Stress Fractures of the Upper Limb

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Abstract

Stress fractures are commonly found in the lower limb, but also occur in the upper limb, and are particularly associated with upper limb–dominated sports such as tennis and swimming and those involving throwing activities. Stress fractures of the clavicle and scapula are rare but have been reported, whereas those of the humerus are more frequent and have been described mainly in adolescent baseball pitchers. Olecranon stress fractures occur in throwers and gymnasts. Stress fractures of the ulna and radius have also been reported in a number of different upper limb–dominated sports. In all cases, these fractures heal with conservative management.

The physician should consider stress fracture as a possible diagnosis in cases of upper limb pain of bony origin where the pain is associated with overuse.

Upper limb stress fractures are far less common than those of the lower limbs, but have been described in upper limb–dominated sports such as tennis, swimming and throwing activities. They have been cited in individual case reports but there are no large series published in the literature.

The physician should always consider the diagnosis of stress fracture in any athlete involved in an upper limb–dominant activity who presents with bony pain of gradual onset and displays bony tenderness on physical examination. Imaging should be used to confirm the diagnosis, although plain radiography frequently fails to reveal a stress fracture. Isotope bone scan or magnetic resonance imaging (MRI) should be performed to confirm the clinical diagnosis.

1. Clavicle

Stress fractures of the clavicle have been described as a late complication following radical neck dissection,[1,2] but only 2 cases of clavicular stress fracture in athletes have been reported.[3,4]

One patient was a 25-year-old right-handed male elite javelin thrower,[3] the other a collegiate springboard diver.[4] The 2 cases presented with insidious onset of pain over the clavicle and local
tenderness. The pain was maximal on abduction of the shoulder above the horizontal plane. Radiographs showed periosteal reaction in both cases and the diagnosis was confirmed with isotope scan in one case and plain tomography in the other. Both athletes returned to full activity after 8 weeks. In the javelin thrower, the authors of the report postulated that repeated stress from contraction of the clavicular portions of the deltoid and pectoralis major muscles contributed to the development of the fracture. In the diver it was thought that the position on water entry with the fingers and wrists extended, the forearms pronated and the hands overlapping, may have transmitted impact stress from the hands to the clavicle.

2. Scapula

Stress fractures of the scapula are also rare. There have been reports of scapula body stress fracture related to occupation: 3 stress fractures in lorry drivers\(^5-7\) and one in a automobile assembly line overhead worker\(^8\) appear in the literature. Scapular stress fractures in athletes have been reported in a gymnast,\(^9\) a jogger using hand-held weights,\(^10\) at the base of the acromial process in a professional American football player\(^11\) and in the coracoid process in a trap shooter.\(^12\)

Veluvolu et al.\(^{10}\) reported the case of a 30-year-old man who had been jogging with weights in his hands for about 8 weeks. He complained of pain in the right shoulder for 2 weeks. Isotope bone scan showed a linear band of increased uptake in the superomedial portion of the right scapula superior to the spinous process. Later radiographs showed a fracture through this region. The authors suggested that the likely cause was overuse of muscle fibres of the supraspinatus in stabilising the humeral head while jogging with weights.

Ward et al.\(^{11}\) described a 28-year-old male offensive lineman, with no history of significant trauma, who developed pain in the shoulder during an American football game. He had not noticed pain before the game but was lifting weights in a intensive prescribed programme. Physical examination revealed point tenderness over the acromion and pressure applied to the tip of the acromion caused pain at the base of the acromial arch. Anteroposterior, lateral, West Point and modified oblique view radiographs demonstrated an incomplete transverse radiolucent line in an area of sclerotic bone at the underside of the acromion near its origin from the scapula spine. The fracture was best seen on tomography. A technetium bone scan revealed increased activity in this region. Weightlifting and football activities were discontinued for 6 weeks. Following this, the patient gradually resumed weightlifting and contact sport activities and was playing competitive football within 2 months without pain or tenderness. Follow-up radiographs 2 months later showed callus in the area of the fracture. The authors felt that the intense weightlifting programme had contributed to the development of the stress fracture.

