

Golf-related stress fractures: a structured review of the literature

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Background: *Stress fractures are troublesome injuries. Sites of occurrence are activity-related and specific anatomical sites are endemic to certain sports. Little is known about stress fracture patterns in golf.*

Objective: *A structured review of the literature was conducted to identify the occurrence and injury sites of golf-related stress fractures.*

Methods: *A literature search of MEDLINE, CINAHL, and SPORTDiscus was conducted using a combination of controlled vocabulary and truncated text words to capture all articles relevant to golf-related stress fractures. Articles meeting inclusion criteria were descriptively analyzed.*

Results: *The search resulted in 164 articles, of which 13 met the inclusion, and reported 44 cases of golf-related stress fractures. Seven anatomical injury sites were identified with rib stress fracture being the most commonly reported. Stress fractures occurred on the golfer's lead-side in 80% of cases.*

Conclusion: *Golf-related stress fractures are infrequent injuries. The ribs were the most common stress fracture site, and a predilection for lead-side involvement was reported.*

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KEY WORDS: golf; stress fracture; golf injury; golf injuries; bony stress injury; athletic injuries

Contexte : *Les fractures de stress sont des blessures pénibles. Les sites d'occurrence sont fondés sur les activités et les sites anatomiques particuliers sont endémiques à certains sports. On en sait peu sur les fractures de stress au golf.*

Objectif : *Un examen structuré de la littérature a été réalisé dans le but de déterminer la fréquence et les sites de blessures des fractures de stress associées au golf.*

Méthodes : *Une recherche dans la littérature de MEDLINE, CINAHL et SPORTDiscus a été effectuée à l'aide d'une combinaison de vocabulaire contrôlé et de mots de textes tronqués pour obtenir tous les articles pertinents aux fractures de stress associées au golf. Les articles qui correspondaient aux critères d'inclusion étaient analysés d'un point de vue descriptif.*

Résultats : *La recherche a permis de trouver 164 articles, desquels 13 correspondaient à l'inclusion, et a rapporté 44 cas de fractures de stress associées au golf. Sept sites de blessures anatomiques ont été déterminés, la fracture de stress aux côtes étant celle qui a le plus souvent été rapportée. Les fractures de stress se produisaient du côté dominant des golfeurs dans 80 % des cas.*

Conclusion : *Les fractures de stress associées au golf sont des blessures qui ne sont pas fréquentes. Les côtes constituaient le site le plus commun de fractures de stress et une prédilection pour le côté dominant a été rapportée.*

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MOTS CLÉS : golf; fracture de stress; blessure de golf; blessures de golf; fracture de stress osseuse; blessures de sport

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Introduction

With the remarkable ability of golfers, such as Tiger Woods and Vijay Singh, who captivate audiences worldwide, it is not surprising golf is becoming increasingly popular. In the United States, there are over 26 million golfers, and approximately 6 million of these golfers play more than 25 rounds a year.¹ The sport has typically been regarded as low impact with most participants seemingly unaware of the potential for golf-related injuries.² Epidemiological studies^{3,4} have shown, golf injuries are not uncommon. A recent study reported an annual aggregate injury rate of 15.8 injuries per 100 players.³ In a study of 703 golfers, greater than 80% of injuries were attributed to overuse, and injury prevalence increased if one played four or more rounds of golf a week or hit over 200 balls a week during practice.⁴

The prevalence of golf injuries may be attributed to the repetitive asymmetrical loads imparted to the body by the golf swing. This has been purported to create distinct side-specific injury patterns in golfers.^{2,5} Such injuries have been described as lead-side or trail-side, depending upon the side of the body involved when performing the golf swing. For example, in a right-handed golfer the lead-side refers to the left side of the body and the trail-side to the right. In support of this notion are the side-specific injury patterns that have been identified in male and female golfers.² For instance, in professional male golfers, the low back, lead wrist, and lead shoulder have been reported as the most common sites of injury; whilst in females the lead wrist, lead hand, and low back were most common.²

