Where do golf driver swings go wrong? Factors influencing driver swing consistency.

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Abstract
One of the challenging skills in golfing is the driver swing. There have been a large number of studies characterizing golf swings, yielding insightful instructions on how to swing well. As a result, achieving a sub-18 handicap is no longer the top problem for golfers. Instead, players are now most troubled by a lack of consistency during swing execution. The goal of this study was to determine how to consistently execute good golf swings. Using 3D motion capture and full-body biomechanical modeling, 22 experienced golfers were analysed. For characterizing both successful and failed swings, 19 selected parameters (13 angles, 4 time parameters, and 2 distances) were used. The results showed that 14 parameters are highly sensitive and/or prone to motor control variations. These parameters sensitized five distinct areas of swing to variation: (a) ball positioning, (b) transverse club angle, (c) transition, (d) wrist control, and (e) posture migration between takeaway and impact. Suggestions were provided for how to address these five distinct problem areas. We hope our findings on how to achieve consistency in golf swings will benefit all levels of golf pedagogy and help maintain/develop interests to involve more golf/physical activity for a healthy lifestyle.

Are anthropometric, flexibility, muscular strength, and endurance variables related to clubhead velocity in low- and high-handicap golfers?

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Abstract
The present study assessed the anthropometric profile (International Society for the Advancement of Kinanthropometry protocol), flexibility, muscular strength, and endurance of 20 male golfers. These data were collected in order to determine: a) the relationship between these kinanthropometric measures and clubhead velocity; and b) if these measures could distinguish low-handicap (LHG) and high-handicap (HHG) golfers. Ten LHG (handicap of 0.3 +/- 0.5) and 10 HHG (handicap of 20.3 +/- 2.4) performed 10 swings for maximum velocity and accuracy with their own 5-iron golf club at a wall-mounted target. LHG hit the target significantly more (115%) and
had a 12% faster clubhead velocity than HHG (p < 0.01). The LHG also had significantly (28%) greater golf swing-specific cable woodchop (GSCWC) strength (p < 0.01) and tendencies for greater (30%) bench press strength and longer (5%) upper arm and total arm (4%) length and less (24%) right hip internal rotation than HHG (0.01 < p < 0.05). GSCWC strength was significantly correlated to clubhead velocity (p < 0.01), with bench press and hack squat strength as well as upper arm and total arm length also approaching significance (0.01 < p < 0.05). Golfers with high GSCWC strength and perhaps greater bench press strength and longer arms may therefore be at a competitive advantage, as these characteristics allow the production of greater clubhead velocity and resulting ball displacement. Such results have implications for golf talent identification programs and for the prescription and monitoring of golf conditioning programs. While golf conditioning programs may have many aims, specific trunk rotation exercises need to be included if increased clubhead velocity is the goal. Muscular hypertrophy development may not need to be emphasized as it could reduce golf performance by limiting range of motion and/or increasing moment of inertia.


**Kinematic analysis of swing in pro and amateur golfers.**

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**Source**

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**Abstract**

As golf grows in popularity, golf related injuries have increased. The purpose of this study was to calculate and compare upper body kinematics of healthy male golfers from different skill levels. Kinematic data were obtained from 18 professional, 18 low handicap, 18 mid handicap and 18 high handicap golfers with an optoelectronic system at 240 frames per second. Ten displacement parameters were calculated at address, peak of back swing and ball contact. Angular velocity parameters and respective temporal data were calculated during the downswing phase. Most parameters were significantly different between the higher skilled golfers (professional, low handicap) and the least skilled golfers (high handicap). At the peak of the swing, professionals produced the largest magnitudes for left shoulder horizontal adduction (125 +/- 6 degrees ), right shoulder external rotation (66 +/- 11 degrees ), and trunk rotation (60 +/- 7 degrees ). During the downswing, the professionals produced the largest angular velocities for the club shaft (2413 +/- 442 degrees /s), right elbow extension (854 +/- 150 degrees /s), right wrist (1183 +/- 299 degrees /s) and left wrist (1085 +/- 338 degrees /s). The results of this study show that improper mechanics of golf swing existed in middle and high handicap groups. These improper mechanics may contribute to golf related injuries.
Shoulder motions during the golf swing in male amateur golfers.

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Source
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Abstract

STUDY DESIGN:
Prospective descriptive biomechanical analysis of shoulder motion in golf.

OBJECTIVE:
To characterize normal shoulder motion during the driving swing in male recreational golfers of various age groups.

BACKGROUND:
Shoulder trauma accounts for approximately 12% of all golf-related injuries. To design sport-specific rehabilitation programs for the injured golfer and exercise programs for the healthy golfer, clinicians and teachers need quantitative information describing range of motion requirements about the shoulder for the amateur player. METHOD AND MEASURE: Sixty-five male golfers were divided into 3 age groups: college, middle, and senior. A high-speed, 6-camera motion analysis system recorded 3-dimensional bilateral shoulder motion (vertical elevation, horizontal adduction, external rotation, and shoulder tum) for 3 swings of the driver. Group means for ranges and functional end points of motion were compared using a single-factor 1-way ANOVA (alpha = 0.05).

RESULTS:
All maximum values of shoulder motion were lower in the senior group than in the other 2 groups. At peak backswing, senior golfers exhibited 38 degrees less right-side shoulder external rotation than college golfers. However, from address, seniors horizontally abduct the right arm 18 degrees more than college golfers. In the older golfers, total range of motion was reduced for both shoulders in the vertical plane and for the left shoulder in the horizontal plane.

CONCLUSIONS:
This study describes shoulder motion for asymptomatic golfers of various age groups. These data may serve as a baseline reference for assessing disease- or injury-related changes in the golf swing and for designing sport-specific exercise and rehabilitation programs.
Abstract

Background

Golf is a popular past time that provides exercise with social interaction. However, as with all sports and activities, injury may occur. Many golf-related injuries occur in the upper limb, yet little research on the potential mechanisms of these injuries has been conducted.

Objective

To review the current literature on golf-related upper limb injuries and report on potential causes of injury as it relates to the golf swing.

Discussion

An overview of the golf swing is described in terms of its potential to cause the frequently noted injuries. Most injuries occur at impact when the golf club hits the ball. This paper concludes that more research into golf-related upper limb injuries is required to develop a thorough understanding of how injuries occur. Types of research include epidemiology studies, kinematic swing analysis and electromyographic studies of the upper limb during golf. By conducting such research, preventative measures maybe developed to reduce golf related injury.

Keywords: Golf, injury, shoulder, elbow, wrist, review

Introduction

Golf is a popular recreational activity that can be played by all ages, genders, and skill levels. Although seemingly uncommon, golf-related injuries do occur, with the three most common injury sites being the lower back, the elbow and the wrist. Together these three sites account for approximately 80% of all injuries sustained by golfers [1-4]. While a number of investigators have conducted research into back-related golfing injuries [5-8] and reviewed how these injuries were sustained [9,10], little research has been identified on how golfing injuries occur in the elbow and wrist [11,12]. The purpose of this paper is to review the function of the upper limb during the golf swing. Also presented is a review of golf-related injuries of the wrist, the elbow and the shoulder as they relate to the golf swing. Finally, there is a discussion on avenues for potential research to understand golf-related upper limb injuries.
Methods
A search of the literature was conducted in the following databases: Medline, Cinahl and Mantis (1966 to present, 1982 to present and 1980 to present respectively). A search of the terms: golf and injury and shoulder or elbow or wrist revealed 45 papers. After setting criteria that required blinded peer-reviewed English language journals only, 42 papers were eventually selected. The literature was collated and sorted according to injury site and relevance. The reference lists of selected papers were examined to determine if any reference papers not found in the original search were relevant. The authors conducted an assessment of methodology and shortcomings of studies, with the findings presented in the discussion section.

The golf swing
The golf swing is a dynamic movement with the potential to cause injury to the golfer. Various injuries occur in different sections of the swing and frequently involve soft tissue injuries [1-4]. An understanding of the mechanics of the golf swing will facilitate appropriate knowledge of the etiology of the injury, thereby improving management. This is particularly true of upper limb golf-related injuries as the arms go through a large range of motion (ROM) during the swing, while providing the link between the fast moving club and the power-generating torso.

The golf swing can be defined as the process of swinging the club to hit the ball. Other than the address position (Figure 1A) it can be divided into seven parts: early backswing (Figure 1B), late backswing (Figure 1C), top of swing (Figure 1D), downswing (Figure 1E), acceleration (Figure 1F), early follow-through (Figure 1G), and late follow-through (Figure 1H).

![Figure 1](image)
A-H. Phases of the golf swing. A. Address position, B. Early backswing, C. Late
backswing, D. Top of swing, E. Downswing, F. Acceleration, G. Early follow-through, H. Late follow-through.

The golf swing is also often divided into 5 phases: the backswing, the downswing, acceleration, early follow-through and late follow-through [9,13]. In the right-handed golfer, the backswing results in the club being moved away from the direction of intended ball flight and is characterised by a rotation of the shoulder girdle to the right. There is resulting right arm abduction, flexion and external rotation with corresponding left arm adduction, flexion and internal rotation. This takes the golf club in the desired direction. To achieve this movement, the right scapula retracts, while the left scapula protracts and this allows their movement around the trunk in a clockwise movement. The muscles that are predominantly active in this phase and produce these movements are upper and middle trapezius on the right, and the subscapularis and serratus anterior on the left [14-18].

