Review

Sport injuries of the elbow

Simon P Frostick, Mohammad Mohammad, David A Ritchie

Department of Musculoskeletal Science, University of Liverpool, Liverpool, United Kingdom
S P Frostick
M Mohammad

Department of Radiology, Royal Liverpool University Hospital, Liverpool L69 3GA
D A Ritchie

Correspondence to: Professor S P Frostick, Department of Musculoskeletal Science, University of Liverpool, Liverpool L69 3GA, United Kingdom.

Accepted for publication 19 July 1999

Athletic injuries of the elbow are common especially in throwing sports such as baseball and tennis. An early diagnosis, early initiation of treatment, and appropriate referrals for surgical management enable athletes to return safely to competition as quickly as possible. Elbow injuries may involve any of the anatomical structures in the region.

The normal range of motion at the elbow joint is 140° of flexion from full extension and from 75° of pronation to 85° of supination.[1] The functional range of motion for activities of daily living is from 30° to 130° of flexion and 50° of supination and pronation.[2] This arc of motion allows independent function but would be very limiting for many athletic pursuits. The most appropriate range of motion varies with the type of sport. For example, a gymnast performing handstands requires at least full extension (if not hyperextension) to lock the elbows, whereas baseball pitchers may have a flexion contracture of their dominant elbow of up to 20° that does not limit their effectiveness.[3]

Elbow injuries in athletes can be classified into acute or chronic. Most injuries in the athlete are chronic overuse injuries. Overuse injuries are the result of repetitive overload resulting in microtears of the soft tissues. They are often myotendinous to the flexor-pronator muscle group and can lead to tendonitis or muscular injury and eventually elbow flexion contracture. Repetitive microrupture of the flexor-pronator muscle group compromises the healing process leading to muscle contracture and fatigue. More repetitive stresses to the ulnar side of the elbow affect the ulnar collateral ligament. Imperfect healing of the medial collateral ligament (MCL) results in its attenuation and elbow instability. Any further valgus stresses induce compression of the radiocapitellar joint.

Table 1 Sports that commonly produce elbow injuries[5]

Sport	*Common injury*
Racquet sports	Lateral epicondylitis with backhand
Golf	Medial epicondylitis on downswing with trailing arm
	Lateral epicondylitis with leading arm
Basketball	Posterior compartment with follow through on jump shot
Water-skiing	Valgus extension overload of the posterior compartment with trick skiing
Bowling	Flexor-pronator soreness
Baseball	Valgus stress of pitching: medial traction, lateral compression, posterior abutment
Volleyball	Valgus stress at impact of striking
Football	Valgus stress with throwing a pass; hyperextension and dislocation and olecranon bursitis with direct trauma
Gymnastics	Radiocapitellar overload and posterior impingement with weight bearing on extended elbow
Weight training	Ulnar collateral ligament sprain, ulnar nerve irritation
Field events	
Shot-put	Posterior impingement with follow through
Javelin	Valgus-extension overload of throwing: medial traction, posterior abutment, lateral compression
Canoeing, kayaking	Distal bicipital tendinitis
Archery	Extensor muscle fatigue, lateral epicondylitis of bow arm
Rock climbing	Brachialis or distal bicipital tendinitis

Incidence

Safran[3] suggests that elbow injuries are becoming more common as more people participate in throwing and racquet sports. The type of injury that is encountered depends, to some extent, on the type of athletic pursuit, but the injuries can be roughly grouped into the enthesopathies (lateral and medial epicondylitis and other rarer similar conditions), valgus stress injuries as the result of altered function of the primary constraint to valgus stress, and the MCL, posterior impingement, and nerve compression syndromes. Osteochondritis dissecans is found in younger athletes. Slocum[4] classified throwing injuries to the elbow but interestingly did not mention injuries such as MCL damage, indicating that this type of injury has only fairly recently been recognised. Table 1 summarises the types of injuries found in relation to particular sports. Injuries to the elbow in throwers are quite common. King *et al*[6] reported that 50% of all pitchers have flexion contractures and about 30% have a cubitus valgus deformity. Tullos and King[1] reported that 50% of baseball pitchers have injuries of either their shoulder or elbow that prevent them from performing at some point in their careers. The same authors also suggested that two thirds of pitchers have radiographic evidence of upper limb joint damage. Conway *et al*[7] found in a group of baseball pitchers undergoing repair for chronic medial instability of the elbow that 68% had a fixed flexion deformity. The common throwing injuries on the medial side of the elbow include MCL injury, posteromedial osteophyte formation, medial epicondylitis, and ulnar nerve injury.[8] Modern techniques of training and treatment may well have reduced the problem to some extent but the overall incidence of athletic injuries to the elbow is increasing because of increased numbers of participants.

Biomechanics of elbow function

One of the major misconceptions about all upper limb joints concerns whether they are weight-bearing or not. The more correct term that should be applied to upper limb joints is that they are load-bearing and the level of the load depends on the position of the limb and the activity being undertaken. Certainly, the upper limb joints bear less load than the hip or knee but to say they are not load-bearing is incorrect. An and Morrey[9] have estimated that, at 90° of flexion, a force three times body weight can be transmitted through the elbow. The stability of the elbow depends on the bony architecture, the collateral ligaments (medial and lateral), and dynamic forces from the extensive musculature that crosses the joint. The contribution made by each component depends on the position of the joint. Further, it must be remembered that the radiohumeral joint and the ulnohumeral joints both play a significant role in stress distribution. In sport injuries of the elbow, it is not only the transmission of load through the joint that is important but also the angular velocities that are achieved in order to launch a projectile, etc. Conway *et al*[7] state that, in the acceleration phase of throwing a baseball, the peak angular velocity across the elbow is 4500° per second. At this level, tissues such as the MCL may be subjected to damaging forces.

The movement of the elbow is extremely complex in all athletic activities. The phases have been studied extensively in baseball pitchers. Although the exact details differ in other overhead sports, the pitcher's elbow movement can be used as a model of the stresses that are applied in such strenuous activity.

