

# Golf Injuries

## A Review of the Literature

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### Abstract

Golf is one of a few activities that people of all ages and skill level can play. Injury as with all sports can occur. The low back is the most common injury sustained whilst playing golf, and the dynamic action of the golf swing is a major contributing factor to injury. The golf swing is a complex movement that utilises the whole body in a coordinated fashion and when repeated frequently can result in injury. Injury can be overuse or traumatic in nature. Overuse injuries predominate in the professional golfer, and amateur golfer injury tends to occur secondary to an incorrect golf swing. Upper limb injuries are also common due to their role in linking the fast moving golf club with the power-generating torso. Fortunately, injury from a club or ball strike is rare. More common are the overuse injuries associated with the back, neck and shoulder. Most golf injury data have been collected retrospectively and further epidemiological study of a prospective nature is required to determine injury incidence and factor relating to the onset of injury.

Golf is a popular sport played worldwide by people of all ages and skill level. Part of its appeal is

that there are no sex, skill or age limits to participation. Golf participation rates are spread across all

age ranges but are high in the older age brackets. This is partly due to the fact that the older/retired population have more leisure time to pursue activities and golf is low impact with a general aerobic component, which makes it a perfect recommendation for medical practitioners wanting their patients to exercise. Golf is a popular option as it also provides social interaction and can be played at all skill levels due to its handicap system. For many people who play ball sports, age results in decreased fitness, speed and endurance and they are unable to participate at the levels conducive to competition. For those people who like to remain active and competitive, golf is a popular option.

Although they are uncommon, injuries incurred while playing golf are an increasing problem. Considering the popularity of the game and the market that is golf (equipment, tuition, sponsorship), there have been only a small number of studies on golf injuries. Indeed, most of the injury rates in golfers cited, review research produced 10–25 years ago. This observation is also made by the most recent study by Gosheger et al.,<sup>[1]</sup> who reported that most of our understanding of golf injuries relies on two publications produced >10 years ago, McCarroll et al.<sup>[2]</sup> in 1990, Batt<sup>[3]</sup> in 1992 and one produced >20 years ago by McCarroll and Gioe.<sup>[4]</sup> This article examines the available literature on the epidemiology of golf injuries and investigates the differences in injury location and mechanism seen in professional golfers when compared with amateur golfers. The article determines areas of common injuries and where possible presents the likely mechanism of the common injuries that occur in golfers.

The investigators conducted a MEDLINE, SportDiscus and EMBASE search with the key words 'golf' and 'injury' between the years 1965 to present. The results were collated and those studies that examined injuries associated with playing golf were included. Initially there were 206 relevant papers included in the search criteria. On analysis of reference lists of selected papers, a number of references were from conference proceedings and these papers were included. In total, >250 papers relating to golf injuries were collated and examined.

A good understanding of golf injuries requires the practitioner to consider the quality, quantity and type of golf swing employed by the golfer. Skill level is determined by how many shots/strokes they have to complete a game (or round) of golf of 18 holes. Par is the score that a professional would be expected to score on a championship golf course. The par for such a course is generally 72. For example, a person who scored 90 strokes on a par 72 course, would be rated at 18 over par. If this score was averaged over several performances, a handicap of 18 would apply. The lower the handicap, the more skilful the golfer.

The average Australian golf club handicap is 18.1 in males and 27.5 in females.<sup>[5]</sup> A gradual increase in handicaps as age increases, with the 18–30 year age group being the peak age group for handicap players in Australia with an average handicap of 14.4 for males and 22.5 for females (see table I).<sup>[5]</sup> In the US, the average handicap is 16.1 for men and 29.2 for women.<sup>[6,7]</sup> The American data also reveal that for men, the middle quartile (25–75%) for golf handicaps range from 10 to 20,<sup>[6]</sup> with the females range being 22–35.<sup>[7]</sup>

In Australia, golf participation rates by civilian persons >18 years of age during a 12-month period prior to census interview in 1999–2000 was 1.1 million, a figure that corresponds to a participation rate of 7.5%.<sup>[14]</sup> This rate equated to golf being the fourth most popular non-organised activity behind walking, swimming, aerobics/fitness and the second most common organised activity behind aerobics/fitness.<sup>[14]</sup> In males, golf was the most popular sport accounting for 890 300 participants (12.4% of the population), while there were 193 300 female participants (2.6% of the population).<sup>[14]</sup> Of golf participation, 50.3% was classed as organised (involving some form of club organisation), while the highest participation rate for golf was recorded in the 55–64 year age group (9.3% or 176 000 people), followed by those aged 45–54 years (8.8% or 233 700).<sup>[14]</sup> In Australia (with a population of approximately 20 million), there were 477 084 registered golfers in 2002.<sup>[5]</sup> In New Zealand, with a population of approximately 4 million, there are approximately