At the top of the backswing, the wrists are in radial deviation, with the right wrist also displaying submaximal extension (Figure 1D). The downswing phase starts from the top of the backswing and involves the club returning along a similar path to the backswing in preparation to hit the ball, and it involves rapid arm movement. The combined movement of left rotation of the shoulder girdle and scapular rotation, in an anti-clockwise direction around the trunk, is required during the downswing, resulting in increased activity in the left medial scapulae stabilisers/ retractors. To achieve right-sided internal shoulder rotation and flexion, the pectoralis major is very active, while the right upper serratus anterior contracts to assist scapular protraction [14-18].

As seen in Figure 1F, the wrists remain in a similar position to the top of the backswing, a position that is termed 'cocked'.

The acceleration phase of the golf swing is the continuation of the downswing to ball impact. The club head is accelerated to its peak velocity in this phase just prior to contact with the ball, making this the most active phase of the entire golf swing. Bilaterally, the pectoralis muscles are the most active muscles, being the major movers of the shoulder girdle. There is continuation of the right side activity seen during the early downswing, while the left pectoralis appears to maintain an eccentric contraction to control the left arm abduction and external rotation. The muscles involved in scapular movement are also active: the upper serratus on the right to protract the scapula and the levator scapulae on the left side to aid scapular tilting [14-18]. Just prior to impact there is a large increase in wrist flexor muscle activation; what has been termed the ‘flexor burst’ [11,19,20]. Part of this activity is to return the wrists back (thus club head back) to a position to hit the ball, the 'uncocking' of the wrists.

The early follow-through of the golf swing occurs after ball impact and is the phase where deceleration of trunk rotation occurs. There is a 'rolling' of the forearms at impact that is continued into the early follow-through. This results in left arm supination and right arm pronation followed by left arm external rotation and right
arm internal rotation. Bilaterally, the pectoralis major muscles continue to be very active. The active muscles in the shoulder during this phase are the right subscapularis and the left infraspinatus to control the movement seen in the follow-through [14-18].

In the late follow-through, the muscle activity decreases as the golfer nears the end of the swing. The most active muscles in this phase are similar to the early follow-through, but with a lesser degree of activity. The only exception in the upper body is the right serratus anterior, which is more active in this phase as it aids in the protraction of the scapular around the trunk [14-18].

Wrist/Hand injuries

The wrist is one of the most common sites of injury in golfers [3,4]. The wrist accounts for 13–20% of all injuries in amateurs and 20–27% of all injuries in professionals in golf injury epidemiology studies [1-4]. During the golf swing, the wrist is the anchor point between the club and the body. This results in the wrist displaying a large range of motion [19,20]. Wrist injuries commonly occur at the impact point of the golf swing and may result from hitting an object other than the ball. The injury is the result of the sudden change in load applied to the club, and subsequently the golfer, resulting in tissue disruption to the hands and wrist. This commonly occurs in amateurs due to hitting the ball 'fat' (i.e., hitting the ground before the ball). Professionals also sustain wrist injuries but these injuries usually occur in slightly different circumstances. The professional (or amateur) may hit an obscured rock whilst playing from 'the rough' (longer grass that borders the shorter grass of the fairway, the central area that is preferable to hit from). In many major tournaments, particularly "links" courses commonly seen in the United Kingdom, the rough tends to be thick. Whilst attempting to extricate the ball, the long strands of grass tend to wrap themselves around the hosel (that part of the club that joins the shaft to the club head) and shaft of the club. This results in a similar deceleration of the club head during the downswing as hitting the ground, which lends itself to injury. Injury may be either acute where enough force is produced to cause excessive soft tissue elongation in a single swing, or by way of repetitive microtrauma if repeated many times in a short timeframe. Injuries of this nature tend to occur at the hand and wrist but can also occur at the elbow. Muscular strains (particularly the flexor carpi ulnaris [FCU]) and ligamentous strains are common [21,22], but fractures of the hook of hamate may also occur due to this mechanism [23].

Overuse injuries to the wrist are also common and are due mainly to repetitive wrist movement during practice or from alteration to the swing that results in stress to unaccustomed areas. According to a study of the Spain National Insurance Scheme for sportsmen, 10% of golf injuries occur in the wrist. This is contrary to the statistics produced in golf epidemiology studies. A reason for this difference could be differing definitions of what an injury is in each study. The Spanish study found that overuse or sudden changes in swing were the common injury mechanisms, and the FCU was the most common site of injury [21].

Tendonopathy, or more specifically tendonosis has replaced tendonitis as the clinical descriptor of the overuse syndrome [24,25]. The primary reason for this change is
due to the majority of overuse tendonopathies displaying collagen degeneration and fibre disorientation. However they do not display the presence of inflammatory cells [24], hence the "itis" is inaccurate. The injury mechanism is either a sudden increase in the volume of practice or alteration of the grip (causing increased loading on an unaccustomed part of the wrist), and then subsequent practice [26]. Onset of the pain is gradual. It tends to have a persistent nature until any aggravating factor(s) are modified or adequate repair (healing) time elapses [24-26].

The FCU of the right wrist in right-handed golfers is vulnerable to injury from microtrauma due to the large forces produced by the swing just prior to impact. This is particularly true when golfers take divots (hit the ground) [26]. As the club hits the ground, a sudden resistance occurs that loads the flexor tendon. If the forces are great enough microtrauma can occur, which combined with repetition through practice may lead to injury. Injury to the FCU results in pain at the proximal border of the trapezium and is increased with wrist flexion.

In the presence of a faulty swing style, the beginner is also susceptible to extensor carpi ulnaris (ECU) injury [26]. Commonly, the beginner 'casts' the club in the early downswing (the early uncocking of the wrist during the downswing and a source of lost power and control), which loads the ECU [26]. Beginners are often overenthusiastic in their practice in an endeavour to improve their game. This may result in repetitive loading, microtrauma, and injury to the ECU. A sign of ECU injury includes ulnar wrist pain with tenderness of the dorsal base of the ulnar styloid where the ECU runs through the sixth dorsal compartment. There is often pain on resisted supination and on ulnar deviation in this instance.

An uncommon injury seen in golfers is a fracture to the hook of hamate. Hamate fractures may be acute in nature due to the impingement of the hamate between the hand and the butt end of the club, leading to a fracture in the leading hand (the left hamate in a right-handed golfer) [23]. The literature records acute hamate fractures in golfers as early as 1972 [23]. Stress fractures of the hamate may also occur due to a sudden change in grip positioning or strength with accompanying excessive practice [27]. The ulnar border of the wrist is the site of pain for hamate fractures, with hamate tenderness and positive percussion being an indication for imaging. Care must be taken, however, as x-rays may initially not reveal the fracture [28]. Bone scans or MR imaging will show the fracture.

Other unusual golf-related injuries to the wrist and surrounding structures have also been reported in the literature. These include a case of an amateur golfer with a compression neuropathy of the median nerve in the right palm due to mechanical compression of the median nerve in the right palm by the head of the first metacarpal bone of the left hand [29]. Extensor carpi ulnaris (ECU) tendon dislocation over the ulnar dorsal ridge of the ulnar head aggravated by excessive practice has also been reported [30]. This case was resolved by extensor retinaculum release and partial ulnar head resection after conservative therapy failed. The unusual "hypothenar hammer syndrome" has also been reported in a golfer due to the repetitive hitting of practice balls with a 'faulty' grip causing repeated pressure on the ulnar artery underlying the hypothenar eminence. This practice resulted in
thrombus formation in the ulnar artery [31]. While unusual, putting grip alterations have resulted in pain to the volar radial wrist due to a flexor carpi radialis strain. It was reported that this was accentuated by palpation and that a return to the original grip with manual therapy resolved the condition [32].

**Elbow injuries**

Elbow injuries are common in golfers, especially in amateurs and particularly in females. This is thought to be due to the increased carrying angle seen in the female population [3]. Elbow injuries account for 25–33% of all injuries in amateurs and 7–10% of all injuries in professionals. Ironically, lateral elbow injuries are more common, at a rate of 5:1 when compared to medial elbow injuries (including the so-called Golfer’s elbow) [2].

Medial elbow injuries are thought to result from traction-based insults to the elbow, usually to the trailing arm (right elbow in the right-handed golfer). It is the wrist/hand flexors and forearm pronators that are injured at their insertion into the medial epicondyle. These injuries are usually of a traumatic nature and occur at the time of impact. The mechanism is a sudden deceleration of the club head, leading to an increased loading of the medial elbow. This can be due to hitting obscured rocks and tree roots, and in professionals trying to hit repeatedly out of long and thick rough. With amateurs, the hitting of a ‘fat’ shot is the more likely mechanism. Signs of medial epicondylitis (Golfer’s elbow) include pain and tenderness to palpation of the medial epicondyle. Pain is often aggravated by resisted forearm flexion and forearm pronation. There may be trigger point referral along the radial border of the forearm into the dorsum of the hand.

