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INJURIES IN OVERHEAD ATHLETES (J DINES AND C CAMP, SECTION EDITORS)

Upper Body Injuries in Golfers

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Abstract

Purpose of Review Golf is a sport that can be played by an athlete of any age, which enhances its popularity. Each golfer's swing is unique, and there is no "right" way to swing the golf club; however, the professional golfer often has more of a consistent swing as opposed to an amateur golfer. A collaborative, team approach involving the golfer with a swing coach, physical therapist, and physician often can be informative on how to prevent golf injury, but also how to treat golf injury if it occurs.

Recent Findings As a rotational sport, the golfer needs to be trained and treated with respect for how the body works as a linkage system or kinetic chain. A warm-up is recommended for every golfer before practicing or playing, and this warm-up should account for every segment of the linkage system. Though it has been thought of as a relatively safe sport, injuries can be seen with golfers of any age or skill level, and upper body injuries involving the cervical and thoracic spine, shoulder, elbow, and wrist are common.

Summary A narrative review is provided here of the epidemiology of golf injury and common injuries involving each of these upper body regions. In addition, treatment and injury prevention recommendations are discussed.

Keywords Golf · Cervical spine injury · Thoracic spine injury · Shoulder injury · Elbow injury · Wrist injury

Introduction

Golf is a popular sport played worldwide. There are no gender, skill, or age limits to participate in golf, which is one of the many reasons it is so popular. In addition, it allows for social interaction and can provide moderate-intensity physical activity [1]. While not often thought of as a sport associated with many injuries, golf-related injuries are reported by professional and amateur golfers [2•, 3•, 4]. There are factors out of the golfer's control that may lead to injury, such as obstructions the golfer may hit or wet grass they may slip on when they are hitting a ball. Within the golfer's control, however, is the golf swing, which requires a synchronized action of multiple body parts, muscle strength, timing, and coordination of movements to generate high clubhead speeds. In many instances, the golf swing exceeds 100mph in an effort to drive a ball more than 300 yards [5]. The golf swing is idiosyncratic to the golfer and there is no "right" way to swing a golf club. The upper body, including the cervical and thoracic spine, shoulder, elbow, and wrist, are common areas for injury related to the golf swing to occur. A narrative review of upper body injuries in the golfer is presented here. When referring to the golf swing or golfer, a right-handed golfer will be the reference point, the "lead" side will be the left side, and the "trail" side will be the right.

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Golfers' Habits and Motivation

Amateur and professional golfers are very different. One major area of difference was highlighted by Theriault and Lachance, who noted that the habits of golf practice differ substantially between amateurs and professionals [6]. This is important when later considering the etiology of golf injury. An amateur's availability to practice may often be impacted by their work or school schedule, for instance. Alternatively, a professional golfer plays golf to make a living and, therefore, may play every day or most days of the week 6 to 10 h a day.

A study of 600 amateur golfers showed that they played an average of 3.0±1.4 days and 14.7±7.7 h per week [6]. Amateur and professional golfers' motivations are different, even though both types of golfers share the same interest and, in some cases, the same passion for the sport. Professional golfers are inherently motivated, as golf performance is the main source of income. When looking at amateur golfers' main motivations to play golf, it is noteworthy that 88.7% of the group practicing golf as a recreational activity were motivated by the health and leisure aspect, with 44.7% reporting this to be the main motivation. Contact with the natural environment was the second main motivator for amateurs playing golf. Besides the pleasure of practicing golf itself, the amateur golfer also seeks to gain health benefits from contact with the natural environment and from the physical exercise and energy expenditure related to walking. Studies evaluating calorie expenditure playing golf typically identify golf as a moderate-intensity physical activity with energy expenditure of 3.3–8.15 kcal/min [1, 7–14], 264–450kcal/h [1, 9, 10, 14] and total energy expenditure of 531–2467 kcal/18 holes [1, 8–11, 14–22]. Golfers walking 18 holes take between 11,245 and 16,667 steps [1, 18, 23–25], walking 4–8 miles [1, 9, 17–19, 23, 24, 26], while those riding a golf cart accumulate 6280 steps [1, 25] or just under 4 miles [9].

Epidemiology

Consistent with differing motivations, injuries affecting amateur players appear to differ when compared with professionals [3•]. One of the reasons may have to do with differences in swing biomechanics. There has been a shift with the professional swing to more of a modern swing with an emphasis on creating an "X-factor," which is the difference in relative rotation of the shoulders with respect to the hips during the golf swing, as opposed to the classic swing where the shoulder and hip rotations are more synchronous [3•, 27, 28]. A large X-factor at the top of the backswing is thought to generate high club speed at impact. Cheetham et al.'s work showed that the "X-factor stretch," how the X-factor changes at the beginning of the downswing, is even more important to an effective swing [28]. It has also been noted that forearm muscles in the trail and lead arm are used differently [3•, 29]. Amateur golfers, in contrast with professional golfers, had more muscle activity in the pronator teres of the trail arm in the forward swing phase and a trend toward increased activity in the acceleration phase. Professional golfers, in contrast, had more pronator teres muscle activity of the lead arm in the acceleration phase and a trend toward increased activity in the early follow-through phase. Professionals also swing with greater clubhead speeds and, as previously noted, have increased playing volume per week [3•, 30]. For instance, it was noted that greater than 70% of professionals hit more than 200 balls per week, whereas less than 20% of amateurs hit the same amount per week.

There have been a number of studies looking at establishing the most frequent injuries affecting amateur golfers. Batt [31] received questionnaire responses from 193 out of 461 male and female amateur golfers from a golf club and identified actual injuries while playing golf and incidental injuries, which were other injuries compromising an individual's ability to play golf. Mean age was 49.5 and mean handicap 14.2 in men, and mean age was 53 and mean handicap 23.4 in women. Overall injuries, including actual and incidental, were reported by 57%, with the occurrence being slightly less (56%) among men than among women (59%). Actual injuries were reported by 61 (32%), and incidental injuries were reported by 82 (42%). In terms of actual injuries, the wrist was most common in men and the elbow was most common in women. When thinking about etiology specific to injury, this study highlighted the problems of overuse, incorrect swing, and playing conditions. Wrist problems were seen more frequently in younger male golfers, whereas shoulder problems occurred in older, less able players.

In 2007, another study of Australian amateur golfers used a prospective survey to examine golf injuries over a 1-year period to determine injury rates, mechanism, and treatment [32]. It also looked to determine the effects of risk factors on golf injury, including age, gender, handicap, play/practice habits, warm-up habits, and equipment. A total of 588 golfers, 473 men (average handicap 17.8) and 115 women (average handicap 26.7), completed the follow-up survey. Seventy-eight players reported a total of 93 injuries, and no player reported more than two injuries. Men reported an injury rate of 16.5 injuries/100 players, and women had an injury rate of 13 injuries/100 players. Incidence rate of golf injury was 15.8 injuries per 100 golfers, equating to 0.36 to 0.60 injuries/1000 h/person. Elbow and forearm injuries were second most common (17.2%), and shoulder/upper arm injuries (11.8%) were fourth most common. Almost half the injuries were sustained during the golf swing, mostly during ball impact or follow-through. Recurrent injuries were most common, and it was more likely that injuries occurred over time as opposed to acutely.

There was another study in 2007 by Fradkin et al. which looked at 304 golfers with a median age of 53 who filled out a questionnaire and described the impact that golf injury can have on future golf and on life [33]. Golf injury was defined as "damage to the body that occurs as a result of competing, training and/or participating in golfing activity." The majority of golfers (71.4%) were male with a median USGA handicap of 13, and they had been playing golf for a median of 18.5 years. The majority of golfers injured needed 1–2 weeks of treatment (29.8%), and 51.3% reported an impact on their lives. The most common injury sequelae were an inability to play (47.4%) and an altered swing (21.1%). Almost two-thirds (64%) missed time playing golf due to their injury. Golfers frequently missed 1–3 games (46.8%), but a substantial number missed more than 6 (27.4%). Eight of the golfers (7.2%) needed time off from school or work due to their injuries, with most requiring 1–2 weeks of absence (50.0%). Overall, the most common mechanisms of injuries cited for amateurs were overuse, poor biomechanics of swing, and hitting the ground or an object during the swing [34–38].

A recent systematic review by Robinson et al. noted injuries as an issue with professional golfers, but also highlighted the limitations in the literature with regard to a focus on injuries sustained by professional golfers [3•]. The level of golf research published is of relatively low quality, as it pertains to professional golfers as the gold standard methodology of sports injury surveillance, and key aspects of injury reporting were not used. All studies were retrospective, and a few relied on recall of injuries by players. It was not possible to obtain a synthesis of the data to give overall percentages of injuries because there are limitations in the various studies conducted in terms of description of time points along with the at-risk population. There were differences in how injury was defined, and some studies talked about injury severity based on time out and others described it in terms of tournaments missed. There are also limitations in terms of various studies' descriptions of the nature of an injury, whether it is new or old, and the mechanism. Finally, studies, particularly with regard to professional golfers, are limited in their report of injury by diagnosis and instead report injury by anatomical location. For professional golfers, in terms of upper limb injuries in general, the left side was injured five times more frequently than the right, the lead side in the right-handed golfer. Limited information exists on the risk factors for injury or the mechanism of injury. Only two articles report frequency and anatomic distribution of injury in female golfers along with male golfers. In one article, hand/wrist injuries were the most common injury (38%), cervical spine injuries only contributed 2% of injuries, and there were no reports of thoracic spine injuries [4]. Another article found low back (41%) to be the most common injury, followed by cervical/thoracic injuries (26%), and wrist injuries (9%) [39].