As previously noted, greater than 80% of golf injuries have been attributed to overuse.⁴ In sports, an overuse injury of particular concern is the development of a stress fracture. A stress fracture is a partial fracture to bone that occurs as a result of repetitive sub-maximal loading in the absence of acute trauma.⁶ Overtime, if not removed, this repetitive loading will exceed the adaptive capacity of bone; eventually resulting in a stress fracture.⁷ Two types of stress fractures have been described; an *insufficiency fracture* (resulting from normal stress applied to abnormal bone) and a *fatigue fracture* (normal bone subjected to repetitive stresses over time leading to mechanical failure).⁸ Fatigue stress fractures are often associated with an activity that is 1) new or different for the person, 2) strenuous, and 3) repeated with a frequency that ultimately produces signs and symptoms.^{7,8}

Sites of occurrence of stress fracture are activity-related and certain sites are endemic to certain sports.⁷⁻¹⁰ It is important to identify stress fractures promptly, as continued activity without treatment may result in a complete or catastrophic fracture.

While specific stress fractures have been identified in many sports⁷⁻¹⁰, little is known about the anatomical injury sites of stress fractures in golf. A structured review of the literature of golf-related stress fractures can help identify stress fracture sites and their occurrence. Currently, such a review does not exist. The purpose of this article is to review the literature on the occurrence and injury patterns of golf-related stress fractures.

Methods

A literature search was conducted during April 2009 using MEDLINE (1950–2009), CINAHL Plus with Full Text (1937–2009), and SPORTDiscus with Full Text (1985–2008) through EBSCO Publishing. Search terms included controlled vocabulary from these databases (MeSH terms: “Fractures, Stress,” “Fractures, Bone,” “Fractures, Closed,” “Cumulative Trauma Disorder,” and “Golf”; CINAHL headings: “Fractures, Stress,” “Fractures, Bone,” “Fractures, Closed,” “Cumulative Trauma Disorder,” and “Golf”) and truncated text words (“stress fracture*,” “fracture*,” “cumulative trauma disorder*,” “golf*,” and “golf injur*”). All terms from the controlled vocabularies were exploded and searched as major concepts when available.

Controlled vocabulary search terms “Fractures, Stress,” “Fractures, Bone,” “Fractures, Closed,” “Cumulative Trauma Disorder”; and text words “stress fracture*,” “fracture*,” “cumulative trauma disorder*” were combined with the Boolean operator “OR” to capture all relevant articles pertaining to a closed fracture. Similarly, the controlled vocabulary search term “Golf,” and text words “golf*,” and “golf injur*” were combined with the Boolean operator “OR” to obtain maximum exposure for relevant articles pertaining to golf. The results of the two searches were combined with the Boolean operator “AND” to identify articles that would be utilized for screening for inclusion. In addition, scanning of reference lists was performed from the retrieved studies to identify any articles that may have been missed from the literature search.

Relevant articles were screened using abstracts and citations. Articles were included if they met the following criteria: the primary focus was the reporting of bony stress injuries or stress fractures; increased participation in golf was ascribed as the primary causative factor leading to injury; the article was published in a peer-reviewed journal; was at minimum a case report experimental design; and was written in English.

Results

A total of 164 articles were retrieved from the literature search. Upon applying inclusion criteria, 144 articles did not report a golf-related stress fracture as its primary focus; one article could not be retrieved due to the inability to contact the journal or primary author; one article was a small opinion piece; and six articles that met the criteria were excluded as they were not written in English. Thus, 13 articles were accepted for the review.

Of the 13 articles accepted, five were retrospective case series and eight were case reports. These studies identified seven different sites of golf-related stress fractures: rib,^{11–16} hook of the hamate,¹⁷ tibial diaphysis,^{18,19} proximal phalanx,²⁰ sternum,²¹ ulnar diaphysis,²² and acromion²³. Of the sites reported, rib stress fracture was the most frequently reported in three case series^{11,13,15} and three case reports,^{12,14,16} summing to 30 reported cases (see Table 1). The hook of the hamate stress fracture was described in one case series,¹⁷ identifying seven cases (see Table 2); a tibial stress fracture was reported in one case report¹⁸ and one case series,¹⁹ accounting for three cases (see Table 3); and the other stress fracture sites each were reported in one case report,^{20–23} respectively (see Table 4). A total of 44 cases of golf-related stress fractures were included in this review. Nearly 80% of the stress fractures occurred on the golfer's lead-side (35 cases); and side-specificity of injury was not reported in 1 case of stress fracture of the sternum.