**Table I.** Overview of golf injury epidemiology studies

Study	Source of data	No. of respondents	Most common injuries	mechanism/comments
McCarroll et al. <sup>[2]</sup>	Amateur	1144 (942 males; 202 females)	Males: lower back, elbow, wrist/hand Females: elbow, lower back, shoulder	Excessive play/practise, poor swing mechanics, hitting the ground, 50% of all injuries occurred at impact
Batt <sup>[3]</sup>	Amateur	193 (164 males; 29 females)	Males: wrist, back Females: elbow	Incorrect swing/miss-hit (affecting wrist back more commonly), overuse type injuries (wrist was the most common) A player that had a low handicap <10 was more likely to injure their wrist or elbow or experience a muscular injury than those with a higher handicap
Nicholas et al. <sup>[8]</sup>	Amateur	368	47.6% had been struck by a golf ball in the lower extremity followed by the trunk and upper extremity injury sites	Most serious injury being struck by a golf ball Contusion followed by concussion and fracture was the most common sequelae
Theriault et al. <sup>[9]</sup>		528 golfers (347 females; 181 females)	Upper limb (42.4%), spine (39.7%), lower limb (17.9%)	Technical injury (53.9%), overexertion of the trunk during the swing (30.8%), overuse (14.1%)
Burdorf et al. <sup>[10]</sup>	Back pain in beginner males	196	Baseline survey: life-long cumulative incidence of back pain was 63% 28% had a history of back pain within 1mo prior to answering the survey	Those that were athletes had increased odds ratio of 2.1 to previous back pain compared with non-athletes
Gosheger et al. <sup>[1]</sup>	Amateur and professional golfers	643 amateurs (70.9% male) 60 professionals (90% male)	Professionals: back, wrist, shoulder Amateurs: elbow, back, shoulder	>4 of 5 injuries were attributed to overuse, particularly in the back, shoulder, knee and elbow
McCarroll and Gioe <sup>[4]</sup>	Professional	226 (127 males; 99 females)	Male: low back, left wrist, left shoulder (in right-handed golfers) Female: left wrist, low back, left hand Overall: left wrist, low back	
Sugaya et al. <sup>[11]</sup>	Low back pain amongst elite/professional	283 golfers (regular tour males 115, senior tour males 55, and 113 female tour, 45%)	Low back, followed by neck/high back and elbow and shoulder equally	72% experienced injuries that caused them to miss a tournament or perform at a lower level, mostly due to back and upper extremity injuries Low back pain location: 51% right-side pain, 28% left side and 21% central
McNicholas et al. <sup>[12]</sup>	Sports medicine clinics data collection	286	The most common site of injury was reported as the upper limb, followed by the trunk and the knee	25% female, 27% were <40y of age, 8% were >60y Nearly 90% were recreational golfers Of the upper limb injuries, lateral epicondylitis was the most common problem area, followed by shoulder impingement and medial epicondylitis
Finch et al. <sup>[13]</sup>	Sports medicine clinics and emergency departments	34	Lower back, elbow and knee	Overuse, a twist or rotational component of the swing, which the authors attributed to poor swing mechanics and an aggravation of previous injury Elbow injury was due to overuse (two-thirds), miss-hits (one-third)

**Table II.** Incidence of injury for the most common locations for various groups of golfers<sup>[1-4,8-13]</sup>

Area	Amateur (%)	Professional (%)	Male (%)	Female (%)
Low back	15–34	22–24	25–36	22–27
Wrist	13–20	20–27	18–28	12–36
Elbow	25–33	7–10	8–33	6–50

138 000 registered golfers.<sup>[15]</sup> In both countries, to be a registered golfer, you must be a member at any one of the Golf Clubs affiliated to the Australian Golf Union or NZ Golf, respectively. The number of registered golfers in Europe is 3 741 680 as at March 2003,<sup>[16]</sup> while in the US, the number of golfers with a handicap is 4.5 million and the number of golfers >18 years who have played in the last 12 months is 26.2 million.<sup>[17]</sup>

## 1. Epidemiological Studies

A number of studies have been conducted that examine the occurrence of injuries in golfers.<sup>[1-4,8-13,18]</sup> Both amateur<sup>[1-3,8-10,12,13,18]</sup> and elite/professional golfers,<sup>[1,4,11]</sup> as well as male and female player groups,<sup>[1-4,8-13]</sup> have been the focus of these studies. A summary of epidemiology studies is shown in table I. Researchers have used varying methodological procedures to report these statistics. Research data have been collected from the distribution of surveys by mail,<sup>[2-4,8-11]</sup> direct interview of players,<sup>[1]</sup> and data collection at hospitals and sports medicine clinics.<sup>[12,13]</sup> Common injuries of the different sub-groups of golfers is shown in table II.

### 1.1 Professional

In professional golfers, the most common site of injury for males was the low back, followed by the left wrist and left shoulder (in right handed golfers).<sup>[1,4]</sup>

In the female professional, the most common site of injury was the left wrist, followed by the low back and left hand.<sup>[4]</sup> Overall, the two most common injury sites in professionals was the left wrist closely followed by the low back,<sup>[4]</sup> although Sugaya et al.<sup>[11]</sup> found that the lower back followed by the neck were the two most common injury sites. The most common mechanism of injury for professional golfers (male and female) was the high frequency (repet-

itive) of practising the golf swing, followed by hitting an object other than the ball while swinging the golf club or a golf swing injury that occurred during competition.<sup>[4]</sup>

Professionals are susceptible to overuse injuries due to the amount of practise they perform in their pursuit of excellence.<sup>[4]</sup> Even though professionals are adapted to withstand a higher frequency/intensity of play, excessive play can promote overuse injury. As the professional depends on earning a living from golf, they often continue with practise even though they have an injury. As a result, the professional golfer is more likely to aggravate an injury condition more than the amateur golfer.

### 1.2 Amateur

In amateur golfers, common injury sites include the low back, wrist, the elbow and the shoulder. Several researchers<sup>[2,13]</sup> reported the lower back as the most common injury site in males while Batt<sup>[3]</sup> reported the wrist as the most common site injured. Theriault et al.<sup>[9]</sup> and McNicholas et al.<sup>[12]</sup> did not split the upper limb into regions and hence found it the most common injury site. Elbow injuries, particularly in females, were a common injury site in golfers.<sup>[1-4]</sup>

Most of the golf-related injuries seen at hospital emergency departments involved the head,<sup>[18]</sup> while Nicholas et al.<sup>[8]</sup> reported that being struck by a golf ball occurred mostly in the lower extremity, with the trunk and then the upper extremity less likely. In the case of elbow injuries, most injuries that occurred were diagnosed as lateral epicondylitis ('tennis elbow'), particularly in the left elbow (non-dominant) of the right-handed golfer.<sup>[2,12,13]</sup> The most common mechanisms of injury in golfers are overuse (too much play/practise), poor biomechanics of the swing and hitting the ground of an object during the swing.<sup>[1-3,13]</sup> Catastrophic injury may occur as a con-

sequence of being struck by either a golf club or golf ball, although this is rare.<sup>[12,18]</sup> Excessive play/practice was reported to be the most common source for injury to occur.<sup>[2,13]</sup> Incorrect swing/miss-hit (poor swing mechanics) was reported by Batt<sup>[3]</sup> to be the most common mechanism of injury in which the wrist or back were the most likely to be injured. Theriault et al.<sup>[9]</sup> reported technical injury (53.9%) as the most likely reason to sustain an injury (most likely relates to poor mechanics). Being hit by a golf ball was the most likely reason for an adult to be admitted to hospital for a golf-related injury, while for a child it was being struck by a golf club. Adult injuries were most likely to occur on a golf course, whilst a child was most likely to be injured in the home environment.<sup>[18]</sup>