Two notable studies looked at injuries in both professional and amateur golfers. One study found that amateurs sustained 2.07 injuries during their golf career compared to 3.06 injuries in professionals [40]. They also reported that 19.4% of amateurs hit >200 balls per week compared with 73.3% of professionals, and 11.6% of amateurs played at least four rounds of golf per week compared with 30% of professionals. Most common amateur injuries were elbow (24.9%) and shoulder (18.6%). Gosheger et al. analyzed the injury data of a total of 703 golfers, 643 amateurs (456 men and 187 women) and 60 professionals (54 men and 6 women), with a questionnaire [30]. While injury itself was not defined, the study group only concentrated on injuries that could positively be associated with golf by the player and not occurred previously. Overall, 82.6% of injuries involved overuse, and 17.4% were single-trauma events. Professionals were injured more often, typically in the back, wrist, and shoulder, whereas amateurs reported mainly elbow, back, and shoulder injuries. The severity of reported injuries was minor (less than 1 week) in 51.5%, moderate (greater than 1 week) in 26.8%, and major (greater than 1 month) in 21.7% of cases.

The most common upper body injuries in golfers are listed in Table 1.

Phases of the Swing

When thinking about a golf-related injury, particularly as it relates to the cervical and thoracic spine along with the shoulder, elbow, and wrist, it is important to think about the phases of the golf swing [5]. Identifying the phase of the golf swing where a golfer feels pain may lead to more specifically identifying the diagnosis and a potentially modifiable swing adjustment to decrease pain. There are three separate pairs of actions that occur in six phases of the golf swing [6]. There is the ball address (starting position) and the backswing, the forward swing up to ball impact which includes club acceleration, and then the complete follow-through (end of swing). Each phase of the swing involves the use of specific muscles and joints whose main functional purpose is to create a multi-lever system that generates maximal speed from the clubhead in a precise trajectory and in a wide arc of motion to hit a fixed object on the ground.

During the address phase (Fig. 1), overextended straight arms or locked elbows and abnormally high muscle tension

Table 1 Most common upper body injuries in golfers

Body region	Injury
Cervical spine	- Spinous process avulsion fracture - Cervical disc tear and herniation - Cervical facet sprain or arthritis - Cervical ligament, muscle or fascial pain
Thoracic spine	- Thoracic disc tear and herniation - Thoracic facet sprain or arthritis - Asymmetric thoracic osteophytosis - Thoracic ligament, muscle or fascial pain
Shoulder	- Labral injury - Biceps tendinopathy - Glenohumeral instability from injury to the labrum or capsule - Acromioclavicular joint sprain or arthritis - Rotator cuff tendinopathy and subacromial impingement - Glenohumeral osteoarthritis
Elbow	- Lateral epicondylitis - Medial epicondylitis
Wrist	- Hook of the hamate fracture - Extensor carpi ulnaris tendinitis or tenosynovitis or subluxation - Flexor carpi ulnaris tendinitis or tenosynovitis

Fig. 1 Ball address

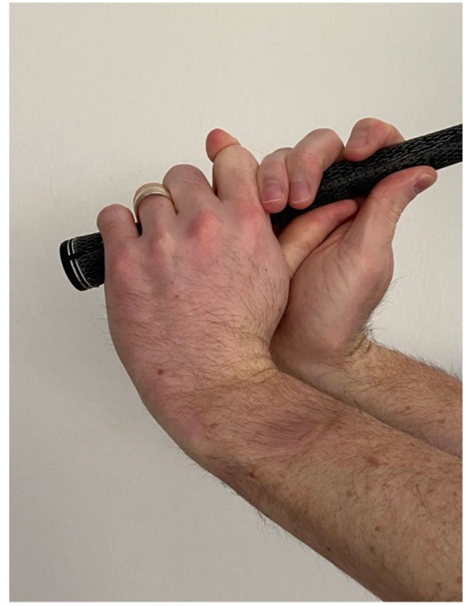

Fig. 3 Highlighting forces at the left thumb and right wrist

in the forearms from a tight grip reduce effectiveness in creating speed in the downswing and can induce elbow and wrist injuries at ball impact [6]. A grip without interlocking hands or too loose a grip increases the danger of dropping the club, causing a loss of precise ball impact and injury to the elbow, wrist, or hand with ground impact. During the backswing phase (Fig. 2), an excess backswing can increase stress in the left thumb and right wrist (Fig. 3). Excess arm/shoulder elevation on the backswing, with the left arm crossing the left shoulder, impinges the subacromial soft tissues, such as rotator cuff tendons and bursa, and it requires optimal stabilization from the rotator cuff muscles.

In the forward swing and acceleration phase (Fig. 4), thoracic and abdominal muscle strains can occur after vigorous trunk rotation on the downswing. At the ball impact phase (Fig. 5), lateral or medial epicondylitis can occur if the grip is too tight or the elbows are held too tightly or are overextended. Excessive wrist flexion/extension in the

Fig. 2 End of backswing

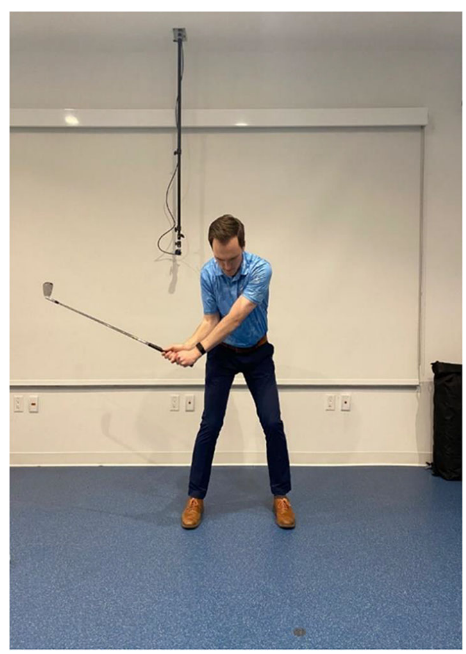

Fig. 4 Forward swing and acceleration

Fig. 5 Ball impact

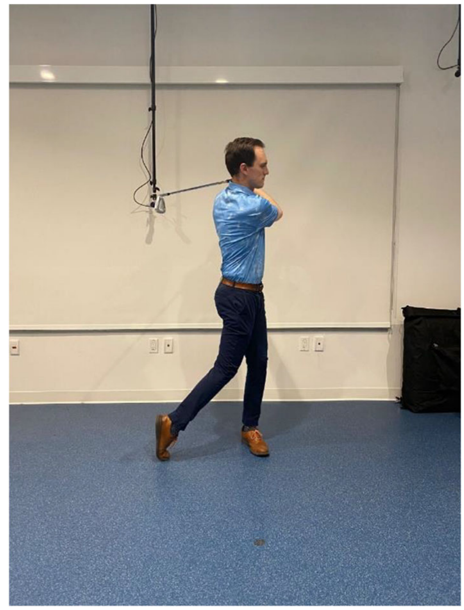

Fig. 7 Late follow-through

downswing, or hitting the ground after losing balance, can cause serious hand and wrist injuries. In the early follow-through phase (Fig. 6), shoulder ligaments and rotator cuff muscles can experience excessive mechanical stress in a vigorous follow-through. Injuries in the late follow-through phase (Fig. 7) typically occur in the low back and lower extremities. Having the golfer bring a video of their swing to their appointment or asking them to demonstrate their swing can be very helpful in identifying the diagnosis and also potentially the etiology of a golf injury.

Fig. 6 Early follow-through

Diagnoses Based on Anatomical Location of Injury and Treatment

C-Spine

Spinal injuries, including cervical, thoracic, and lumbar spine, are the most common type of injury, accounting for 55% of injuries in professionals and 35% of injuries in amateurs [2•, 41, 42]. Despite being the second most common body region injured in professional golfers, the current golf literature does not have any study that focuses on cervical spine injuries or any study that looks specifically at diagnoses within the cervical spine. In comparison to the prevalence of cervical spine injuries in amateur golfers (2–4%) [3•, 31, 33, 40, 43], professionals seem to be stricken with injury in this region more often but there is no literature that comments on etiology, prevention or outcome of these injuries. There has been a case report of lower cervical spinous process fractures, which can be associated with the golf swing [44]. This case report describes an avulsion fracture of the C6 and C7 cervical spinous processes, in a novice middle-aged female golfer with intractable neck pain. The injury mechanism was speculated to be similar to clay-shoveler's fracture. If a patient complains of long-lasting neck pain and has a history of golf activity, further consideration should be given for and study should be conducted to rule out lower cervical spinous process fracture.

In the author's experience, cervical disc-mediated pain, such as annular tears and herniations, and facet joint-mediated pain, such as a sprain or arthritis from these joints, can be sources of pain. Secondary to a disc herniation or degenerative change in the cervical spine, the golfer can experience nerve pain in the arm known as cervical radiculopathy. Primary or secondary to cervical disc or facet injury, muscle and fascial pain can affect a patient's functionality. In terms of treatment, there are focused therapeutic exercises with physical therapy, with the goal of offloading and dissipating forces around the painful structures noted above. When physical therapy does not alleviate pain or improve functionality, anti-inflammatory or neuropathic medications can be utilized along with targeted injections to painful structures. With signs of progressive neurologic change, surgical consultation would be indicated.

T-Spine

As discussed, there has been a trend in golf toward a more modern swing that maximizes thoracic rotation, storing potential energy for the greatest release of power upon impact of the golf club with the golf ball. During downswing, there is a lateral translation force with bending force on the trailside along with unwinding the torso with an axial rotation force. This creates a reverse-C (Fig. 8) involving the thoracic spine, and this force can be eight times the normal weight of a golfer [45]. Over time, this results in asymmetric spinal degeneration on the trailing side [2•, 39, 42]. While not highlighted much in the literature, Gosheger et al. found that injuries of the thoracic spine force the longest absence of play, expressed as time lost due to injury (137.4 days), which is five times the average of time lost due to an injury [30]. Thoracic spine injuries are felt to be uncommon because of increased biomechanical support by the thoracic cage, including associated ribs, sternum, costal cartilages, and associated ligaments, but among the most feared due to potential for catastrophic injury [45]. Because they are uncommon, they can be missed by providers when caring for the golfer.