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Stress fracture of the coracoid process has been described in association with trap shooting.\(^{12}\) A 27-year-old female professional trapshooter regularly shot trap at the rate of 200 to 1000 rounds per week. She complained of aching in the shoulder at the point at which the butt of the rifle rests. On physical examination the patient had point tenderness directly over the coracoid process and tenderness along the bicipital groove. Resistance against adduction and flexion of the shoulder caused increased pain over the coracoid process. Anteroposterior and lateral radiographs of the shoulder were normal; however, the axillary view demonstrated a fracture through the mid portion of the base of the coracoid process. Treatment consisted of rest from trap shooting until asymptomatic and then gradual resumption of activity. Six weeks after the onset of symptoms the patient had no point tenderness over the coracoid process and full active painless range of motion of the shoulder. Gradual resumption of shooting caused no shoulder pain and the patient returned to her usual rate of trap shooting.

3. Humerus

Stress fracture of the humerus has been described in baseball pitchers,\(^{13-17}\) a tennis player,\(^{18}\)
a javelin thrower, a body-builder and a weightlifter. The majority of these fractures occurred in adolescents and were associated with a recent increase in activity.

Sterling et al. reported the case of a 14-year-old athlete competing in swimming and baseball as well as weight training. He felt and heard a 'pop' in his right arm while throwing a baseball. Before the injury the patient had deep aching arm pain and tenderness in the region of the mid-shaft of the humerus. Physical examination after the initial injury showed swelling, ecchymosis and extreme pain with active and passive motion of the arm. X-rays revealed a closed comminuted spiral fracture of the humerus which extended proximally. The patient was placed in a cuff and collar for 1 week and then a humeral fracture brace was supplied. Three weeks after the event the patient had no complaints and the alignment of the fracture was anatomical. His pain had ceased about 1 week earlier. Rehabilitation was instituted with an active range of motion, stretching and progressive resistance exercises. Six weeks postinjury, radiographs demonstrated abundant callus formation. The brace was removed 11 weeks after the injury and the patient was allowed to begin swimming. He returned to full activity 16 weeks after the injury.

Allen described the case of a 13-year-old Little League baseball pitcher who sustained a displaced spiral fracture of the mid-humerus while in mid-pitch. He had had pain in the region of the mid-humerus at rest and during pitching during the preceding week. Presumably, this was a case of a stress fracture which had progressed to an overt fracture during the stress of a forceful side arm curve ball pitch.

Branch et al. reported 12 cases of spontaneous humeral shaft fractures in a men’s Over 30 Baseball League. Three-quarters of the pitchers had arm pain at some point before the fracture and 11 of the 12 heard a crack at the time of the occurrence. Nine of the fractures were spiral. There were 2 nerve injuries associated with the fracture, one to the radial and one to the cutaneous nerve. The authors noted 4 common factors associated with these fractures: (i) age over 30 years; (ii) a prolonged period of lay-off from pitching; (iii) lack of a regular exercise programme; and (iv) prodromal throwing arm pain.

Bartsokas et al. reported a 20-year-old male body-builder who presented with left shoulder and upper arm pain that developed insidiously over a 4-week period. The patient had been ‘bulking up’ for 3 weeks before the onset of pain by lifting heavier weights than usual. Progressive worsening of shoulder and upper arm pain was reported, particularly with bench presses but also brought on by incline presses, biceps curls and overhead presses. Symptoms were present only during exercise but flared at each weightlifting session despite 1 week of rest and treatment with anti-inflammatory medication. Examination demonstrated mild pain on manual resistance testing of shoulder movements, especially on internal rotation and abduction. Mild tenderness to palpation was noted over the insertion of the anterior deltoid muscle. A radiograph revealed a small lucent line in the cortex of the mid-humerus along its anterior aspect. Isotope bone scan showed an area of focal increased activity in the mid portion of the humerus. The patient was prescribed 6 weeks’ rest, followed by a gradual resumption of training.