### 1.3 Methodological Analysis

In reviewing the data produced by these studies, a number of methodological issues need to be considered. The response rate of surveys should be reported or otherwise evaluated, as the response rate indicates how representative the data collected is of the whole golfing population. The higher the response rate, the more representative the data is of the golfing population.<sup>[19]</sup> Response rates of the retrospective studies reviewed ranged from 20.6% to 57%<sup>[2-4,8,11]</sup> and 78.4% in prospective studies.<sup>[10]</sup> The type of data the survey is trying to obtain also reflects on the results produced. Retrospective studies are easier to produce as they are examining what has occurred in the past, while prospective studies involve looking at what happens from a set of time forward for a defined period of time, a year for example.<sup>[20]</sup> This prospective type of study is harder to institute because of increased costs and time spent on the study, as well as having problems associated with dropout rates, but produces stronger conclusions.<sup>[21]</sup> The golf literature is primarily retrospective in nature.<sup>[2-4,8,11]</sup> Many of the retrospective studies ask the participant about injuries sustained in their career, which gives rise to the phenomenon of recall bias. Recall bias is the inaccurate reporting of data that results from alteration in recollection of events that occurred in the past.<sup>[22]</sup> If a golfing career

has only been 3–5 years, injuries can be more readily recalled than if the subject has been playing golf for >40 years. Gosheger et al.<sup>[1]</sup> has also noted this potential limitation of the golf literature.

The data produced by a study need to be large enough to be able to draw conclusions. The more subjects in a study sample, the more representative is that study sample of the population it is trying to represent.<sup>[23]</sup> Sample sizes ranging from 34 (8 in females<sup>[3]</sup>) to 1144 participants appear in the golf literature.<sup>[2]</sup>

The above data demonstrate that there is a paucity of high-quality, large studies examining the epidemiology of golf injuries. Further studies into the epidemiology of golf injuries require redress of methodological issues identified above that affect the accuracy of collected data. The next discussion will present a closer look at the data of specific injury sites.

## 2. Specific Injury Sites

### 2.1 Low Back Injuries

The low back has been reported as being the most common site of injury in a golfer,<sup>[2,4,11,13]</sup> accounting for 23.7–34.5% of all injuries. Due to the mechanics of the swing, the low back is subject to large ranges of motions and forces.<sup>[24]</sup> The forces that occur as a result of the mechanics of the golf swing may be categorised as:

- downward compression
- side to side bending
- sliding, back to front shearing.<sup>[25]</sup>

Peak compressive load during the golf swing has been shown to be 8-times bodyweight (compared with rowing [7-times] or jogging [3-times]).<sup>[25]</sup>

In an analysis of the differences in the golf swing of amateurs and professionals, research has found that amateurs reach 90% peak muscle activity compared with 80% in professionals and the lumbar spine is under more load in amateurs.<sup>[25]</sup> The study found that both groups of players had the same compression loads, but amateurs incurred 80% more lateral bending and peak shear loads and 50% more torque than their professional counterparts.<sup>[25]</sup> Anec-

dotal evidence from personal observations/experiences of the authors suggests that these characteristics are mainly due to the amateur player trying to hit the ball further by swinging harder, particularly with the driver (the club used to hit the ball the furthest distance). The professional player has practised enough to produce a nearly identical swing each time they play a full shot. As a result of this practise, their swing is grooved and becomes second nature and thus efficient to them. In most cases, amateurs lack this desirable feature and this may predispose to injury as poor swing mechanics increase the forces generated by the golf swing.

The golf swing is a complicated action with intrinsic and extrinsic factors affecting the golfer's ability to hit the ball with power and accuracy. As a result of this complexity, injuries can occur. If the swing is not as free flowing and as efficient as possible, injuries are likely to occur.

The golf swing involves a large range of motion and is repetitive, especially during practise. Com-

bined with the large forces produced in the lower back, this may result in the increased risk of strains, disc herniation and facet arthropathy.<sup>[26]</sup>

A number of swing types are common in golf. A basic understanding of the golf swing types is required for practitioners to be able to understand how golf swing-related injuries may occur. There is the classic golf swing that was popular in the early/mid part of the twentieth century and there is the modern swing that Jack Nicklaus introduced in the 1960s. The modern swing generated more power to the ball, increasing the distance the ball travelled. It also produced higher shots that stopped shortly after landing, which was helpful in shots to the green. The main differences in the swings was the large pelvic and shoulder rotation in the classic backswing as opposed to the limited pelvic rotation compared with shoulder rotation in the modern backswing (figure 1).<sup>[27]</sup> This differential in rotation generates a coiling effect of the trunk that helps with power development. The follow-through position was also



Fig. 1. Backswing. Modern (a) compared with classic (b).

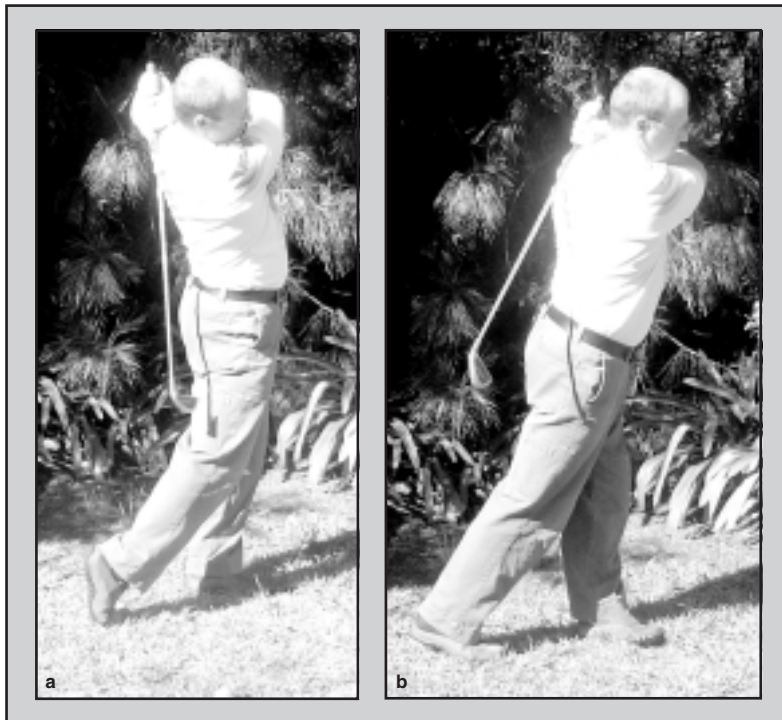


Fig. 2. Follow-through. Modern (a) compared with classic (b).