Fig. 8 Reverse-C

The spine is often thought of in terms of three columns: anterior (anterior vertebral body, anterior annulus fibrosus, and anterior longitudinal ligament); middle (posterior longitudinal ligament, posterior annulus fibrosus, and posterior wall of the vertebral body); posterior (laminae, pedicles, spinous processes, facets, ligamentum flavum, interspinous ligaments, and facet capsules) [46]. A fourth column of the thoracic spine has been described that makes up the thoracic cage, including the ribs, sternum, and costosternal/costovertebral articulations [45, 47]. Because of the anterior biomechanical support from this fourth column, thoracic spine injuries are felt to be uncommon, as studies report that a complete rib cage with intact sternum increases thoracic spine stability in flex-ex, lateral bending, and axial rotation up to 40% [48, 49]. The orientation of the facet joints more vertically in the coronal plane limits flexion and extension but allows for powerful axial rotation, augmenting torsional maneuvers through the shoulder because it allows for lateral bending and rotation. Thoracic musculoligamentous injuries can occur with more acute high-energy mechanisms, often with violent bending or rotational motions or with more chronic overuse, high-repetition mechanisms. Acutely, these injuries mirror whiplash-type injuries in the cervical spine as they are caused by violent rotational or bending forces. Treatment usually includes a period of rest and activity modification, physical therapy, medications such as non-steroidal anti-inflammatory medications, and muscle relaxants. With regard to physical therapy, an active program with adjunctive passive modalities can be beneficial. Passive modalities can help decrease acute pain with massage, ultrasound, and hot and cold modalities. Active modalities include exercises for postural mechanics, core strengthening, and trunk stabilization.

Thoracic disc herniations typically result from axial loading and rotation on a flexed spine [45, 50]. The incidence in the general population of thoracic disc herniations is 1/1000 to 1/1,000,000. They occur commonly in the fourth and fifth decades of life and are slightly more common in males. They are less common in the thoracic spine compared to the cervical or lumbar spine. The symptoms of a thoracic disc herniation include axial pain, radiating pain, or symptoms of myelopathy, such as balance change, weakness in the lower extremities, numbness and tingling in the lower extremities, bladder or bowel incontinence, or saddle anesthesia. The majority of herniations reported are below T8, and radicular symptoms are typically in a T10 distribution regardless of the location of the herniation [51, 52]. There can be symptoms in the upper extremities in high thoracic herniations, whereas middle and lower thoracic herniations can mimic lumbar disc pathology. Activity modification and physical therapy can be helpful in terms of conservative treatment for thoracic disc herniations. When conservative measures do not alleviate the patient's pain or when there are signs of myelopathy, surgery would be indicated.

There are injuries to the bone that are also reported in the literature [2•]. There are two cases in the literature of osteophyte complexes that form near the costovertebral junctions, referred to as asymmetric thoracic osteophytosis, on the trail side (right side in the right-handed golfer) felt to be due to reverse-C posture at impact. In both cases, after activity modification and physical therapy did not alleviate the patient's pain, injections targeted at the facet joints ended up relieving pain.

Stress fractures occurring in spinous processes, transverse processes, or ribs can result from overuse in golf. Given the nature of golf, you typically do not see the acute fracture or even potential spinal cord injury that you may get with higher-energy activities. A collaborative review from three institutions was published on 19 cases (13 men, 6 women) of stress fractures of the posterolateral aspect of the ribs in golfers [53]. Eighteen of the cases were in beginners, and one was in an experienced golfer who had dramatically increased his practice time on the driving range. Fourth to sixth ribs were most commonly injured with the lead side in 16/19 cases. While the mechanism is not known, fatigue of the serratus anterior was felt to be the mechanism of injury. Electromyelogram (EMG) studies have demonstrated that the serratus anterior muscle of the leading arm had constant moderate activity through all phases of the golf swing [53, 54]. This constant activity may leave it susceptible to fatigue. Stress fractures can also occur in the spinous processes of amateur golfers, particularly beginner amateur golfers, that have a similar mechanism to clay-shoveler's fracture [55]. Allowing time for bone healing with slow progression back to golf, often after swing modifications, is the general treatment approach for these bone injuries.

Shoulder

The shoulder is cited as the third most commonly injured area in the professional golfer, behind the lumbar spine and wrist/hand [4, 5, 30]. In amateurs in the USA, it is cited as the fourth most commonly injured area, but in Europe, it is the second. In a survey of professional golfers, the lead shoulder (left shoulder in right-handed golfer) was injured three times more commonly than the trail shoulder [4, 5]. Some reports suggest more than 90% of shoulder problems in the golfer occur in the lead shoulder [5, 56, 57]. This is possibly due to increased load in the lead shoulder with an emphasis on creating the X-factor and X-factor stretch previously described, resulting in extremes of shoulder adduction along with pushing the limits of flexion, and internal and external rotation. Often, in this setting, poor scapular mechanics along with poor peri-scapular strength, endurance, and control are present.

Overall, shoulder injuries are felt to occur in professionals from overuse, whereas with the amateur golfer, poor swing mechanics and trauma like hitting the ground awkwardly seem to be the more common cause. Like with injury in other body regions, it is important to think of phases of the golf swing as symptoms will frequently occur in a specific phase.

Often to maximize power and clubhead speed, consistent with the X-factor emphasis in the modern swing, the golfer will try to maximize shoulder turn relative to hip turn during the golf swing, specifically the backswing. Frequently as golfers age, the shoulder rotation has been shown to decrease [5, 58]. In professional golfers, through EMG and high-speed photography [5, 57, 59, 60], no significant muscle activity differences were seen between male and female professionals during the swing. It is important to note that professionals usually have swings that are repeatable, whereas amateurs and recreational golfers frequently have erratic muscle control and cannot reproduce the same swing with each shot [5, 57, 61]. The supraspinatus and infraspinatus have low synchronized activity in the lead shoulder during the swing and are active mainly during takeaway and follow-through to abduct and externally rotate the shoulder and provide glenohumeral joint stability. The subscapularis in both shoulders is the most active rotator cuff muscle showing activity during all phases of the swing, but more so during acceleration. The latissimus dorsi acts mostly during the downswing and acceleration phases, and pectoralis major, acting maximally during acceleration and follow-through, demonstrates the most activity of any of the shoulder muscles. The deltoid is mostly non-active, although the anterior deltoid is most active during follow-through where it acts as a flexor.

In reference to scapular mechanics, more specifically, the trapezius helps with scapular retraction and has the greatest activity during the downswing and acceleration phases for the lead arm and during takeaway in the trail arm. In assessing the action of the rhomboid musculature and levator scapulae, for the lead arm, scapular retraction and elevation were most active during the downswing and acceleration phases. For the trail arm, both muscles were active during the downswing to help with scapular protraction and overall scapular stabilization. The last muscle assessed was the serratus anterior. In the lead arm, the serratus has low synchronized activity throughout the entire swing, which potentially explains why it can be susceptible to fatigue in some golfers. In the trail arm, there is scapular protraction, and peak activity was demonstrated during the downswing, acceleration, and follow-through phases.

When thinking about clinically assessing the shoulder and formulating a differential diagnosis, the clinician should first think about the patient's age [5]. The young patient typically is more susceptible to instability or traumatic injury. The middle-aged patient commonly deals with subacromial impingement, rotator cuff disease, and acromioclavicular (AC) joint disease in the lead shoulder at the top of the backswing (Fig. 9). In the older patient, frequently you see rotator cuff disease along with glenohumeral joint osteoarthritis. In the clinical assessment, it is also important to think about the phases of the golf swing when diagnosing shoulder pathology.

Fig. 9 Lead shoulder position in backswing where symptoms of subacromial impingement, rotator cuff disease and acromioclavicular arthritis are felt

For instance, in the backswing, the lead shoulder internally rotates, forward flexes, and adducts across the body. It can be susceptible to subacromial impingement and AC joint disease or may worsen pain related to these diagnoses. Posterior shoulder discomfort at the top of the backswing, when the lead arm is fully adducted, can be a sign of posterior glenohumeral instability. When thinking about the follow-through, the lead shoulder is abducted and externally rotated, and symptoms, particularly anterior symptoms, in this phase could suggest anterior instability or biceps tendinitis.

Rotator cuff disease and subacromial impingement are very common in the golfer. Some golfers will even have rotator cuff disease at baseline, which can perpetuate poor swing mechanics with weakness at initial takeaway. In a review of 412 patients with golf-related injuries, 85 had shoulder symptoms and 93% had rotator cuff or subacromial disease [5, 60]. Fortunately, in golf, the demands placed on the shoulders in terms of range of motion and rotator cuff activity are usually less than those required for true overhead athletes. It is important to optimize scapular and glenohumeral biomechanics [62].

Exercise-based tendon rehabilitation is the most evidence-based management of tendinopathy with an initial standard load progression (Fig. 10) [62–64]. The normal progression involves first isometric exercise, which has been shown to relieve tendon pain, relieve cortical inhibition, and be useful before strength work to allow maximal muscle strength. When pain is controlled, then progression to isotonic exercises is appropriate. Isotonic exercises improve tendon stiffness and muscle strength. When adequate strength and endurance are achieved in the affected muscle and kinetic chain deficits improve, the next stage involving an increase in speed and energy storage exercises can begin. This stage involves a gradual increase in faster functional movements while maintaining a base of isometrics and strength and endurance exercises on alternative days. Exercises are done with body weight and involve whole kinetic chain movements. The last stage involves energy storage and release exercises and sports-specific exercises restoring the elastic properties of the kinetic chain. Sports-specific drills and exercises should be slowly introduced and progressed until return to sports-specific activities is achieved. In addition to physical therapy addressing scapular mechanics and progressive loading for the rotator cuff tendons and increasing endurance of the rotator cuff muscles, modifications like shortening the backswing or abbreviating the follow-through can be helpful. Oral medications such as non-steroidal anti-inflammatory medications and glycerol trinitrate patches have been shown to be helpful in

