Review Article

Golf Injuries: Epidemiology, Pathophysiology, and Treatment

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Abstract

Increasing numbers of people are playing golf. Golf is a unique sport in that the ability to participate at a high level is not limited by age. In addition, participants tend to play more rather than less as they grow older. Injuries can occur at any point during the golf swing, from takeaway through follow-through. Upper extremity injuries can affect the hands, elbow, and shoulder and are usually a result of the golf swing at impact. Injuries are also common in the lower back as well as the lower extremities. Most injuries are the result of overuse and poor swing mechanics. When treating golfers, it is important to have a good understanding of the biomechanics and forces of the golf swing to diagnose and manage the vast spectrum of injuries incurred in this sport.

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Participation in the game of golf peaked in the middle of the first decade of the 21st century and has declined slightly since then because of the economic downturn. Despite this decline, in 2009, the National Golf Foundation reported that 25.6 million people in the United States participated in the sport.[1] Golf remains a popular sport because participants can be young or elderly, male or female, and of modest income or great wealth. A high level of performance in golf is not limited by a person's age. Golf injuries can be either acute or chronic, resulting from overuse. Most injuries are the result of overuse, and left untreated, they can lead to chronic musculoskeletal problems.[2] Common injuries have been documented in the low back, elbow, shoulder, wrist, and knee.[2-4] When treating golfers, it is vital to have a general knowledge and understanding of the golf swing and swing biomechanics in addition to the orthopaedic injuries themselves and management options.