different with a relatively neutral spinal position and forwards body momentum in the classic swing as opposed to the hyperextended spine and upwards body momentum on the modern swing (figure 2). This reverse 'c' position of the follow-through in the modern swing (producing hyperextension of the lumbar spine and right lateral flexion) has the potential to result in facet irritation if constantly repeated.<sup>[28]</sup> A third swing is gaining popularity, which combines elements of both swing types. The hybrid swing utilises the backswing of the modern swing with its power generating potential and the follow-through of the classic swing with its neutral spine. This swing is thought to generate similar power to the modern swing, without the hyperextended spine (and potential for injury) of the modern swing.<sup>[29]</sup>

Refuting the data that show that golf may increase the likelihood of experiencing discal problems is research that showed golfers had 0.59 relative risk of herniated disc to those that do not play sport, while those that play >2 times per week

have 0.19 relative risk. This raises the question of whether golf has a protective mechanism to discal problems compared with not playing the game.<sup>[30]</sup> However, golfers with discal-associated low back pain would not play golf due to the belief that the golf swing will aggravate their condition. Thus, there may be some selection bias in this finding.

Sugaya et al.<sup>[11]</sup> examined the prevalence of low back pain amongst elite/professional golfers at three major golf tournaments and final qualifying test. Of the 283 golfers that responded (only one player was left handed and excluded from the study for consistency purposes), the most common injury site was low back, followed by neck/high back and elbow and shoulder equally. Of these golfers, 72% experienced injuries that caused them to miss a tournament or perform at a lower level. An injury to the low back was responsible for missed play 55% of the time. Of the players who experienced low back pain and recorded pain location, 51% had right-side pain, 28% left side and 21% central. An important

statistical correlation between right-sided back pain and the follow-through was found when analysing where the pain occurred during the swing ( $p < 0.05$ ). This study also took radiographs of 16 players (there was no selection criteria, which raises the question of selection bias) with low back pain and found that compared with age-matched controls, golfers had statistically more osteophytic formation at L3/4 ( $p < 0.01$ ), and in total ( $p < 0.01$ ). They also found that facet changes were statistically different overall ( $p < 0.01$ ) and at L4/5 ( $p < 0.01$ ) and L3/4 ( $p < 0.05$ ).

In another study, Burdorf et al.<sup>[10]</sup> conducted a 1-year prospective study on back pain amongst males taking up golf. 221 completed the first survey (88% response) with 89% completing the follow-up survey (196). The baseline survey showed the life-long cumulative incidence of back pain as 63%, with a 28% reporting a history of back pain within the 1 month prior to the completion of the survey. Those that were athletes had an odds ratio of 2.1 for previous back pain compared with non-athletes. During the 12-month prospective period of the study, 8% reported a first time occurrence of back pain and 45% reported the recurrence of back pain. Only six subjects attributed golf to this recurrence. Compared with those who only played golf, those who also played one other sport had a risk of 1.4 to recurrence of back pain

The rate of back injury in junior golfers has been investigated. This study found that the incidence of back pain in golfers was not different to age-matched controls when compared with others studies in similar aged children.<sup>[31]</sup> However, in those junior golfers with back pain, most pain was reported to occur in the right lumbar region. This figure correlated to right side lumbar pain in 93% of right-handed players. This right side predominant pain location in right-handed golfers is similar to that found in professional (adult) golfers described by Sugaya et al.<sup>[11]</sup>

Compression fractures in older females during the golf swing have been reported in the literature.<sup>[32]</sup> The compression fracture sites were confined to the lower thoracic and upper lumbar vertebrae, and were reported in healthy postmenopausal

women who were previously diagnosed, or subsequently diagnosed, with osteoporosis. This shows that the most common site of stress in the back appears to occur around the thoracolumbar region, a transition segment of the spinal column. The question that needs to be asked is "If there was no osteoporosis, would the compression fractures have occurred?". Further research into this area is needed.

## 2.2 Wrist/Hand Injuries

Along with the low back, the wrist is the most common site of injury in golfers.<sup>[3,4]</sup> The wrist provides the anchor point of the club to the arms and body during the swing. As such, the wrist moves through a relative wide range of motion during the swing.<sup>[33,34]</sup> Motions include flexion, extension, radial and ulnar deviation, with pronation and supination of the forearms also being a feature of the golf swing.

The most common injury mechanism in wrist injuries occurs as a result of hitting an object other than the ball. These injuries are usually of the acute nature. The injury is the result of a sudden decrease in movement of the accelerating hands and wrist at impact that can produce enough forces to disrupt tissue structures. Injuries of this nature tend to occur at the hand and wrist, but can also occur in the elbow. Muscular strains and ligamentous strains are common, but fractures of the hook of hamate may also occur due to this mechanism. Hitting off stones of hard ground may also produce similar injuries. The hitting of a 'fat' shot, i.e. hitting the ground first during the process of hitting the ball is another possible source of this mechanism of injury, which tends to occur mainly in the amateur ranks. The professional golfer can sustain a similar type of injury in slightly different circumstances. In major tournaments, particularly at the links courses of the UK, the rough tends to be quite thick and long. As a result, if a ball is nestled in the rough, a lot of force is required just to get the ball back onto the fairway. Combine this with the fact that long strands of grass tend to wrap themselves around the hosel and shaft of the club during the downswing, which has the



potential to place more force on the upper limb and cause injury.