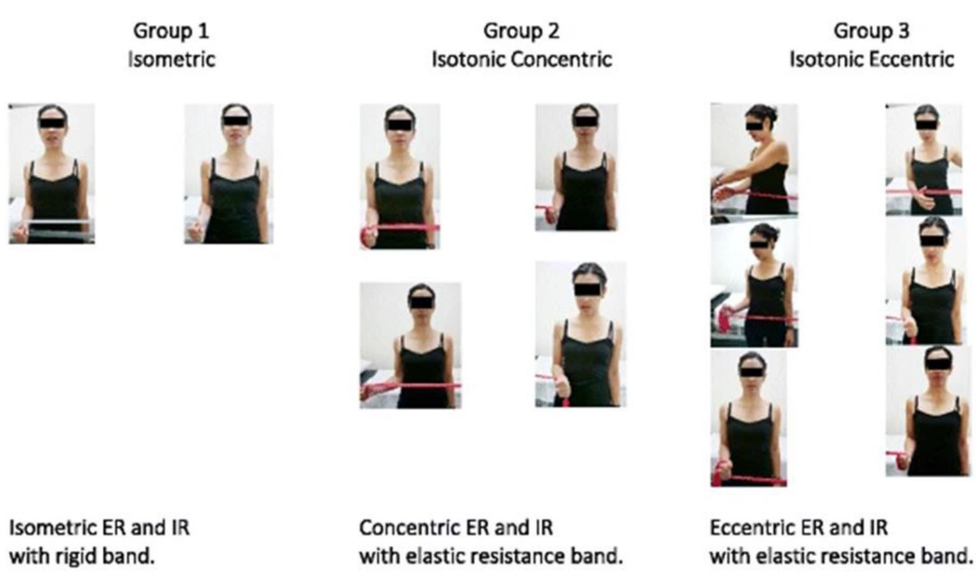

Fig. 10 Therapeutic exercise for rotator cuff tendinopathy. From Kinsella R, Cowan, SM, Watson L, Pizzari T. A comparison of isometric, isotonic concentric and isotonic eccentric exercises in the physiotherapy management of subacromial pain syndrome/rotator cuff tendinopathy: study protocol for a pilot randomized controlled trial. *Pilot Feasibility Stud*. 2017;3:45 [106], under the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0).

the short-term effect and improved clinical outcomes respectively. When conservative measures fail, surgical consideration can be given. A study of twenty-nine recreational golfers undergoing arthroscopic rotator cuff repair found that 90% returned to pain-free golf and were able to play at the same or a similar competitive level, based on their handicap [5, 65].

AC joint disease is also very commonly seen in the golfer. A review of 35 low handicap or professional golfers found that AC joint disease was the most common cause of pain (53%), followed by rotator cuff tendinitis and impingement (26%) [5, 66]. The majority of golfers experienced pain at the top of the backswing when the arm is in maximal adduction and forces across AC joint are high [5, 67]. It was noted that treatment in the study involved physical therapy, swing modifications, and, when conservative measures failed, distal clavicle excision, and all but one golfer returned to play.

Instability of the glenohumeral joint is another problem that golfers can encounter. Many high-level golfers during the swing will attempt to maximize their shoulder turn in relation to their hip turn [5, 68]. This maximizes flexibility to the extent that, at times, some golfers will develop hyperlaxity. With overuse and repetitive trauma, capsule and labral structures can become attenuated and injured. This instability was noted to have a 12% incidence in 35 professional and competitive golfers [5, 69]. These golfers described a sensation of pain and instability at the top of the backswing again when the lead arm was fully adducted. This correlated with exam findings of posterior instability during the load and shift test and posterior apprehension with loading. There can also be anterior instability at the end of the follow-through phase of the swing when the arm is in maximal abduction and external rotation.

Superior labrum and biceps tendon injuries can occur in golfers despite more frequently being seen in overhead athletes. Two case reports involving professional golfers [5, 70] described internal impingement, where there is repetitive contact of the humeral head with the posterosuperior aspect of the glenoid when the arm is abducted and externally rotated, leading to both anterior and posterior labral fraying. For one golfer, symptoms resolved with modification to shorten the backswing, and for the other, labral debridement and addressing anterior capsular laxity resolved symptoms. Superior labrum anterior to posterior (SLAP) tears can occur in golfers at the end of the backswing or the beginning of the downswing and affect the lead shoulder. Oftentimes, patients will experience mechanical symptoms such as catching or locking. Biceps tendinitis can be most marked during the part of the follow-through when the lead arm is maximally rotated and the shoulder is extended. With most shoulder pathology affecting the labrum and biceps tendon, rest, physical therapy, and anti-inflammatory medications will help alleviate symptoms. However, when conservative measures do not give definitive relief, shoulder arthroscopy can be considered.

Osteoarthritis is the last major disease entity of the shoulder which occurs in the golfer. It is estimated that 25% of golfers in the USA are 65 years or older [5, 71]. In this age group, osteoarthritis is prevalent, and many patients are avid golfers [5, 72]. It was found to have a 3% incidence in a group of elite golfers [5, 66]. Physical therapy, oral pain medications, injections, and ultimately shoulder arthroplasty are the general treatment options for osteoarthritis. A recent meta-analysis looked at return to golf after arthroplasty [73•]. The overall rate of return to golf after shoulder arthroplasty was 80%. After total shoulder arthroplasty, reverse shoulder arthroplasty (RSA), and hemmiarthroplasty, the return rates were 94.9%, 70.5%, and 52.4%, respectively. The mean time to return after shoulder arthroplasty was 6 months. Papaliodis et al. assessed golf performance after press-fit RSA and found that those that had surgery on the dominant arm improved handicap by 2.1, whereas for the non-dominant arm, handicap improved by 0.8. Those that received RSA in the dominant arm had a mean 13.6-yard driving distance improvement compared to 8.5 on the non-dominant side [73•, 74]. Change in handicap was reported by two studies [73•, 74, 75] and reduced by 1.4 and 4.9 strokes. These same two studies described driving distance change: one described an increase in distance by 12.2 yards, and the other one reported a decrease by 5.3 yards [74, 76].

Elbow

Kohn et al. found that elbow injuries in golfers occurred in 4% of professional golfers and 24% of amateurs [77, 78]. Mallon noted that when looking at male amateur golfers, the low back is most commonly injured, followed by the elbow, and with female amateurs, the elbow is the most commonly injured body part [40, 77, 79]. The possible reason suggested for this is an increase in carrying angle in females [31, 77]. The overall factors linked to elbow injury include overuse, poor swing mechanics, conditioning, warm-up, age, equipment, and pre-existing pathologic mechanisms.

Two of the most common elbow injuries in golfers are medial and lateral epicondylitis. Despite medial epicondylitis being often referred to as golfer's elbow, McCarroll et al. found that lateral elbow pain was five times more common than medial elbow pain in amateur golfers [40, 77]. Medial epicondylitis, typically seen in the right elbow of the right-handed golfer, is felt to be caused by sudden applied forceful resistance during the swing in a single trauma or by repetitive excessive muscular contraction, and further, strokes requiring large divots [6, 77]. Lateral epicondylitis, seen in the left elbow of the right-handed golfer, is typically caused by single trauma or by repetitive forceful extension of the forearm accompanied by twisting motion, especially when associated with excessive gripping of the golf club [6, 77]. Gripping the club too tight and having golf club grips that are too slippery is also a common cause of injury, as it causes changes in force generated in the muscles and tendons of the forearm [34, 80]. Just prior to impact in the downswing, there is a flexor burst where there is a large increase in wrist flexor activity [34, 81]. The right wrist is radially deviated and extended but is moving toward neutral, placing a large amount of stress on the wrist, which can result in acute or chronic injury. Some of these forces can be transmitted to the elbow and result in injury to the medial elbow in the right arm (trail elbow) and lateral elbow in the left arm of right-handed golfers [34, 82].

There are other less common diagnoses to consider for the elbow as well. Ulnar neuritis was found to be associated with medial epicondylitis by Kohn et al. in 20% of cases [77, 78]. With catching and locking, osteoarthritis or loose bodies may be the cause of pain.

In terms of treatment, most specialists agree that an injured elbow should begin moving as soon as possible. Activity modification, specifically avoiding provocative activities, and a short period of immobilization of the hand and wrist in a splint for 1 to 2 weeks can be helpful. While counterforce braces are often tried during provocative activities, which cannot be stopped, use of braces and larger-sized golf grips showed no statistically significant force difference produced specifically between those that used the devices and those that did not use them [34, 81]. As pain begins to improve, physical therapy can be considered. Before addressing the elbow, special attention should be given to the shoulder and wrist. Improving muscle strength, endurance, and control around the shoulder and wrist can help decrease the amount of abnormal load to the elbow. Special attention should be given to optimizing scapular and glenohumeral kinematics [62]. After optimizing shoulder mechanics, strength, and control, attention can be directed to exercise for the elbow. Given that most elbow injuries in the golfer essentially involve lateral or medial tendinopathy, the tendon progression noted previously with the rotator cuff can again be followed. NSAIDs and glycerol trinitrate patches have also been shown to be helpful adjuncts from a conservative standpoint. Two main injection options have been tried, including steroid and platelet-rich plasma (PRP). In a study looking at PRP versus corticosteroid for lateral epicondylitis, PRP reduced pain and significantly increased function, exceeding the effect of corticosteroid [83]. What was noted with this study and has been noted clinically with corticosteroid injections is that patients initially improve in the short-term with the corticosteroid injection but then decline. Dry needling has also been shown to be effective for lateral epicondylitis [84•]. Surgery is looked at as a last resort for tendinopathies when all conservative measures have been exhausted.

Wrist

The wrist is commonly injured playing golf. After excluding spine injuries, in both professional and amateur golfers, the hand/wrist region has been quoted by some as the second most commonly injured area of the body [3•, 4, 31, 34]. The wrist moves through a wide range of motion during the swing [34, 85, 86]. The most common injury mechanism occurs as a result of hitting an object other than the ball and is of the acute nature, resulting from a sudden decrease in movement of the accelerating hands and wrist at impact, which can create high forces that disrupt tissues. Similarly, hitting off the hard ground or hitting a "fat" shot (hitting the ground first before hitting the ball) is another possible mechanism of injury most often seen in amateurs.