Injury of the lateral aspect of the elbow, the insertion of the wrist/hand extensors into the lateral epicondyle, is more likely to be due to overuse [33]. Gripping the club too tightly during the swing (causing associated extensor eccentric contraction) or changes to the grip with subsequent practice (often fatigue-based) may result in changes in forearm musculature forces and are potentially a source of lateral epicondylitis. Signs of lateral epicondylitis include pain and tenderness to palpation of the lateral epicondyle. Pain is often aggravated by resisted forearm extension and on occasions gripping objects or shaking hands. There may be trigger point referral along the ulnar border of the forearm into the palmar aspect of the hand.

Excessive practice may also result in injury to the lateral elbow. The large increase in flexor activity just prior to impact, the ‘flexor burst’ [11] accompanied by the rapid wrist movement at the same time places a large stress on the elbow joint and may result in injury due to accumulating microscopic damage [34].

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. Research focusing on the mechanics of the elbow and related musculature would allow for the accurate aetiology of golf-related elbow injuries to be determined. Understanding how these injuries occur in golfers would ensure the development of appropriate management strategies targeting golf specific injury mechanisms.
Shoulder injuries

Shoulder pain in golfers is a relatively common occurrence compared to other sites of the body, accounting for approximately 8–18% of all golf injuries [1-4].

The shoulder goes through a large ROM during the golf swing 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 [35]. Consequently, excessive practice can produce problems of the shoulder due to overuse.

Injuries to the shoulder in golfers are mainly restricted to the lead shoulder, the left shoulder in right-handed golfers. Studies have found that shoulder pain may be localised to the acromioclavicular (AC) joint, with the potential for either osteoarthritis or distal clavicle osteolysis (which implies horizontal plane compression loading of the joint) [36]. A second study found that posterior instability and subacromial impingement were common findings in golfers with shoulder pain [37]. This pain and instability were reproduced at the top of the backswing (maximal horizontal adduction) [37]. Previously, Bell found that maximal forces about the AC joint occurred in horizontal abduction and adduction. Similar positions are 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), which emphasizes the potential for injury to the AC joint by excessive practice of the golf swing [38].

The practitioner should ascertain the phase of the golf swing that produces the patients shoulder pain; this may facilitate the diagnosis [39]. Posterior shoulder pain in the left shoulder of a right-handed golfer at the top of the backswing should alert the clinician to tightness of the rotator cuff musculature, tightness of the posterior capsule, or posterior capsulitis [39]. Anterior joint line pain at the top of the backswing implies impingement of the humeral head and anterior labrum, while pain localised to the AC joint indicates possible degeneration or impingement of the AC joint [39].

The follow-through phase of the swing may produce posterior shoulder pain due to impingement of either the posterior labrum or the underside of the rotator cuff muscles [39]. Shoulder pain that is generalised and occurs throughout the swing may be due to scapular lag, which alters the mechanics of the shoulder during the swing [39].

A study of golfers who underwent shoulder arthroplasty and were able to return to golf, found that the right shoulder was operated on more frequently (14 out of 26). However, this study made no mention of the cause of the patients shoulder pain. The study also asked a group of surgeons about their opinion of the patient returning to golf after arthroplasty. Out of 44 respondents, 91% encouraged a return to play. This survey showed that shoulder arthroplasty does not necessarily prohibit a return to golf [40].
It is noteworthy that a lack of trunk rotation may require the much smaller shoulder rotators to become excessively active to maintain the momentum of the golf swing. Such a scenario would likely result in the shoulder dysfunction frequently noted in golfers, particularly instability in professionals. It is also worthy to note that those with back problems may potentially induce a shoulder problem in their attempt to reduce the loads on a painful back. Baulbian noted similar observations in his research on a modified golf swing where the back swing is shortened. This research reported that the forces generated in the lower back were reduced by this swing, but the forces generated in the shoulder were greater [41]. This results in the potential for this swing to produce shoulder injury that maybe the result of impingement, instability or rotator cuff tendonopathy. Pain location and shoulder orthopaedic testing helps to differentiate between each clinical entity, though MRI is required to provide a definitive diagnosis.

Discussion
On examining the literature on golf injuries to the upper limb, it is apparent that the majority of papers are case report-based. A case study reports on an individual patient's outcomes and as a result there are inherent limitations such as a lack of control and an inability to generalize findings to the whole population. This type of study, however, provides a platform for the establishment of a testable hypothesis to be made with further research [42]. The studies on golf injury epidemiology allow for a comparison of injury frequency to specific injury sites and also between different groups of golfers (based on gender, skill and age). Most of these studies are retrospective in nature. These types of studies allows for a great deal of data to be gathered, but are susceptible to recall bias. Recall bias occurs when what is thought to have occurred in the past is different to what truly occurred. The use of prospective studies would dramatically reduce recall bias.

How the data are collected influences the accuracy of the data set. Response rates influence how well the results collected can be extrapolated to the population in question. The higher the response rate, the more likely the data are applicable to the whole population in question. Response rates were generally poor ranging from 20.6% to 43%. However, if the sample size is large enough, such data may still be helpful when comparing sites and rates of injury.

An anonymous survey sent in the mail is more likely to be accurate, when compared to a personal interview, particularly with sensitive questions. The majority of the epidemiology studies cited use an anonymous mailed survey that was sent to a group of golfers.

It is apparent that little direct research has been conducted into golf-related upper limb injuries. Much of what if known about injuries relating to the upper limb comes from studies of racquet sports, particularly tennis. While a number of studies have analysed muscle activity in the shoulder musculature during the golf swing, the studies analysed the swing of professional/elite golfers. In many cases, this data may not be applicable to the 'average' golfer (e.g. handicap of 18) due to a difference in the golf swing. To overcome this, research on the swing of the 'average' golfer concentrating on what occurs at the shoulder is needed. This type of study should
also look at different swing types: the modern swing, the classic swing and the more recent hybrid swing. Many injuries in golf relate to the wrist and elbow and occur at impact during the golf swing. Research into the forces that occur in the 'perfect' swing and also what occurs in different types of swings/incidents such as miss hits and hitting the ground could provide information on why such injuries occur. Data collected in the research mentioned above may inform injury management (including conditioning / rehabilitation programs) and also potentially prevent upper limb injuries during golf.

**Conclusion**
The golf swing is a complex body movement involving a large ROM of the upper limb that acts as a link between the golf club and the body. Injuries to the upper limb account for the majority of golf-related injuries recorded. Many injuries occur as the club impacts the ball and are muscle-related. An understanding of how the body moves and the muscle activity achieved during the golf swing helps the health practitioner to understand why these injuries occur. Further study into the different types of golf swing and the different skill levels of golfers is required to fully understand the upper limb function in the golf swing. Such understanding may enable the development of management and prevention programs to reduce the upper limb injuries caused by golf.

**Authors' contributions**
AJM: Conception and design, search data, paper collection, drafting manuscript, final approval.

HPP: Conception and design, search data, critical review of manuscript, final approval.

**References**


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Injuries and overuse syndromes in golf.


Source

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Abstract

BACKGROUND:
Although golf is becoming more popular, there is a lack of reliable epidemiologic data on golf injuries and overuse syndromes, especially regarding their severity.

OBJECTIVE:
To perform an epidemiologic study of the variety of different musculoskeletal problems in professional and amateur golfers and to find associations of age, sex, physical stature (body mass index), warm-up routine, and playing level with the occurrence of reported injuries.

STUDY DESIGN:
Retrospective cohort study.
METHODS:
We analyzed the injury data from a total of 703 golfers who were randomly selected over two golfing seasons and interviewed with the use of a six-page questionnaire.

RESULTS:
Overall, 82.6% (N = 526) of reported injuries involved overuse and 17.4% (N = 111) were single trauma events. Professional golfers were injured more often, typically in the back, wrist, and shoulder. Amateurs reported many elbow, back, and shoulder injuries. Severity of reported injuries was minor in 51.5%, moderate in 26.8%, and major in 21.7% of cases. Carrying one's bag proved to be hazardous to the lower back, shoulder, and ankle. Warm-up routines were found to have a positive effect if they were at least 10 minutes long.

CONCLUSIONS:
Overall, golf may be considered a rather benign activity, if overuse can be avoided. If not, golf can result in serious, chronic musculoskeletal problems.
Shoulder injuries in golf.

Kim DH, Millett PJ, Warner JJ, Jobe FW.

Source

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Abstract

Although often perceived as a leisurely activity, golf can be a demanding sport, which can result in injury, usually from overuse and sometimes from poor technique. The shoulder is a commonly affected site, with the lead shoulder, or the left shoulder in the right-handed golfer, particularly vulnerable to injury. A thorough understanding of the biomechanics of the golf swing is helpful in diagnosing and managing these injuries. Common shoulder problems affecting golfers include subacromial impingement, acromioclavicular arthrosis, rotator cuff tear, glenohumeral instability, and glenohumeral arthrosis. Although the majority of patients with these disorders will respond to nonsurgical treatment, including rest and a structured program of physical therapy, further benefits can be obtained with subtle modifications of the golf swing. Those golfers who fail to respond to nonsurgical management can often return to competitive play with appropriate surgical treatment.

