very protracted position of the arms at the catch.

5.8 Patellofemoral Pain

5.8.1 Pathophysiology

The abnormal tracking of the patella leads to increased wear of the hyaline cartilage on the undersurface of the patella. This results in an inflammatory response and eventually retropatellar pain.

5.8.2 Mechanism of Injury

As rowing is a non-weight-bearing activity, rowers' knees typically do not sustain traumatic ligamentous or meniscal damage, but rowers may instead experience bouts of generalised patellofemoral pain, which can develop in two ways. First, at the catch, a significant load is placed on the fully flexed knee, which may lead to patellofemoral complaints. Overcompression at the catch will further strain the surrounding ligaments. Secondly, at the finish of the stroke, there is a tendency for the knees to buckle slightly or pop up early. They should be held firmly in extension while the blade is being released in order to align the patella properly. However, the makeup of certain rowing shells prevents the rower from fully extending their legs at the finish, preventing the medial quadriceps muscle, vastus medialis, from functioning.[3] The remaining three muscle bellies of the quadriceps are strengthened throughout the stroke cycle, causing an imbalance, and finally leading to lateral tracking of the patella. The iliotibial band (ITB), which attaches to the patella through the lateral retinaculum, also may play a large role in patellar positioning. The added pull in the outside leg of a sweeper may exacerbate the patellar problem.

Additionally, female rowers may be predisposed to patellar tracking problems due to anatomical considerations; equipment limitations such as foot stretcher angle or wide foot placement may further compound the problem.[1]

5.8.3 Assessment

Assessment of a rower presenting with generalised knee pain should include a history of previous injury (such as patellofemoral dislocation or subluxation), locking, swelling, or giving way. Patellofemoral pain is generally dull, localised to the retropatellar area, and worse with going up or down stairs or sitting with the knee bent for prolonged periods of time (positive 'theatre' sign). Lateral tracking of the patella may be evident with knee flexion, and malalignment such as genu valgum ('knock-kneed') or genu recurvatum (hyperextension of the knees), along with excessive pronation of the foot or internal tibial torsion, may increase the abnormal mechanical forces on the joint. It is not unusual for the athlete to experience crepitus in the joint and mild swelling, but a large knee effusion or significant locking or catching should suggest other diagnoses such as meniscal pathology.

5.8.4 Management of Injury

Treatment consists of strengthening the vastus medialis obliquis muscle, which can ameliorate patellar tracking and improve symptoms. Often, taping the patella to prevent tracking can also help in the short term. Bracing is not advised due to the potential limitation to range of motion. Modifying the position of the shoes in the boat with or without heel wedging is a simple yet effective way to alleviate symptoms, along with the standard conservative treatment of ice and NSAIDs.

5.9 Iliotibial Band Friction Syndrome

As the iliotibial tract slides over the lateral condylar prominence of the knee, inflammation and pain can result from friction, leading to this common complaint. Full knee compression at the catch, coupled with varus knee alignment, may contribute to lateral knee pain in rowers.[1] This is caused by friction of the ITB over the lateral femoral condyle at end range extension. Rowers who abruptly switch to running often encounter similar problems. This may be due to underdevelopment of the gluteus medius muscle.

ITB friction syndrome is almost always associated with tightness of the ITB and weakness of the hip abductors. Pain can occur on the lateral aspect of the knee where the ITB crosses a bony protuberance (Gerdy's tubercle) or less commonly higher up the leg where it is stretched over the greater trochanter (trochanteric bursitis). The remainder of the knee examination is usually normal. Unilateral ITB symptoms should always prompt further examination for leg length discrepancy or pelvic malalignment.

Stretching the ITB and strengthening the hip abductors are the key to successful rehabilitation, along with stretching, massage and taping.

5.10 Forearm and Wrist

5.10.1 Pathophysiology

Forearm and wrist injuries are relatively common in the rower. The most common injuries include exertional compartment syndrome (ECS), lateral epicondylitis, deQuervain's and intersection syndrome, and tenosynovitis of the wrist extensors (also known as 'sculler's thumb'). These injuries in the general population are most often due to excessive wrist motion, and the sport of rowing is no exception.

5.10.2 Mechanism of Injury

Most often, forearm and wrist problems can be traced back to poor technique or fatigue. Both forearm tendinitis and tenosynovitis are commonly seen in the rower, and excessive wrist motion during the feathering action is usually to blame.

Proper technique includes having a relaxed grip and controlling the movement of the oar as it feathers (turning the oar so that it moves parallel to the water on the recovery) and squares (perpendicular to the water for proper blade entry, drive and release). The rowing stroke has components of ulnar deviation at the release, coupled with varying degrees of flexion and extension. Sweep rowing involves feathering the blade with the inside arm only (the arm closest to the blade), while the outside arm stays loose and controls the height of the blade off the water, among other things. For both sweepers and scullers, the handle should roll easily, using the palm and fingers without excessive use of the thumb or wrist.