Other injury mechanisms that involve the wrist are overuse related, often due to the repetitive nature of practise, or from changes to the swing that result in stress to structures unaccustomed to the type of stress the golf swing produces. A study of the Spain National Insurance Scheme for sportspeople found that 10% of golfers experienced a wrist injury.<sup>[35]</sup> Causes of wrist injury were reported as overuse or sudden change in swing.<sup>[35]</sup> This survey found that wrist injuries from golf may be categorised as either articular (mostly occurring via fractures, particularly the hook of hamate) or extra-articular most often tenosynovitis, with the flexor carpi ulnaris the most common site of injury.<sup>[35]</sup>

Hook of hamate fractures result from the hamate becoming impinged between the hand and the butt end of the club. This results in a fracture of the hamate of the leading hand, for example the left hamate in a right-handed golfer,<sup>[36]</sup> and has been reported in the golf injury literature as far back as 1972.<sup>[37]</sup> Stress fractures may also occur at this site due to sudden increases or changing the golf club grip.<sup>[38]</sup>

The site of pain with a hamate fracture is in the hypothenar area of the palm, with tenderness to palpation of the hamate an indication for imaging. However, plain x-ray films may not initially show the fracture.<sup>[36,39]</sup> A carpal view x-ray may show the fracture, although a CT of the wrist should show the injury if there this film is negative and there is still a clinical suspicion for it.

Complications to the healing of the fracture include non-union of the fracture site, a concomitant ulnar nerve lesion and/or the rupture of the flexor tendons over the broken edge of the hamate.<sup>[35,40]</sup> Hook of hamate fractures tend to present late (usually several months after the injury) and often require surgical excision of the fracture segment at this point.

Tendinitis is a much maligned term used to describe overuse syndrome about the wrist/elbow, with the term tendinopathy been indicated for use as a general clinical descriptor.<sup>[41]</sup> It has an overuse

mechanism, which results from either a sudden increase in the volume of practise or the changing of the grip (causing increased loading on an unaccustomed part of the wrist), and subsequent practise.<sup>[42]</sup> It is gradual in onset, persistent in nature and continues until the aggravating factor(s) is stopped or rested until allowed to heal.<sup>[35,41,42]</sup>

Large forces are produced in the golf swing just prior to impact, particularly in the flexor tendons. In the case of right-handed golfers, the flexor carpi ulnaris of the right wrist is vulnerable to injury from microtrauma due to these forces, particularly when golfers take divots (hit the ground). There is a slight increase in resistance experienced as the club encounters the ground, a resistance that heavily loads the flexor tendon. In addition, beginner golfers may experience pain due to extensor carpi ulnaris overuse, which is the result of 'casting' the golf club early in the downswing (the early uncocking of the wrist during the downswing and a source of lost power and control).<sup>[43]</sup>

Unusual cases of injury in the surrounding structures also occur. Hsu et al.<sup>[44]</sup> reported the case of an amateur golfer with mechanical compression of the median nerve in the right palm by the head of the first metacarpal bone of the left hand. This compression may occur during the acceleration phase of the downswing just prior to impact, particularly if the right hand is leading the left hand during the downswing and if the right-hand grip is too tight.

Abnormal anatomy along with overuse can also produce injury of the wrist. Oka and Handa<sup>[45]</sup> reported the case of a 20-year-old golf trainee presenting with right wrist pain when swinging the golf club during a practise session. Examination revealed extensor carpi ulnaris tendon dislocation past the ulnar head and to the ulnar-volar side on supination of the forearm. On returning to the neutral position, the tendon reduced in a snapping manner, extending beyond the ulnar head, which reproduced the pain. Surgery to partially resect the ulnar dorsal ridge of the ulnar head with release of the extensor recinaculum resulted in resolution of symptoms.

A highly unusual case of hypothenar hammer syndrome in a golfer has been reported. Hypothenar

hammer syndrome results from a thrombus formation of the ulnar artery with hand ischaemia. They usually occur in occupations that involve vibrating tools and those people who hammer objects with their hypothenar eminence, hence its name. Most cases that occur in the sporting arena occur in baseball and are the result of repetitive blunt trauma. In the presenting case, the proposed mechanism was the repetitive hitting of practise balls with a 'faulty' grip causing repeated pressure on the ulnar artery underlying the hypothenar eminence, which resulted in injury and thrombus formation.<sup>[46]</sup>

McHardy and Pollard<sup>[47]</sup> have reported of the unusual onset of wrist pain after a change in the putting grip, which resulted in the supination of the right wrist in a right-handed golfer. This grip change caused increased stress on the insertion of flexor carpi radialis and resultant pain. Manual therapy and a return to the previous grip resolved symptoms.

### 2.3 Elbow Injuries

The elbow is a common site for injury, particularly in amateur and female golfers. A possible reason suggested for this is the increased carrying angle found in females.<sup>[3]</sup> Although injury to the common flexor bundle at the medial epicondyle is commonly called 'golfers' elbow, it is the lateral epicondyle that is the site of more golf-related injuries. In a study of golf injuries, McCarroll et al.<sup>[2]</sup> found that of all elbow injuries, 85% occurred to the lateral aspect. Differences in the mechanism of injury are the likely explanation for this difference. A sudden deceleration of the club head can result in injury to the medial aspect of the elbow, while overuse is the more likely mechanism to occur at the lateral aspect of the elbow.<sup>[48]</sup> Traumatic injury usually occurs as the result of hitting an object at impact (other than the ball) during the swing. In professionals, this is mostly the result of hitting an obscured tree root/rock in the rough or trying to hit the ball out of heavy rough (for example St Andrews at the British Open). This may also occur in amateurs. In addition, a more common mechanism involves the amateur hitting the ground first when attempting to hit the ball (hitting a ball 'fat'). A possible explanation for

hitting the ball 'fat' is poor swing mechanics and with a steep downswing predisposing to hitting the ball 'fat'.