Minimizing Injuries and Enhancing Performance in Golf Through Training Programs

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Abstract

Context:

Golf is a popular sport, particularly in older populations. Regardless of age and skill level, golfers risk injury to the back, shoulder, wrist and hand, elbow, and knee. Because of the unique compressive, shear, rotational, and lateral bending forces created in the lumbar region during the golf swing, the primary sport-related malady experienced by amateurs and professionals is low back pain. Extrinsic and intrinsic injury risk factors have been reported in the literature. A growing body of evidence supports the prescription of strength training routines to enhance performance and reduce the risk of injury.

Evidence Acquisition:

Relevant studies were reviewed on golf injuries, swing mechanics, training routines, and general training program design. The following electronic databases were used to identify research relevant to this report: MEDLINE (from 1950–November 2009), CINAHL (1982–November 2009), and SPORTDiscus (1830–November 2009).
Results:

Injuries may be associated with lack of warm-up, poor trunk flexibility and strength, faulty swing technique, and overuse.

Conclusions:

Implementing a training program that includes flexibility, strength, and power training with correction of faulty swing mechanics will help the golfer reduce the likelihood of injury and improve overall performance.

Keywords: golf, sports performance, injury prevention, swing mechanics, training program

Golf is a popular sport, particularly in older populations. It is a great low-impact opportunity for many individuals to stay active. That is not to say that golfers are not at risk for injury. Common injuries have been documented in the lower back, elbow, shoulder, and knee. These injuries have been associated with lack of warm-up, poor trunk flexibility and strength, faulty swing technique, and overuse. A growing body of evidence in the literature suggests that participating in strength training routines will not only enhance performance but reduce injury incidence.

Methods
Selection of Articles

Table 1 presents the Medical Subject Headings used in the search strategy for this review. If we identified fewer than 250 articles by a search strategy, we reviewed the study abstracts from that category to identify potentially relevant articles. We also reviewed the reference list of each selected article to identify additional relevant publications.

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<th>Table 1.</th>
<th>Search strategy by heading and number of articles.</th>
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Inclusion Criteria

The inclusion criteria were as follows: First, the report’s study design must have been a randomized controlled trial, a quasi-experimental single-case design, a nonrandomized historical cohort comparison, a case series, or a case report. Second, the report had to be published in a scientific peer-reviewed journal. Last, the training program presented had to describe one of the following exercise components: warm-up, stretching (static or dynamic), flexibility training, strength training, or power training.
Exclusion Criteria

Articles that were not published in a peer-reviewed scientific journal or that failed to
detail an exercise program were excluded from this study.

Swing Mechanics Overview

The majority of injuries sustained by professional golfers relate to overuse. However, the majority of injuries experienced by amateur golfers are due to faulty swing mechanics, which makes understanding the golf swing necessary when trying to reduce injuries in the amateur population. The golf swing can be divided into the setup, backswing, transition, downswing, and follow-through. Because of the large release of energy during the downswing and the deceleration of that energy during the follow-through, these phases are responsible for the majority of injuries during golf. Of course, the importance of the other phases cannot be overlooked because faulty mechanics during setup, backswing, and transition may contribute to faulty mechanics during the downswing and follow-through.

The following description of general swing mechanics is for a right-handed golfer:

The left side of the body is the lead, whereas the right side of the body is back. The setup position, also known as the address, is the starting position of the golf swing. When one is in the proper setup position, the hips and knees should be slightly flexed, and the arms should hang loosely. The hips, feet, and shoulders should be aligned with the target. The feet should be situated so that the ball is generally closer to the left foot, although this somewhat depends on club length—given that the longer clubs, such as the driver, require the ball to be closer to the left foot than do shorter clubs, such as wedges. The left shoulder should be slightly higher than the right at the setup position.

The backswing begins with the takeaway. During this phase, the arms and shoulders work together as a triangular pendulum to begin taking the clubhead away from the ball. As the clubhead rises, the golfer continues to rotate the knees, hips, and spine, shifting weight toward the right foot. The top of the swing is known as the transition phase (Figure 1). At this point, the lower body begins the downswing while the upper body and club continue rotating away from the ball, which builds potential energy into the biomechanical system to be released during the downswing. By the time the upper body and club begin the downswing, the pelvis has already progressed to a 45° position.

Figure 1.
Transition phase of the golf
Weight is shifted from the right foot to the left foot as the downswing progresses. The potential energy stored during the transition phase is released from the ground up, culminating in the clubhead. This sequential release of energy is what gives the most power at the point of impact. After impact with the ball, the body decelerates segmentally into the follow-through (Figure 2). During this phase, the hips extend while the spine and shoulders rotate past the original ball position. For PGA Tour players, the average total swing time is 1.21 ± 0.14 seconds.

Follow-through phase of the golf swing. Analysis of muscle activity during the golf swing reveals heightened activity of the scapular stabilizers, erector spinae, abdominal obliques, and hamstrings during the backswing. The scapular stabilizers, pectoralis major, gluteus maximus, gluteus medius, vastus lateralis, biceps femoris, adductor magnus, and abdominal obliques are the most active muscles during the downswing into impact. During follow-through, the vastus lateralis, gluteus medius, abdominal obliques, adductor magnus, rotator cuff, and hamstrings all play a major role.

Designing a Training Program for Golf

Many studies have examined factors that may contribute to injuries in golf. Gosheger et al found that simple modifications reduce the incidence of injuries, such as using a bag cart and performing a 10-minute warm-up before game play. Other studies have identified that increased hip flexibility can be helpful as well. Additional factors that increase the risk of sustaining a sports-related injury include decreased static trunk strength, delay in trunk muscle recruitment, and limited trunk endurance.

A growing body of evidence has demonstrated that strength training programs specifically affect performance in golf. Fradkin et al found that a warm-up of windmills, trunk twists, static stretching, and air swings with a club for 7 weeks increased the golfers’ clubhead speed by 24% when compared with that of the control group. Thompson et al focused on engaging older golfers (ie, in their 60s and 70s) in an 8-week progressive functional training program that included flexibility, core stability, balance, and basic resistance exercises. This group showed a significant increase in clubhead speed and Senior Fitness Test scores. Lephart et al conducted an 8-week strength training program for middle-aged golfers. Those who participated in this golf-specific exercise routine (including trunk...
rotations, side bending, and resisted swings) 3 to 4 times per week demonstrated significant improvements in clubhead speed, ball speed, carry distance, and total distance. Fletcher et al. found that the use of free-weights and plyometrics may be more effective than machine weights in regard to clubhead speed and driving distance. Finally, the study by Doan et al. found significant improvements in National Collegiate Athletic Association Division I golfers not only in clubhead speed but in putting distance control with an 11-week training program that included many classic weight-lifting exercises.

Summary of studies of golf-specific training programs. These studies provide initial evidence supporting the prescription of strength training programs for preventing injuries and enhancing performance in golfers. This population may respond well to intervention because golfers are unlikely to perform even a simple warm-up. The approach that we are suggesting follows 4 specific elements: flexibility, strength, power, and swing mechanics. Golf is time consuming and so its not common that people have time to play and do exercises as well, so it could be that these groups improve because they're doing something rather than specifically what they are doing. Check whether blind controls in research, doing something is probably better than nodding nothing.

In the design of individual workouts, the order of the exercises should be considered (Table 3). Each should start with a dynamic warm-up, then power exercises, followed by routines that use multiple joints and large muscles (ie, squats and bench press). As the athlete begins to fatigue, they should focus on transitioning from multijoint exercises to single-joint exercises, isolating the smaller muscles, such as the rotator cuff. The workout should conclude with static stretching.

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<td>Flexibility</td>
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<td>For golfers, a lack of flexibility in the hip flexors and limitations of internal rotation correlate with injuries to the low back. Golfer should therefore perform daily stretching of the hip flexors and internal rotation of the hip (Figures 3 and 4).</td>
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They may also find it useful to stretch for trunk rotation and basic overall shoulder flexibility as well, given that these areas are also integral to the swing. Stretching should be performed for 1 set of 30 seconds at least once a day. Because static stretching during warm-up can be detrimental to performance, we recommend dynamic stretching before an event, such as trunk twists and walking knee to chest.

Strength
Although golf is known as a game dominated by technique, many studies have shown that strength training may be helpful in not only preventing injuries but also having a great effect on performance. Nearly all major muscle groups are highly active during the golf swing; thus, it is best to first build overall strength capacity before initiating functional training. A basic routine addressing all major muscle groups should provide the foundation for the program. For the legs, this includes a combination of front squats (Figure 5) and dead lifts. It also includes variations of the bench press and rows for the upper body while setting aside time for the all-important scapular stabilizers and rotator cuff (Statue of Liberty exercise, Figure 6). A flexible bar overhead is oscillated for 30 seconds while holding the arm statically against a resistance band or tubing. Because muscular endurance capacity is a major factor in golf, all exercises should be performed in the 15-repetition range, focusing on maintenance of form over any other variable.
Statue of Liberty rotator cuff exercise. Although core strengthening is part of the above-mentioned activities, the higher demand on the trunk during the golf swing justifies specific core stability exercises, such as planks (Figure 7) and rotations. The ability to hold the plank position for 60 seconds is ideal for the amateur golfer.