Discussion

The majority of golf injuries reported in the literature are relatively benign and are classified as muscular strains and sprains.^{1–3,24,25} Although, the true incidence of golf-related stress fractures is unknown, the results of this review identified 13 articles in the English literature that reported a total of 44 cases of golf-related stress fractures. An epidemiological study by Fradkin et al²⁵ found frac-

tures accounted for 3.8% of self-reported golf injuries. While the authors did not sub-classify the types of fractures identified, it is likely a subset of the fractures reported included stress fractures. Interpreting the results of Fradkin et al²⁵ in conjunction with the results of the present review, it seems the occurrence of stress fractures in golf is not common. Reflective of the rarity of these injuries, the articles included in this review consisted of case series and case report experimental designs.

While golf-related stress fractures were seemingly rare, they seemed to have a predilection for certain anatomical sites. The most common stress fracture site was the ribs followed by the hook of the hamate. The ribs and hook of the hamate accounted for 68% and 16% of reported golf-related stress fractures, respectively. The less common sites included the tibial diaphysis, proximal phalanx, sternum, ulnar diaphysis, and acromion. Stress fractures were predominantly reported to have occurred on the golfer's lead-side (35 cases) as opposed to the trail-side (8 cases). Considering there seemed to be an anatomical preference of stress fracture sites in golfers, a detailed review of each site is presented.

Stress Fracture of the Ribs: Rib stress fracture was the most common golf-related stress fracture reported in this review (see Table 1). Golfers who presented with stress fracture of the ribs were almost exclusively novice golfers who participated in high-volume, high-frequency practice/training regimens. The site of occurrence was most often the lead-side posterolateral ribs with ribs four to six most frequently involved. Symptoms were typically reported as having presented with a gradual onset of vague posterolateral thorax pain that often prevented the golfer from further play. The diagnosis was often delayed as they were treated for a muscle strain or thoracic spine joint dysfunction with either a lack of therapeutic benefit or worsening of symptoms. Radiographic evidence of fracture was often unremarkable, and bone scintigraphy was frequently needed to confirm the diagnosis. Healing was usually uneventful with relative rest, and golfers were often able to return to play with no sequelae.

Rib stress fracture was reported to occur on the lead-side in 22 cases and on the trail-side in eight cases. When rib stress fracture was reported to occur on the golfer's lead-side, the proposed mechanisms of injury ascribed by the authors included: the repetitive striking of the ground

Table 1 *Articles reporting rib stress fractures in golf*

Author	Cases	Location	Subject Characteristics	Proposed Mechanism	Treatment	Outcome
Rasad ¹¹	3	• Case 1: Lead-side posterolateral ribs 4 & 6 • Case 2: Lead-side posterolateral ribs 4 & 5 • Case 3: Lead-side posterolateral ribs 6 & 7	All were beginning golfers in their first year of participation	Increased training intensity coupled with improper technique	Relative rest	Not Reported
Lord & Carson ¹²	1	• Lead-side posterolateral ribs 6, 7 & 8	Beginning golfer in first year of participation	Increased training intensity & lead-side serratus anterior fatigue	Relative rest for 6 weeks followed by serratus anterior rehabilitation for 4 weeks	Returned to golf in 10 weeks and remained asymptomatic
Orava et al ¹³	5	• Case 1: Trail-side, rib 7 at mid-axillary line • Case 2: Trail-side, ribs 6 & 7 at mid-axillary line • Case 3: Trail-side, anteromedial 7th rib • Case 4: Lead-side, 3rd rib at mid-axillary line • Case 5: Trail-side, posterolateral 6th rib	All 5 were beginning golfers in their first year of participation	Increased training intensity coupled with improper technique	Relative rest	All patients returned to golf and remained asymptomatic Timeframe for return to golf was case-specific with an average return to golf of 5.8 weeks.
Read ¹⁴	1	• Trail-side, 5th Anterolateral rib	Amateur golfer for 13 years	Faulty technique: failure to rotate the thorax through the golf swing	Not Reported	Not Reported
Lord et al ¹⁵	19	• 16 lead-side rib injuries • 3 trail-side rib injuries • Ribs 4–6 most commonly injured • All ribs were injured on the posterolateral aspect	18 beginners, 1 professional	Sudden increase in golfing activity & serratus anterior fatigue	Relative rest followed by serratus anterior and general conditioning rehabilitation	Not Reported
Goyal et al ¹⁶	1	• Lead-side, posterior 4th & 5th ribs	Golf experience not described	High golfing frequency	Not Reported	Not Reported