Besides the traumatic injuries, overuse injuries often result from changes in the grip of amateurs. Gripping the club too tight and having golf club grips that are slippery are also common causes. All of these factors result in changes in forces generated in the forearm musculature and are a source of potential injury.<sup>[43]</sup>

In the golf downswing, just prior to impact, there is a large increase in wrist flexor activity, the flexor burst.<sup>[49]</sup> At this point in time the right wrist is still radially deviated and extended, but moving towards neutral. This combination places a large amount of stress on the wrist and may result in an acute injury if the ground is hit or a gradual injury from excessive practise due to microscopic damage.<sup>[27]</sup> Some of these forces can be transmitted to the elbow and result in injury to the medial elbow in the right arm (trail elbow) in the right-handed golfer or to the lateral elbow in the left arm (leading) in right-handed golfers.<sup>[50]</sup>

To combat these overuse injuries, research has been conducted on the use of braces and larger sized golf grips on the forces generated in the forearm muscles. Interestingly, there was no statistical difference in forces produced between those that used the devices compared with those that did not use them.<sup>[49]</sup> Even though the elbow is a common injury site in golfers, little research has been conducted in this area. Most of the elbow injury mechanisms and management plans are based on racquet sports-related injuries.

### 2.4 Shoulder Injuries

Shoulder pain in golfers is a relatively common occurrence, accounting for approximately 8–12% of all golf injuries,<sup>[2-4]</sup> although Gosheger<sup>[1]</sup> placed this figure at 17.6%. That playing golf causes susceptibility to shoulder injuries is unusual as the sport is not an overhead sport that requires elevation of the humerus. When the humerus is in the overhead position (>90° elevation), the shoulder is susceptible to instability. Most sports with high injury rates for

the shoulder complex fall into this category, for example swimming, pitching and racquet sports.<sup>[51]</sup> However, overuse of the shoulder in the form of excessive practise can produce problems of the shoulder, including but not limited to: subacromial impingement, rotator cuff pathology, acromioclavicular dysfunction, glenohumeral instability and arthritis.<sup>[52]</sup>

The shoulder goes through a large range of motion including a large degree of left shoulder horizontal adduction and right shoulder external rotation in the backswing. In the follow-through there is a large degree of left shoulder external rotation and horizontal abduction and right shoulder horizontal adduction.<sup>[53]</sup> A study on professional golfers (<3 handicap, age range 26–63 years) with shoulder pain found that out of 35 subjects (all right handed), all but one had left shoulder pain, 53% (n = 18) reported pain in the acromioclavicular (A/C) joint and 41% (n = 14) had some A/C osteoarthritis, while 9% (n = 3) had distal osteolysis of the clavicle (this implies a compressional loading to the A/C joint in the horizontal plane).<sup>[54]</sup> Hovis et al.<sup>[55]</sup> found that in elite golfers, those with shoulder pain in the left shoulder (lead shoulder in right-handed golfers) had posterior instability (eight out of a cohort of eight) and many had signs of impingement subacromially (n = 6). They found that the pain and feeling of instability was reproduced at the top of the backswing (maximal horizontal adduction).

In a previous study, Bell et al.<sup>[56]</sup> found that the position that produced the maximum force across the A/C joint was horizontal abduction and adduction. These positions are similar to those attained by the arm at the top of the back swing (left arm horizontal adduction) and at the end of the follow-through (left arm horizontal abduction). This position is also similar to the anterior instability apprehension test (the end position). Therefore, A/C joint injury in high level golfers may be associated with anterior glenohumeral instability and repetitive loading of the A/C joint from hitting a large number of golf balls per day.

When a patient presents with shoulder pain due to the golf swing, the practitioner should ascertain at

what point in the swing produces the patient's pain. Tightness of the posterior capsule, posterior capsulitis or tightness of the rotator cuff musculature often causes posterior shoulder pain at the top of the backswing. If, however, posterior shoulder pain occurs at the end of the follow-through, impingement of either the posterior labrum or the underside of the rotator cuff muscles may be the source of the patients' pain symptoms. Anterior shoulder pain at the top of the back swing can be caused by impingement of the humeral head and anterior labrum, producing anterior joint line pain, or the pain may be localised to the AC joint indicating possible degeneration or impingement of the AC joint.<sup>[57]</sup>

Jensen and Rockwood<sup>[58]</sup> retrospectively reviewed 24 golfers who had shoulder arthroplasty and found that 23 were able to return to play, the other golfer was unable to return to golf due to osteoarthritis of the hip and knee. The 23 that returned to golf had in total 26 shoulder arthroplasties, 12 to the left and 14 to the right. All were right-handed golfers. Before surgery, 11 patients were unable to play golf, but were able to do so after the surgery. Only three patients reported mild pain during play and six reported mild pain that resolved quickly after play. In the same study, surgeons were asked to complete a survey on patients playing golf after surgery. Forty-four responded and 91% encouraged a return to play. Although this study found that arthroplasty results in golfers being able to return to golf, and useful in its findings it raises more questions than it answers. These questions include:

- Was golf the reason for the shoulder complaint?
- What was the previous sporting history of the patients and how long have they been playing golf?
- Of the 11 patients that were unable to play golf prior to surgery, how many had left shoulder pain and how many had right shoulder pain?

It is known that previous studies have shown that the left shoulder is more likely to be injured by golfers due to larger movements and stress positions, even though the game of golf is less likely to injure the shoulder compared with overhead sports

such as swimming, baseball and cricket.<sup>[51]</sup> The study could make no conclusion as to the aetiology of the shoulder complaints. A prospective long-term investigation is required to provide answers to such questions.

### 2.5 Knee Injuries

Although knee injuries are not a leading cause of golf injuries (approximately 6%),<sup>[1-4]</sup> the forces produced in the knee can be large. The right knee has its peak force at the end of the backswing when the club is moving slowly (compression 540N). The left knee has its peak force near impact and follow-through (compression 756N).<sup>[59]</sup> Add to these compressive forces, the fact many of the golfers are older and experience osteoarthritis in the hips and knees (with reduced range of motion), the issue of the effect of golf on arthritic knees needs to be evaluated. Also as many in the golfing population may have undergone total hip or knee replacements, the question of the replacement on golfing activity is of much interest.