Prone plank.

Power

Regarding movement analysis, the golf swing can be described as a power movement. Total swing time is 1.21 ± 0.14 seconds for PGA Tour players. Power should be a major component of any golf training program. A delay in muscle recruitment is common in golfers with low back pain. Power exercises are quick movements for short durations against resistance. Although sport-specific trunk plyometrics have been effective for golfers, Olympic lifts may be useful. The power snatch, power clean, and push jerk not only encourage explosiveness but may enhance coordination and control throughout the body. Power lifts are often added progressively as simpler free-weight exercises are mastered. The push jerk (Figure 8) is taught first, followed by the clean, because the former should be more intuitive to most athletes. For advanced or elite golfers, the power required for the snatch may be a competitive advantage.

Swing Mechanics

Understanding swing mechanics is a fundamental component of training golfers. A short conversation with any teaching professional reveals that most success in golf comes from hitting the ball well. A golfer who hits the ball well will always outdrive a golfer who simply hits it hard. As a result of participating in a strength training
program, the golfer will be able to swing the club harder while still maintaining control.

**Conclusion**

When working with golfers of all levels, from older recreational athletes to high level professionals, the sports medicine professional can provide useful insight. Through an understanding of basic swing mechanics, incidence of injuries, and human physiology, an ideal training program can be designed to enhance the game for any golfer. This training program can also be used as a rehabilitation guide for returning golfers to sport.

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**Footnotes**

§References 4, 8, 10, 11, 13, 17, 21, 23, 34.

No potential conflict of interest declared.

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**Go to:**

**References**


Source
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Abstract
BACKGROUND CONTEXT:
The golf swing imparts significant stress on the lumbar spine. Not surprisingly, low back pain (LBP) is one of the most common musculoskeletal complaints among golfers.

PURPOSE:
This article provides a review of lumbar spine forces during the golf swing and other research available on swing biomechanics and muscle activity during trunk rotation.

STUDY DESIGN:
The role of "modern" and "classic" swing styles in golf-associated LBP, as well as LBP causation theories, treatment, and prevention strategies, are reviewed.

METHODS:
A PubMed literature search was performed using various permutations of the following keywords: lumbar, spine, low, back, therapy, pain, prevention, injuries, golf, swing, trunk, rotation, and biomechanics. Articles were screened and selected for relevance to injuries in golf, swing mechanics, and biomechanics of the trunk and lumbar spine. Articles addressing treatment of LBP with discussions on trunk rotation or golf were also selected. Primary references were included from the initial selection of articles where appropriate. General web searches were performed to identify articles for background information on the sport of golf and postsurgical return to play.

RESULTS:
Prospective, randomized studies have shown that focus on the transversus abdominus (TA) and multifidi (MF) muscles is a necessary part of physical therapy for
LBP. Some studies also suggest that the coaching of a "classic" golf swing and increasing trunk flexibility may provide additional benefit.

**CONCLUSIONS:**
There is a notable lack of studies separating the effects of swing modification from physical rehabilitation, and controlled trials are necessary to identify the true effectiveness of specific swing modifications for reducing LBP in golf. Although the establishment of a commonly used regimen to address all golf-associated LBP would be ideal, it may be more practical to apply basic principles mentioned in this article to the tailoring of a unique regimen for the patient. Guidelines for returning to golf after spine surgery are also discussed.

PMCID: PMC3546185  
Asymmetry of the Isokinetic Trunk Rotation Strength of Korean Male Professional Golf Players  
Jung Hyun Bae, M.D., Don-Kyu Kim, M.D., Ph.D., Kyung Mook Seo, M.D., Ph.D., Si Hyun Kang, M.D., and Junah Hwang, M.D.

**Abstract**

**Objective**
To determine whether there is side to side difference of the trunk rotation muscle in Korean male professional golf players. Healthy controls who did not play golf were also evaluated and compared with professional golf players.

**Method**
Fifty-one professional golf players and 50 healthy controls participated in this study. Bilateral isokinetic trunk rotation strength that represented the aiming side and non-aiming side trunk rotator function in a golf swing and other parameters were evaluated using the Biodex System III Isokinetic Dynamometer at angular velocities of 30, 60, and 120 degree per second.

**Results**
The professional golf players' peak torque and total work on their aiming sides were significantly higher than on their non-aiming side at all angular velocities. Additionally, the golf players' peak torque on their aiming side was significantly higher than those of the healthy controls only at the 60 degree per second angular velocity, but there was a slight and consistent trend in the others. Finally, the difference between the aiming side and the non-aiming side of the professional golf players and the healthy controls was also significant.

**Conclusion**
The aiming side rotation strength of the male professional golf players was higher than that of non-aiming side. The controls showed no side-to-side differences. This
finding is attributed to the repetitive training and practice of professional golf players. A further study is needed to investigate if the strengthening of the trunk rotation muscle, especially on the aiming side, could improve golf performance.

**Keywords:** Golf, Muscle strength, Torso, Rotation

**INTRODUCTION**

The golf swing has five phases: the set-up, backswing, the moment when the club is taken away behind the shoulder; downswing, the motion of swinging a club from the top of the swing to the point of impact; impact, the moment when the club strikes the ball; and follow-through that occurs after the ball has been hit. The direction of the direction of the last swing is called the aiming side.1

To develop acceleration of the golf club in the downswing phase, the weight of the lower body must be shifted, and pectoralis major, latissimus dorsi, and rotator cuff must be activated and the trunk rotation, external oblique of the aiming side, and internal oblique and latissimus dorsi of the non-aiming side are mainly associated. For stabilization of the trunk, the erector spinae, quadratus lumborum, and rectus abdominis are involved.2-4

During the golf swing, the lumbar spine and its surrounding structures are exposed to lateral bending forces that are generated when the trunk is bent laterally from an upright position, anterior-posterior shearing forces that exert in the anteroposterior direction, compressive forces that press down discs caudally, and torsion that is developed as a result of twisting of the vertebral segments about the spine.1 The compressive forces are almost eight times the body weight during the swing, and the torsion is directly associated with the development of low back pain.5

The forces generated by the golf swings of both the professionals and the amateurs influence the muscles, ligaments, discs, and joints of the lumbar spine. Professional golfers practice constantly and develop a consistent swing, which places a relatively slight force on the lumbar spine and its surrounding structures, but have problems because of overuse. Amateur golfers do not play as frequently and often have multiple inconsistencies in their swing, which leads to back pain as a result of poor swing mechanics. In addition, recent golf trends tend to focus more on power and driving distance, moving from the classic golf swing that accompanies hip and shoulder rotation, such as that of Bobby Jones or Walter Hagen, to the modern golf swing that emphasizes a large shoulder turn with a restricted hip turn. The modern golf swing places larger forces on the spine and its surrounding structures than the classic golf swing, and causes more significant golf-associated low back pain and injuries.5

Professional golfers practice their golf swings repeatedly to improve their golf performance spending 8-10 hours practicing since they were aspiring golfers. This is presumed to result in the asymmetry of the development and functional application of the lateral trunk muscles of the aiming side. As no objective and credible studies have been conducted on Korean professional golfers, to validate the hypothesis that the trunk rotation strength of the aiming side of Korean male professional golf players is superior to healthy controls and another hypothesis that their trunk rotation strength differs from that of healthy controls, the authors assessed the
trunk rotation strength of professional golfers who have practiced repeated golf swings for a long period to compare their trunk rotator functions on their aiming and non-aiming sides, and compared these to those of healthy controls.

MATERIALS AND METHODS

Subjects

Fifty-one Korean male professional golf players and 50 healthy individuals who did not play golf participated in this study. None of them had experienced low back pain and injury in the past year. The mean age, golf career, height, and body weight of the professional golfers were 22.31±4.25 years, 9.12±2.92 years, 176.50±5.26 cm, and 74.67±7.89 kg, respectively, and the mean age, height, and body weight of the healthy controls were 21.13±3.07 years, 175.40±5.66 cm, and 69.75±7.91 kg, respectively. Among the 51 professionals, 50 players were right-handed and one player was left-handed. Among the 50 healthy controls, 49 were right-handed and one was left-handed.

The informed consent of the subjects to participate in the following procedure was obtained, and ethical approval was granted by the Chung-Ang University College of Medicine Ethics Board.

Method

The bilateral isokinetic trunk rotation strength of the subjects was evaluated using the Biodex System III Isokinetic Torso Rotation Attachment (Biodex Medical Systems Inc., New York, USA). The axis of rotation of the Torso Rotation Attachment was aligned with the long axis of each subject’s spine, and the leg straps and hip pads were tightened to restrict the lower body movement (Fig. 1). When the apparatus had been properly adjusted, the subjects were given an opportunity to perform trunk rotation practice repetitions to become familiar with the desired movement. The subjects were instructed to concentrate on using most of their trunk muscles to perform the isokinetic rotation movements.

![Fig. 1](Biodex System III Torso Rotation Attachment. (A) Non-aiming side rotation (right). (B) Neutral position. (C) Aiming side rotation (left).)