Table 2 *Article reporting hook of the hamate stress fractures in golf*

Author	Cases	Location	Subject Characteristics	Proposed Mechanism	Treatment	Outcome
Aldridge et al ¹⁷	7	All cases involved injury to the lead-side hook of the hamate	Competitive PGA tour golfers	Cumulative loading from the golf club handle and anatomical structures inserting on to the hook of the hamate	Surgical excision of the fractured fragment in all cases	Return to golf in 3 months; however, 4 patients returned to golf earlier with no deleterious effects

Table 3 *Articles reporting tibial stress fractures in golf*

Author	Cases	Location	Subject Characteristics	Proposed Mechanism	Treatment	Outcome
Gillies et al ¹⁸	1	Lead-side tibial diaphysis	Professional Golfer	Repetitive chronic torsional force on a fixed tibia led to prodromal “shin” pain. A powerful “drive” caused a complete fracture	Immobilization in a long leg cast	Not Reported
Gregori ¹⁹	2	Lead-side tibial diaphysis in both cases	2 Professional Golfers	Repetitive torsional force on a fixed tibia led to prodromal “shin splints” A powerful “drive” caused a complete fracture	Case 1: Immobilization in a long-leg cast Case 2: Intramedullary nailing and long-leg cast immobilization	Case 1: Return to golf after 9 months Case 2: Return to golf after 10 months

Table 4 Articles reporting other types of stress fractures in golf

Author	Cases	Location	Subject Characteristics	Proposed Mechanism	Treatment	Outcome
Gramp et al ²⁰	1	Lead-hand second proximal phalanx	Novice Golfer	Altered biomechanics and overuse	Relative rest for 2 months	Resolution of imaging findings with a 2 month follow-up MRI
Barbaix ²¹	1	Sternum	Semi-professional golfer	Not reported	Exploratory surgery to rule out other pathology resulted in 9 weeks of rest	Not reported
Koskinen et al ²²	1	Lead-side ulnar diaphysis	Amateur golfer	Externally rotated grip and increased training intensity	Relative rest and correction of grip	Return to golf 19 weeks after onset of symptoms; however, occasional pain was still experienced
Hall et al ²³	1	Lead-side base of the acromion at the spine of the scapula	Amateur golfer	Powerful muscular contraction of the posterior fibres of the deltoid	Sling immobilization, analgesia, and physiotherapy	Rapid functional recovery; however, time frame was not reported

with the club¹¹ and fatigue of the lead-side serratus anterior.^{12,15,16} The majority of reported cases made mention of the role of serratus anterior fatigue as a possible injury mechanism.^{12,13,15,16} This supposition was based on electromyography data of the golf swing that reported constant activity of the lead-side serratus anterior; whereas, the serratus anterior of the trail-side exhibited a discrete on-off firing that coincided with scapular protraction and retraction respectively.^{26,27} This muscle activation pattern is thought to render the serratus anterior of the lead-side more susceptible to fatigue.^{12,15} With high-volume and high-frequency training, fatigue may cause decreased activation of the serratus anterior. A decrease in activation of

this muscle has been shown to shift the concentration of compressive and tensile loads towards the posterolateral aspect of the ribs.²⁸ The frequent descriptions of posterolateral rib stress fracture reported in the golf literature is suggestive of this injury mechanism.^{11,12,13,15}