Rettig and Beltz reported a 15-year-old elite tennis player who had a history of onset of pain just above the elbow without a history of trauma. His symptoms worsened after he began playing more intensively, and he was unable to play for 2 months because of severe pain. On examination he had full range of motion of the shoulder and elbow and had point tenderness over the lateral aspect of the distal third of the humerus. Initial x-rays of the humerus were unremarkable, but a bone scan showed abnormal uptake within the ventral aspect of the mid-shaft of the humerus. A computerised tomography (CT) scan showed a vertical fracture through the ventral cortex of the humerus. The patient was rested for an additional 4 weeks and then commenced the slow return to tennis. Approximately 2 weeks after his return, he developed the same symptoms of pain. It was therefore felt that this was
a case of delayed union and external electrical stimulation was begun. His symptoms and signs resolved completely over the next 2 months and, after a gradual weight training and flexibility programme, the player was allowed to return to tennis. He had no further problems. Interestingly, it was noted that the patient was undergoing a growth spurt during the initial occurrence of symptoms and had grown some 5 inches in the 5 to 6 months before symptom onset. It was also noted that he was of slight build. It is unclear whether this was a true delayed union and therefore whether the electrical stimulation affected the healing or not.

The most probable explanation for the occurrence of stress fractures in these younger athletes is that the high level of activity among the adolescents placed a degree of stress upon immature bone, possibly aggravated by a period of rapid growth.

From the few cases of stress fracture of the humerus reported in the literature, the recommended treatment involves a minimum of 4 weeks’ absence from the aggravating activity and then gradual resumption of activity over another 4-week period. A strengthening programme may be of some benefit.

4. Olecranon

A small number of stress fractures of the olecranon have been reported and this possibility should be considered in the diagnosis of overuse elbow injuries, especially among throwers and gymnasts. The usual presentation is gradual onset of pain in the elbow over a period of a few weeks.

There appear to be 3 different types of stress fracture of the olecranon. One is a stress fracture of the growth plate reported in adolescent gymnasts. This fracture appears as a radiolucency extending from the posterior (nonarticular) aspect of the ulna to the articular surface in a transverse fashion. Sclerosis of the fracture margins with persistent radiolucency and no relief of pain are signs of a delayed union or a nonunion. The second type is a stress fracture of the tip of the olecranon seen in throwers, and the third is a stress fracture of the olecranon itself.

Hulkko et al. described 4 javelin throwers with stress fractures of the olecranon. In one of these patients, acute painful dislocation of the fracture occurred during a competitive throw. Two patients had a stress fracture of the tip of the olecranon. One of these was treated conservatively but did not heal for 18 months; the other was treated by excision of the tip and was able to throw after 2 months. The other 2 patients had slightly oblique, more distally located stress fractures which were treated with a tension band and 2 Kirschner wires. The fractures healed in 4 months. One had a refracture 11 months after the primary operation which was successfully treated with a compression screw and 2 bone pegs.

Maffulli et al. reported 2 cases of stress fracture through the olecranon growth plate in gymnasts aged 18 and 19. Conservative management was successful in one, and the other required internal fixation. This paper also described 8 younger gymnasts with traction apophysitis of the olecranon, and postulated that the lesions were probably age-dependent. The authors suggested that when the olecranon apophysis is not fully ossified, traction forces may cause disturbance of blood flow and result in localised areas of avascular necrosis with disturbed ossification and fragmentation, known as traction apophysitis. When the apophysis is more mature but not yet fused, the same forces may produce a stress fracture through the growth plate. Other authors have described similar stress fractures through the olecranon growth plate.

Wilkerson and Johns reported a case of nonunion of a stress fracture of the olecranon epiphyseal plate. The 14-year-old gymnast presented initially with a dull ache and local tenderness. Radiographs revealed a widening of the epiphyseal plate, and a diagnosis of stress fracture was made. Three months after discontinuing gymnastics the patient was found to be asymptomatic, with a full range of motion. Approximately 6 months later the patient returned with a recurrence of pain, limited extension and radiographic evidence of nonunion.
nonunion site was surgically excised and packed with iliac crest bone graft. The site was then fixed using a tension band wire technique and the patient commenced on rehabilitation with emphasis on strengthening the range of motion. At 12 months postsurgery the fracture site was completely healed and the range of motion was normal.