In the isokinetic measurement, the angular velocity was linearly related to the peak torque. Angular velocities faster than 120 degree per second may cause problems in measurement. Though the golf swing reaches up to 200 degree per second, the angular velocities in the measurement were set within the traditional range of the peak torque of 60-120 degree per second. The angular velocity at 30 degree per second was also measured due to the characteristics of this study which is required
to assess the peak torque. The isokinetic rotations at 30, 60, and 120 degree per second were measured after the ROM limits of the aiming side and the non-aiming side trunk rotation were set at 45 degree. Five trunk rotations in both directions were performed repeatedly, and the peak torque and the total work were measured, with a five-minute rest period between the procedures.

Data analysis

The data were analyzed using PASW 18.0 for Windows PASW (IBM Inc, New York, USA).

All the professional golfers swung to the left as their aiming side whether they were left-handed or right-handed, but the aiming side of the healthy controls could not be determined because they did not play golf. Therefore, in the data analysis, left rotation was categorized as the aiming side, and right rotation was referred to as the non-aiming side. The paired-samples t test was used to compare the aiming side and non-aiming side rotations at each angular velocity, and the independent-samples t test was used to compare the differences between the professional golfers and the healthy controls with respect to both their aiming side and non-aiming side rotation. Null hypotheses of no difference were rejected if p-values were less than 0.05.

RESULTS

30 degree per second angular velocity

The peak torque of the professional golfers was 140.58±30.92 Nm in the aiming side rotation and 131.83±27.87 Nm in the non-aiming side rotation, significantly (8.75±9.76 Nm) less than in the aiming side rotation. The total work was 747.11±185.49 J in the aiming side rotation and significantly (44.63±69.74 J) less at 702.48±187.59 J in the non-aiming side rotation. No significant differences in the peak torque and the total work were found in the group of healthy controls. No significant differences in the peak torque and the total work between the aiming side and non-aiming side rotations were found among the professional golfers and the healthy controls (Table 1).

60 degree per second angular velocity

The peak torque of the professional golfers was 127.36±26.37 Nm in the aiming side rotation and significantly (9.69±9.60 Nm) less at 117.67±25.20 Nm in the non-aiming side rotation. No significant differences were found in the peak torque and the total work between the aiming side and non-aiming side rotations among the professional golfers and the healthy controls (Table 1).
side rotation. The total work was 659.64±144.01 J in the aiming side rotation and significantly (31.54±34.84 J) less at 628.10±144.52 J in the non-aiming side rotation. The peak torque of the healthy controls was 117.21±21.66 Nm in the non-aiming side rotation and significantly (4.79±11.40 Nm) less at 112.42±24.76 Nm in the aiming side rotation. In a comparison between the professional golfers and the healthy controls, only the peak torque with respect to the aiming side rotation was significantly different. The peak torque of the professional golfers was 127.36±26.37 Nm, and of the healthy controls, significantly (14.94±25.76 Nm) less at 112.42±24.76 Nm (Table 2).

![Table 2](image)

Results of the Isokinetic Trunk Rotation Measurement at the 60 Degree per Second Angular Velocity

The peak torque of the professional golfers was 117.03±24.99 Nm in the aiming side rotation and significantly (5.99±6.99 Nm) less at 111.04±23.85 Nm in the non-aiming side rotation. The total work was 599.27±148.13 J in the aiming side rotation and significantly (53.91±36.51 J) less at 545.36±136.94 J in the non-aiming side rotation. No significant differences in the peak torque and the total work were found in the group of healthy controls. No significant differences in the peak torque and the total work between the aiming side and non-aiming side rotations were found among the professional golfers and the healthy controls (Table 3).

![Table 3](image)

Results of the Isokinetic Trunk Rotation Measurement at the 120 Degree per Second Angular Velocity

Comparison of the differences between the professional golfers and the healthy controls for both the aiming side and non-aiming side rotations

The difference in the peak torques for the aiming side and non-aiming side rotations of the professional golfers at the angular velocity of 30 degree per second was 8.75±9.76 Nm, which significantly differs from the -5.44±15.43 Nm of the healthy controls, yet no significant difference was found in the total work values. The differences in the peak torque and the total work for the aiming side and non-aiming side rotations of the professional golfers at the angular velocity of 60 degree per second were 9.69±9.60 Nm and 31.54±34.84 J, respectively, which significantly differ
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from the -4.79±11.40 Nm and 7.38±51.60 J of the healthy controls. The differences in the peak torque and the total work for the aiming side and non-aiming side rotations of the professional golfers at the angular velocity of 120 degree per second were 5.99±6.99 Nm and 53.91±36.51 J, respectively, which significantly differ from the -0.22±7.65 Nm and 13.54±45.08 J of the healthy controls (Table 4).

Table 4

Side-to-Side Differences of the Subjects in the Aiming Side Rotation and Non-aiming Side Rotation

DISCUSSION

To improve athletic performance, it is important for athletes to know the muscles involved in each movement and to practice so as to enhance their muscular functions. To make this possible, motion analysis, EMG analysis that uses surface electrodes, and an isokinetic muscular strength function test are the primary tools. This study assessed the isokinetic trunk rotation strength of Korean male professional golf players who had practiced repeated golf swings for a long period. Comparison of the difference between their aiming side and non-aiming side based on their isokinetic trunk rotation strengths revealed that the aiming side trunk rotator function of the golfers was superior to that of the non-aiming side. The same comparison in the health controls did not differ.

In a study7 in 2006 of 32 elite male golfers and 40 healthy non-golfing control subjects to investigate the same hypothesis as that in this study, no significant difference in the peak torque of the subjects in their dominant and non-dominant rotations at 90 degree per second was found, unlike in this study. Although the findings of the study in 2006 were not statistically significant, the peak torque toward the aiming side tended to be consistently higher than that toward the non-aiming side. Though tennis differs from golf, repeated trunk rotations are also performed in tennis. In a study8 of the isokinetic trunk rotation strengths of 109 elite tennis players at 60 degree per second and 120 degree per second angular velocities, female tennis players demonstrated slightly greater backhand rotation peak torques than forehand rotation peak torques, whereas no significant difference was found in the male subjects. Moreover, the statistically significant higher peak torques of the female subjects were not clinically meaningful when compared with the peak torques of the male subjects.

Most professional golf players practice golf swings along with separate exercises for muscular strength and stability, but it is common for them to keep their symmetric balance in such exercises. Moreover, as suggested in a previous study of 118 Korean professional golfers, the mean number of practices per week was 5.4 and the mean number of rounds per week was 3.8, and they reach 1,000 swings per day.9
Therefore, unlike tennis players who use both forehand and backhand strokes, the major factor that causes side-to-side differences in golf is most likely repetition of one-way swings.

Though the peak torque of the non-aiming side rotation at the angular velocity of 60 degree per second was higher than that of the aiming side rotation in the healthy controls, because the other parameters were insignificant, it is reasonable to judge that there is no difference in the trunk rotator functions in the aiming and non-aiming side rotations in the healthy controls.

The comparisons between professional golfers and healthy controls showed a significant difference in the peak torque of the aiming side rotation only at 60 degree per second. No statistically significant difference was found between the angular velocities of 30 and 120 degree per second, but the professional golfers tended to show greater peak torques than the controls. No statistically significant difference was found in the non-aiming side rotations at all the angular velocities, and the tendency indicated in the aiming side rotation was not seen. Accordingly, the left rotation of professional golfers, or their trunk rotator function on their aiming side, is presumably strengthened through repeated practice, which supports the second hypothesis and validates the differences in the trunk rotator functions of professional golfers and healthy controls.

The total work is used as a parameter of muscular endurance. A previous study\(^5\) found that the total work significantly decreased in golfers with low back pain. Yet due to limitations in the environment at the time of the measurement, not enough rotations were performed, and the total aiming side rotation work of the professional golfers was significantly higher than their total non-aiming side rotation work, requiring cautious interpretation of the results.

Professional golfers are conventionally expected to show greater muscular strength and endurance than healthy control subjects, yet there was a parameter in which the healthy control subjects showed a higher peak torque or total work than the professional golf players, though with difference was not statistically significant. Possible reasons for this are as follows. First, the healthy controls consisted of college students in their early 20s who were engaged in various sports activities. Second, because golf is characterized by intermittently performed rotary motions and instant impulses rather than steady movements for a long period, golfers might have been trained to employ instant maximal muscle strength rather than endurance. Even in a previous study of elite golf players, the measurement of the elite golfers was not always higher than that of the healthy controls.

In the assessment of the trunk rotator function, a five-minute rest period was set between the procedures. This was regarded in a previous study of professional golfers as enough time for the replenishment of the ATP and phosphocreatine stores in the muscle after short-term maximal exercise; but as suggested in the results of this study, repeated tests tended to lead to a decrease in the peak torque and the total work. Therefore, it is suggested that the interval between measurements must be further examined.
CONCLUSION

Based on the results of this study that measured the trunk rotation strength of Korean male professional golf players and compared it with that of healthy controls, both the muscular strength (peak torque) and endurance (total work) in the aiming side rotation of the professional golf players were greater than those in the non-aiming side rotation, unlike the trunk rotation strength of the healthy controls. These findings are attributed to the repetitive practice of the professional golf players and their characteristics in a real game; and based on this asymmetry, further studies are required to investigate if trainings to strengthen the trunk rotation strength on the aiming side could influence golf performance.