Mallon and Callaghan<sup>[60,61]</sup> conducted surveys of both golfers who had a total knee replacement and also knee surgeons. They found that most (87%) had no pain during play and only 35% reported mild pain after play. However, pain in the left knee during play and pain after play was statistically different ( $p < 0.01$ ) to pain in the right knee. Most surgeons (94%) did not discourage golf and 90% reported not giving any particular instruction to patients, while the remainder told patients to start with short shots and also use a shorter, easier swing after the procedure. Seventy-two percent of surgeons thought golf would not affect those with a knee replacement, while two-thirds recommended the use of a cart whilst playing. The average age of the respondents was 65.4 years who played golf 3.7 times per week. Handicap increased by 1.9 strokes compared with their handicap at the time of the operation, while they lost 11m (12.2 yards) off their drives. However, the average follow-up period from the operation was 4.7 years. Whilst these figures appear to suggest falling performance following total knee arthroplasty, the fact that the operation was, on average, 4.7 years earlier and the subjects were 4.7 years older must be con-

sidered a confounding variable in measures of range of motion, power, etc. Much of the fall could be explained by aging as opposed to any consequences associated with the procedure.

Although extremely uncommon, fractures of the patellar due to golf have been reported in the literature.<sup>[62,63]</sup> A case study reported a golfer who experienced a patellar osteochondral fracture during the follow-through of a drive.<sup>[57]</sup> Internal rotation of the femur on the tibia was the proposed mechanism of injury. The patellar slides tangentially over the lateral femoral condyle with the knee in the flexed position, which may result in an osteochondral fracture of the patellar or femoral condyle.

A second case study reports a fracture of the patella following reconstruction of the anterior cruciate ligament (ACL).<sup>[58]</sup> Six months after an ACL reconstruction, the patient was told that he could increase activity. He started to hit golf balls. The patient initially tried short irons, which were okay. He then attempted to use the driver. On the first attempt, he felt a pop with immediate pain and swelling. X-ray revealed a transverse fracture of the patella.

### 3. Major Injury – Head and Eye Injuries

Although very uncommon, injuries to the head and eyes occur in golfers. A relatively large body of literature is devoted to this type of golf-related injury.<sup>[64-74]</sup> Most injuries are the result of being struck by either a stray golf ball, or getting struck by the club head of a fellow competitor during their swing.

This mechanism of injury is extremely uncommon, but has the potential to cause the greatest amount of injury. Due to the size of the ball and the speed that it can achieve, damage to the region it hits can be quite large. The same can be said for being struck by a club. Standing behind someone who unexpectedly takes a practise swing or standing too close to them during a golf swing is the most common source of this injury mechanism. This is particularly true for the younger population.

A 1991 study at a regional referral centre for children with head injuries found that, over 1 year, 11 golf-related injuries were seen (232 total head

injuries and 27 sports related).<sup>[64]</sup> All of these children were boys with nine sustaining skull fractures (seven required surgery to elevate a depressed fracture). Nine injuries were the result of being struck by a club and two by a golf ball. Interestingly, only one was sustained on the golf course and none of the 11 had adult supervision. Overall, these 11 injuries sustained accounted for 40% of all the sports-related injuries seen, 50% of all depressed skull fractures seen, 18% of all skull fractures and 4.7% of all hospital admissions. Care must be taken to reduce the chance of these incidents occurring by having an adult supervise children playing golf. This adult needs to know how the swing works so as to keep the children a safe distance from the child swinging the club and also not in front of where the ball is being aimed. Sensible supervision can possibly eliminate the majority of these injury cases.

Around the golf course, players can be hit by a stray ball. The shouting of the word 'fore' is the common way of informing golfers that a golf ball is headed in their direction. To reduce the chance of being seriously injured when this occurs, the golfer should keep in the same spot, turn their back to the call and duck down whilst covering their face and head with their hands. Many times on the golf course you see golfers responding to the call of 'fore' by turning in the direction of the call and looking up into the air. This position exposes the face, eye and head to the flight of the ball, which can cause significant damage if it strikes these areas.

Eye injuries as a result of golf can sometimes occur.<sup>[67]</sup> However, compared with sports such as racquet sports (squash in particular), football and hockey their occurrence is extremely low.<sup>[75]</sup>

As stated previously in this section, the golf ball and golf club are often travelling high speeds and are small enough to fit within the orbital rim of the skull. A 1980 case study reported a patient presenting to hospital.<sup>[66]</sup> History revealed the ball had travelled approximately 183m and struck the patient in the left eye by a golf ball. Immediate and complete visual loss occurred. X-ray revealed no fracture. After 2 months there still was no sight in the eye. A 6-year retrospective study on patient treat-

ments at the University of Michigan hospital reported nine golf-related ocular injuries.<sup>[67]</sup> Seven of these injuries were the result of being struck by a golf ball, with the other two the result of being struck by a golf club. Eight of the nine patients had a ruptured globe. Enucleation of the eye was required in six patients. Being struck by a ball accounted for four of these procedures and two resulted from club head strikes. Interestingly, if the subject was wearing glasses at the time of being struck by the golf ball, only one out of the four patients required enucleation. A further case study demonstrated a optic nerve avulsion as a result of a 10-year-old child being hit by a golf club.<sup>[68]</sup>

Head injuries as the result of falling out of a golf cart are rare occurrences but have been reported in the literature. Tung et al.<sup>[74]</sup> reports on three cases of head injuries from golf buggy falls. One case sustained a moderate head injury with a small cerebral contusion and skull fracture. Two cases sustained severe head injuries involving extensive cerebral contusions and extradural haematoma, which required craniotomy. Two of the three made good recoveries, the other remained in a vegetative state. What cannot be answered from these studies was the cause of the fall and if age was a factor in a fall from the cart, or was negligence a factor (i.e. cart drivers not following appropriate instructions for use)? Because of increased litigation, all golf buggies have handling instructions informing occupants of the risks associated with their use.