The act of throwing a baseball can be divided into several phases; each phase involves complex body movements with the elbow playing a central role in each phase. Werner *et al*[10] divided the throwing motion into six phases: wind up, stride, arm cocking, arm acceleration, arm deceleration, and follow through. Wind up starts when the thrower begins the movement and is completed when the front of the knee reaches its maximum height. The elbow is flexed throughout this phase. The stride phase ends when the front foot contacts the mound and during this phase the throwing arm and ball separate from the lead arm and glove. The elbow in this phase extends at first and then flexes. Minimal muscle activity and elbow kinetics are present during the wind up and stride phases. The arm cocking phase starts when the front foot contacts the mound and ends when the arm reaches maximum external rotation. Shortly after the arm cocking phase begins, the upper torso is rotated to face the batter.[11] Elbow flexors are active during the early part of the arm cocking phase.[10] About 30 millseconds before maximum external rotation, the triceps become active and elbow flexors become inactive, resulting in a decrease in flexion torque and thus the elbow begins to extend.[11] At the conclusion of the arm cocking phase, the shoulder is abducted, extended, and externally rotated to about 130° and the elbow is flexed to about 90°. In this position, the elbow begins to be subjected to severe valgus stress.[12] During the arm cocking phase, the arm rotates externally at the shoulder and a varus torque is produced at the elbow to prevent the joint from going into valgus. An abnormal load on the elbow in this phase may lead to serious injury. In the transitional moment from arm cocking to arm acceleration, the shoulder rotates internally, the forearm is in near-full supination, and the elbow flexes another 20–30° increasing the valgus load on the medial side of the elbow.[12] This moment is called the moment of explosion or initiation of speed.[13] The arm acceleration phase is the short time from maximum external rotation to ball release; during this phase the elbow extends rapidly to 20° of flexion at ball release, with a maximum speed as high as 2500° per second[11] to 4500° per second.[7] During arm acceleration, the need to resist valgus stress at the elbow can result in wedging of the olecranon against the medial aspect of the trochlear groove and the olecranon fossa. This impingement leads to osteophyte formation at the posterior and posteromedial aspects of the olecranon tip and can cause chondromalacia and loose body formation.[14] The arm deceleration phase begins from ball release and when the arm reaches its maximum internal rotation. Soon after ball release, high compressive forces are generated at the shoulder and elbow to prevent distraction.[11] These compressive forces are greatest with throwing a "fastball" or "slider pitches".[15] During the later stages of acceleration, the triceps muscle contracts to extend the elbow, placing tensile forces on the olecranon process.[16] The follow through phase begins at maximum internal rotation and ends when the pitcher attains a balanced fielding position.[11] During the follow through phase, the elbow flexes into the resting position.[17] Forces at the elbow during follow through are significantly less than during arm deceleration.[11] This description of the position changes that occur in baseball pitching shows that the elbow is put under severe stress at several points in the manoeuvre, each of which can result in serious injury.

The act of throwing depends on a stable elbow joint. Considerable emphasis has been placed on the role of the MCL in the stability of the elbow to valgus stress. In a number of articles and reviews, Morrey and others refer to the anterior bundle of the MCL as being the primary stabiliser against valgus stress.[18 19] The radial head is regarded as being the secondary stabiliser to valgus stress, which in the presence of a normal MCL plays no part in resisting a valgus deforming force. Interestingly, there is little in the literature about the role of the muscles acting about the elbow and their ability to resist deforming forces. Hamilton *et al*[20] showed alterations in the electromyographic characteristics of the extensor/supinator and flexor/pronator groups during different phases of baseball pitching when comparing pitchers with an MCL injury with those without. Further, it is evident that in some sports—for example, gymnastics—there appears to be hypermobility of the elbow joint. Ellenbecker *et al*[21] have shown that in uninjured baseball pitchers there is an increase in the opening of the medial joint space of the dominant arm compared with the non-dominant on valgus stress testing. This may suggest that there is

Table 2 Valgus extension overload syndrome[23]

Medial tension injury type	*Description*
I	MCL injury, MCL subacute injury with inflammation, MCL partial tear, MCL complete tear
II	Posteromedial impingement, chondromalacia, osteophyte formation, olecranon stress fractures and loose bodies
III	Flexor-pronator injury, medial epicondylitis, partial rupture of flexor-pronator muscle type
IV	Ulnar nerve entrapment, cubital tunnel syndrome, ulnar nerve subluxation, lateral compression injury
V	Radiocapitellar overload syndrome, lateral elbow pain, capitellum and radial head chondromalacia, capitellum and radial head osteochondritis dissecans

MCL, medial collateral ligament.

chronic stretching of the MCL before an injury occurs which presumably could put the MCL at risk.

In baseball pitchers, most elbow injuries occur during the late cocking and early acceleration phase.[8] Bennett[22] and Slocum[4] were the first to divide throwing injuries of the elbow into two types: medial tension and valgus compression. This concept has been refined so that throwing injuries now fall into a broad group termed valgus extension overload syndrome (table 2). During the early part of the acceleration phase, excessive stress causes a wedging effect of the olecranon into the olecranon fossa. This impingement leads to osteophyte formation at the posterior and posteromedial aspects of the olecranon tip. A chondromalacic lesion may be found on the trochlear of the humerus as a result. Moreover, the olecranon osteophyte can break off as a loose body in the joint. If the posteromedial impingement is preventing optimum performance in the athlete, surgical excision of the posteromedial aspect of the olecranon tip may be required.[14] In a pitcher with an attenuated MCL, more of the valgus stability depends on the articulation of the radial head with the capitellum.[24] Repetitive loading of the radiohumeral joint can lead to osteochondral fractures of the capitellum which can displace and become a loose body within the joint.[8]

In gymnasts, the upper extremities transmit high loads during tumbling, handstands, one arm balance, and trunk stabilisation on the bars. The most common elbow injury in gymnasts is a traction injury to the ulnar aspect of the elbow joint.[25] These injuries include partial tears of flexor muscle mass, MCL strains, and medial epicondyle traction injuries. In gymnastics, excessive forces are applied to the triceps, especially during vaulting and floor exercises, when the repeated flexion and extension of the elbow inflames the triceps insertion.[26] Inflammation of the triceps insertion is described as the jumper's knee of the elbow.[27]

In tennis, the load on the elbow is dependent on the type of stroke used. During the serve, the elbow functions through a range of 100°, from 116 to 20° of flexion, but during ground strokes, the range of motion is significantly smaller, with 11° for forehand and 18° for backhand.[28] Morris *et al*[29] found that the pronator teres and triceps play significant roles in power production for the serve. Kibler[28] indicated that the elbow joint contributes 15% of the force produced during the tennis serve. The motion for ground strokes creates smaller demands on the elbow.

Physical examination of the thrower's elbow

The examination of the elbow includes inspection, palpation of bony and soft tissues, range of motion assessment, resisted muscle testing, a neurological examination, and special tests. A complete and thorough history is important including site and severity of pain and the aggravating movements.

Athletes with chronic instability of the elbow due to either complete disruption or attenuation of the MCL have pain and soreness along the medial elbow during the acceleration phase (85%), "projectile release" or contact between the racquet and ball (35%), and during follow through (25%).[7]

The mechanism of injury should be explained thoroughly as it is usually the best guide for diagnosis. For example, feeling a pop on the medial elbow while throwing followed by soft tissue swelling and pain indicates an MCL injury. In contrast, the throwers with ulnar nerve pathology often complain of neurological symptoms in the hand.[30]