Professional golfers often play on links courses where rough tends to be longer or on other courses where rough is grown out for tournaments. During the downswing, the hosel and shaft get wrapped up in the grass, which can place more force on the upper limb [34]. Other injuries are overuse related. Hook of the hamate fractures are the main bony injury cited where the hamate is impinged between the hand and the butt end of the club. The tendinopathies fall under this overuse category as well and typically result from a sudden increase in the volume of practice or changing of the grip, and subsequent practice [34, 87]. In the flexor tendons, large forces are produced just prior to impact, and the flexor carpi ulnaris of the right wrist of the right-handed golfer, in particular, is vulnerable to injury from microtrauma due to these forces. In beginner golfers, frequently in the downswing, they will uncock the wrist which is not only detrimental in terms of power and control, but also can cause pain due to extensor carpi ulnaris (ECU) overuse [34, 80].

There was a prospective cross-sectional study in elite professional golfers by Hawkes et al. in 2013 looking at the prevalence, variety, and impact of wrist problems in professional golfers on the European tour [88]. The majority of injuries occurred in the leading wrist (up to 67%), and the most common location was the ulnar side of the wrist (35%). 87% of ulnar-sided problems and 100% of radial-sided problems were in the leading wrist. There was no significant difference between the symptomatic and asymptomatic groups in terms of playing years or performance. The most significant injury in terms of absence from competition was ECU tendon subluxation. In this injury scenario, there is direct contact with a hard object and the ECU will contract on impact with sudden and extreme force, which can cause rupture of the structures holding the ECU in place, leading to subluxation and instability.

In this study, two golfers suffered an acute tear of the ECU retinaculum and subsheath and underwent immediate surgery. The burden of this injury was seen in the golfer as they experienced 24 weeks of reduced practice and missed 12 tournaments. Two golfers dealt with ECU subluxation, which was a more insidious presentation, and opted for non-operative treatment. They had good outcomes but missed just as many tournaments and practice as those that underwent surgery. Overall, there were 43 injuries in 128 responders (31%). Around 37%

of the professional golfers in this study were found to be playing with ongoing wrist problems. It was noted that professionals tend to experience more wrist and hand injuries than amateurs, which was felt possibly to be due to technique [4, 30, 88]. Professionals tend to hit through the ball to take a divot to place more spin on the ball, which results in increased contact force to the wrist and hand. In identifying the injury diagnosis, it is also important to think about the movement of the hand and wrist during the golf swing. The lead wrist begins in a position of ulnar deviation and then goes into maximal radial deviation at the top of the backswing. It then returns to ulnar deviation until impact, which predisposes to tendon problems on the radial and ulnar side of the wrist. The trail wrist begins in neutral and goes into extension and then flexion.

For acute, traumatic, and chronic overuse injuries, treatment should be focused on restoring functional capacity to the wrist [6]. When pain or limited range of motion is observed, activity modification and sometimes stopping golf practice are required. NSAIDs, ice, compression, and sometimes immobilization with splinting are often required for a short 1–2 weeks to decrease pain and sometimes inflammation. Gradual rehabilitation with strengthening and stability exercises can be helpful as pain improves. Evaluating modifiable aspects of the golf club and swing can be helpful as well. Parziale et al. noted that oversized grips that are generally larger and softer can help to reduce the compressive force pressure necessary to hold a club [89]. The golfer can reduce grip pressure and avoid using strong grip position by rotating the left hand counter-clockwise. Golf swing modifications could include avoiding excessive wrist motion at takeaway or transition and adopting a flat or more elliptic swing plane in which the hands are kept at or near shoulder height during transition and the completion of follow-through. This allows the golf ball to be swept off the turf and may help to reduce wrist and hand injuries.

Prevention

Initial assessment of how the golfer moves can be helpful to identify golf swing faults that could lead to injury. Gulgin et al. used the Titleist Performance Institute level 1 screen to identify strength and flexibility variables and golf swing faults [90]. Three significant associations were found between a physical limitation and a golf swing fault: toe touch and early hip extension; and bridge on right side with early hip extension and loss of posture. In addition, when a golfer could not overhead deep squat or single leg balance on the left side, they were 2–3 times more likely to exhibit an early hip extension, loss of posture, or slide during the golf swing as compared with those who could perform these movements. Based on the findings with this study, it is important to address a golfer's core strength, balance, and hamstring flexibility to help avoid common golf swing faults.

In working toward injury prevention in the golfer, it is important to think of the core in the context of rotational movement and torque production as the body moves as a linkage system, also known as the "kinetic chain." The kinetic chain describes the linkage of multiple body segments allowing for transfer of forces and motion [91]. An efficient kinetic chain requires optimal anatomy, physiology, including muscle flexibility, strength, endurance, and task-specific motor patterns, and mechanics throughout all involved segments [91, 92]. Breakdown in the kinetic chain from inadequate muscle strength, flexibility, and endurance, variation in motor control, joint injury, and improper muscle activation patterns can lead to dysfunction, decreased performance, and injury [91, 93, 94]. A "catch-up" phenomenon has been referred to in the literature and involves a break in the kinetic chain that alters forces in distal segments, leading to pain and possible injury [91, 92, 95].

The core should be considered in two parts [96]. First, the torso located between the shoulder and hip joints forms what is thought of traditionally as the core. The muscles that attach the pelvis, spine, and ribcage function in this context primarily to stop motion. The second part of the core facilitates function with muscles that cross the shoulders and hips to the upper and lower limbs, and with its size and ability to become rigid, helps anchor the limbs. In most athletic movements, such as the golf swing, the hip musculature generates power, which is then transferred upward through the linkage to the arms through a "stiffened" core [96–99]. Stiffness is the key precursor to stability and efficient force transfer and is a key to injury prevention. McGill highlighted 4 key principles of spine stability that direct specific training, enhance performance, and prevent numerous injuries related to this instability: (1) proximal stiffness involving the lumbar spine and core enhances distal segment athleticism and speed of the limbs; (2) a muscular guy wire system is necessary for flexible spine to successfully bear load; (3) muscular co-activation creates stiffness to eliminate micromovements in the joints that lead to tissue degeneration and pain; (4) abdominal armor is necessary for some occupational, combative, and impact athletes [96, 99, 100].

The serape effect involves features of both ends of the core in a spiral pattern and was originally described by Logan et al. to essentially explain how higher level ballistic movement works, such as throwing a ball or swinging a golf club [101]. A serape is a woolen outer garment worn by people in Latin American countries and is worn in a shawl-type fashion hanging around the shoulders and crossing diagonally on the anterior aspect of the trunk. Muscular action by the pairs of muscles, including the rhomboids, serratus anterior, and external and internal obliques, working as a unit is called the "serape effect" (Fig. 11). The serape muscles add to the summation of internal force and transfer internal force from the trunk to the limbs. Most forceful limb movement in sport tends to be diagonal in nature because when one limb is used to impart force to an object, the diagonally opposite limb works to maintain balance when the performer is in the upright position. As the athlete moves a limb through a range of motion, there is a tendency for a lever or limb to resemble a circle as angular momentum is generated. The limb is moving through an arc diagonal to the long axis of the body. The spatial connection of the musculature to the shoulder and hip joints indicates that a diagonal line of pull provides the most favorable arrangement of aggregate muscle action and exertion of force (Fig. 12).

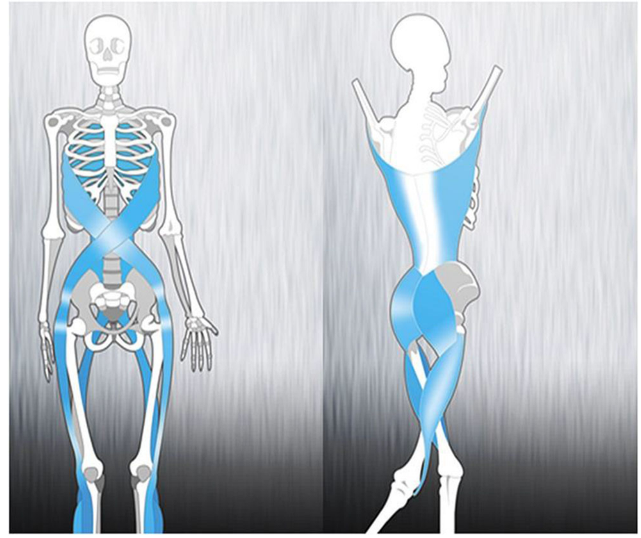

Fig. 12 Body seen as serape involving muscles arranged in series along spiral lines with myofascial connections between muscles and their tendons. Many of the muscles and tendons do not connect directly to bone but through pathways ranging further than the length of one muscle. For example, the thoracolumbar fascia connects the lower limbs through the gluteus maximus muscle to the upper limbs through the latissimus dorsi muscle. From Santana JC, McGill SM, Brown LE. Anterior and posterior serape: the rotational core. *Strength Cond J.* 2015;37(5):8–13; with permission [96].

Core stiffness needs to be tuned with the appropriate muscle activity to best enhance the storage and recovery of elastic energy similar to an elastic band [96]. The muscles of the shoulders, hips, and limbs are generating forces to create the motion in a rotational athlete in a pulsed sequence. The core is the stiffened anchor that allows for distal athleticism. The architecture of the serape creates a stiff core in a spiral pattern. Proximal ends of the hip and shoulder are anchored by the core to produce faster arm and leg motion across the body. This is a vital part of all rapid reciprocal motion, such as that involved with the golf swing.

There are numerous things that can be proactively done in an effort to prevent golf injury. A golfer is allowed to play with a maximum of fourteen clubs. It would greatly benefit the golfer to make sure they are playing with the optimal club head and shaft. For instance, there are differences in golf club shaft stiffness and weight, and playing with a club that has a shaft that is too stiff or heavy can result in an unnecessary effort that leads to injury. There are also differences in club lengths. Having clubs that are too short or too long could contribute to unnecessary torques and loads on the lumbar spine, leading to injury. The golfer would benefit from getting their clubs appropriately fitted by a golf club technician and specialist. In addition, consideration should be given to switching golf grips at the first sign that the grip is allowing the club to slip in the golfer's hand, as this can lead to excessive muscle use that can result in overuse syndromes and injury. Ideally, golf grips should be replaced every 40–50 rounds to reduce slipping, and some players may find it helpful to use a glove in the lead hand if not also the trail hand.