Many factors contribute to forearm and wrist problems in rowers. Wrongly sized grips, poor rigging, and wet or rough conditions can cause the rower to use excessive wrist motion. This may lead to an inflamed tenosynovium.[53] 'Sculler's thumb' – hypertrophy of the muscle bellies of abductor pollicis longus and extensor pollicis brevis[54] – may arise due to improper use of the thumb to feather the oar at the finish of the stroke, or allowing the palm to slide down the grip while keeping the thumb locked against the end of the handle. This hypertrophy compresses the underlying radial extensor tendons, leading to swelling over the dorsal aspect of the forearm.

Forearm problems have been observed more commonly in inexperienced rowers, due to an inability to relax at the finish of the stroke when the oar is being extracted from the water, as well as poor stabilising techniques in the shoulder and trunk (unpublished observations). Also common at all levels is improper initiation of the pull-through with the elbow and not the shoulder girdle. These factors can lead to ECS, a problem most commonly found in the lower extremity (often the volar compartment) but also found in racquet sports as well as rowing.[55]

A study by du Toit et al.[56] found that environmental conditions during racing situations such as fast flowing water and high winds, along with improper use of the wrist, also contributed to a higher incidence of tenosynovitis in canoeists. An overly tight grip of the oar handle is typical in colder weather.[3] This is corroborated by Nowak and Hermsdorfer[57] who observed that cooling of the digits of the hand resulted in higher grip forces due to reduced sensory feedback.

5.10.3 Assessment

The most important first step in assessment is to establish the site of pain. The most common tendinitis of the wrist in athletes, DeQuervain's syndrome, is also known as tenosynovitis of the first dorsal compartment.

Intersection syndrome, also known as 'oarsmen's wrist', is commonly misdiagnosed as DeQuervain's tenosynovitis.[58] This syndrome involves the second dorsal compartment muscle bellies of extensor carpi radialis longus and brevis, although it remains controversial as to whether friction from the crossover with the muscle bellies of abductor pollicis longus and extensor pollicis brevis in the first dorsal compartment plays a role.[58]

Lateral epicondylitis is characterised by pain over the lateral aspect of the elbow as well as with resisted wrist extension.[1] If ECS is suspected, intercompartmental pressure is measured at rest and immediately after the exacerbating activity. Diagnosis is confirmed if pressure remains elevated for a prolonged period of time post-exercise. 'Sculler's thumb' may be observed as swelling over the dorsal aspect of the forearm,[54] due to the compression of the radial extensor tendons caused by the hypertrophy of abductor pollicis longus and extensor pollicis brevis.[54]

5.10.4 Management of Injury

Conservative treatment may involve stretching, deep tissue massage, myofascial release techniques, acupuncture, stretching techniques, and bracing or taping. Ice and NSAIDs will normally diminish acute pain and swelling, and the problem should resolve itself if adequate rest is taken from the exacerbating activity. When these fail, cortisone injection is often very successful. Immobilisation and surgical intervention is usually only required in the more severe cases.

It is beneficial at times to train on the ergometer where no feathering is involved if this action is the source of pain. However, a loose and relaxed grip should be promoted and excessive wrist motion discouraged in order to improve symptoms over the long term. A 'tennis elbow' brace may be helpful and a looser grip should be encouraged upon return to the water. An excellent preventative strategy in colder weather is to adopt the use of fleece 'pogies', which cover the outside of the hands while still allowing the palm to grasp the handle of the oar.

5.11 A Word on Weight Lifting

Weight lifting can occasionally present a problem to rowers, as it tends to be an add-on to strenuous endurance training on the water and is usually not as well supervised by coaches and trainers. Additionally, rowers are typically tall and lean with long limbs, while weight lifters are normally shorter, with greater bulk and shorter limbs. Problem exercises to be aware of include back extensions, cleans and deadlifts. These exercises are normally a great addition to a weight-lifting programme but must be taught and supervised appropriately. Weight lifting has been implicated in the development of rib stress fractures[6,39] and low back injuries,[10] among others. It is strongly recommended that an athlete who is serious about rowing work on core stability exercises and Pilates work before even attempting weight-lifting exercises. This will be the best complement for avoidance of injury whether in the gym or on the water.

6. Dermatological Issues

6.1 Blisters

Rowing blisters (figure 3) are found on the anterior aspects of the fingers and palm. They are caused by excessive friction with the oar handle, leading to separation of the skin layers and subsequent fluid accumulation between them. Blisters can become very painful to the rower and may lead to infection ('sausage fingers') if not cared for properly in the acute stages.