Examination of the patient requires complete exposure of the trunk and both arms. This provides the clinician with a full view of the neck, shoulders, and arms. The following structures should be palpated and tests carried out. (*a*) The medial epicondyle as it is the origin of the flexor pronator group and its base is the origin of the ulnar collateral ligament. (*b*) The medial supracondylar ridge should be examined for osteophytes and any other potential causes of nerve compression syndromes. (*c*) Tenderness or bony prominence along the proximal one third of the ulnar border may be associated with stress fracture in throwers.[30] (*d*) The lateral epicondyle is painful in cases of lateral epicondylitis. Tenderness over the supinator muscle and not over the lateral epicondyle or conjoint tendon differentiates radial tunnel syndrome from unresolved lateral epicondylitis.[31] In addition, several other physical findings in radial tunnel syndrome are absent in patients with tennis elbow—for example, pain may be produced with resisted supination or resisted extension of the middle finger ("positive middle finger sign").[32] On physical examination of patients with posterior interosseous nerve compression, there is weakness in the long thumb abductor, thumb and digital extensors, and the extensor carpi ulnaris, and when wrist extension is tested, there is radial deviation of the extended wrist due to weakness of the extensor carpi ulnaris.[32] (*e*) The MCL is occasionally referred to as the anterior cruciate ligament of the elbow. It extends from the medial epicondyle to the medial margin of the ulnar trochlea notch. It is difficult to palpate but pain can be elicited on valgus stress testing. Conway *et al*[7] describe the valgus stress test as follows: "the arm of the standing patient was postioned in the coronal plane of the body, with the shoulder in abduction and external rotation and the forearm supinated. The elbow was flexed 30° to reduce the constraints provided by the configurations of the bones of the elbow. The patient's hand was held between the examiner's arm and chest wall; this left one of the examiner's hands free to apply valgus stress on the elbow and the other hand free to palpate the medial joint line beneath the ulnar collateral ligament". (*f*) A neurological examination should be performed. It should be determined if the ulnar subluxes or dislocates from the groove. It must be remembered that in some athletes ulnar neuritis may be associated with MCL instability. (*g*) Valgus extension overload test is positive in the case of painful elbow due to posteromedial osteophyte in the medial side of olecranon fossa.[14] Impingement in this area is a common finding in throwers. The test is performed by placing the arm in forced extension and exerting valgus stress, simulating the position of the arm during the acceleration phase of pitching. The palpating finger over the posteromedial olecranon tip will elicit tenderness. Crepitus may be felt. (*h*) In patients with radiocapitellar chondromalacia or degenerative changes, if the examiner places a finger over the radial head while gently supinating and pronating the elbow in different degrees, crepitus, popping, and pain may be elicited.

Imaging techniques

Plain radiographs of the elbow should include an anteroposterior view in extension and full supination, a lateral view with the elbow in 90° of flexion, both external and internal oblique views in extension, and an axial projection of the olecranon process.

In cases of MCL injuries, routine radiographs may show calcification within the ligament and chronic traction spurs on the ulna or loose bodies. A gravity valgus stress radiograph of both the symptomatic and asymptomatic elbows can be useful in assessing medial joint line opening, although a negative radiograph should not rule out the diagnosis of MCL insufficiency.[33]

More detailed imaging methods may be needed to determine the exact extent of an injury especially when there is ligamentous damage. In a recent study of the reliability of imaging techniques,[34] computed tomography (CT) arthrograms and magnetic resonance imaging (MRI) scans were compared in baseball pitchers with MCL injuries who were undergoing surgery. Both CT arthrogram and MRI had 100% sensitivity in detecting complete tears, but only CT arthrography was helpful in detecting partial undersurface tears (71% sensitivity compared with 14% for MRI) in which a thin superficial layer of the anterior bundle is still intact. Both methods showed high specificity in detecting tears (CT arthrogram 91%, MRI 100%). A further study determined the role of MR arthrography in similar injuries.[35] This study showed that MR arthrography is likely to be useful in detecting both complete and partial tears of the MCL.

Plain films will also detect most cases of osteochondritis dissecans of the capitellum. Cystic changes within the capitellum and flattening or irregularities of the articular surface can be seen, especially in the anteroposterior view. Loose bodies can sometimes be seen on plain films, but often CT arthrography or MRI is needed. A bone scan may be positive in cases in which the plain radiographic findings are unhelpful, but CT/MRI will provide definitive answers.[36] MRI is useful in identifying early osteochondritis dissecans in the elbow. Decreased signal is seen in the capitellum on T_1 weighted images, with increased signal on T_2 weighted images.[35]

CT of the elbow provides excellent bony details; also small loose bodies that escape detection on plain films can be identified with CT. So, in general, CT and MRI are helpful when symptoms persist and plain radiographs fail to define the disorder precisely. MRI is now the imaging method of choice for detecting and staging osteochondritis dissecans. Intact cartilage, contrast enhancement of the lesion, and absent "cystic" defects are in keeping with a stable lesion (fig 1) whereas cartilage defects with or without incomplete separation of the fragment, fluid around an undetached fragment, and a dislodged fragment denote an unstable lesion. Therefore MRI plays a crucial role in the decision on which patients require arthroscopy and possible intervention.[37–39] Osteochondritis has to be differentiated from the normal pseudo-defect of the capitellum, but this defect occurs on the posterolateral aspect of the capitellum whereas osteochondritis dissecans is classically on the anterior aspect. Panner's disease (osteochondrosis of the capitellum) is similar to osteochondritis dissecans but occurs in children of five to seven years of age and carries a good prognosis.[40] Residual deformity and loose bodies are commonly found with osteochondritis dissecans but are unusual with Panner's disease. In rare cases, MRI may be helpful in diagnosing lateral epicondylitis (fig 2). Ruptures of the distal biceps tendon are also readily confirmed by MRI (fig 3).

Elbow arthroscopy may be a useful modality in the diagnosis and treatment of athletic elbow injuries. It is difficult to learn and requires high quality equipment. For the few experts in the technique, the indications for its use in the elbow have broadened to include loose body and osteophyte removal, synovectomy, joint contracture release, evaluation of undiagnosed elbow pain, evaluation and treatment of acute fractures, and diagnosis of MCL tears.[41] The advantage of elbow arthroscopy is that extensive direct visualisation of the elbow joint can be achieved and treatment undertaken with minimal soft tissue damage. At present it is not possible to be certain that rehabilitation is any faster than with open techniques and therefore whether the athlete can return to competition earlier. Experience with the shoulder has been that the rehabilitation time after arthroscopic techniques is at least as long as after open techniques and some surgeons protect the joint for considerably longer.

Figure 1 Imaging results for a 14 year old girl (a gymnast) with lateral elbow pain (diagnosis osteochondritis dissecans of the capitellum). (A) Oblique arthrographic image of the capitellum; sagittal (B) T_1 weighted spin echo, (C) T_2 weighted magnetisation transfer contrast gradient echo and (D) T_1 weighted volume spectral presaturation inversion recovery magnetic resonance images. The arthrographic image shows an ill defined 10 mm subtle subchondral lucency (curved white arrows) affecting the anterior portion of the capitellum but the overlying cartilage appears intact. On the magnetic resonance images, the osteochondral lesion displays inhomogeneous mainly intermediate signal intensity on both T_1W/T_2W resulting from some reparative granulation/fibrous tissue (black arrowheads). Some reactive change is noted in the adjacent humeral marrow. The overlying cortex has an ill defined irregular margin, and the articular cartilage (straight white arrows) is thickened and inhomogeneous. However, there is no fluid between the osteochondral lesion and parent bone and the lesion is considered stable.