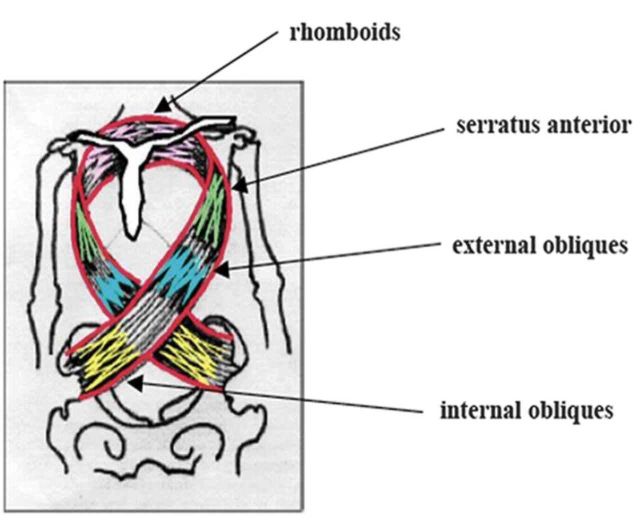

Fig. 11 Original serape looking like a scarf wrapped around the neck, crossing the front of the body and inserting into the pant line. From Santana JC, McGill SM, Brown LE. Anterior and posterior serape: the rotational core. *Strength Cond J.* 2015;37(5):8–13; with permission [96].

Poor swing mechanics is an often-cited etiology for golf injury, especially in the amateur golfer [3•]. Working with a PGA professional on correcting any swing faults can make the game more enjoyable and improve one's score, but it can also help reduce injury. A warm-up before playing has been associated with decreased injury. Gosheger et al. noted that 570 golfers in their cohort did not warm up at least 10 min before playing, whereas 133 warmed up for greater than 10 min [30]. Those who warmed up for 10 min or less reported an average of 1.02 injuries per player versus 0.41 injuries per player for those who took more than 10 min to warm up. It was not specified what exercises were specifically done in the warm-up. While there is no literature specifying the ideal golf warm-up, Table 2 steps through the author's recommended warm-up, specifically with a focus on fine tuning the core and joint mobilization. The focus should be more toward muscle activation as opposed to muscle stretching.

Table 2 The Golf Warm-Up. From https://www.hss.edu/playbook/5-exercises-for-the-perfect-golf-warm-up/ [107]

Five key focus areas for golf warm-up	Recommended exercises
1. Core and gluteal strengthening	**A. McGill Big 3** (curl-up, side-plank and "bird-dog") These exercises work on core stability with the abdominal bracing concept while sparing the spine of excessive load. Go through the circuit 3 times with 10 reps per exercise each circuit. **B. Basic squat** with push-hands or hold a golf club across the shoulder blades (similar to bend-the-bar technique) and connect a belt above knees. Start with bend-the-bar technique (with the golf club serving as the bar) to activate the latissimus muscles and belt above knees to activate gluteal muscles. Hip hinge to activate the gluteal muscles and spare the knees. As you go through the squat, pull down on the club for latissimus activation, and spread the floor with the feet and push out with the knees for further gluteal activation. Spend 6 seconds down and 2 seconds up, slow to fast. Stop lowering when the lumbar spine flexes. Complete three rounds with 10 repetitions per round.
2. Mobilization for the lower extremity (hip and ankle)	A. Place hands on golf club and place club across shoulders and plant your feet as if you were going to squat. Rotate your hips to each side, think of pointing your belt buckle to the right and to the left. Slightly roll onto the inside and outside of the feet as your twist. Try completing 3 rounds and 10 repetitions each way. B. Repeat the first exercise but this time one leg at a time with the other leg just having the big toe touching the ground, as opposed to the whole foot flat on the ground. Recommend 3 rounds and 10 repetitions each way.
3. Mobilization for the thoracic spine with shoulders	A. Clasp hands behind your head. With hands behind the head, raise your elbows upward to activate the thoracic back. You can also stand to the side of the golf and lean into the cart. Hold for 5–10 seconds, repeating 5–10 times. B. Hinge slightly at the hips like you are addressing a golf ball. Clasp hands behind the head and bring elbows together and then spread them apart. Recommend 3 rounds and 10 repetitions each round.
4. Mobilization for upper extremity (elbow and wrist)	A. Extend, flex, ulnar and radial deviate (up, down, side-to-side) the wrist both without resistance first. After one round, add resistance by holding a golf club in the hand. Recommend 3 rounds per hand and 10 repetitions (one repetition includes all four directions).
5. Coordinated full body movement	A. Brace your core and push hands into hips to extend hips back to activate the back muscles. Lift one leg off the ground, reaching back behind you. Slowly rotate the leg internally and externally. Practice 10 repetitions (1 internal and external rotation) for 3 rounds. Repeat on other leg. If unable to maintain balance with the leg reaching in the air, toe-touch the reaching leg to the ground to help maintain balance.

During the round of golf, carrying a heavy golf bag for approximately 4–5 h is physically demanding and does seem to take its toll on the golfer. Gosheger et al. found more shoulder, lumbar spine, and ankle injuries in golfers who carried their bag on a regular basis. Wallace and Reilly found that carrying a golf bag over only a nine-hole distance caused significant shrinkage and decreased shock absorbance of the intervertebral discs [30, 102].

Long-term, preseason physical conditioning is an important injury prevention strategy for all golfers [6, 103, 104]. Such a program should emphasize exercises that enhance both flexibility and muscular strength and endurance of different functional body segments that come together to produce the golf swing. Golf is considered a moderate-intensity physical activity, and attention should be paid to cardiovascular conditioning [1, 6]. Continuous heart rate monitoring of five golfers playing an 18-hole golf course revealed an average heart rate of 108 beats/minute, or activity at 35–41% of maximal oxygen consumption capacity [6, 11]. For many aerobically unconditioned individuals, maintaining this workload over the course of 4–5 h could slowly hamper their golf performance, induce metabolic fatigue, and possibly contribute to increased injury risk. A study demonstrated that a subgroup of previously injured amateur golfers reported significantly higher levels of tiredness after regularly playing an 18-hole golf round than a subgroup of injury-free amateur golfers [6, 105]. Therefore, a light-to-moderate, preseason aerobic conditioning program could enhance golf performance over a whole day of golfing, potentially resulting in less fatigue and fewer injuries.

After an injury has occurred, treatment of any musculoskeletal condition in the golfer ideally involves a collaborative team approach. When having an injury, the golfer benefits from first seeing a physician and getting a clear diagnosis. This diagnosis is communicated both with the golfer's swing coach and with a physical therapist. Physical therapists often can help in terms of developing strength, necessary control, and modifying other areas outside of the painful area to help decrease pain. A swing coach can then help with any potential modifications to the swing to maintain performance at a high level but with decreased pain. This helps to prevent future injury.

Conclusion

Playing golf has been associated with numerous upper body injuries, specifically impacting the cervical and thoracic spine, shoulder, elbow, and wrist. The golfer has the ability to make significant efforts from an equipment, swing analysis, warm-up, and strength and conditioning perspective that can help prevent golf injury. When injuries occur, getting the appropriate diagnosis is critical to ensuring a golfer is on the correct path of treatment. Appropriate care of the golfer includes a collaborative model involving a physician, physical therapist, and golf swing instructor to help facilitate getting the golfer back on the course.

Compliance with Ethical Standards

Conflict of Interest Andrew Creighton, Jennifer Cheng, and Joel Press declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- • Of importance
- •• Of major importance