#### 4. Other Injuries

Although uncommon, other types of injuries can occur on the golf course. These include syncope of a golfer after hitting a drive and turning the head after being distracted whilst putting.<sup>[76]</sup> Treatment given to this golfer was a transvenous ventricular demand pacemaker, with the mechanism of the event being sinus arrest due to the sudden turning of the head. Golf is an 18-hole event that takes 4–5 hours to play a standard round. This is a long time to be exposed to the elements, particularly the sun in summertime. As a result, sunburn and sunstroke are a distinct possibility as is dehydration if inadequate fluids are

consumed. Skin cancer in the form of melanoma is a potential hazard of long-term exposure to the sun, a factor that may predispose the older golfer to this condition. In cold and wet conditions, hypothermia is a rare occurrence, although frostbite of the toes may occur in non-waterproofed shoes. Anecdotal evidence suggests that many golfers acquire an almost fanatical zeal to the game. This results in golfers continuing to play despite adverse environmental conditions. In poor weather, lightning strikes can occur.<sup>[77,78]</sup> Popular professional Lee Trevino was struck by lightning in 1975 playing in the Western Open at Butler National Golf Club in Chicago. The freak accident permanently damaged the flexibility and sensitivity of his lower back, but with a series of operations, he was able to recover from injuries sustained and go on to the upper echelon of golf.<sup>[79]</sup> Although uncommon, lightning strikes can cause serious injury to the cardiovascular and neurological systems.<sup>[80,81]</sup>

Golf is not considered to be a strenuous activity. Research has shown 108 beats/minute to be the mean heart rate over 18 holes in healthy middle-aged men.<sup>[82]</sup> Further studies have been conducted on the effects on hilly courses on heart rate.<sup>[83,84]</sup> They report that a peak of 70% in males and 80% in females of maximum heart rate was found on some hills. Considering that individuals in the older age groups play golf, there is seen a decrease in cardiac output with increasing age and it is often in these older groups that cardiovascular insufficiencies tend to be present, the golf course is a potential site of cardiovascular problems for golfers.<sup>[85,86]</sup>

Parkkari et al.<sup>[87]</sup> found that walking during golf was a safe form of activity in healthy sedentary middle-aged males, while study on the cardiovascular load whilst pulling a cart at golf for nine holes showed that for players without heart disease the game provided an adequate training stimulus.<sup>[88]</sup> The same study found that for those with heart disease and/or are less fit, there was a chance that they could exceed their safe activity level.<sup>[88]</sup> Conversely, Unverdorben et al.<sup>[89]</sup> found that competitive golf in cardiovascular patients reached an inten-

sity that may positively influence cardiovascular risk factors, depending on the type of the course.

As a result, studies into the cardiovascular requirements during golf have found that golf on a level course can be considered an activity that provides a level of cardiovascular exercise that is in a safe range, and has potential benefits. However, on hilly courses, the cardiovascular effort required by golf may potentially result in the exceeding of a safe level in those with cardiovascular insufficiencies.

#### 4.1 Stress Fractures

Stress fractures are the result of overuse and may occur in any area of the body that is subjected to a sudden increase in stress.<sup>[90,91]</sup> Previous studies on stress fractures reported on 169 patients with a stress fracture and found that the ribs were the third most common injury site and that golf was the fifth most common sport (out of 19) for them to occur.<sup>[92]</sup> In golf, there have been case reports of stress fractures of the ribs,<sup>[93-95]</sup> the ulnar diaphysis,<sup>[96]</sup> the tibia,<sup>[97]</sup> the sternum<sup>[98]</sup> and the hook of hamate.<sup>[37-39]</sup>

A study was conducted on beginner golfers (<1 year of golf). It reported on 11 golfers with a chief complaint of anterior, posterior or lateral chest pain. X-ray and bone scan analysis resulted in the diagnosis of rib stress fractures. All lesions were found on the posterolateral segments of the ribs, six on the right and eight on the left (three golfers had two fracture sites). Of note, those players with right-side fractures had a history of divot taking with their swings. All patients reported hitting around 400 balls per week. The forces acting on the ribs by the serratus anterior due to the retraction and protraction of the scapular during the golf swing was the proposed mechanism for stress fracture of the ribs.<sup>[93]</sup>

A case of ulnar diaphysis stress fracture was reported in a middle-aged golfer (handicap 30) who reported left wrist pain of no sudden onset. She reported playing golf everyday, and had been receiving professional tuition. There was no report of hitting the ground or casting of the club in the downswing. The mechanism of injury was thought to be supination and overuse of the flexor muscles of

the hand. The authors proposed that the injury occurred during the follow-through.<sup>[94]</sup>

Stress fractures of the tibia usually occur in the transverse plane, involve the diaphysis and occur in athletes and the military. Whilst it is uncommon to be found in golfers, a study reported the occurrence of complete distal tibia stress fractures in two professional male golfers.<sup>[95]</sup> Both stress fractures occurred in the left shin, resulting in spiral fractures of the tibia and in one case the fibula as well. Both golfers reported a history of shin pain for a few months previous to the fracture with one receiving physiotherapy treatment for shin splints. Ultrasound aggravated this pain. Both felt sharp pain while making a drive, with one hearing a loud 'crack'. X-rays revealed the fracture. Both returned to play 9–10 months after the incident. Repeated torsion of the left tibia during the follow-through in right handed golfers was the proposed injury mechanism.<sup>[95]</sup>

## 5. Conclusions

Despite the fact that golf is a low-intensity sport, it is associated with a significant number of injuries. This review of the literature shows that the three most common injury sites are the low back, the elbow and the wrist. The shoulder followed by the knee are also sites frequently injured by golfers. Although uncommon, injuries sustained to the head and eye may occur, and are often serious or catastrophic in nature. Other injuries to occur include stress fractures, cardiovascular insufficiencies and environmental issues such as lightning strikes, sunburn and skin cancer. Poor swing mechanics and overuse are frequently associated with such injury, but injuries are also sustained from hitting the ground or being hit by a golf ball or club.

Whilst there are numerous case reports on golf-related injuries in nearly every area of the body, there are a limited number of epidemiological studies on golf injuries. Much of our understanding of golf injuries relies on research conducted 10–25 years ago. During this time, advances in golf equipment may have made this research redundant as many variables that may influence injuries have changed. It is the recommendation of this review

that further research into the epidemiology of golf injuries be conducted. The authors are presently conducting a large scale, prospective study on golf injuries in Australia that is aimed to fill the gap that is in the golf injury literature.

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