Elbow arthroscopy is a technically demanding procedure, and a detailed knowledge of the elbow anatomy is needed to avoid neurovascular complications from improper portal placement. The patient is placed in a supine position on the operating table, with the arm suspended freely over the edge of the table to allow full access to the elbow. The shoulder is abducted to 90° and the elbow flexed to 90°. The arm position is maintained with Chinese finger traps attached to an overhead pulley using a counterweight of 2–5 kg. Elbow flexion maintains relaxation of the neurovascular structures in the antecubital fossa and allows capsular laxity facilitating distension.[42] The soft spot of the elbow is located before portal placement. It lies in the centre of a triangle bordered by the olecranon tip, radial head, and the lateral epicondyle. The elbow joint is usually distended with saline introduced. The anterolateral portal is established first; it is just anterior and proximal to the radial head and is located 2–3 cm distal and 1 cm anterior to the lateral epicondyle.[43] The second portal that is

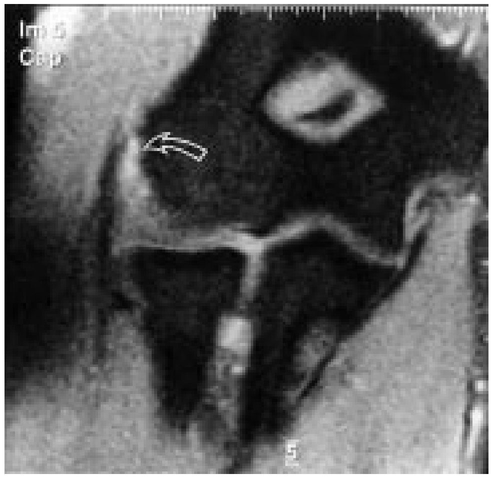

Figure 2 Coronal T_2 weighted fast spin echo fat suppressed magnetic resonance image of the elbow of a patient with lateral epicondylitis showing a tear of the common extensor origin (arrow).

usually established is the anteromedial. This can be positioned by either an inside out method or an outside in technique. The anteromedial portal is 2 cm anterior and 2 cm distal to the medial epicondyle.[44] The anterolateral and anteromedial portals allow a thorough examination of the anterior compartment of the elbow. Once the anterior compartment has been examined, the direct lateral portal is placed at the soft spot of the elbow. A second lateral working portal can be established 1 cm distal to the direct lateral portal if needed.[44] The posterolateral portal is made under direct visualisation with the arthroscope in the lateral portal; it is located 3 cm proximal and 1 cm lateral to the tip of the olecranon along the lateral edge of the triceps.[43] The direct posterior portal is established while the scope is in the posterolateral portal. It is placed through the triceps 3 cm proximal to the tip of the olecranon.[43] The posterior portals allow good visualisation of the posterior structures and joint surfaces.

Principles of treatment

The basic principles of treatment of all sporting injuries are that the injuries are speedily and effectively treated with the aim of returning the patient to their sport at the same level as previously as soon as possible. Whether these principles are achievable or not depends on the severity of the injury, the efficacy of the treatment modalities, and the motivation of the sports person. Treatment of injuries of the elbow should start with prevention. Prevention depends on several factors. Firstly, correct training techniques are required to ensure optimal performance without injury. This concept presupposes that there is an understanding of both the optimisation of performance and the causes of injury and normal physiological function. It is to be hoped that, for elite and professional sports persons, good quality coaching are available as well as exercise physiologists, etc. Sports persons other than the elite are unlikely to have access to such professionals so that primary prevention may not be an option. Secondly, prevention requires education about proper warm up, stretching exercises, and avoidance of fatigue. Once an athlete develops an overuse injury, an aggressive non-operative programme is undertaken. The acronym PRICEMM contains the elements of rehabilitation (table 3). The use of various modalities such as ultrasound depends on the preferences of the therapists involved. Our experience is that these methods have very little use in the treatment and rehabilitation of sports persons. In acute injuries, initial rest and reduction of swelling is required before the formal rehabilitation programme is commenced. Wilk *et al*[45] described the phases of rehabilitation after elbow injuries as follows: (*a*) immediate controlled motion; (*b*) immediate strengthening; (*c*) dynamic stabilisation; (*d*) functional progression.

The progression through each phase depends on the response to treatment. Those who provide treatment for these injuries need to have in mind a set of achievable milestones that will demonstrate resolution of the problem to both the patient and therapist but also, when not achieved, indicate that the problem may be more complex than originally thought. The success of non-operative methods of treatment depends on our understanding of the problem in terms of both normal and abnormal physiology, how well the treatment can be applied, and the motivation of the patient. Moreover, it must be remembered that correction of an elbow problem may need a much more holistic approach both physically and psychologically.

Table 3 PRICEMM[3]

P	Protection
R	Rest
I	Ice
C	Compression
E	Elevation
M	Medication
M	Modalities

Some specific conditions

LATERAL AND MEDIAL EPICONDYLITIS

The most common problem with the elbow in athletes is lateral epicondylitis, called tennis elbow in the United Kingdom. Lateral epicondylitis is an overuse injury. It is well known that it affects tennis players but it also affects athletes participating in other racquet sports, throwing athletes, golfers, labourers, and musicians.[46] The term tennis elbow is inappropriate and anachronistic as 95% of cases of lateral epicondylitis occur in non-tennis players.[47] Field and Savoie[48] estimate that 50% of people partaking in any sport that involves "overhead arm motions" will develop lateral epicondylitis. It is associated with repetitive and excessive use of the wrist extensors. Pathologically there is degeneration of the origin of the extensor carpi radialis brevis at the common extensor origin. Coonrad and Hooper[49] described the pathology of tennis elbow as necrosis, round cell infiltration, focal calcification, and scar formation in the extensor carpi radialis brevis origin. Nirschl and Pettrone[50] showed that pathologically there is invasion of blood vessels, fibroblastic proliferation, and lymphatic infiltration (angiofibroblastic hyperplasia). As the process continues, mucoid degeneration at the origin of the tendons occurs.[51] The term tendinosis is sometimes used to distinguish the problem from acute tendinitis.[52] The pathological changes involve the extensor carpi radialis brevis tendon in nearly all cases, but the anterior edge of the extensor communis tendon

Figure 3 Distal biceps tendon rupture in a professional rugby league player. Sagittal (A) T_1WSE and (B) T_2WFSE fat suppressed and (C) axial T_2WFSE fat suppressed magnetic resonance images. Complete avulsion of the biceps tendon close to its insertion at the radial tuberosity (white arrow). The retracted tendon shows an irregular stump surrounded by fluid (arrowheads).