Nuber and Diment[29] described 2 cases of stress fracture of the olecranon in throwers, successfully treated by conservative methods. Both patients presented with pain around the olecranon while pitching. They were initially diagnosed with tendinitis and continued to pitch until an episode of severe pain was felt during pitching. In both cases, x-rays before the episode of acute pain were reported as normal, while x-rays after the episode showed evidence of olecranon stress fracture. In one case, the patient was placed in a posterior splint for 3 weeks. After this the patient began elbow range-of-motion and forearm exercises for the next 6 weeks. Follow-up tomograms done at 3 months showed evidence of healing and the patient resumed light throwing. He was able to gradually progress to his previous level of throwing without recurrence of his symptoms. The second patient was prescribed complete rest until follow-up x-rays 5 weeks later showed evidence of fracture healing. He continued his activity restriction for 2 more months and then began exercising and throwing, returning to his previous level of throwing in 6 months.

Nuber and Diment[29] felt that the transverse stress fracture of the olecranon and the olecranon tip fractures were not the same entity, even though they were both seen in throwers. They stated that tip fractures were more likely to be seen in patients who present with a painful elbow after a particularly strong throw. Patients with stress fractures, however, were more likely to present with a longer history of pain that recurred when they resumed throwing. Radiographically, the tip avulsion fractures involve as much as one-third of the proximal olecranon. The stress fractures occur in the middle third of the olecranon. Tip fractures are likely to go on to nonunion, may form loose bodies and seem to respond best to surgical excision. The olecranon stress fractures, on the other hand, appear to respond to conservative methods.

In the stress fractures of the growth plate and the olecranon itself, if the diagnosis is made relatively early, there is a reasonable chance that conservative management could be successful and the athlete will resume sport in 8 to 12 weeks. The treatment of choice for a stress fracture of the tip of the olecranon is surgical excision, which appears to enable the athlete to return to his sport at approximately 8 weeks.

5. Ulna

Stress fractures of the ulna have been described in baseball[30,31] and softball[32] pitchers, tennis players,[33-36] volleyball players,[32,37] weightlifters,[38-41] bowlers[42] and a golfer.[43] Athletes present with pain in the region of the ulna shaft during and after athletic activity. Physical examination reveals tenderness and pain with movements. Radiographs show either a small crack in the cortex of the ulna or a slight haze of new periosteal bone at the site of the stress fracture. Bone scans can be used to confirm the diagnosis when radiographs fail to show any abnormality. All the reported affected athletes have returned to activity in 4 to 6 weeks after a period of rest from the aggravating activity and gradual resumption.

Mutoh et al.[32] described stress fractures of the ulna in a softball pitcher throwing underarm and a volleyball player who experienced pain during underhand manoeuvres. Both actions involved repetitive movements of the unilateral upper limb with a light load following contraction of the flexor muscles. In the volleyball player where wrist flexion was more pronounced, the stress was more proximal; in the softball player it was more distal.

Bollen et al.[33] described 2 stress fractures of the ulna in tennis players. In the first case, a 17-year-old right-handed female professional tennis player complained of gradually increasing pain in the left forearm when using the double-handed backhand stroke. The only physical findings were tenderness over the middle third of the ulna and...
pain on resisted pronation. Radiographs were unremarkable but an isotope bone scan showed markedly increased uptake over the site of tenderness (fig. 1). In the second case, a 21-year-old right-handed male professional tennis player also complained of pain in the left forearm. He had been undertaking intensive backhand training over the previous few weeks and had developed increasing pain over the anteromedial aspect of the forearm on ball contact when using the double-handed backhand stroke. He also had tenderness to palpation of the anteromedial aspect of the ulna at the junction of the proximal and middle thirds. Radiographs were normal but bone scan confirmed the presence of a stress fracture. Both of these patients were treated with standard procedures for stress fractures, with rest of the affected limb and gradual resumption of activities after resolution of the tenderness.

The authors felt the injury mechanism was similar to that reported in softball players by Tanabe et al.\cite{37} (repetitive excessive pronation). In the double-handed backhand stroke of tennis players, pronation occurs during the phase of ball strike and follow-through, and presumably causes similar torsional stresses to those found in softball players. Young et al.\cite{34} reported a similar case in a 15-year-old female tennis player.

