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Golf Injuries and Biomechanics of the Golf Swing

-A Review-

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ABSTRACT

I min C-uppsats i Idrottsmedicin har jag gjort en review av olika studier och artiklar som behandlar golfrelaterade skador och golfsvingens biomekanik. Det mesta av materialet har jag funnit genom MEDLINE.

Bland manliga professionella spelare på USA touren är ländryggen mest utsatt för skador. Kvinnliga proffs skadar handleden oftast följt av ländryggen. De studier som är gjorda på amatörer visar lite olika skadepanorama men armbåge, rygg och handled är de tre vanligaste skadeställena i samtliga studier. Trots att ryggen ofta är utsatt för skador i golf kunde man i en holländsk studie inte visa att golf ensam är en riskfaktor för att orsaka ryggproblem. Sammanfattningsvis kan sägas att vänster sida, eller den sida som är mot målet oftast drabbas av skador. "Overuse" är den absolut vanligaste orsaken till golfrelaterade skador.

Bland professionella spelare i USA har man funnit en skadeincidence på 81% för herrar och 88% för kvinnor, med ett snitt på 2 skador per spelare. Bland amatörer är siffran något lägre med en incidence på 60% och ett snitt på 1,28 skador per spelare. Bland de professionella kunde man inte relatera antal år på touren eller spelarens ålder till skadeincidensen. Bland amatörer kunde man se att de äldre spelarna skadade axlarna oftare än sina yngre medspelare.

Golfsvingen är en biomekaniskt komplex rörelse, utförd med hög hastighet. EMG-studier visar att musklerna runt ryggraden stabiliserar medan magmusklerna arbetar för att rotera bålen. För att utveckla mer kraft i golfsvingen bör en spelare stärka pectoralis major, latissimus dorsi och rotatorcuffen enligt en studie. Inga signifikanta skillnader i muskelaktivitet mellan professionella män och kvinnor har kunnat påvisas. Amatörer utsätter kroppen för större krafter än vad professionella spelare gör men uppnår en lägre klubbhuvudshastighet vid bollträffen.

Det bör påpekas att det finns få jämförande studier eller studier som berör samma område inom området biomekanik och golf. Det är också värt att notera att de studier som finns publicerade om skador ofta har ett stort bortfall och att det är svårt att bedöma dess vetenskapliga nivå.

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1 BACKGROUND

Golf is becoming an increasingly popular sport. From 1970-1995 the number of golf players in the world has more than doubled. This year, 1998, there are more than 400.000 golf club members in Sweden. Despite the fact that golf is not considered a strenuous sport its participants sustain injuries. The diversity of ages and abilities among golf players leads to wide spectra of injuries. However, few reports of injuries resulting from golf exist. The existing documentation consists primarily of case reports of golf related injuries.

The media´s increasing interest for professional golfers, and the fitness centres which sees many new customers among golfers, has raised the interest for golf injuries and their prevention.

1.1 History of the Golf Swing

The classic or older golf swing of the 1920´s, when the players were using hickory shafts, was characterised by a long flowing backswing, a large hip turn and a collapse of the left wrist at the top of the backswing. The finish was a relaxed, straight up and down, or "I" finish, with little physical strain. Since then, professionals have made technique changes, and the modern equipment has been improved in order to gain greater distance. The modern golf swing is physically more demanding, and puts a lot of stress to the lumbar spine. The golf swing of today is characterised by a maximum upper body wind-up against a minimal lower body rotation. The finish is a "reversed C", producing sharp rotation and hyperextension of lumbar spine (Stover et al. 1976).

2 OBJECTIVE

To review the information of the world´s knowledge of the biomechanics of the golf swing and golf related injuries. Most of the information has been found from MEDLINE or from the Swedish Golf Federation.

The questions were,

- What are the patterns of golf injuries, incidence, site of injury, age, sex, ability of play (hcp)?
- Are the injuries due to overuse or to acute traumatic causes?
- What are the biomechanics of the golf swing?
- Are there biomechanic differences dependent on sex and ability at play (hcp)?
- Which injuries can be related to the biomechanics of the golf swing, and how?