In contradiction to the more prevalent lead-side injury, when rib stress fracture occurred on the golfer's trail-side, authors of these articles attributed this discrepancy in injury location to different injury mechanisms. One author¹⁴ reported a failure of the golfer to rotate the body properly through the golf swing and another author¹³ postulated a possible thoracic cage impingement mechanism of the trail-side ribs. These injury mechanisms were

thought to contribute to increased stress localization to the ribs of the golfer's trail-side, subsequently causing rib stress fractures at this site.

Considering stress fracture of the ribs was the most common golf-related stress fracture reported; clinicians who treat golfers should be cognizant of the potential for this injury. Rib stress fracture should be included in the differential diagnosis when a golfer presents with vague thoracic and/or thorax pain.

Stress Fracture of the Hook of the Hamate: Hook of the hamate fractures are rare; however, they are endemic in sports involved in gripping a club, racquet, or bat.¹⁷ Hook of the hamate fractures in golfers have long been reported in the literature since the first description by Milch in 1934.²⁹ The most cited mechanism of injury was the golfer striking an object other than the ball, causing the end of the club to abut the hook of the hamate of the lead wrist. Recently, some authors have questioned the validity of this acute traumatic mechanism and have proposed a mechanism of repetitive bony overload causing a stress-induced injury.^{17,30,31}

Championing this contention, Aldridge et al¹⁷ reported seven cases of highly competitive golfers with fractures of the hook of the hamate of their lead hand with no temporal relationship between onset of pain and a traumatic event (see Table 2). All patients were amateur or professional golfers on the Professional Golfer's Association (PGA) tour. As competitive golfers the subjects were required to perform over 200 golf swings a day. All subjects reported a gradual onset of vague hand pain over the hypothenar region. Upon examination, all subjects reported palmar tenderness to palpation over the hypothenar region and exacerbation of symptoms during their golf swing. They reported no antecedent trauma.

Fractures of the hook of the hamate were confirmed in all seven golfers by either radiography, CT, or MRI. All fractures were complete, but minimally displaced. Each patient underwent excision of the fracture fragment and returned to pre-existing level of play within 3–6 months. The authors theorized the golfers sustained a stress fracture to the hook of the hamate as a result of repetitive low-grade impaction of the end of the golf club on the hypothenar region, coupled with persistent tensile loading of the musculo-ligamentous attachments of the hook of the hamate.

It remains plausible there may be a subpopulation of golfers with hook of the hamate fractures that resulted from a stress-induced injury over-time. Repetitive loading of the hamate from the end of a golf club may weaken the bone to such a level that a seemingly low load such as striking a golf ball off the tee or hitting a ball "fat" results in a fracture of the hook of the hamate.¹⁷ If this hypothesis were true, it would call into question the mechanism of injury of many of the reports of hook of the hamate fractures discussed in the literature. This could potentially affect the results of this present review, as 12 studies were excluded because their primary focus were hook of the hamate injuries described as a fracture rather than as a stress fracture. As recommended by Aldridge et al¹⁷, further study is needed to ascertain if golfers experience prodromal symptoms and/or imaging findings that are consistent with a stress reaction of bone prior to hook of the hamate fractures.

Stress Fracture of the Tibial Diaphysis: Tibial stress fractures are often transverse fractures that involve the diaphysis.¹⁰ Spiral and oblique tibial stress fractures are rare.¹⁹ Three cases of tibial stress fracture (2 spiral and 1 oblique) have been reported in professional golfers, and all three cases reported similar injury characteristics (See Table 3).^{18,19} In all cases, the lead tibia was affected, and the patients reported prodromal symptoms of "shin splints" localized to the affected tibia. Acute fracture incidents occurred during the generation of a powerful swing off the tee. In all three descriptions, spectators reported hearing a loud audible "crack" as the golfers completed their swings.