Bell and Hawkins\cite{36} described the case of a 19-year-old right-handed tennis player who presented with pain in his left wrist while hitting a double-handed backhand. He described the pain as being just proximal to the ulnar styloid, involving both the dorsal and volar aspects of the forearm. He was tender to palpation along the ulnar aspect of the distal forearm. Direct palpation of the distal third of the ulna, 3 to 4cm proximal to the ulnar styloid, produced pain similar to that encountered during backhands. Marked dorsiflexion of the wrist and pronation/supination also elicited pain. Plain x-rays of the forearm demonstrated a discrete area of periosteal elevation along the dorsal aspect of the distal ulna. A diagnosis of stress fracture was made and treatment consisted of a modification of the patient’s swing pattern with an attempt to utilise a one-handed backhand. A dorsally applied extension block splint was applied on a temporary basis. After 4 weeks the patient returned to his full level of activity and resumed his double-handed backhand, at that time pain-free. Repeat x-rays at that time showed additional callus.

Escher\cite{42} described the case of a 16-year-old right-handed bowler who reported 3 weeks of increasing pain in the proximal right ulna. He bowled 3 to 8 games per day using a 16lb (7.25kg) fingertip ball. An isotope bone scan showed increased uptake in the ulna in the area of his pain. Management consisted of 5 weeks’ bowling cessation with a gradual return to activity. The author postulated that the fracture was caused by stress on the ulna at the origin of the flexor profundus muscle from repeatedly grasping the ball with a fingertip grip.

Koskinen et al.\cite{43} reported a case of a 44-year-old golfer who presented with a 4-week history of a painful left wrist. The report does not mention whether the golfer was right- or left-handed. Radiographs showed a periosteal reaction on the radial side of the distal ulnar diaphysis. An MRI disclosed cortical thickening and an area of low signal density on T1-weighted images and oedema on T2-
weighted images consistent with healing stress fracture. One week later, radiographs showed a lucent fracture line with periosteal callus. The patient’s golf instructor recognised that excessive external rotation was used with the affected left hand.

6. Radius

Stress fracture of the radius was first described in the military setting. Farquharson-Roberts and Fulford[44] described a case in which a 23-year-old naval recruit developed bilateral radial stress fractures after training or ‘field gun running’, an activity which involves catching a heavy gun barrel across the forearms and manhandling a heavy gun over simulated obstacles. Radiographs showed stress fractures of the radius bilaterally in the proximal third along the anterior cortex. Treatment consisted of 6 weeks’ rest and a progressive return to training. No complications were reported and the fractures appeared well healed on radiography 6 weeks later.

Stress fractures of the radius have also been described in gymnasts,[45-47] a tennis player,[48] a pool player[49] and a cyclist.[50] Stress injuries of the distal radial growth plate are seen frequently in young gymnasts.[45,47]

Ahluwalia et al.[46] described a 24-year-old female gymnast with a 3-month history of bilateral forearm pain. The pain began when the gymnast increased her training from 9 to 18 hours per week. Radiographs showed no abnormality, but an isotope bone scan demonstrated focally increased activity in the radial shafts of the radius in both arms.

Eisenberg et al.[50] reported the case of a 12-year-old boy who presented with a 3-week history of pain in the left wrist and forearm. He stated that he had been riding a bicycle very hard for several months and had been doing ‘wheelies’ by jerking the front wheel of the bicycle off the ground and riding on the back wheel only. The front wheel then came back down to the ground with a hard thud, jarring his forearm. The left forearm was tender at the junction of the mid and distal thirds of the radius and x-rays revealed a fracture line at the distal radial diaphysis with periosteal new bone formation.

Loosli and Leslie[48] described a 25-year-old right-handed high level female tennis player who developed increasing pain in her right wrist. Physical examination revealed diffuse tenderness of the distal radius and over the second and third metacarpals dorsally. Hyperextension of the wrist caused pain at the back of the hand and extension of the thumb to resistance caused pain to the back of the hand and wrist as well as in the proximal second and third metacarpals. x-Rays were normal; however, a bone scan showed markedly increased uptake in the distal radius. At the time of diagnosis the patient had had persistent pain for 5 months in spite of reduced activity in a splint. She was therefore placed in a short arm cast for 3 weeks, followed by a posterior splint for 3 more weeks. When the posterior splint was applied she began an isometric strengthening programme for her wrist flexors and extensors. After her immobilisation she began a strengthening programme of resistive exercise using latex tubing. The patient began hitting the tennis ball painlessly approximately 8 weeks after the start of immobilisation. She gradually progressed to tennis every other day in a painless fashion and in 2.5 months was able to hit a tennis ball comfortably. She had returned to painless, full competitive level tennis at 3 months.