References


Electromyographic analysis of the scapular muscles during a golf swing.

Kao JT, Pink M, Jobe FW, Perry J.

Source

Kerlan-Jobe Orthopaedic Clinic, Centinela Hospital Medical Center, Inglewood, California.

Abstract

To describe the role of the scapular muscles in the golf swing, we studied 15 competitive male golfers. Four muscles were studied bilaterally using dynamic electromyography and cinematography. In the trailing arm, the levator scapulae
elevates while the rhomboid muscles retract the scapula during takeaway; both then stabilize the scapula through the remainder of the swing. In the leading arm, these muscles retract the scapula during forward swing and acceleration. The trapezius muscle in the trailing arm also demonstrates high activity during takeaway to aid in scapular retraction. In the leading arm, trapezius activity is high in forward swing and through the remainder of the swing to promote scapular retraction. The serratus anterior muscle activity is high in the trailing arm during forward swing and through the remainder of the swing to maximize scapular protraction. In the leading arm, the serratus anterior muscle has constant activity through all phases of the swing, which may explain the clinical scenario of muscle fatigue in high demand golfers. The golf swing and uncoiling action requires that the scapular muscles work in synchrony to maximize swing arc and clubhead speed. This study demonstrates the importance of the scapular muscles in the golf swing and the need for specific strengthening exercises.

Shoulder muscle activity and function in common shoulder rehabilitation exercises.

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Abstract
The rotator cuff performs multiple functions during shoulder exercises, including glenohumeral abduction, external rotation (ER) and internal rotation (IR). The rotator cuff also stabilizes the glenohumeral joint and controls humeral head translations. The infraspinatus and subscapularis have significant roles in scapular plane abduction (scaption), generating forces that are two to three times greater than supraspinatus force. However, the supraspinatus still remains a more effective shoulder abductor because of its more effective moment arm. Both the deltoids and rotator cuff provide significant abduction torque, with an estimated contribution up to 35-65% by the middle deltoid, 30% by the subscapularis, 25% by the supraspinatus, 10% by the infraspinatus and 2% by the anterior deltoid. During abduction, middle deltoid force has been estimated to be 434 N, followed by 323 N from the anterior deltoid, 283 N from the subscapularis, 205 N from the infraspinatus, and 117 N from the supraspinatus. These forces are generated not only to abduct the shoulder but also to stabilize the joint and neutralize the antagonistic effects of undesirable actions. Relatively high force from the rotator cuff not only helps abduct the shoulder but also neutralizes the superior directed force generated by the deltoids at lower abduction angles. Even though anterior deltoid
force is relatively high, its ability to abduct the shoulder is low due to a very small moment arm, especially at low abduction angles. The deltoids are more effective abductors at higher abduction angles while the rotator cuff muscles are more effective abductors at lower abduction angles. During maximum humeral elevation the scapula normally upwardly rotates 45-55 degrees, posterior tilts 20-40 degrees and externally rotates 15-35 degrees. The scapular muscles are important during humeral elevation because they cause these motions, especially the serratus anterior, which contributes to scapular upward rotation, posterior tilt and ER. The serratus anterior also helps stabilize the medial border and inferior angle of the scapular, preventing scapular IR (winging) and anterior tilt. If normal scapular movements are disrupted by abnormal scapular muscle firing patterns, weakness, fatigue, or injury, the shoulder complex functions less efficiency and injury risk increases. Scapula position and humeral rotation can affect injury risk during humeral elevation. Compared with scapular protraction, scapular retraction has been shown to both increase subacromial space width and enhance supraspinatus force production during humeral elevation. Moreover, scapular IR and scapular anterior tilt, both of which decrease subacromial space width and increase impingement risk, are greater when performing scaption with IR ('empty can') compared with scaption with ER ('full can'). There are several exercises in the literature that exhibit high to very high activity from the rotator cuff, deltoids and scapular muscles, such as prone horizontal abdusion at 100 degrees abduction with ER, flexion and abduction with ER, 'full can' and 'empty can', D1 and D2 diagonal pattern flexion and extension, ER and IR at 0 degrees and 90 degrees abdution, standing extension from 90-0 degrees , a variety of weight-bearing upper extremity exercises, such as the push-up, standing scapular dynamic hug, forward scapular punch, and rowing type exercises. Supraspinatus activity is similar between 'empty can' and 'full can' exercises, although the 'full can' results in less risk of subacromial impingement. Infraspinatus and subscapularis activity have generally been reported to be higher in the 'full can' compared with the 'empty can', while posterior deltoid activity has been reported to be higher in the 'empty can' than the 'full can'.

**Effect of rotator cuff muscle imbalance on forceful internal impingement and peel-back of the superior labrum: a cadaveric study.**


**Source**
Orthopaedic Biomechanics Laboratory, VA Long Beach Healthcare System, Long Beach, CA 90822, USA.

**Abstract**
**BACKGROUND:**
Throwing athletes with shoulder pain have been shown to have decreased rotator cuff muscle strength. Shoulder internal impingement and labral peel-back mechanism, as may occur during the late cocking phase of throwing motion, are thought to cause rotator cuff injury and type II superior labrum anterior and posterior lesions. Therefore, the objective of this study was to assess the effect of
rotator cuff muscle force on internal impingement and the peel-back of the superior labrum by quantifying maximum external rotation, glenohumeral contact pressure, and position of the cuff insertion relative to the glenoid.

**HYPOTHESIS:**
A change in rotator cuff muscle force will lead to increased external rotation, glenohumeral contact pressure, and overlap of the cuff insertion relative to the glenoid.

**STUDY DESIGN:**
Controlled laboratory study.

**METHODS:**
Eight fresh-frozen cadaveric shoulders were tested at the simulated late cocking position. Glenohumeral contact pressure, location of the cuff insertion relative to the glenoid, and maximum humeral external rotation angle were measured. The forces of the supraspinatus, subscapularis, and infraspinatus muscles were determined based on published clinical electromyographic data. To assess the effect of cuff muscle imbalance, each muscle force was varied. Horizontal abduction positions of 20 degrees, 30 degrees, and 40 degrees with respect to the scapular plane were tested.

**RESULTS:**
Decreased subscapularis strength resulted in a significant increase in maximum external rotation (P < .001) and increased glenohumeral contact pressure (P < .01). The cuff insertion overlapped the edge of the glenoid at 30 degrees and 40 degrees of horizontal abduction for all muscle loading conditions.

**CONCLUSION:**
Decreased subscapularis muscle strength in the position simulating the late cocking phase of throwing motion results in increased maximum external rotation and also increased glenohumeral contact pressure.

**CLINICAL RELEVANCE:**
Athletes with decreased subscapularis muscle strength, such as fatigue with repetitive throwing, may be more susceptible to rotator cuff tears and type II superior labrum anterior and posterior lesions. Subscapularis muscle strengthening exercises may be beneficial for preventing these injuries.

Electromyographic analysis of the shoulder during the golf swing.
Pink M, Jobe FW, Perry J.
Source
Biomechanics Laboratory, Centinela Hospital Medical Center, Inglewood, CA 90307.
Abstract
Golf is a popular sport throughout the world, yet there is little in the literature that discusses the mechanics of the swing. The purpose of this study is to analyze the EMG activity in eight shoulder muscles of both the right and left arms during the golf
rotator cuff function during a golf swing.

Jobe FW, Moynes DR, Antonelli DJ.

Abstract
A study of bilateral shoulder muscle activity during the golf swing was undertaken using electromyography and high-speed photography. Understanding of the muscle firing patterns could lead to injury prevention and development of appropriate training and conditioning regimens. The swings of seven adult male right-handed professional golfers without shoulder problems were examined. Indwelling electrodes were inserted into the supraspinatus, subscapularis, infraspinatus, latissimus dorsi, pectoralis major, anterior deltoid, middle deltoid, and posterior deltoid on the right side. Each subject was allowed to warm up until he felt comfortable. Films of each subject were taken at 450 frames per second. The swing was broken into four segments to which electromyographic signals were synchronized electronically. The EMG tracings were subjected to analog-to-digital conversion and a relative measure of quantity obtained. All tests were repeated on the left side for each subject. Results indicate that all portions of the deltoid were inactive on the right side throughout the swing. The deltoid was likewise inactive on the left except for a brief spurt from the anterior portion during the milliseconds immediately preceding ball contact. Of the rotator cuff muscles, on the left the supraspinatus fired at a low level throughout the swing, as did the infraspinatus. The latter had a slightly larger burst of activity immediately after ball contact. The subscapularis was more active than any other muscle throughout the swing. The cuff muscles on the right side showed as much activity overall as those on the left. In addition, the latissimus dorsi and pectoralis major seemed to provide power bilaterally, with marked activity during the acceleration phase.(ABSTRACT TRUNCATED AT 250 WORDS)

Electromyographic shoulder activity in men and women professional golfers.

Jobe FW, Perry J, Pink M.

Source
Kerlan-Jobe Orthopaedic Clinic, Centinela Hospital Medical Center, Inglewood, California 90307.