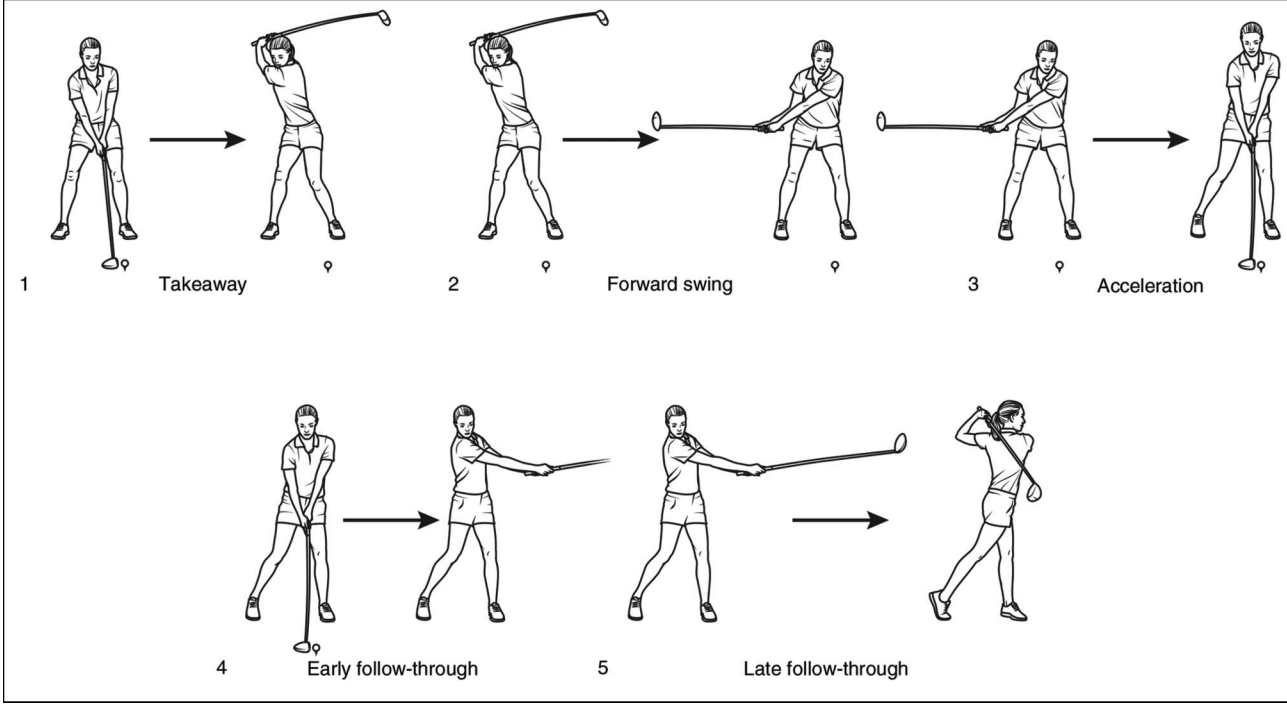
Kinematics and Biomechanics

To effectively understand the injuries and ailments that can affect golfers, it is important to have an understanding of the golf swing and the forces and motions involved from the lower extremity, through the trunk, and into the upper extremities. The golf swing can be divided into five phases: takeaway, forward swing, acceleration, early follow-through, and late follow-through[5-7] (Figure 1). The authors of several studies have examined muscle activity in the forearm, shoulder, scapula, and trunk.[5,7-11] All body side references discussed in this article pertain to right-handed golfers.

Shoulder and Scapula

The golf swing, although not a strenuous motion on the shoulders, is a rapid movement and requires the coordinated firing of the rotator cuff and scapular muscles to protect the glenohumeral joint. Both the infraspinatus and supraspinatus seem to

Figure 1



The five phases of the golf swing, as shown for a right-handed golfer.

be most active on electromyography (EMG) during the extremes of shoulder motion, where they act as external rotator and abductor muscles, respectively. According to Pink et al,[9] in professional golfers, the right infraspinatus exhibits the most activity during takeaway and the left infraspinatus exhibits greater activity during the follow-through phases. The right subscapularis shows highest activity during the acceleration phase as the right shoulder undergoes rapid internal rotation. The left subscapularis is mostly active during takeaway when the left shoulder is in maximal internal rotation. Kao et al[10] analyzed the scapular muscles in 15 low-handicap (<5 [proficient]) golfers during the golf swing. They found that the upper, middle, and lower trapezius act together to help retract the scapula with activity in the trailing arm primarily during takeaway and with activity in the leading arm during acceleration. The scapula is protracted by the upper and lower serratus anterior with activity in the trailing arm primarily during acceleration and early follow-through. All scapular muscles assist in a coordinated biscapular motion with clockwise rotation around the trunk during takeaway and counterclockwise rotation throughout the remainder of the swing, maximizing swing arc.

Trunk

Watkins et al[7] examined trunk muscle activity in professional golfers using EMG and found that muscle activity during takeaway is relatively low overall. During acceleration, all trunk muscles are active to generate power to drive the ball. The left gluteus shows higher activity than the right because it serves as a stabilizer over the right-side muscles' so-called pushing off effect. During early follow-through, overall trunk muscle activity decreases compared with the acceleration phase, but the abdominal oblique muscles remain relatively active. The activity in the right abdominal oblique, which is higher than that in the left abdominal oblique during acceleration, decreases; activity in the left abdominal oblique remains fairly constant. During follow-through, the entire trunk is decelerating with a decrease in trunk muscle activity.

Forearm

Farber et al[5] examined the forearm musculature in both professional and amateur golfers using EMG. Substantial differences were noted in muscle activity between groups. Extensor carpi radialis brevis (ECRB) muscle activity in the lead arm (left arm in a right-handed golfer; right arm in a left-handed golfer) peaked during the acceleration phase in amateur golfers and during the forward swing phase in professionals. ECRB activity in the

trail arm of the amateurs peaked in the acceleration phase. In the professional golfers, ECRB activity in the trail arm decreased during forward swing and increased during acceleration. Pronator teres (PT) activity was relatively low in the lead arm of both amateurs and professionals. PT activity in the trail arm peaked during forward swing in amateurs and professionals. Professional golfers tended to have increased PT activity in their lead arm and decreased activity in their trail arm compared with the amateurs, likely reflecting superior swing technique in professionals who pull the golf club through the arc with their lead arm rather than push it with their trailing arm. The flexor carpi radialis muscle activity of the lead arm peaked during forward swing in the amateur group and during acceleration in the professional group. Flexor carpi radialis activity in the trail arm of both amateur and professional golfers peaked during forward swing. Flexor carpi ulnaris muscle activity in the lead arm and trail arm peaks during forward swing in both amateur and professional golfers.