3 STATISTICS OF GOLF INJURIES

3.1 Professionals

Five hundred questionnaires were mailed to tournament professionals, of whom 226 answered. The study´s validity can be questioned with a nonrespondent rate of almost 55%, and this should be taken in consideration when reading the found results. However, according to the study, the exposure of injuries was 81% for men and 88% for women, with an average of two injuries during their career. Average time loss from the tour caused by an injury was 9.3 weeks for men and 2.78 weeks for women. The time loss varied from a day to more than a year. Fifty-four percent of the professionals considered their injuries chronic, and as many as 10 to 33% of the tournament professionals played while carrying an injury (McCaroll and Gioe, 1982).

Among male professionals lower back injuries were the most common (25%), followed by left wrist (16.1%) and shoulder injuries (10.9%). Females were most often injured in the left wrist (23.9%) and in the lower back (23.7%). The incidence of injuries was most frequent in the left or target-side arm. In total, the two most common sites of injury were the left wrist and the lower back. Together they stand for almost 50% of the injuries among tournament players according to this study. They were followed by the left hand, shoulder, and knee (McCaroll and Gioe, 1982).

The high competitive demands on these professionals require continuous practise, which can often lead to overuse syndromes. McCaroll found that the dominant mechanics of injury were too much play or practise (69%), followed by contact with object other than ball during the swing (20%). Almost 50% of the players were injured at impact, and 29% were injured during the follow-through. Among women as a group as much as 63% of the injuries occurred at impact and only 14% during the follow-through. The most commonly injured site at impact was the wrist. Among men 42% were injured at impact, and 38% during follow-through, with the back being the area that suffered the most injuries during follow-through (McCaroll and Gioe, 1982). Wrist injuries were most often related to a single traumatic event, such as hitting a root or a rock (McCaroll, 1996).

Neither the golfer´s age nor the number of years on the tour was significant in relation to the incidence of injury according to this study (McCaroll and Gioe, 1982).

In another study, a medical team examined 88 competitors during 7 years British Open (1984-1990). The competitors were male and came to see the medical team during the competitions because of some complaints. During the 7-year period the average consultation rate were 1 of 200 players. Ninety-eight percent of the examined players sustained musculoskeletal problems and 65% of the players´ problems originated in the axial skeleton and most often in the lower back. According to this study 57% of the complaints were acute exacerbation of chronic conditions. In the axial skeleton 62% of the complaints were considered as chronic. In the lower limbs, acute complaints dominated (64%), and in the upper limbs the ratio was 50% chronic, and 50% acute (Hadden et al., 1991).

3.2 Amateurs

The golf swing is a very unusual motion at a very high speed. The motion of the body generates a club-head speed of 100 mph in less than a fifth of a second. The amateur golfers are anxious to copy the techniques of champions, but to attain their skills requires practice. Weekend golfers do not put the same demands on their bodies as professionals do; however their technique is less efficient (Stover et al., 1976; McCaroll and Mallon, 1994).

A survey of 461 British amateur golfers received 193 respondents, which is a response rate of only 42%. In this study, however not very reliable because of the high degree of nonrespondents, the wrist was found to be most commonly injured among men (28%), closely followed by the back (25%). Among females the elbow was the most commonly injured site (50%). The main reason to the injuries was incorrect swing, followed by overuse and poor physical conditions. The elbow and wrist injuries were found to occur more frequently in younger and more able players with lower handicap. The small number of shoulder injuries affected older and less skilled players (Batt, 1992).

In a study of American amateur golfers 4036 mail questionnaires were sent but only 1144 were returned (28%). According to this study, however not very valid because of the poor response rate, the incidence of injuries was 62% for men and 61% for women, with an average of 1.28 injuries per injured person. The most commonly injured site among male amateur golfers was the lower back area (36%), followed by the elbow (32.5%). Among females the elbow (35.5%) was most commonly injured followed by the lower back area (27.4%). Amateurs injure the elbow far more frequently than professionals do, according to the authors. Of the elbow injuries only 17% were medial epicondylitis sometimes called "golfers elbow". Most often the elbow injuries were lateral sided with a higher injury frequency in the target side´s arm, the medial epicondylitis most often occurred in the trailing arm. The most commonly causes of injury were excessive play or practise. On second place came hitting the ground or an object other than ball, followed by poor swing mechanics. The elbow was most often injured at impact, and the back problems were most frequent during takeaway and follow-through. When comparing different groups there was a small increase in injuries in the lower handicap golfer. Forty-five percent of the amateurs considered their injuries chronic (McCaroll et al., 1990).