is involved in 30% of cases.[52] Plancher *et al*[53] reported that the extensor carpi radialis longus and the extensor carpi ulnaris may also be involved. Lateral epicondylitis in young tennis players develops as a result of incorrect production of the single arm backhand stroke.[54] Giangarra *et al*[55] compared single and double handed backhand strokes and concluded that using a double handed stroke may allow impact forces to be transmitted through rather than absorbed by the elbow. In right handed golfers, lateral epicondylitis can develop in the left elbow. This occurs in the power portion of the down stroke when the left elbow is extending sharply so that at impact the lateral elbow extensors forcefully and isometrically control hand/wrist motion. On the follow through, the left wrist supinates to cause increased torque on the extensor/supinator origin on the lateral epicondyle.[56]

Kelley *et al*[57] were able to show that, in patients suffering from lateral epicondylitis, there was increased electromyographic activity in the wrist extensors and pronator teres at the point of ball impact and follow through compared with uninjured individuals. Lieber *et al*[58] studied sarcomere length in the extensor carpi radialis brevis and determined that there is a biphasic lengthening of the sarcomeres and postulated that the eccentric contraction may cause muscle damage. Lateral epicondylitis is a common diagnosis but care must be taken not to miss a radial tunnel syndrome, which may be either presenting in association with the epicondylitis or mimicking it. The incidence of lateral epicondylitis is 47% in recreational tennis players and 45% in world class players.[59] Gruchow and Pelletier[60] also noted a 40% incidence of lateral epicondylitis in recreational tennis players. Nirschl[61] noted a 50% incidence of lateral epicondylitis in tennis players older than 30 in a study performed on 200 club players. The male to female ratio is approximately one. The median age of onset of tennis elbow is

41 years although it has been diagnosed in children as young as 12 and people as old as 80. Kitai *et al*[62] compared tennis players with and without lateral epicondylitis. In this study, the players without symptoms were found to be younger and played tennis for fewer hours each week. Most athletes respond to non-operative methods of treatment. This includes activity modification, physiotherapy, and occasionally local steroid instillation. Plancher *et al*[53] emphasised that most athletes respond to non-surgical treatment but also stated that, in carefully selected resistant cases, surgery is successful in 85–95%. Assendelft *et al*[63] performed a systematic review of the literature on the use of steroids in the treatment of lateral epicondylitis, and were only able to find very poor evidence for their benefit and then probably only short term. Labelle *et al*[64] were unable to find any good quality evidence to support any treatment modality for lateral epicondylitis! Comerford P (unpublished work) suggests that, in a situation in which there is dominance of the extensor carpi radialis brevis, lateral epicondylitis will occur and suggests that retraining the primary elbow flexors and lengthening of the wrist extensors is beneficial.

Medial epicondylitis (golfer's elbow) is only 20% as common as lateral epicondylitis.[61] Some 80% of cases of medial epicondylitis are found in men.[65] Lateral epicondylitis in golfers has been reported as often as medial epicondylitis.[66] Lateral epicondylitis more commonly occurs in the left arm, whereas medial epicondylitis occurs more commonly in the right arm. Right handed golfers develop lateral epicondylitis in the left elbow, the pulling arm. Medial epicondylitis occurs as a result of hitting the ground rather than the ball.[67] In amateurs, the lateral elbow was found much more commonly to be the source of injury by nearly 5 to 1 than the medial side.[68] Lateral elbow pain most often involves the lead arm.[69] Among male amateur golfers, the elbow was the most commonly injured site.[67] Field and Savoie[48] have suggested that medial epicondylitis is precipitated by repetitive valgus strain on the elbow. The condition typically presents with pain in the region of the common flexor origin but particularly at the junction of the pronator teres and flexor carpi radialis. As with lateral epicondylitis, the treatment of choice is non-operative, but occasionally surgery is required. Increased flexor electromyographic activity has been found in golfers with medial epicondylitis in the address and swing phases of the stroke.[70] Comerford P (unpublished) has suggested that medial epicondylitis may be due to overactivity of the wrist flexors and unloading can result in resolution of the symptoms.

NERVE INJURIES AND COMPRESSION SYNDROMES

Ulnar nerve

Ulnar neuritis is a common finding in patients with chronic elbow instability, and surgery to stabilise the elbow can precipitate similar symptoms. Conway *et al*[7] reported a 21% postoperative incidence of ulnar nerve symptoms and signs.

Childress[71] noted that 16.2% of the general population had evidence of recurrent dislocation of the ulnar nerve. He divided these into two types. In the first there is an incomplete dislocation of the ulnar nerve; in this group the ulnar nerve is susceptible to direct trauma. In the second type, the nerve dislocates completely and neuritis of the friction type develops more often. Recurrent subluxation of the ulnar nerve is more often found in athletes who exhibit congenital musculoskeletal hyperlaxity.[72] Although these previous data seem to indicate frequent occurrence of a subluxing or dislocating ulnar nerve, it is our personal experience that this is a rarity.

Entrapment of the ulnar nerve can occur as the result of a combination of any of four major aetiological factors. (*a*) Traction injuries to the nerve may occur because of the dynamic valgus forces of pitching especially when combined with valgus instability of the elbow.[73] Apfelberg and Larson[74] showed that the ulnar nerve must elongate on average by 4.7 mm during elbow flexion. Valgus instability due to MCL incompetence results in further traction of the ulnar nerve as it courses around the medial epicondyle. (*b*) Progressive compression can occur at the cubital tunnel or where the nerve passes between the two heads of the flexor carpi ulnaris. Normally the ulnar nerve is not fixed at the elbow and requires freedom to move longitudinally with elbow movement. Compression at the cubital tunnel can occur secondary to inflammation and adhesions from repetitive stresses. O'Driscoll *et al*[75] observed that with elbow flexion there is a decrease in the size of the cubital tunnel because of the anatomic orientation of the cubital tunnel retinaculum resulting in compression and flattening of the ulnar nerve. Entrapment at the origin of the flexor carpi ulnaris is due to overdevelopment secondary to resistance weight training exercises. (*c*) Recurrent subluxation of the nerve due to acquired laxity from repetitive stress or trauma leading to friction neuritis. (*d*) Irregularities within the ulnar groove such as spurs commonly seen from overuse injuries in throwers.

In the throwing athlete multiple factors may operate in the aetiology of the ulnar neuritis.