Hip and Knee

Bechler et al[12] examined EMG activity in the hip and knee musculature of competitive golfers. The authors found that pelvic rotation was initiated during forward swing by the trail hip extensors and abductors in conjunction with the lead adductor magnus. The lead hamstrings kept the knee flexed to provide a stable base for pelvic rotation. Peak EMG muscle activity recorded in the hips and knees generally occurred earlier than in the trunk and shoulder, confirming the sequential muscle firing pattern that occurs during the swing phase in competitive golfers. As with baseball batters, golfers experience rotational velocities about the hip in a closed kinetic chain.[13] According to a study examining hip rotational velocities during the forward swing and acceleration phases, the lead hip (left hip in a right-handed golfer; right hip in a left-handed golfer) experiences a substantially higher internal rotation velocity compared with the trail hip external rotation velocity.[13] This higher rotational velocity in the lead hip likely influences the overall stresses acting on the hip.

Epidemiology of Injuries

Little epidemiologic literature exists on golf injuries. McHardy et al[3] performed a 1-year prospective study on injuries in 588 golfers in Australia. The overall incidence for rate of injury was 15.8 injuries per 100 golfers (range, 0.36 to 0.60 injuries per 1,000 hours per person); 46.2% of injuries were reportedly sustained during the golf swing, and injury was most likely to occur at the point of ball impact (23.7%). Studies have shown that the low back is one of the most commonly injured sites, followed closely by the elbow/forearm, shoulder/upper arm, and foot/ankle.[2,4,8,14]

Respondents to a survey by McCarroll[15] noted that too much play or practice (ie, overuse) was the most commonly reported mechanism of injury in both professional and amateur golfers. In a survey of 193 amateur golfers, Batt[4] found that poor swing mechanics and overuse were the two most cited causes of injury. In a retrospective cohort series by Gosheger et al[2] examining injuries in 703 golfers (643 amateurs [71% of them male], 60 professionals [90% of them male]) during two golf seasons, 82.6% of reported injuries involved overuse and 17.4% were single-trauma events. Professional golfers were injured more often overall. More elbow injuries were sustained by the amateur golfers. Carrying one's golf bag was shown to be associated with a higher risk of injury to the low back, shoulder, and ankle. Warm-up routines lasting ≥10 minutes had a positive effect in reducing injury rates.

Specific differences in swing biomechanics were noted between high-handicap (ie, amateur) and low-handicap (ie, professional) golfers; these biomechanics can affect the relative risk of injury. High-handicap golfers attempt to generate more power and club speed using their upper extremity strength rather than their trunk rotation. Such use of the upper extremity results in greater spinal torque and lateral bending forces on the lumbar spine, resulting in greater swing variability. The superior balance and flexibility of low-handicap golfers allow for greater trunk rotation on the downswing and larger angular velocities for the club shaft, trail elbow extension, and wrist extension.

Shoulder Injuries

The golf swing requires a coordinated effort of the rotator cuff and scapular muscles.[9,10] The shoulder region is a common source of pain in golfers, mostly secondary to rotator cuff disease and subacromial impingement involving the lead shoulder.[2,4,6] Golfers often experience symptoms in the shoulder at extremes of motion, such as at the top of the takeaway phase or the end of the follow-through phase.