A study of 416 patients with golf related injuries at an Orthopeadic Clinic found that 21% of the injuries were shoulder injuries. After examinations it was found that almost 93% of the shoulder injuries involved the rotator cuff (Jobe et al., 1986).

A one-year prospective study on back pain among 196 men who began to play golf was performed in The Netherlands. The incidence of recurrent back pain was 45%, and 8% had their first time back pain during the time period. Previous back pain was a strong predictor of back pain during the 12 months study. No significant correlation of incidence of back pain and frequency of play or duration were found. The results indicate that golf is probably not a strong independent risk factor for back pain and the group did not have a significant higher back pain incidence than general populations (Burdorf et al., 1996).

At an emergency department in Great Britain, 33 patients with injuries caused by golf clubs were reported over a period of 2 months. The injured person had an average age of 8.1 years and only one of the injuries happened on a golf course. All injuries occurred while observing another persons golf swing and 24 of the injuries were to the face and the forehead. 27 had simple lacerations but 3 patients presented compound skull fractures (Pennycook et al., 1991).

Golf related ocular injuries have accounted for only 1.5% to 5.6% of all sports-related ocular injuries. Of eight patients the mechanism of injury in six patients was a golf ball projectile, while two were struck by a golf club. The visual prognosis is poor and the enucleation rate is high due to the fact that both the club head and the ball are small, hard objects, that travel at high velocity, and can fit within the orbit (Mieler et al., 1995).

4 TRUNK

4.1 Biomechanics of the Trunk

4.1.1 Hip and Spine Motion

The spine and hip motion during the golf swing were analysed and compared between players on the PGA Tour, The Senior PGA Tour, and amateur golfers. In total 121 players were analysed. The PGA Tour players and the Senior PGA Tour players had a similar swing pattern; these two groups are sometimes put together and called the professionals.

At address, the right side bending was between 2 to 10 degrees among the professionals, with the upper body being open 1 to 10 degrees, relative to the hips. The upper body rotation initiated takeaway, and during the backswing it rotated faster than the hips. Side bending at the top of the backswing was 10 degrees or less to the left. The hips indicated the change of direction in the downswing. During the downswing the upper body rotated faster than the hips. Right side bending increased substantially and forward bending increased and then decreases as the club approached impact. At impact the right side bending was 23 degrees more than at address, and the forward bending had decreased from address. The hips and upper body were open 10 degrees more at impact than at address. Prior to impact the upper body decelerated and the hips decelerated dramatically immediately after impact.

The biggest difference between the amateurs and the PGA Tour players was the side bending at impact, and the top of the backswing. In the backswing, the amateurs had a deeper left side bending, and in the downswing, they attained less right side bending than did Tour players; probably because they slide the hips away from the target in the backswing and to the target in the downswing rather than rotating. The professionals showed less individual swing to swing variation than amateur players did.

Amateurs rotated more slowly than the two groups of Tour players, both in the backswing and in the downswing, maybe because of a less efficient co-ordination between the trunk and the arm motions. In the backswing many amateurs rotated their hips excessively; in the downswing the amateurs required an additional 31% more time to rotate the same amount of degrees as the PGA Tour players did. The faster rotation contributes to a faster club head speed at impact among Tour professionals. Senior Tour players achieved less total backswing rotation than PGA Tour players and amateurs (McTeigue et al., 1994).

4.1.2 Muscle Activity of the Trunk

The muscle activities in 13 male professionals while performing a golf swing were analysed. The muscles examined were erector spinae, upper gluteus maximus, abdominal oblique, and upper and lower rectus abdominis. Dynamic surface electromyography (EMG) was used, and the muscle activities were measured in percent of maximum manual muscle testing (MMT) of each muscle. The swing were divided into five phases as follows:

1. Takeaway: from ball address to the top of the backswing;
2. Forward swing: from the end of the back-swing until the club is horizontal;
3. Acceleration: from horizontal club to ball contact;
4. Early follow-through: from ball contact to horizontal club;
5. Late follow-through: from horizontal club to end of motion.