Abstract
Men and women both enjoy the game of golf. Special considerations are made for women, such as the courses on the professional tours. Thus, one can ask what
differences might exist between men and women golfers. This study compares the electromyographic firing patterns of normal shoulder musculature in men and women professional golfers. Eight shoulder muscles (pectoralis major, latissimus dorsi, supraspinatus, infraspinatus, subscapularis, anterior, middle and posterior deltoids) were studied using indwelling electromyography. A visual analysis revealed that women tended to have slightly more activity during the takeaway and forward swing phases, and the men tended to have more activity during acceleration and follow-through. However, an independent two-tailed t-test (P = 0.05) showed these differences not to be statistically significant. This finding is in keeping with injury incidence data from the LPGA Tour, PGA Tour, and Senior PGA Tour, which showed that all three tours have a similar incidence of shoulder injuries. This study does not compare the relative strength of men and women, however.

A retrospective service audit of a mobile physiotherapy unit on the PGA European Golf Tour.

Smith MF, Hillman R.
Source
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Abstract
OBJECTIVES:
A 2-year retrospective audit was conducted to evaluate injury diagnosis and treatment provision from a mobile physiotherapy unit serving the Professional Golf Association (PGA) European Tour.

DESIGN:
Across two competitive seasons (2005/06), service data was collected at 36 tournaments (18 in 2005 and 18 in 2006). Service at each tournament was from Tuesday to Sunday, and equated to 216 days in total. Each approach made to the unit throughout this time was anonymously recorded as either i) a 'contact' where an injury diagnosis and/or treatment was provided, or ii) a 'non-contact' where no service was administered and players used the on-board fitness suite.

RESULTS:
Across the audit period a total of 7430 approaches were made to the unit, equating to 206 per event or 34 per service day. From all approaches 6705 'contacts' were documented with 2328 injuries recorded. A total of 9933 separate treatments were administered equating to 276 per event or 46 per day. Non-contacts equated to 725, representing only 9.8% of all approaches. Of the 2328 reported injuries, 66.6% (1551) were back-related, with 16.6% (385) and 16.8% (392), being related to upper and lower limbs, respectively. Of the 9933 treatments, 71.3% (7087) related to massage (40.7%), manipulation (15.6%) and stretching therapies (15.0%). As an overall trend, the total number of injury diagnoses and treatments increased across the 2-year period. The number of reported injuries rose by 25.6% (2005 = 1032; 2006 = 1296), whilst treatments rose by 17.2% (2005 = 4575; 2006 = 5359).
CONCLUSIONS:
This retrospective audit provides a valuable insight into a servicing mobile physiotherapy unit on a professional sporting tour. Findings reveal the specific type and location of injuries encountered by PGA European Tour players as well as the range of treatments administered. In developing effective support services to the professional player on tour, data presented will allow for a more structured injury management system based of typical injury occurrence and treatment provision.

Post-contraction changes in human muscle spindle resting discharge and stretch sensitivity.
Ribot-Ciscar E, Tardy-Gervet MF, Vedel JP, Roll JP.
Source
Laboratoire de Neurobiologie Humaine, Université Aix-Marseille I, URA CNRS 372, France.

Abstract
The activities of human muscle spindle primary endings were recorded in the lateral peroneal nerve using the microneurographic method. The aim of the study was to test whether voluntary isometric contraction causes any after-effects, first in the resting discharge of muscle spindle primary endings and secondly in their responses to a slow ramp stretch. To investigate the latter point, the initial angular position of the ankle was passively adjusted until the unit fell silent, in order to introduce a delay in the responses to muscle stretch. The results were as follows: (1) most of the units did not exhibit the “post-contraction sensory discharge” reported to occur in numerous animal experiments; this means that the muscle spindle resting discharge was essentially the same before and after isometric voluntary contraction. (2) Isometric voluntary contraction led to changes in muscle spindle stretch sensitivity which resulted in a reduction in the stretch threshold and a decrease in the muscle spindle dynamic sensitivity. These data suggest that the after-effects observed may have been triggered by static fusimotor neurones. The results are discussed with reference to the theory according to which the processing by the CNS of muscular proprioceptive messages deals mainly with signals arising from muscles stretched during movement, and it is concluded that the coactivation of alpha and gamma motoneurones during the contraction facilitates the coding of the parameters of forthcoming stretching movements, by the muscle spindles.

Weight-bearing hip rotation range of motion in female golfers.
Gulgin H, Armstrong C, Gribble P.

Abstract
BACKGROUND:
Many sports involve movements during which the lower extremity functions as a closed kinetic chain, requiring weight-bearing (WB) range of motion (ROM). Assessment of the capacity for internal and external rotation motion at the hip is typically performed with the individual in a prone, supine, or seated position. Such
measurements represent ROM in a non-weight bearing (NWB) position, and, as a result, may not appropriately assess the capacity of the joint to meet the demands of the athlete’s sport. To date, no research exists which documents WB hip ROM in golfers relative to the ROM demands of the golf swing or the symmetry of weight-bearing hip rotation ROM in female golfers.

**OBJECTIVES:**
Weight-bearing hip rotation ROM was measured in female golfers and compared to the actual hip rotation ROM that occurred during a full golf swing.

**METHODS:**
Fifteen right-handed, female collegiate golfers participated in the study. The WB hip rotation ROM was measured during three different stance conditions and during full golf swings using a custom-built testing device. These actions were captured using a 3-D motion analysis system.

**RESULTS:**
The golfers WB ROM was symmetrical for external rotation and internal rotation, p = 0.648 and p = 0.078, respectively. During the backswing, the golfers used approximately 20-25% of their available WB right internal rotation, and 50-75% of their available WB left external rotation. For the downswing, the golfers used approximately 34-37% of their available WB right external rotation and 84-131% of their available WB left internal rotation. The golfers used significantly more external and internal hip rotation ROM on the left (lead) hip during both phases of the full golf swing (p < 0.001), demonstrating an asymmetrical movement pattern.

**DISCUSSION:**
In general, golfers did not exceed the measured WB ROM limits during the golf swing but did demonstrate decreased WB internal rotation on the lead hip.

**CONCLUSION:**
Clinicians need to pay special attention to functional (WB) hip rotation ROM in female golfers in order to assess injury risk related to the rotational hip asymmetry present during the golf swing.


**Low back pain in professional golfers: the role of associated hip and low back range-of-motion deficits.**

Vad VB, Bhat AL, Basrai D, Gebeh A, Aspergren DD, Andrews JR.

Source
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**Abstract**
**BACKGROUND:**
Low back pain is fairly prevalent among golfers; however, its precise biomechanical mechanism is often debated.

**HYPOTHESIS:**
There is a positive correlation between decreased lead hip rotation and lumbar range of motion with a prior history of low back pain in professional golfers.
STUDY DESIGN:
A cross-sectional study.

METHODS:
Forty-two consecutive professional male golfers were categorized as group 1 (history of low back pain greater than 2 weeks affecting quality of play within past 1 year) and group 2 (no previous such history). All underwent measurements of hip and lumbar range of motion, FABERE’s distance, and finger-to-floor distance. Differences in measurements were analyzed using the Wilcoxon signed rank test.

RESULTS:
33% of golfers had previously experienced low back pain. A statistically significant correlation (P <.05) was observed between a history of low back pain with decreased lead hip internal rotation, FABERE’s distance, and lumbar extension. No statistically significant difference was noted in nonlead hip range of motion or finger-to-floor distance with history of low back pain.

CONCLUSIONS:
Range-of-motion deficits in the lead hip rotation and lumbar spine extension correlated with a history of low back pain in golfers.

influence of hip position and gender on active hip internal and external rotation.
Simoneau GG, Hoenig KJ, Lepley JE, Papanek PE.
Source
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Abstract
A general lack of descriptive details exists for measurements of hip rotation range of motion. This study was designed to establish the influence of gender and hip flexion position on active range of motion of the hip in external and internal rotation. Sixty (39 females and 21 males) healthy college-age (21.8 +/- 1.7 years) subjects were studied. Hip rotation of the dominant leg of each subject was measured in the prone (hip near 0 degree of flexion) and seated (hip near 90 degrees of flexion) positions using a standard goniometer. Data were analyzed using an analysis of variance model. Pearson's r statistics were used to determine the degree of association between measurements of hip rotation made seated vs. prone. A statistically significant difference (p < 0.05) was found between mean hip external rotation (ER) measured seated (36 +/- 7 degrees) and mean hip ER measured prone (45 +/- 10 degrees). Conversely, mean hip internal rotation (IR) measured seated (33 +/- 7 degrees) was not statistically different than mean hip IR measured prone (36 +/- 9 degrees). Females had statistically more active hip internal and external rotation than males (p < 0.05). A moderate degree of association existed between measurements of hip ER taken in the prone vs. seated position (r = 0.57, p < 0.05). For IR, the degree of association between the two measurement positions was slightly higher (r = 0.72, p < 0.05). Unlike the amount of active hip internal rotation which showed little difference between measurements made prone vs. seated, our data indicate that measurement position had a significant effect on the amount of
active range of motion of the hip in ER. These findings are clinically significant for they stress the importance of documenting measurement position. They also stress the need for representative norms to be established for each hip position and gender.