Subacromial impingement pain can occur in golfers when the rotator cuff impinges between the greater tuberosity and the acromion. This impingement can result in rotator cuff tendinitis or partial tears.[16] General nonsurgical treatment options include a trial of physical therapy, NSAIDs, and cortisone

injections. When nonsurgical management fails, surgery may be indicated. Vives et al[17] studied 29 recreational golfers (mean age, 60 years) who underwent surgery for subacromial disease and rotator cuff tears. At a mean follow-up of 3 years, all but three patients had returned to their prior level of play. The authors concluded that acromioplasty and rotator cuff repair could predictably allow for eventual return to pain-free golfing. Internal impingement, such as that seen in overhead athletes, can also occur in golfers.[16] The lead shoulder is in maximal adduction during takeaway, causing the humeral head and rotator cuff to impinge against the glenoid and anterior labrum. The lead shoulder then moves to abduction and external rotation at the end of follow-through, causing cuff impingement against the posterior labrum and glenoid rim. This can result in articular-sided rotator cuff tears, labral tears, and lesions to the articular cartilage of the humeral head.

The acromioclavicular (AC) joint can be a common source of pain in golfers. Mallon and Colosimo[18] found that repetitive adduction of the lead shoulder at the top of the takeaway phase added increased loads on the AC joint. Of 35 professional or low-handicap golfers studied, 53% had AC joint disease that caused their shoulder pain. All but one returned to competition after treatment with physical therapy, swing modification, and steroid injections; distal clavicle excision was performed when nonsurgical management failed.

Glenohumeral instability, both anterior and posterior, has been reported in golfers. Low-handicap golfers will attempt to maximize their shoulder turn relative to their hip turn to generate more power during the swing.[19] This can result in repetitive microtrauma to the capsulolabral tissues. This repeated overuse, which in some golfers is superimposed on an element of hyperlaxity, can result in symptomatic instability. The lead arm can be susceptible to anterior instability when it is in maximal abduction and external rotation during the end of follow-through. Initial treatment is nonsurgical, with a structured physical therapy program focusing on strengthening the rotator cuff and scapular stabilizers. When nonsurgical management fails and symptoms persist, surgical stabilization may be indicated. In one case report, a professional golfer with anterior shoulder pain who demonstrated anterior instability on physical examination was initially treated with physical therapy.[16] However, that nonsurgical treatment was unsuccessful, and the patient subsequently underwent open capsulolabral reconstruction. The patient resumed tour play 1 year postoperatively. The golfer with posterior instability may also experience a popping or clunking sensation associated with pain in their lead shoulder during transition from takeaway to forward swing. In 2002, Hovis et al[20] reported on the surgical management of posterior instability in six elite golfers using arthroscopic posterior thermal capsulorrhaphy. All six golfers returned to play at a mean of 4 months postoperatively. Given the improvement in arthroscopic technique since that particular study, we would recommend against the use of thermal capsulorrhaphy; instead, we are proponents of arthroscopic capsular plication or labral repair, débridement of partial rotator cuff tears, and subacromial decompression in accordance with the underlying pathology for patients in whom nonsurgical treatment is unsuccessful.

Superior labrum lesions and disorders of the biceps can also occur in golfers. General nonsurgical treatment options include a trial of physical therapy, NSAIDs, and cortisone injections targeted to the glenohumeral joint and the biceps sheath. When nonsurgical management fails, surgery may be indicated. Anterior and posterior labral fraying has been described in two case reports on professional golfers.[16] To our knowledge, no studies describe the incidence, management, or outcomes of superior labrum anterior to posterior lesions. However, we have seen these disorders in both amateur- and elite-level golfers in our practice. Surgical management includes arthroscopic débridement, repair, biceps tenotomy, or tenodesis, depending on the extent of the lesion. Superior labrum anterior to posterior tears will often cause pain in the lead shoulder during the end of the takeaway phase or the beginning of forward swing, when the lead arm is in cross-body adduction. In persons with isolated biceps tendinitis, pain is experienced during late follow-through, when the lead shoulder is in maximal abduction, external rotation, and extension (Figure 1).