6.1.1 Management of Injury

Rowing itself will usually take care of the problem, as the majority of blistering occurs in rowers who have been training on land for several weeks and have recently returned to on-water practices. However, there are certain precautions to consider to prevent significant blistering: making sure wooden sweep handles are properly scrubbed and smooth, present blisters kept clean and pliable, and assuring proper grip material for scullers. Over time, rowers develop calluses in the palm of the hand that need to be trimmed regularly. Tape can be used but may cause further blistering if not applied properly. Watching for signs of infection is key to proper management. Open blisters in contact with handles that are shared among team members can increase exposure to infection. One study has shown an increase in the incidence of hand warts among crew members even with intact hands.[59] It is of note that even when hands are healed, new blisters may appear with changes in equipment, humidity, or intensity of training.[3]

Fig. 3. Rowing blisters are the result of excessive friction with the oar handle, leading to separation of the skin layers and subsequent fluid accumulation between them.

6.2 Abrasions

6.2.1 Sculler's Knuckles

Sculler's knuckles, slide bites and rower's rump are abrasions that commonly occur in rowing. They are not usually significant injuries, but should be monitored closely for signs of infection. Scullers may experience abrasions on the dorsal aspect of the right hand, superficially at the proximal interphalangeal joints or the metacarpal phalangeal joints of the first and second digits. This is due to a part of the stroke termed the crossover, whereby the sculler crosses the left hand over the right while simultaneously attempting to keep the handles at a similar height to maintain balance. Inexperienced scullers or inclement weather conditions can cause the rower to bang his or her right knuckles on the handle or hand above, occasionally leading to significant bleeding and pain.

6.2.2 Slide Bites

Novice scullers should have a larger gap between handles (height can be modified on the oarlocks) and also told to keep nails trimmed to avoid severe lesions. Gloves are not advised, as they are thought to inhibit the subtle movements of the palms and fingertips throughout the stroke cycle. Additionally, gloves may cause a decrease in proprioception and therefore a loss of sensation of where the blade is positioned in the water. Weight-room or cycling gloves may also increase friction, leading to further blistering of the palms.

Slide bites or track bites are abrasions that occur on the posterior aspect of the lower leg (figure 4). When a rower pushes his or her legs down through the drive phase, the tracks for the sliding seat sometimes dig into the calf muscles and over time lead to abrasions and scarring. Rowers can wear cut-off socks or tape to protect the area, and modify positions of the tracks if possible.

6.2.3 Rower's Rump

Abrasions on the buttocks from an improperly fitted seat are also fairly common in the rowing population, and can range from slight indentations to skin ulcerations secondary to repetitive chafing.[8] One case study[60] described a 69-year-old man presenting with itching and thickened skin on the buttocks for 3 years as a result of using a homemade rowing machine. He is described as having "well marginated, lichenified plaques on the upper aspect of each buttock that corresponded exactly to contact with the seat of the rowing machine". Treatment included regular application of corticosteroids and a seat cushion when use of the machine resumed. The authors coined the term 'rower's rump' for rowing-associated lichen simplex chronicus, and advise careful selection of rowing machines with properly fitted and padded seats.

Fig. 4. Slide bites or track bites are abrasions that occur on the posterior aspect of the lower leg.

7. Miscellaneous Injuries

7.1 Body Composition Issues and the Female Athlete Triad

Rowing as a sport is divided into two weight categories: lightweight and heavyweight. Although the numbers vary slightly across the various levels and organisations, typically the cut-off weight is 130lb (59kg) for women and 160lb (72.5kg) for men. Any weight classification event is liable to encounter body composition and disordered eating issues, and rowing is certainly not exempt.[61] Although most often observed in lightweight rowers, disordered eating habits can also occur in heavyweight rowers, more commonly women.[61] This is most likely due to a large number of factors but may reflect societal values. One interesting study highlights the 'limited value' of setting specific body composition targets for rowers.[62] The authors measured body composition of elite heavyweight oarswomen using five different methods and found a range of 13.6–29.3% in this population. This is contrary to the former view that the critical level of body fat in female Olympic athletes should be 9–11%.[63]

7.1.1 Mechanism of Injury

In the case of lightweight rowing, it is assumed to be to the advantage of the rower to be as close as possible to the maximum weight. Weigh-ins are commonly performed hours before a race, therefore, many rowers decide to sweat off some weight by going for sweat runs or using laxatives and/or diuretics. These types of weight-reduction techniques have been shown to negatively affect plasma and blood volume, stroke volume and cardiac output, endocrine function and thermoregulation.[64]

7.1.2 Assessment

Assessing the rower for the female athlete triad (combination of disordered eating, amenorrhoea and osteoporosis) should include screening of gynaecological function and nutrition, including menstrual history, length and frequency of periods, use of medication or hormonal therapy, desire to lose weight, and diet and weight history.[65] History of stress fracture or increases in quantity and intensity of training can also be helpful. Amenorrhoea can often be the first warning sign and should prompt follow-up.