1. Murray AD, Daines L, Archibald D, Hawkes RA, Schiphorst C, Kelly P, Grant L, Mutrie N. The relationships between golf and health: a scoping review. Br J Sports Med. 2017;51(1):12–9. https://doi.org/10.1136/bjsports-2016-096625.
2. • Naeem K, Wang MS, Kreiner DS, Porter RW. Asymmetrical Thoracic Osteophytosis in Professional Golfers: Case Series and Literature Review. Curr Sports Med Rep. 2021;20(10):506–10. https://doi.org/10.1249/jsr.0000000000000894 **A new diagnosis for thoracic spine pain in the golfer, asymmetric thoracic osteophytosis, is first described in a case series of two patients.**
3. • Robinson PG, Murray IR, Duckworth AD, Hawkes R, Glover D, Tilley NR, et al. Systematic review of musculoskeletal injuries in professional golfers. Br J Sports Med. 2019;53(1):13–8. https://doi.org/10.1136/bjsports-2018-099572 **This is a systematic review of the clinical literature establishing the epidemiology of musculoskeletal injuries affecting professional golfers.**
4. McCarroll JR, Gioe TJ. Professional Golfers and the Price They Pay. Phys Sportsmed. 1982;10(7):64–70. https://doi.org/10.1080/00913847.1982.11947272.
5. Kim DH, Millett PJ, Warner JJ, Jobe FW. Shoulder injuries in golf. Am J Sports Med. 2004;32(5):1324–30. https://doi.org/10.1177/0363546504267346.
6. Thériault G, Lachance P. Golf injuries. An overview. Sports Med. 1998;26(1):43–57. https://doi.org/10.2165/00007256-199826010-00004.
7. Passmore R, Durnin JV. Human energy expenditure. Physiol Rev. 1955;35(4):801–40. https://doi.org/10.1152/physrev.1955.35.4.801.
8. Lampley JH, Lampley PM, Howley ET. Caloric cost of playing golf. Res Q. 1977;48(3):637–9.
9. Crowell B. Energy cost of participation in golf as determined by telemetry: ProQuest Dissertations Publishing; 1970.
10. McGill S. A determination of the energy cost of golf during play: ProQuest Dissertations Publishing; 1963.
11. Murase Y, Kamei S, Hoshikawa T. Heart rate and metabolic responses to participation in golf. J Sports Med Phys Fitness. 1989;29(3):269–72.
12. Loy SF. The effect of the game of golf on cardiopulmonary fitness of middle-aged men: California State University, Northridge; 1979.
13. Burkett LN, von Heijne-Fisher U. Heart rate and calorie expenditure of golfers carrying their clubs and walking flat and hilly golf courses. Int Sports J. 1998;2:78–85.
14. Getchell LH. Energy cost of playing golf. Arch Phys Med Rehabil. 1968;49(1):31–5.
15. US Department of Health and Human Services. 2008 physical activity guidelines for Americans. US Department of Health and Human Services; 2008.
16. Zunzer SC, von Duvillard SP, Tschakert G, Mangus B, Hofmann P. Energy expenditure and sex differences of golf playing. J Sports Sci. 2013;31(10):1045–53. https://doi.org/10.1080/02640414.2013.764465.
17. Dear JB, Porter MM, Ready AE. Energy expenditure during golfing and lawn mowing in older adult men. J Aging Phys Act. 2010;18(2):185–200. https://doi.org/10.1123/japa.18.2.185.
18. Gabellieri JM. The physiological demands of walking during golf: University of Rhode Island; 2011.
19. Parkkari J, Natri A, Kannus P, Mänttäri A, Laukkanen R, Haapasalo H, Nenonen A, Pasanen M, Oja P, Vuori I. A controlled trial of the health benefits of regular walking on a golf course. Am J Med. 2000;109(2):102–8. https://doi.org/10.1016/s0002-9343(00)00455-1.
20. Ludlum DN, Beam SL, Henry SM, Iwaskewcz MW, Aikens EL, Martel GF, et al. Energy expenditure and cardiovascular responses to golf: walking vs. riding. American College of Sports Medicine Conference 2015.
21. Lyerly GW, Beam SL, Epton HH, Fitzsimmons KM, Meyler TJ, Martel GF. Golf: The Effect of Walking versus Riding on Energy Expenditure. Med Sci Sports Exerc. 2011;43(5):602. https://doi.org/10.1249/01.Mss.0000401662.53908.58.
22. Dobrosielski DA, Brubaker PH, Berry MJ, Ayabe M, Miller HS. The metabolic demand of golf in patients with heart disease and in healthy adults. J Cardiopulm Rehabil. 2002;22(2):96–104. https://doi.org/10.1097/00008483-200203000-00008.
23. Tangen J, Sunde A, Sageie J, Hagen P, Kristoffersen B, Istad R, et al. In accordance with governmental recommendations—a study of golf and health. J Sports Sci. 2013;1:15–25.
24. Kobriger SL, Smith J, Hollman JH, Smith AM. The contribution of golf to daily physical activity recommendations: how many steps does it take to complete a round of golf? Mayo Clin Proc. 2006;81(8):1041–3. https://doi.org/10.4065/81.8.1041.
25. Sanders CM, Broker JP, Berning JR, Subudhi AW. The Relationship Between Golf and Walking Benefits: A Pedometer-Based Exercise Assessment. Med Sci Sports Exerc. 2007;39(5):S384. https://doi.org/10.1249/01.mss.0000274510.86518.f5.
26. Lane AM, Jarrett H. Mood changes following golf among senior recreational players. J Sports Sci Med. 2005;4(1):47–51.
27. Cole MH, Grimshaw PN. The X-Factor and Its Relationship to Golfing Performance. J Quant Anal Sports. 2009;5(1). https://doi.org/10.2202/1559-0410.1134.

28. Cheetham PJ, Martin PE, Mottram RE, Laurent BFS. The importance of stretching the "X-Factor" in the downswing of golf: The "X-Factor Stretch" 2001. In: Optimising Performance in Golf [Internet]. Brisbane: Australian Academic Press Ltd.; [192-9].
29. Farber AJ, Smith JS, Kvitne RS, Mohr KJ, Shin SS. Electromyographic analysis of forearm muscles in professional and amateur golfers. Am J Sports Med. 2009;37(2):396–401. https://doi.org/10.1177/0363546508325154.
30. Gosheger G, Liem D, Ludwig K, Greshake O, Winkelmann W. Injuries and overuse syndromes in golf. Am J Sports Med. 2003;31(3):438–43. https://doi.org/10.1177/03635465030310031901.
31. Batt ME. A survey of golf injuries in amateur golfers. Br J Sports Med. 1992;26(1):63–5. https://doi.org/10.1136/bjsm.26.1.63.
32. McHardy AJ, Pollard HP, Luo K. Golf-related lower back injuries: an epidemiological survey. J Chiropr Med. 2007;6(1):20–6. https://doi.org/10.1016/j.jcme.2007.02.010.
33. Fradkin AJ, Windley TC, Myers JB, Sell TC, Lephart SM. Describing the epidemiology and associated age, gender and handicap comparisons of golfing injuries. Int J Inj Contr Saf Promot. 2007;14(4):264–6. https://doi.org/10.1080/17457300701722585.
34. McHardy A, Pollard H, Luo K. Golf injuries: a review of the literature. Sports Med. 2006;36(2):171–87. https://doi.org/10.2165/00007256-200636020-00006.
35. AIHW National Injury Surveillance Unit. A guide to statistical methods for injury surveillance. Canberra: AIHW; 2005.
36. Asch DA, Jedrziewski MK, Christakis NA. Response rates to mail surveys published in medical journals. J Clin Epidemiol. 1997;50(10):1129–36. https://doi.org/10.1016/s0895-4356(97)00126-1.
37. Australian Bureau of Statistics. Participation in Sport and Physical Activities Australia. Doc. No. 4177.02002.
38. Hocknell A. High-performance driver design: benefits for all golfers. J Sports Sci. 2002;20(8):643–9. https://doi.org/10.1080/026404102320183211.
39. Sugaya H, Tschiya A, Moriya H, Margan D, Banks S. Low back injury in elite and professional golfers: an epidemiologic and radiographic study. In: Farrally MR, Cochrane AJ, editors. Science and golf III: proceedings of the World Scientific Congress of Golf. Champaign, IL: Human Kinetics; 1999. p. 83–91.
40. McCarroll JR. The frequency of golf injuries. Clin Sports Med. 1996;15(1):1–7.
41. Cole MH, Grimshaw PN. The Biomechanics of the Modern Golf Swing: Implications for Lower Back Injuries. Sports Med. 2016;46(3):339–51. https://doi.org/10.1007/s40279-015-0429-1.
42. Walker CT, Uribe JS, Porter RW. Golf: a contact sport. Repetitive traumatic discopathy may be the driver of early lumbar degeneration in modern-era golfers. J Neurosurg Spine. 2019;5:1–4. https://doi.org/10.3171/2018.10.Spine181113.
43. Grimshaw PN, Burden AM. Case report: reduction of low back pain in a professional golfer. Med Sci Sports Exerc. 2000;32(10):1667–73. https://doi.org/10.1097/00005768-200010000-00001.
44. Kim SY, Chung SK, Kim DY. Multiple cervical spinous process fractures in a novice golf player. J Korean Neurosurg Soc. 2012;52(6):570–3. https://doi.org/10.3340/jkns.2012.52.6.570.
45. Menzer H, Gill GK, Paterson A. Thoracic spine sports-related injuries. Curr Sports Med Rep. 2015;14(1):34–40. https://doi.org/10.1249/jsr.0000000000000117.
46. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine (Phila Pa 1976). 1983;8(8):817–31. https://doi.org/10.1097/00007632-198311000-00003.
47. Berg EE. The sternal-rib complex. A possible fourth column in thoracic spine fractures. Spine (Phila Pa 1976). 1993;18(13):1916–9.
48. Horton WC, Kraiwattanapong C, Akamaru T, Minamide A, Park JS, Park MS, Hutton WC. The role of the sternum, costosternal articulations, intervertebral disc, and facets in thoracic sagittal plane biomechanics: a comparison of three different sequences of surgical release. Spine (Phila Pa 1976). 2005;30(18):2014–23. https://doi.org/10.1097/01.brs.0000180478.96494.88.
49. Watkins R, Watkins R 3rd, Williams L, Ahlbrand S, Garcia R, Karamanian A, et al. Stability provided by the sternum and rib cage in the thoracic spine. Spine (Phila Pa 1976). 2005;30(11):1283–6. https://doi.org/10.1097/01.brs.0000164257.69354.bb.
50. Hochschuler S. The Spine in Sports. Philadelphia, PA: Hanley & Belfus, Inc.; 1990.
51. Stillerman CB, Chen TC, Couldwell WT, Zhang W, Weiss MH. Experience in the surgical management of 82 symptomatic herniated thoracic discs and review of the literature. J Neurosurg. 1998;88(4):623–33. https://doi.org/10.3171/jns.1998.88.4.0623.
52. Vanichkachorn JS, Vaccaro AR. Thoracic disk disease: diagnosis and treatment. J Am Acad Orthop Surg. 2000;8(3):159–69. https://doi.org/10.5435/00124635-200005000-00003.
53. Lord MJ, Ha KI, Song KS. Stress fractures of the ribs in golfers. Am J Sports Med. 1996;24(1):118–22. https://doi.org/10.1177/036354659602400121.
54. Kao JT, Pink M, Jobe FW, Perry J. Electromyographic analysis of the scapular muscles during a golf swing. Am J Sports Med. 1995;23(1):19–23. https://doi.org/10.1177/036354659502300104.
55. Kang DH, Lee SH. Multiple spinous process fractures of the thoracic vertebrae (Clay-Shoveler's Fracture) in a beginning Golfer: a case report. Spine (Phila Pa 1976). 2009;34(15):E534–7. https://doi.org/10.1097/BRS.0b013e3181a983bb.
56. Mallon WJ. Golf. In: Hawkins RJ, Misamore GW, editors. Shoulder Injuries in the Athlete: Surgical Repair and Rehabilitation. New York, NY: Churchill Livingstone; 1996.
57. Pink M, Jobe FW, Perry J. Electromyographic analysis of the shoulder during the golf swing. Am J Sports Med. 1990;18(2):137–40. https://doi.org/10.1177/036354659001800205.
58. Mitchell K, Banks S, Morgan D, Sugaya H. Shoulder motions during the golf swing in male amateur golfers. J Orthop Sports Phys Ther. 2003;33(4):196–203. https://doi.org/10.2519/jospt.2003.33.4.196.
59. Jobe FW, Perry J, Pink M. Electromyographic shoulder activity in men and women professional golfers. Am J Sports Med. 1989;17(6):782–7. https://doi.org/10.1177/036354658901700611.
60. Jobe FW, Moynes DR, Antonelli DJ. Rotator cuff function during a golf swing. Am J Sports Med. 1986;14(5):388–92. https://doi.org/10.1177/036354658601400509.
61. Jobe FW, Center CHM. Exercise Guide to Better Golf: Human Kinetics; 1994.
62. Cardoso TB, Pizzari T, Kinsella R, Hope D, Cook JL. Current trends in tendinopathy management. Best Pract Res Clin Rheumatol. 2019;33(1):122–40. https://doi.org/10.1016/j.berh.2019.02.001.
63. Malliaras P. Understanding mechanisms to improve exercise interventions in tendinopathy. Phys Ther Sport. 2017;27:50–1. https://doi.org/10.1016/j.ptsp.2016.12.006.