Radial nerve

Radial tunnel syndrome caused by a compression of the radial nerve is uncommon but may be confused with lateral epicondylitis.[65] There are four possible sites of entrapment of the radial nerve. The most proximal site is just anterior to the radial head and is caused by a fibrous band at the entrance to the radial tunnel. The second cause of compression is by vessels from the recurrent radial vessels. The tendinous margin of the extensor carpi radialis brevis is the third site of compression, and the fourth is that caused by the arcade of Frohse.[8] The arcade of Frohse is found as the nerve enters the supinator. The fourth site is the most common. In 5% of cases, the posterior interosseous nerve entrapment can coexist with lateral epicondylitis.[76] In 30% of people, the arcade of Frohse is a thick fibrous band.[77] Behr and

Altchek[8] mentioned that weight lifters and bowlers have been known to develop posterior interosseous nerve syndrome. Compression neuropathy of the posterior interosseous nerve occurs after repetitive pronation and supination of the forearm in tennis players and with the repeated activity of throwing and batting, and in gymnastics. Cabrera and McCue[78] noted that radial tunnel syndrome alone is seen in throwing sports, swimming, golf, tennis, and weight lifting. Radial tunnel syndrome occurs in athletes participating in sports such as weight lifting, rowing, and bowling through vigorous contraction of the extensor muscles.[32] Andrews and Whiteside[31] reported that radial tunnel syndrome occurs in athletes who perform racquet sports and forceful handwork such as rope climbing. These authors also suggested that the most obvious cause of posterior interosseous nerve syndrome in athletes is overuse/muscular hypertrophy at the arcade of Frohse or in the mid or distal supinator muscle. Radial tunnel syndrome has been referred to as "resistant tennis elbow" because many patients have been misdiagnosed as having lateral epicondylitis with unsuccessful treatment.[8] The presenting symptoms and signs depend on the site of compression. However, there may be no motor or sensory deficits with radial tunnel syndrome.[79] Symptoms and signs may be only found in relation to activities. Nerve conduction studies may not contribute to the diagnosis. Surgical decompression may be required.

Musculocutaneous nerve

Entrapment of this nerve has been reported in swimmers, weight lifters, racquet players, and throwing athletes.[65] Compression of the musculocutaneous nerve occurs proximally at the level of the coracobrachialis. In weight lifters, the condition has been found to be secondary to muscle hypertrophy. More commonly, entrapment of the lateral cutaneous nerve of the forearm is encountered. The nerve is compressed between the distal biceps tendon and the brachialis muscle. Entrapment of this nerve has been reported in racquet ball and tennis players probably secondary to repetitive elbow hyperextension.[77]

Median nerve

Pronator teres syndrome is uncommon; it has been reported in throwing sports, racquet sports, weight lifting, gymnastics, and contact sports.[80] Entrapment of the median nerve occurs as the result of compression from muscle hypertrophy of the dominant arm in racquet sports for example or from both arms in strength training.[31] Entrapment can occur at the ligament of Struthers, lacertus fibrosis, between the two heads of the pronator teres, and at the flexor digitorum superficialis arch. As with radial tunnel syndrome, the presenting complaint depends on the anatomical site of the compression. Nerve conduction studies are required to disclose the level of the compression, and surgical decompression is required.

RUPTURE OF THE DISTAL BICEPS TENDON

Morrey[81] noted that distal rupture of the biceps tendon is rare, accounting for 3–10% of all biceps ruptures with none reported in women, and occurs in the dominant arm in over 80%. Davis and Yassine[82] postulated that the rupture occurred as a combination of degeneration in the tendon and hypertrophic lipping at the anterior border of the radial tuberosity. Leighton *et al*[83] describe the typical case as occurring between the 4th and 6th decades, after a single traumatic event. The rupture occurs at the junction of tendon and bone. Patients present with pain, swelling, and local bruising. Discernible biceps weakness is present but difficult to test because of pain. The treatment is by surgical repair. Morrey *et al*[81] showed that, in patients treated by non-operative means, there was a 40% loss of supination strength and on average a 30% loss of flexion strength, whereas in those treated by operative means full power was restored when repaired acutely. The standard method of treatment was described by Boyd and Anderson[84] but recent modifications such as re-attaching the tendon with suture anchors has simplified the procedure. A number of authors have reported good return of function after surgical repair.[83 85–88] Rupture in sports persons is uncommon in an uncommon problem. In the nine patients described by Leighton *et al*,[83] only one sustained the injury in a sport (weight lifting). Our limited experience includes recent treatment of a professional rugby league player who sustained his injury while tackling (fig 3). As with all tendon ruptures in sports persons, it is necessary to be aware that anabolic steroid ingestion may be a contributing factor.

OSTEOCHONDRITIS DISSECANS AND OTHER LESIONS SEEN IN YOUNG ATHLETES

Elbow injuries are a relatively common occurrence in gymnasts. Rettig and Patel[65] estimated that 5% of sport injuries in gymnasts occurred at the elbow. Chan *et al*[89] reported that 19 elite gymnasts of average age 13.5 years had chronic stress injuries at the elbow: seven had pathology affecting the capitellum, four had radial head abnormalities, seven had an abnormal olecranon epiphysis, and one had an injury to the medial articular surfaces. These authors also showed that those with articular surface abnormalities did not return to gymnastics. Jackson *et al*[90] reported 10 cases of osteochondritis dissecans of the capitellum in seven elite gymnasts; only one was still training at 2.9 years follow up. Osteochondritis dissecans of the capitellum is seen most commonly in adolescents. Sport involving repetitive motion—for example, throwing sports—or activities that increase the load across the elbow—for example, gymnastics—are associated with the problem.[36] Most osteochondritis dissecans lesions occur in the dominant extremity.[12] Williamson and Albright[91] reported on a 17 year old female pitcher with bilateral elbow osteochondritis. The treatment of osteochondritis dissecans depends on the extent of the area of devascularisation and whether the affected fragment of bone has separated from the capitellum. In most adolescents with this problem, the symptoms are resolved by rest and restriction of sporting activity.

The pronator teres syndrome should not be confused with forearm splints which are seen in young girls performing handstands during cheerleading and in gymnasts performing load-bearing activities on the extended upper extremity. Forearm aching pain between the radius and ulna that is exaggerated by activity is considered analogous to shin splints of the lower leg.[31]

Conclusion

This review gives an overview of some of the factors that must be considered in the aetiology of injuries in the sporting elbow and provides details of some of the conditions that are encountered. It is likely that our approach to both diagnosis and treatment will change dramatically over the next few years as we gain a better understanding of the physiology of elbow function and the consequences of changes in the physiology in response to sport.