Spiral and oblique tibial fractures are often caused by torsional forces on the tibia.^{32,33} During a golf swing, the lead leg is secured to the ground by spiked shoes. This locks the lead leg in place, and subsequently, the lead tibia must resist a large external torsional load. The torsional load applied to the lead tibia during the golf swing may explain why the reported fractures were spiral and oblique fractures rather than the more common transverse tibial fractures found in runners.^{18,19}

Professional golfers frequently participate in golfing activities. Aside from other physical training, they may strike an average of 800 balls/week.² Increased training intensity, a secured lead foot to the ground, and a large repetitive torsional force applied to the tibia may explain

the generation of prodromal “shin splint” symptoms. Albeit, these symptoms are not common in golfers, their presence should warrant prompt investigation and management to prevent major injury.

Stress Reaction of the Hand: Similar to the assumption that bony stress injury can occur at the hook of the hamate from repetitive abutment from the golf club¹⁷, Grampp et al²⁰ presented a case of overuse edema in the second proximal phalanx of the hand of a 29 year old female golfer (see Table 4). The golfer presented with mild pain and swelling localized to the medial second proximal phalanx of her lead hand. The symptoms commenced following one week of daily training sessions of golf. Radiographs demonstrated moderate soft tissue swelling adjacent to the base of the second proximal phalanx and no bony pathology. A MRI examination utilizing Short Tau Inversion Recovery (STIR) sequences identified diffuse increased signal intensity in the proximal and distal portion of the second proximal phalanx accompanied by focal increased signal intensity of the distal second metacarpal. These findings were reported to be consistent with bone marrow edema. The authors proposed the alteration in signal intensity represented a threshold between a bone bruise and the physiologic stress response of bone corresponding to bone remodeling. The authors attributed the cause of her symptoms to overuse and altered biomechanics; however, details of the precise biomechanical cause were not reported.

Stress Fracture of the Sternum: Sternal stress fractures are rare. The only previous sternal stress fracture reported in sport occurred in a wrestler.³⁴ In 1996, Barbaix²¹ reported a case of a stress fracture of the sternum in a semi-professional golfer (see Table 4). The patient reported having purchased new clubs one month prior to participation in a tournament. In the weeks prior to the tournament, the golfer increased his practice volume and intensity to familiarize himself with his new clubs. He slowly developed pain and swelling at the 3rd and 4th ribs at the sternum. On the day of competition the pain was so severe he withdrew from the tournament. An ultrasound test that consisted of the application of 1 MHz continuous ultrasound at an intensity of 1 W/cm² provoked pain within seconds, and abated when it was reduced to 0.5 W/cm². Bone scintigraphy revealed a hot

spot in the sternum consistent with the diagnosis of a stress fracture. The patient sought a second opinion from an orthopedic surgeon who performed exploratory surgery, and in the absence of pathology the diagnosis of stress fracture of the sternum was confirmed. The authors did not provide a discussion to explain the mechanism that lead to the focal increased stress localized to the sternum. It was unclear whether the stress fracture occurred in the midline, lead-side, or trail-side of the sternum.

Stress Fracture of the Ulnar Diaphysis: Stress fractures of the ulnar diaphysis are rare, and have been reported in tennis, volleyball, softball, and body builders.⁹ The most common site is at the junction between the middle and distal third of the ulna.^{9,22} Koskinen et al²² reported a case of a 44 year old recreational female golfer who presented with lead-side dorsal wrist pain that worsened over time (see Table 4). The patient denied any incident of trauma. Upon examination, her wrist was slightly swollen and palpation of the ulnar side of the distal forearm was tender. Radiographs revealed a spiculated periosteal reaction on the radial side of the distal ulnar diaphysis with no signs of bone destruction. After 10 weeks, a palpable, non-tender, 2 cm long protuberance was located on the distal third of the ulna. A MRI revealed cortical thickening and an area of low signal intensity on T1-weighted images consistent with fracture healing. Mild edema was also noted at the fracture site with marked edema of the interosseous membrane. A radiograph one week following the MRI investigation revealed a lucent line with periosteal callus formation consistent with a stress fracture. The patient was treated with relative rest and technique modification. Her golf instructor recognized the affected lead hand was held in excessive external rotation while gripping the golf club.