Golf is a unique sport in that it is played by an older population in which degenerative joint disease of the shoulder may be prevalent. Arthroplasty has been successful in this population. In one retrospective review of 24 patients who underwent total shoulder arthroplasty, 23 returned to golf at a mean of 4.5 months postoperatively.[21] The mean patient age at time of treatment was 52 years (range, 26 to 72 years). At 53-month follow-up, no patients reported substantial pain or had evidence of component failure.

Elbow Injuries

Both amateur- and elite-level golfers are susceptible to elbow disorders; injury most often results from overuse.[2,22] Some golfers have a tendency

to grip the club very tightly, which also can cause strain. Trauma to the elbow can occur when hitting the ball "fat" (ie, allowing the club head to strike the ground before hitting the ball) or when hitting through heavy rough (ie, thick, high grass). This results in a sudden deceleration that places high strain on the forearm flexors.

Lateral epicondylitis in golfers typically affects the lead arm. The ECRB and extensor muscles help stabilize the left wrist at ball impact. Hitting the ground firmly at impact places additional stress on the muscles; overgripping also can cause stress. Signs of lateral epicondylitis include tenderness over the origin of the ECRB and pain with resisted middle finger extension. The mainstay of treatment is nonsurgical and includes limitation of play and use of NSAIDs. After the pain subsides, a focused course of stretching of the ECRB and ECRL, forearm strengthening, and therapeutic modalities (eg, ice, ultrasound, deep tendon friction, electrotherapy, acupuncture) should be implemented. Cross-friction massage of the common extensor muscle mass and myofascial release are often used as therapy, although more studies are needed to assess whether such therapy results in improved pain and function.[23] Lateral epicondylitis from overgripping may be a sign of proximal weakness. Therefore, glenohumeral and scapular stability must be treated during rehabilitation. Cortisone and platelet-rich plasma injections have been used with varied results.[24] Corticosteroid injections can help with pain but have not been shown to improve outcome compared with placebo in a randomized trial.[25] Forearm straps and wrist splints also can provide symptom relief.[26] A change in club equipment, such as a transition from heavy steel shafts to lighter graphite shafts, may also help golfers with epicondylitis. Some golfers will resort to a wider grip to reduce stress on the lateral epicondyle. Successful outcomes with either open or arthroscopic surgery have been shown if an extensive course of nonsurgical management is unsuccessful.[27,28] The senior author's (O.L.) preferred surgical treatment is an open repair in which the extensor interval is developed, pathologic tissue is débrided and removed, and the extensor origin is reattached to the lateral epicondyle after performing a side-to-side repair.

Medial epicondylitis typically involves the trailing arm in golfers.[5,29] Hitting the ball fat or repetitive hitting off of artificial mats can result in medial epicondylitis. A common mistake when swinging the club is to push the club through the swing with the trail arm during forward swing and acceleration. Players with better swing mechanics will use their lead arm to pull the club through the swing, as suggested by the difference on EMG in PT activity in professional and amateur golfers.[5] Nonsurgical treatment consists of rest, NSAIDs, physical therapy, bracing, and injections. When nonsurgical management is unsuccessful, open débridement of pathologic tissue from the common flexor origin and repair of the defect to the medial epicondyle should be considered.

Wrist Injuries

Both wrists must move through an extensive range of motion (ROM) to execute a proper golf swing, and wrist injuries are common in both amateurs and professionals.[2,3,15,22] Injuries are most common in the lead wrist.[30] Amateurs are at great risk for wrist injury if they hit their shot fat. In professionals, acute wrist injuries usually occur when firm ground is struck or when hitting out of very heavy rough. The wrist is also susceptible to overuse injury that typically involves the lead hand, such as tendinitis. Pain from tendinitis of the flexor carpi ulnaris and extensor carpi ulnaris (ECU) may be experienced during the top of the takeaway phase when the lead wrist moves into excessive radial deviation. Injury and pain at the wrist also can occur immediately after ball impact during early follow-through when the lead wrist undergoes ulnar deviation and supination that may result in an ECU instability and tears of the triangular fibrocartilage complex (TFCC).