1 Tullos HS, King JW. Throwing mechanism in sports. *Orthop Clin North Am* 1973;**4**:709–20.
2 Morrey BF, Askew LJ, An K-N, *et al*. A biomechanical study of normal elbow motion. *J Bone Joint Surg [Am]* 1981;**63**:872–7.
3 Safran MR. Elbow injuries in athletes. *Clin Orthop* 1995;**310**:257–77.
4 Slocum DB. Classification of elbow injuries from baseball pitching. *Texas Med* 1968;**64**:48–53.
5 Whiteside JA, Andrews JR. Common elbow problems in the recreational athlete. *Journal of Musculoskeletal Medicine* 1989;**6**:17–34.
6 King JW, Brelsford HJ, Tullos HS. Analysis of the pitching arm of professional baseball pitchers. *Clin Orthop* 1969;**67**: 116–23.
7 Conway JE, Jobe FW, Glousman RE, *et al*. Medial instability of the elbow in throwing athletes: treatment by repair or reconstruction of the UCL. *J Bone Joint Surg [Am]* 1992;**74**:67–83.
8 Behr CT, Altchek DW. The elbow. *Clin Sports Med* 1997;**16**: 681–704.
9 An KN, Morrey BF. Biomechanics of the elbow. In: Morrey BF, ed. *The elbow*. Philadelphia: WB Saunders, 1993:53–72.
10 Werner SL, Fleisig GS, Dillman CJ, *et al*. Biomechanics of the elbow during baseball pitching. *J Orthop Sports Phys Ther* 1993;**17**:274–8.
11 Fleisig GS, Barrentine SW. Biomechanical aspects of the elbow in sports. *Sports Medicine Arthroscopy Review* 1995;**3**: 149–59.
12 Guerra JJ, Timmerman LA. Clinical anatomy and pathomechanics of the elbow in sports. *Journal of Sports Medicine and Arthroscopy Review* 1995;**3**:160–9.
13 Pappas AM, Vitolo J. Elbow anatomy and function. In: Pappas AM, ed. *Upper extremity injuries in the athlete*. New York: Churchill Livingstone, 1994:303–21.
14 Wilson FD, Andrews JR, Blackburn TA. Valgus extension overload in the pitching elbow. *Am J Sports Med* 1983;**11**:83–8.
15 Escamilla RF, Fleisig GS, Alexander E, *et al*. A kinematic and kinetic comparison while throwing different types of baseball pitches. *Med Sci Sports Exerc* 1994;**26**:S175.
16 Robla J, Hechtman KS, Uribe JW. Chondromalacia of the trochlear notch in athletes who throw. *J Shoulder Elbow Surg* 1996;**5**:69–72.
17 Feltner M, Dapena J. Dynamics of the shoulder and elbow joints of the throwing arm during a baseball pitch. *Int J Sport Biomech* 1986;**2**:235–59.
18 Morrey BF, Tanaka S, An K-N. Valgus stability of the elbow. *Clin Orthop* 1991;**265**:187–95.
19 King GJW, Morrey BF, An KB. Stabilizers of the elbow. *J Shoulder Elbow Surg* 1993;**2**:165–74.
20 Hamilton CD, Glousman RE, Jobe FW, *et al*. Dynamic stability of the elbow: electromyographic analysis of the flexor pronator and the extensor group in pitchers with valgus instability. *J Should Elbow Surg* 1996;**5**:347–54.
21 Ellenbecker TS, Mattalino AJ, Elam EA, *et al*. Medial elbow joint laxity in professional baseball pitchers. *Am J Sports Med* 1998;**26**:420–4..
22 Bennett GE. Elbow and shoulder lesions of baseball players. *Am J Surg* 1959;**98**:484.
23 Joyce ME, Jelsma RD, Andrews JR. Throwing injuries to the elbow. *Journal of Sports Medicine and Arthroscopy Review* 1995;**3**:224–36.
24 Field LD, Altchek DW. Chronic elbow pain, overuse and tendinitis. In Piemer CA, ed. *Surgery of the hand and upper extremity*. New York: McGraw-Hill, 1995:491–506.
25 Goldberg MJ. Gymnastic injuries. *Orthop Clin North Am* 1980;**11**:717–26.
26 Plancher KD, Minnich JM. Sports-specific injuries. *Clin Sports Med* 1996;**15**:207–18.
27 Weiker GG: Upper extremity gymnastics injuries. In: Nicholas JH, Hershmann EB, eds. *The upper extremity in sports medicine*. St Louis: CV Mosby, 1990:861–82.
28 Kibler WB. Clinical biomechanics of the elbow in tennis: implications for evaluation and diagnosis. *Med Sci Sports Exerc* 1994;**26**:1203–6.
29 Morris M, Jobe FW, Perry J, *et al*. Electromyographic analysis of elbow function in tennis players. *Am J Sports Med* 1989;**17**:241–7.
30 Andrews JR, Wilk KE, Satterwhite YE, *et al*. Physical examination of the thrower's elbow. *J Orthop Sports Phys Ther* 1993;**17**:296–304.
31 Andrews JR, Whiteside JA. Common elbow problems in the athlete. *J Orthop Sports Phys Ther* 1993;**17**:289–94.
32 Green DP, Strickland JW. The hand. In: DeeLee JC, Drez JR, eds. *Orthopaedic sports medicine: principles and practise*. Philadelphia: WB Saunders, 1994:945–1017.
33 Johnston J, Plancher KD, Hawkins RJ. Elbow injuries to the throwing athlete. *J Clin Sports Med* 1996;**15**:307–29.
34 Timmerman LA, Schwartz ML, Andrews JR. Preoperative evaluation of the ulnar collateral ligament by magnetic resonance imaging and computed tomography arthrography. *Am J Sports Med* 1994;**22**:26–32.
35 Schwartz ML, Al-Zahrani S, Morwessel RM, *et al*. Ulnar collateral ligament injury in the throwing athlete: evaluation with saline: enhanced MR arthrography. *Radiology* 1995;**197**:297–9.
36 Baumgarten TE. Osteochondritis dissecans of the capitellum. *Sports Medicine Arthroscopy Review* 1995;**3**:219–23.
37 Klekamp J, Green NE, Mencio GA. Osteochondritis dissecans as a cause of developmental dislocation of the radial head. *Clin Orthop* 1997;**338**:36–41.
38 Janarv PM, Hesser U, Hirsch G. Osteochondral lesions in the radiocapitellar joint in the skeletally immature: radiographic, MRI, and arthroscopic findings in 13 consecutive cases. *J Pediatr Orthop* 1997;**17**:311–14.
39 Fritz RC. MR imaging of osteochondral and articular lesions. *Magn Reson Imaging Clin N Am* 1997;**5**:579–602.
40 Bohndorf K. Osteochondritis (osteochondrosis) dissecans: a review and new MRI classification. *Eur J Radiol* 1998;**8**: 103–12.
41 Baumgarten TE, Martin SD. Elbow arthroscopy in sports medicine. *Sports Medicine Arthroscopy Review* 1995;**3**:187–94.
42 Adolfsson L. Arthroscopy of the elbow joint: a cadaveric study of portal placement. *J Shoulder Elbow Surg* 1994;**3**: 53–61.
43 Soffer SR, Andrews JR. Arthroscopic surgical procedures of the elbow: common cases. In: Andrews JR, Soffer SR, eds. *Elbow arthroscopy*. St Louis: Mosby Year Book Inc, 1994:74.
44 Martin SD, Baumgarten TE. Elbow arthroscopy in sports medicine. *Sports Medicine Arthroscopy Review* 1995;**13**:187–94.
45 Wilk KE, Azar FM, Andrews JR. Conservative and operative rehabilitation of the elbow in sports. *Sports Medicine Arthroscopy Review* 1995;**3**:237–58.
46 Maylack FH. Epidemiology of tennis, squash and racquetball injuries. *Clin Sports Med* 1988;**7**:233.
47 Burgess RC. Tennis elbow. *J Ky Med Assoc* 1990;**88**:349–54.
48 Field LD, Savoie FH. Common elbow injuries in sport. *Sports Med* 1991;**26**:193–205.
49 Coonrad RW, Hooper WR. Tennis elbow: its course, natural history, conservative and surgical management. *J Bone Joint Surg [Am]* 1973;**55**:1177–82.
50 Nirschl RP, Pettrone FA. Tennis elbow. The surgical treatment of lateral epicondylitis. *J Bone Joint Surg [Am]* 1979;**61**:832–9.
51 Regan WD, Wold LE, Coonrad R, *et al*. Microscopic histopathology of chronic refractory lateral epicondylitis. *Am J Sports Med* 1992;**20**:746–9.
52 Nirschl RP: Elbow tendinosis/tennis elbow. *Clin Sports Med* 1992;**11**:851–70.
53 Plancher KD, Halbrechet J, Lourie GM. Medial and lateral epicondylitis in athletes. *Clin Sports Med* 1996;**15**:283–305.
54 Schnatz P, Steiner C. Tennis elbow: a biomechanical and therapeutic approach. *J Am Osteopath Assoc* 1993;**93**:782–8.
55 Giangarra CE, Conroy B, Jobe FW, *et al*. Electromyographic and cinematographic analysis of elbow function in tennis players using single- and double-handed back-handed strokes. *Am J Sports Med* 1993;**21**:394–9.
56 Whiteside JA, Andrews JR. Physical examination of the elbow in sports. *Sports Medicine Arthroscopy Review* 1995;**3**: 170–9.
57 Kelley JD, Lombardo SJ, Pink M, *et al*. Electromyographic and cinematographic analysis of elbow function in tennis players with lateral epicondylitis. *Am J Sports Med* 1994;**22**: 359–63.
58 Lieber RL, Ljung BO, Friden J. Sarcomere length in wrist extensor muscles. Changes may provide insights into the etiology of chronic epicondylitis. *Acta Orthop Scand* 1997;**68**:249–54.
59 Priest JD, Braden V, Gerberich JM. The elbow and tennis (part 1). *Physician and Sports Medicine* 1980;**80**:80.