Stress fractures of the ulnar diaphysis are believed to be a result of overuse of the flexors of the wrist. In the above case, due to the golfer's excessive external rotation of her lead wrist, it is possible that her lead forearm underwent excessive supination at the end of the golf swing which caused repetitive torsion of the interosseous membrane in conjunction with overuse of the forearm flexors.

Stress Fracture of the Acromion: Fractures of the scapula are quite rare, and occur most often in concurrence with a considerable traumatic force.³⁵ Hall and Calvert²³

presented an unusual case of a stress fracture of the acromion in a 42 year old female who had recently begun to golf (see Table 4). The patient presented with a 15 day history of left shoulder pain that started immediately after striking a ball off the tee. Her pain prevented her from subsequently participating in golf-related activities. Upon examination, mild swelling and localized tenderness was noted over the spine of the left scapula. Radiographs revealed an undisplaced linear fracture at the base of the acromion that extended into the spine of the scapula. Hematology and bone densitometry were normal. The patient was treated with sling immobilization, analgesics, and physical therapy. Her fracture fully healed and she returned to normal activities. The authors suspected the mechanism of injury was due to the contraction of the posterior fibres of the deltoid as the club swung forward to strike the ball.

Limitations and Future Directions

A major limitation of this study was the articles included in this review consisted of case series and case report literature; representing level IV evidence.³⁶ Caution should be used when interpreting results from such a review, as results drawn from level IV evidence may over or underestimate the truth and may be non-generalizable due to inherent biases in study methodology.³⁷ Given the rarity of these injuries it is not surprising there is an absence of prospective studies investigating the topic.

A problem encountered when analyzing the retrieved articles was the lack of uniform reporting of clinical cases. Intervention details and patient outcomes were inconsistently reported. These limitations made it difficult to generate conclusions about the mechanisms leading to injury and the effect of the interventions prescribed. The majority of reports made attempts to rule out co-morbid conditions affecting bone quality; however, it was difficult to definitively establish if the fractures were fatigue or insufficiency fractures. It cannot be disregarded that, in some cases, the development of stress fracture may have been the result of a co-morbid condition or mere coincidence.

The present review did not include articles written in languages other than English. During the application of inclusion criteria, six relevant articles were excluded because they were not written in the English language. Upon review of the abstracts, the six articles were case

reports reporting stress fracture of the ribs in golfers. Considering the present review included a total of 30 cases of rib stress fractures, it is unlikely the inclusion of an additional six cases would substantially alter the interpretation of the review.

Given the infrequent occurrence of these injuries, case-control research designs may have utility in future research to identify predictive variables leading to stress fractures in golf. Results from these studies could be utilized to develop intervention strategies to prevent these injuries. Stress fractures represent an overuse injury generated from repetitive sub-maximal loading.^{6,7} Consequently, research endeavors that evaluate the effects of golf swing mechanics on the physiological load of the participant may also contribute to the development of effective intervention programs to help golfers safely enjoy their sport.

Conclusions

Although infrequent, golf-related stress fractures do occur. While definitive conclusions cannot be made from level IV evidence, the results of the review do highlight certain similarities relating to injury patterns. Golf-related stress fractures appeared to be site-specific with a preponderance on the golfer's lead-side. The majority of stress fractures were reported in beginner and novice golfers who had recently increased their practice/training volume or intensity. The most common site of stress fracture was the golfer's lead-side ribs. Stress fractures in novice golfers were frequently reported to be found in the ribs; whereas, in professional golfers they occurred at the hook of the hamate and tibial diaphysis.

The articles included in this review represented the current state of the literature. With the increasing popularity of golf worldwide it is important clinicians are aware of both the common and rare injuries that can occur as a result of golf participation. The intent of this review is to increase awareness of these injuries to better assist the clinician when evaluating the golfer who presents with an atypical injury presentation.

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