7.1.3 Management

Koutedakis et al.[66] studied the effects on performance of using two different periods of weight reduction with elite lightweight rowers. The first period was 6–8 weeks of weight reduction, which resulted in a reduction in all physical performance parameters measured ($\dot{V}O_{2max}$, respiratory anaerobic threshold, upper body peak power and mean power, and knee flexor and extensor strength). The second period of 16–17 weeks, however, was associated with a beneficial influence on each performance parameter, excluding a non-significant decrease in mean power. However, it should be noted that in many cases rowers might attempt to lose weight in even shorter periods of time than described in the literature.

For athletes already diagnosed with the triad disorders, the reader is referred to management strategies outlined in a review article by Lebrun and Rumball.[65]

7.2 Environmental Exposure

The very nature of rowing demands long training hours in an outdoor setting. Rowers are subject to varying weather conditions, from hot, humid weather in the summers to cold, dry, snowy conditions during the winter months. Exposure to the environment cannot be avoided, but can be controlled to a certain degree. In the summer months, hydration status should be closely monitored. Pronounced or prolonged sweating can lead to dehydration and loss of electrolytes.[67] It is advisable to drink sport solutions containing carbohydrates and electrolytes to replace fluids during longer training sessions. Heat adaptation and acclimation requires 5–15 days and should be considered before racing is undertaken in a warmer environment.[67] Sun protection is also very important, as the rower experiences both direct sunlight as well as light reflected off the water. During the colder months, layering is advised with wind barrier fabric if necessary.[67] Fleece ‘pogies’ are designed to protect the hands while also allowing grip of the handle with bare hands. Hats are also recommended. It is particularly important for the coach boats to supervise rowers closely in this type of weather, especially as the water turns colder. Flipping, or tipping the boat as it is sometimes referred to, is more dangerous during this time than at any other point in the season due to the icy waters. In general, a coach boat should be in proximity whenever possible, and waves and weather patterns should be monitored closely. By no means should a rower be on the water in a lightning storm. Rowers should make sure that adequate clothing is worn for the ambient temperature and that all equipment is in good working order. Lifejackets are a requirement and should be stored in the boat in an easily accessible location.

8. Conclusion

Prevention is by far the best option. The last few weeks preceding the on-water or competitive season are ideal for scheduling the preparticipation physical examination (PPE). During this examination, the clinician is in an ideal position to assess general range of motion, flexibility, and any existing muscle asymmetries or strength deficiencies. The PPE also presents an opportunity to educate the rower on ways to decrease his or her chances of getting injured. There are several points to keep in mind when discussing preventative methods with the athlete:

- There is always the potential for injury when switching abruptly from land-based winter training to water training, and vice versa. If the rower is accustomed to two rowing practices a day and switches immediately to two ergometer sessions daily, injury risk is greatly increased.
- Rowers should ease into strength training if not accustomed to doing weights. When initiating a weight programme, it is beneficial for the rower to start off light for the first week as the body adapts.
- Cross-training sessions should be added to the programme, particularly during the winter months, to counteract or prevent any muscle imbalances.

- Core strength cannot be overemphasised. Weak abdominals contribute to lower back pain. This is evidenced in sweep rowing particularly, as good obliques are linked to earlier return of proper posture throughout the drive.[1]
- Encourage the rower to stretch, particularly the lower extremity and lumbar region. Inflexibility may lead to hyperflexion at the catch, and possible injury.

By far, the most logical preventative measure to be taken is avoidance of sharp increases in intensity or volume without adequate rest and recovery. If the athlete has been training indoors for several months or is returning from an injury it is wise to gradually increase time spent on the water. Rowers should be comfortable with the equipment and rigging. It may be advisable to decrease the load on the oars or the drag on the ergometer to prevent early overuse injuries.

Although the majority of overuse problems are described in depth in the literature, there is a paucity of information regarding specific rowing injuries and treatment. This is especially true of one of the most common and debilitating rowing injuries: the rib stress fracture. Further research is also warranted to establish the prevalence of injuries in the rowing population. Most importantly, the research undertaken in this population should be well designed, clinical, and critically reviewed, not simply anecdotal.

Physicians, physiotherapists, athletic trainers and other healthcare practitioners would gain considerably by working together to be educated about the intricacies of the sport and specific rowing injuries, allowing improved detection and prevention and providing a safer and more enjoyable environment for rowers of all ages and abilities.

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