A sudden, forceful impact to the wrist resulting from striking the ground before the ball may cause disruption of the ECU tendon sheath, which can result in a painful snapping sensation when impact causes wrist supination, ulnar deviation, and flexion. Initial treatment should include rest and splinting of the wrist in extension, radial deviation, and supination. If symptoms do not resolve, repair of the tendon sheath may be necessary.[31-33]

The repetitive rotation motions seen about the wrist can put the TFCC at risk for tears. Golfers will present with ulnar-sided wrist pain and may have a palpable click with forearm rotation. Initial treatment involves rest, immobilization, NSAIDs, and steroid injections. Most TFCC issues can be managed with therapy, including cross-friction massage followed by ice massage and rest. Supportive taping and bracing can be implemented to help a player get through a round or tournament. If nonsurgical management is unsuccessful, surgical treatment can be recommended; the specific treatment will depend on the size and location of the TFCC tear.[34,35]

Fractures of the hook of hamate have been reported in golfers. A forceful strike to the ground with the head of the club may cause the hook of hamate to fracture in the hand holding the end of the club. Tenderness can be elicited with direct

palpation over the hook of hamate. Radiographs and sometimes a CT scan may be necessary to confirm the diagnosis. Initial treatment should involve wrist immobilization and rest. If symptoms persist, surgery may be considered to excise the hook of hamate.[36]

Low Back Injuries

The golf swing can produce large loads in the spine and back musculature. The back has been cited as the most common source of injury for the golfer.[3,14] High compression, shear, lateral-bending, and rotational loads exist in the lumbar spine during the golf swing, and the compression loads represent forces equivalent to approximately eight times body weight.[37,38] Low back pain (LBP) can be a result of a traumatic event, but more often, it has an insidious onset in the golfer and is associated with a process known as the cumulative load theory.[39] The distribution of stress placed on the back during the golf swing is asymmetric. This is a result of the asymmetric trunk velocity during the takeaway phase, which is slower compared with the forward swing and follow-through phases. LBP has been found to occur more commonly on the trail side.[39] Based on the analysis of forces created by the golf swing, golfers are predisposed to muscle strains, herniated nucleus pulposus, stress fractures of the vertebral body and pars interarticularis, spondylolisthesis, and facet arthropathy.[37]

In caring for golfers with back pain, specific aspects of different types of golf swings must be understood. The modern golf swing emphasizes a large shoulder turn with restricted hip turn by keeping the lead foot flat on the ground throughout the swing. This creates a large hip-shoulder separation angle (ie, X-factor) that increases torsional loads in the spine and stretches the viscoelastic elements.[39] The classic golf swing emphasizes reducing the hip-shoulder separation angle by raising the lead heel during the takeaway to increase hip turn, which results in reduced torque on the spine. With the modern swing, the golfer will experience increased lateral bending and exaggerated hyperextension of the back on follow-through, whereas the classic swing is characterized by an erect I-shaped finish with the shoulders parallel to the ground. This more erect finish is thought to prevent LBP.[40]

Management of LBP should include preventive exercises in addition to ice, rest, and NSAIDs. Stabilization exercises have been shown to reduce the recurrence of LBP in persons presenting with their first episode of LBP.[41] Identifying and treating strength and mobility limitations elsewhere in the kinetic chain can alleviate LBP indirectly. For example, in our experience increasing thoracic rotation ROM through a combination of manual interventions performed by the physical therapist and active stretching performed by the golfer is particularly useful for treating professional golfers with LBP by physical therapists on the Professional Golfers Association (PGA) Tour. Most professional golfers on the PGA Tour engage in pre-round exercise routines designed specifically to emphasize activation and mobility of the scapular, trunk, and hip musculature. Post-round prevention programs focus on improving general flexibility in the large muscles of the low back and hips, as well as treating muscular asymmetries created from repetitive swinging of the golf club. Such asymmetries, if left untreated, may increase susceptibility to injury.