60 Gruchow HW, Pelletier D. An epidemiology study of tennis elbow: incidence, recurrence and effectiveness of prevention strategies. *Am J Sports Med* 1979;7:234–8.
61 Nirschl RP. Soft tissue injuries about the elbow. *Clin Sports Med* 1986;**5**:637–52.
62 Kitai E, Itay S, Ruser A, *et al*. An epidemiological study of lateral epicondylitis in amateur male players. *Ann Chir Main Memb Super* 1986;**5**:113–21.
63 Assendelft WJ, Hay EM, Adshead R, *et al*. Corticosteroid injections for lateral epicondylitis: a systematic review. *Br J Gen Pract* 1996;**46**:209–16.
64 Labelle H, Guibert R, Jonlas J, *et al*. Lack of scientific evidence for the treatment of lateral epicondylitis of the elbow. *J Bone Joint Surg [Br]* 1992;**74**:646–51.
65 Rettig AL, Patel DV. Epidemiology of elbow, forearm and wrist injuries in the athlete. *Clin Sports Med* 1995;**14**:289–97.
66 Jobe FW, Schwab DM. Golf for the mature athlete. *Clin Sports Med* 1991;**10**:269–82.
67 MacCarrol JR. The frequency of golf injuries. *Clinics Sports Med* 1996;**15**:1–7.
68 MacCarrol JR, Rettig AC, Shelbourne KD. Injuries in amateur golfers. *Physician and Sports Medicine* 1990;**18**:122–6.
69 MacCarrol JR, Mallon WJ. Epidemiology of golf injuries. In: Stover CN, MacCarrol JR, Mallon WJ, eds. *Feeling up to par: medicine from tee to green.* Philadelphia: FA Davis, 1994.
70 Glazebrook MA, Curwin S, Islam MN, *et al*. Medial epicondylitis. An electromyographic analysis and an investigation of intervention strategies. *Am J Sports Med* 1994;**22**:674–9.
71 Childress HM. Recurrent ulnar nerve dislocation at the elbow. *Clin Orthop* 1975;**108**:168–73.
72 Childress HM. Recurrent ulnar nerve dislocation at the elbow. *J Bone Joint Surg [Am]* 1956;**38**:978–84.
73 Del Pizzo W, Jobe FW, Norwood L. Ulnar nerve entrapment syndrome in baseball players. *Am J Sports Med* 1977;**5**:182–5.
74 Apfelberg DB, Larson SJ. Dynamic anatomy of the ulnar nerve at the elbow. *Plast Reconstr Surg* 1973;**51**:76–8.
75 O'Driscoll SW, Horii E, Carmichael SW. The cubital tunnel and ulnar neuropathy. *J Bone Joint Surg [Br]* 1991;**73**:613–17.
76 Werner CD. Lateral elbow pain and posterior interosseous nerve entrapment. *Acta Orthop Scand* 1979;**174**(suppl):1.
77 Cabrera JM, McCue FC. Nonosseous athletic injuries of the elbow, forearm and hand. *Clin Sports Med* 1986;**5**:681–700.
78 Lorei MP, Hershman EB. Peripheral nerve injuries in athletes. Treatment and prevention. *J Sports Med* 1993;**16**:130–47.
79 Bruce JF. Hand. In: Miller MD, ed. *Review of orthopaedics*, 2nd ed. Philadelphia: WB Saunders, 1996:244–69.
80 McCue FC. The wrist and hand. In: Kulund DN, ed. *The injured athlete*, 2nd ed. Philadelphia: JB Lippincott, 1998:371–404.
81 Morrey BF. Tendon injuries about the elbow. In: Morrey BF, ed. *The elbow and its disorders.* Philadelphia: WB Saunders, 1985:497–501.
82 Davis WM, Yassine Z. An etiological factor in tear of the distal tendon of biceps brachii tendon. *J Bone Joint Surg [Am]* 1956;**38**:1365–8.
83 Leighton MM, Bush-Joseph CA, Bach BR. Distal biceps brachii repair. *Clin Orthop* 1995;**317**:114–21.
84 Boyd HB, Anderson LD. A method of reinsertion of the distal biceps brachii tendon. *J Bone Joint Surg [Am]* 1961;**43**:1041–3.
85 Baker BE, Bierwagen D. Rupture of the distal tendon of biceps brachii. *J Bone Joint Surg [Am]* 1985;**67**:414–17.
86 Norman WH. Repair of avulsion of insertion of biceps brachii tendon. *Clin Orthop* 1985;**193**:189–94.
87 Agins HJ, Chess JL, Hoekstra DV, *et al*. Rupture of the distal insertion of the biceps brachii tendon. *Clin Orthop* 1988;**234**:34–8..
88 Davison BL, Engber WD, Tigert LJ. Long term evaluation of repaired distal biceps brachii tendon ruptures. *Clin Orthop* 1996;**333**:186–91.
89 Chan D, Aldridge MJ, Maffuli N. Chronic stress injuries of the elbow in young gymnasts. *Br J Radiol* 1991;**64**:1113–18.
90 Jackson DW, Silvino N, Reiman P. Osteochondritis in the female gymnast's elbow. *Arthroscopy* 1989;**5**:129–36.
91 Williamson LR, Albright JP. Bilateral osteochondritis dissecans of the elbow in female pitcher. *J Fam Pract* 1996;**43**:489–93.