Orloff and Resnick[49] reported the case of a 22-year-old pool player who complained of a painful mass on the dorsum of the distal part of the right forearm. The pain was accentuated by rotation of the forearm in a movement designed to put ‘English’ (side spin) on the billiard ball. He spent at least 4 consecutive hours playing pool 3 nights per week. Radiographs demonstrated fluffy periosteal reaction extending 2cm along the dorsoulnar margin of the distal third of the radius. 16 weeks later, the pain had subsided and radiographs revealed a healing stress fracture.

7. Metacarpal

There are a total of 8 cases of metacarpal stress fractures reported in the literature, 5 in sports
people and 3 occupationally related. The occupationally related stress fractures involved the second metacarpal and resulted from extrinsic pressure from a solid object, such as an ice-cream scoop\textsuperscript{51} or a pen,\textsuperscript{52} exerting a force on that bone.

Details are available regarding 3 of the 5 reported stress fractures of the metacarpal in athletes. The other 2 were reported as part of a large series.\textsuperscript{53} Two of the cases in athletes involved stress fracture of the second metacarpal bone in tennis players.\textsuperscript{54,55} The third involved a stress fracture of the fifth metacarpal in a softball pitcher.\textsuperscript{56}

There are certain similarities between the metacarpal and metatarsal bones. The second metacarpal is the longest and has the largest base of all the metacarpals, articulating at the base with the trapezoid, trapezium, capitate and third metacarpal. Movement at the second carpometacarpal joint is limited in directions other than flexion/extension. The fifth metacarpal articulates with other bones only on the lateral aspect of the base with the fourth metacarpal and hamate, while its medial surface is nonarticular and presents a tubercle for the insertion of the extensor carpi ulnaris. The conformation of its base allows for a greater range of motion than the second, third and fourth metacarpals in directions other than flexion/extension. In the metatarsal bones, the relative frequency of stress fractures of the second metatarsal probably reflects its immobility at the base, while the fifth metatarsal articulates only at part of its base and has insertion from the powerful peroneus brevis tendon.

As with so many stress fractures, the precipitating factors in the development of these 3 described metacarpal stress fractures are a combination of increased load and changes in technique. The 2 cases of stress fracture of the second metacarpal in tennis players\textsuperscript{54,55} described an increase in training volume and intensity as well as an alteration in technique. Intrinsic pressure from a solid object, the racket, on the second metacarpal bone provides a fulcrum for an external compressive load.\textsuperscript{57}

The softballer who presented with a stress fracture of fifth metacarpal (fig. 2) had recently increased training intensity in preparation for a major competition and had altered the grip for her curve ball. This involved an increased degree of abduction of the fifth finger and delivery of the ball with the fingers perpendicular to the direction of the pitch, thus increasing abduction forces.\textsuperscript{56}

In all the described cases of stress fracture of the metacarpals, relative rest and avoidance of aggravating activity resulted in clinical healing within 4 weeks. Attention must be paid to the errors in technique and training overload which first precipitate the problem.

8. Conclusions

Stress fractures of the upper limb are infrequent but not rare. The case reports from the literature summarised here probably only represent a small proportion of all upper limb stress fractures, which are examples of bone stress injuries due to repetitive muscle pull.

The diagnosis of stress fracture should always be considered in overuse syndromes of the upper limb. Careful anatomical examination is required. The presence of localised bony tenderness should make the clinician suspicious of stress fracture. A plain radiograph should be performed, but if that proves negative, the clinician should immediately...
proceed to isotope bone scan or MRI when clinical symptoms and signs indicate possible stress fracture.

Upper limb stress fractures generally heal with rest from the aggravating activity. Problems with the individual athlete’s technique then need to be addressed before he or she returns to sport.

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