Hip Injuries

Acetabular labral tears have been documented in elite athletes, including professional golfers.[42,43] Golfers experience rotational velocities at their hip during the golf swing that can result in joint stress. Despite this, the incidence of hip injuries secondary to golf is approximately 2.8%.[2] When hip injuries occur, 78% are attributed to overuse.[2] In a 2004 study, Vad et al[44] found a statistically significant correlation between limited lead hip internal rotation ROM and history of LBP in professional golfers. Thus, improving hip rotation ROM, particularly lead hip internal rotation ROM, comprises a substantial portion of pre- and post-round programs for many professional golfers.

In golfers, hip pathology can include femoroacetabular impingement, labral tears, chondral defects, loose bodies, and arthritis. Previously, total hip arthroplasty was the only option for managing debilitating hip pain. With advances in instrumentation and technique, hip arthroscopy has become an option for more golfers, young and older, but arthroscopy has limited indications for osteoarthritis. In a hip arthroscopy study by Byrd and Jones[45] with a 10-year follow-up, two recreational golfers returned to sport by 3 months postoperatively. One was a 70-year-old man who was found to have arthritis and labral damage and who underwent total hip arthroplasty >7 years later. The other was a 34-year-old man with chondral and labral damage.

Knee Injuries

Knee injuries are rare and comprise approximately 4% to 9% of golf injuries.[2,4] Most injuries to the knee are a result of overuse or mechanical faults. One published case report documents an acute bucket-handle meniscal tear in the lead knee of a 42-year-old golfer who was treated arthroscopically.[46]

The golf swing generates forces about the knee that cause internal and external rotation of the tibia on the femur. The knee ligaments and menisci resist these forces. Most pathology of the knee in golfers can be managed nonsurgically with NSAIDs, physical therapy, and corticosteroid injections. In cases of early osteoarthritis, viscosupplementation may provide some relief. Patients with acute or chronic meniscal tears that remain symptomatic after a trial of nonsurgical treatment may benefit from arthroscopic repair or partial meniscectomy. For those with substantial pain and advanced degenerative joint disease, total knee arthroplasty can allow return to golf with minimal modifications.[47]

Ankle Injuries

Despite minimal literature describing golf-related injuries to the foot and ankle, the authors of a 1-year prospective study of 588 golfers found this to be the third most commonly injured site.[3] These injuries occurred mostly secondary to accidents, such as slipping or tripping over something.[2]

Ankle stability is provided by both static and dynamic restraints. Static restraints include the anterior and posterior talofibular ligaments and the calcaneofibular ligament. The peroneal tendons provide the primary dynamic restraint. Although not described in the literature, golfers can sustain ankle sprains as well as tendinopathies[48] about the ankle. Most ankle injuries can be managed nonsurgically with rest, ice, NSAIDs, proprioceptive training, and bracing as needed.

Summary

Although golf is a noncontact sport played at varied intensity, serious musculoskeletal injury can occur when poor mechanics are used. Most injuries in golf are secondary to overuse, and the most common sites of injury are the back and upper extremity. Good conditioning and warming up can help golfers train their body to better withstand the repetitive forces involved in the golf swing. A well-rounded, golf-specific exercise program should emphasize improving strength and stability in the lumbar spine, periscapular musculature, and hips while also maximizing mobility in the hip joints and thoracic spine. It is important for the treating physician to understand the phases of the golf swing as well as the forces and biomechanics about the various joints to properly diagnose and treat golfers at all levels, from recreational to elite.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 25 is a level I study. References 24 and 26 are level II studies. References 2, 20, 28, 36, 41, and 44 are level III studies. References 17, 18, 21, 27, 30-33, 35, 38, 39, 42, 43, and 45 are level IV studies. References 29, 34, 37, 40, and 46-48 are level V expert opinion.

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