64. van Ark M, Cook JL, Docking SI, Zwerver J, Gaida JE, van den Akker-Scheek I, Rio E. Do isometric and isotonic exercise programs reduce pain in athletes with patellar tendinopathy in-season? A randomised clinical trial. J Sci Med Sport. 2016;19(9):702–6. https://doi.org/10.1016/j.jsams.2015.11.006.
65. Vives MJ, Miller LS, Rubenstein DL, Taliwal RV, Becker CE. Repair of rotator cuff tears in golfers. Arthroscopy. 2001;17(2):165–72. https://doi.org/10.1053/jars.2001.19654.
66. Mallon WJ, Colosimo AJ. Acromioclavicular joint injury in competitive golfers. J South Orthop Assoc. 1995;4(4):277–82.
67. Bell R, Acus R, Noe D. A study of acromioclavicular joint forces [abstract]. J Shoulder Elbow Surg. 1993;2(suppl 1-2):S24.
68. Burden AM, Grimshaw PN, Wallace ES. Hip and shoulder rotations during the golf swing of sub-10 handicap players. J Sports Sci. 1998;16(2):165–76. https://doi.org/10.1080/026404198366876.
69. Hovis WD, Dean MT, Mallon WJ, Hawkins RJ. Posterior instability of the shoulder with secondary impingement in elite golfers. Am J Sports Med. 2002;30(6):886–90. https://doi.org/10.1177/03635465020300062101.
70. Jobe FW, Pink MM. Shoulder pain in golf. Clin Sports Med. 1996;15(1):55–63.
71. Stover C, Stoltz J. Golf for the senior player. Clin Sports Med. 1996;15(1):163–78.
72. Jobe FW, Schwab DM. Golf for the mature athlete. Clin Sports Med. 1991;10(2):269–82.
73.• Robinson PG, Williamson TR, Creighton AP, Cheng J, Murray AD, Prather H, et al. Rate and Timing of Return to Golf After Hip, Knee, or Shoulder Arthroplasty: A Systematic Review and Meta-analysis. Am J Sports Med. 2022;12:3635465211064292. https://doi.org/10.1177/03635465211064292 **This article was a systematic review and meta-analysis which assessed the rate and timing of returning to golf and the factors associated with rate and timing to return to golf after hip, knee or shoulder arthroplasty.**
74. Papaliodis D, Richardson N, Tartaglione J, Roberts T, Whipple R, Zanaros G. Impact of Total Shoulder Arthroplasty on Golfing Activity. Clin J Sport Med. 2015;25(4):338–40. https://doi.org/10.1097/jsm.0000000000000148.
75. Jensen KL, Rockwood CA Jr. Shoulder arthroplasty in recreational golfers. J Shoulder Elbow Surg. 1998;7(4):362–7. https://doi.org/10.1016/s1058-2746(98)90024-6.
76. Schumann K, Flury MP, Schwyzer HK, Simmen BR, Drerup S, Goldhahn J. Sports activity after anatomical total shoulder arthroplasty. Am J Sports Med. 2010;38(10):2097–105. https://doi.org/10.1177/0363546510371368.
77. Stockard AR. Elbow injuries in golf. J Am Osteopath Assoc. 2001;101(9):509–16.
78. Kohn HS. Prevention and treatment of elbow injuries in golf. Clin Sports Med. 1996;15(1):65–83.
79. Mallon WJ. Ask the doctor [column]. Golf Digest. 1986-1991.
80. Murray PM, Cooney WP. Golf-induced injuries of the wrist. Clin Sports Med. 1996;15(1):85–109.
81. Glazebrook MA, Curwin S, Islam MN, Kozey J, Stanish WD. Medial epicondylitis. An electromyographic analysis and an investigation of intervention strategies. Am J Sports Med. 1994;22(5):674–9. https://doi.org/10.1177/036354659402200516.
82. Loftice J, Fleisig GS, Zheng N, Andrews JR. Biomechanics of the elbow in sports. Clin Sports Med. 2004;23(4):519–30, vii-viii. https://doi.org/10.1016/j.csm.2004.06.003.
83. Peerbooms JC, Sluimer J, Bruijn DJ, Gosens T. Positive effect of an autologous platelet concentrate in lateral epicondylitis in a double-blind randomized controlled trial: platelet-rich plasma versus corticosteroid injection with a 1-year follow-up. Am J Sports Med. 2010;38(2):255–62. https://doi.org/10.1177/0363546509355445.
84.• Güngör E, Karakuzu Güngör Z. Comparison of the efficacy of corticosteroid, dry needling, and PRP application in lateral epicondylitis. Eur J Orthop Surg Traumatol. 2021. https://doi.org/10.1007/s00590-021-03138-2 **This study compared the short-term efficacy of dry needling, corticosteroids and PRP in management of alteral epicondylitis and concluded that dry needling is an effective and safe application for the short-term treatment of lateral epicondylitis.**
85. Cahalan TD, Cooney WP 3rd, Tamai K, Chao EY. Biomechanics of the golf swing in players with pathologic conditions of the forearm, wrist, and hand. Am J Sports Med. 1991;19(3):288–93. https://doi.org/10.1177/036354659101900314.
86. Chao EYS, Tamai K, Cahalan TD. Biomechanics of the golf swing as related to club handle design. Biomech Sports. 1987:107–11.
87. Clancy WG Jr, Hagan SV. Tendinitis in golf. Clin Sports Med. 1996;15(1):27–35.
88. Hawkes R, O'Connor P, Campbell D. The prevalence, variety and impact of wrist problems in elite professional golfers on the European Tour. Br J Sports Med. 2013;47(17):1075–9. https://doi.org/10.1136/bjsports-2012-091917.
89. Parziale JR, Mallon WJ. Golf injuries and rehabilitation. Phys Med Rehabil Clin N Am. 2006;17(3):589–607. https://doi.org/10.1016/j.pmr.2006.05.002.
90. Gulgin HR, Schulte BC, Crawley AA. Correlation of Titleist Performance Institute (TPI) level 1 movement screens and golf swing faults. J Strength Cond Res. 2014;28(2):534–9. https://doi.org/10.1519/JSC.0b013e31829b2ac4.
91. Chu SK, Jayabalan P, Kibler WB, Press J. The Kinetic Chain Revisited: New Concepts on Throwing Mechanics and Injury. Pm r. 2016;8(3 Suppl):S69–77. https://doi.org/10.1016/j.pmrj.2015.11.015.
92. Kibler WB, Wilkes T, Sciascia A. Mechanics and pathomechanics in the overhead athlete. Clin Sports Med. 2013;32(4):637–51. https://doi.org/10.1016/j.csm.2013.07.003.
93. Lintner D, Noonan TJ, Kibler WB. Injury patterns and biomechanics of the athlete's shoulder. Clin Sports Med. 2008;27(4):527–51. https://doi.org/10.1016/j.csm.2008.07.007.
94. Seroyer ST, Nho SJ, Bach BR Jr, Bush-Joseph CA, Nicholson GP, Romeo AA. Shoulder pain in the overhead throwing athlete. Sports Health. 2009;1(2):108–20. https://doi.org/10.1177/1941738108331199.
95. van der Hoeven H, Kibler WB. Shoulder injuries in tennis players. Br J Sports Med. 2006;40(5):435–40; discussion 40. https://doi.org/10.1136/bjsm.2005.023218.
96. Santana J, McGill SM, Brown LE. Anterior and Posterior Serape: The Rotational Core. Strength Cond J. 2015;37:8–13.
97. Carr G, Carr GA. Mechanics of Sport: A Practitioner's Guide: Human Kinetics; 1997.
98. Kirkpatrick P. Batting the Ball. Am J Phys. 1963;31(8):606–13. https://doi.org/10.1119/1.1969691.
99. McGill S. Low Back Disorders: Evidence-based Prevention and Rehabilitation: Human Kinetics; 2007.
100. McGill SM. Ultimate Back Fitness and Performance (5th edition). Backfitpro: Waterloo, Canada; 2014.

101. Logan GA, McKinney WC. The Serape Effect. J Health, Phys Educ, Recreat. 1970;41(2):79–80. https://doi.org/10.1080/00221473.1970.10613972.
102. Wallace P, Reilly T. Spinal and metabolic loading during simulations of golf play. J Sports Sci. 1993;11(6):511–5. https://doi.org/10.1080/02640419308730021.
103. Pink MM, Jobe FW, Yocum LA, Mottram R. Preventative exercises in golf: arm, leg, and back. Clin Sports Med. 1996;15(1):147–62.
104. Jobe FWMDRBB. 30 exercises for better golf. Inglewood, Calif.: Champion Press; 1986.
105. Thériault G, Lacoste E, Gadoury M, Ouellet S, Leblanc C. Golf injury characteristics: a survey from 528 golfers. Med Sci Sports Exerc. 1996;28:65.
106. Kinsella R, Cowan SM, Watson L, Pizzari T. A comparison of isometric, isotonic concentric and isotonic eccentric exercises in the physiotherapy management of subacromial pain syndrome/rotator cuff tendinopathy: study protocol for a pilot randomised controlled trial. Pilot Feasibility Stud. 2017;3:45. https://doi.org/10.1186/s40814-017-0190-3.
107. Creighton A. 5 exercises for the perfect golf warm-up 2020 [Available from: https://www.hss.edu/playbook/5-exercises-for-the-perfect-golf-warm-up/.

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