The target or leading side of a golf player is the side facing the target, for a right-handed player the left side. The trailing or non-leading side is consequently the side not facing the target.

Relatively consistent patterns of muscle activity were found in the trunk muscles examined. During the takeaway the muscles activities were relatively low. Target side erector spinae, and abdominal oblique were the only muscles recorded with an activity of more than 20%MMT. This phase is the least strenuous in the golf swing.

During the forward swing, gluteus maximus, expressed the highest muscle activity during a complete golf swing (84%). This indicates that especially the trailing side, gluteus maximus, is an important hip stabiliser as the golfer shifts the weight to the target side and the golf club begins to accelerate. The trailing side erector spinae, and both sides abdominal oblique muscle also show notable activity with more than 50%MMT during the forward swing.

The acceleration phase requires the greatest conversion of muscle energy to club head acceleration. The target side´s gluteus maximus, and erector spinae, and the trailing side's abdominal oblique muscle activity were more than 40%MMT. The relatively high activity level of the trunk muscles during the acceleration phase indicates, according to the authors, their importance to generate power to drive the ball. The target side's gluteus maximus activity was higher than the trailing side's, indicating that it works as a stabiliser at impact, while the trailing side's muscles are causing the acceleration.

During the early follow-through a muscle activity over 30%MMT were recorded in both sides' abdominal oblique, and the target side's gluteus maximus, and erector spinae. Overall the muscle activity decreased during the early follow-through phase that represents the end of acceleration. The exception was the target side's abdominal oblique activity, which remained at the same level of activity as during the acceleration.

During the late follow-through, the golf swing is decelerating, and so is the trunk. The muscle activity continued to decrease by an activity below 20%MMT, except for the target side's abdominal oblique, which remained at the same level of activity throughout the swing (Watkins et al., 1996).

The EMG activities were examined in the erector spinae, and abdominal oblique among 23 golfers with hcp 5 or below, while performing a golf swing. The swing was divided into the same phases as above. The results of the study concluded that during the takeaway there were relatively low activity in all muscles (below 30%MMT). During the forward swing, the muscle activities recorded were above 50%MMT among all muscles except the target side's erector spinae. During the acceleration phase all muscles had an activity of 50%MMT or more except the target side's abdominal oblique. In the early follow-through phase, the activity decreased in all muscles, an activity over 40%MMT were noted in the trailing side's abdominal oblique. In late follow-through the muscle activity were reduced, except for the target side's abdominal oblique, and trailing side's erector spinae which remained at the same level as the during the early follow-through (Pink et al., 1993).

The abdominal oblique functioned primarily for flexion and rotation bilaterally and effected posture less than 25% of the time. The erector spinae muscles contracted for posture and for stabilisation. According to the authors the high, and constant amount of activity in the erector spinae can lead to fatigue, causing injury to the back or secondary muscle groups which attempt to compensate the fatigue (Pink et al., 1993).

The biomechanics of the back were studied in four professional and four amateur golf players. The muscle activity was recorded for rectus abdominus, external oblique, and paraspinal muscles. The amateurs generated higher peak myoelectrical activity than the professionals during a golf swing. The professionals generated 34% greater club head acceleration at impact, but generated lower spinal loads and EMG activity. The authors explained it by the different timing, where the professionals used the arms and wrists to generate speed, compared to the amateurs who were using the trunk or were swinging from the top. The professionals had smaller standard deviations in the study, indicating a more similar basic swing. The EMG analysis of the trunk muscles in this study showed that the right side's muscles lead the swing during the forward- and acceleration phase. During the follow-through, the paraspinal muscles´ activity decreased, while the anterior muscles continued to fire.

Comparing the left and right side´s muscles, the paraspinal muscles activities were basically symmetrical, while the right side's rectus abdominis, and external oblique developed greater peak activity than the left side's muscles (Hosea et al., 1990; Hosea et al., 1994).

4.1.3 Forces to the Lower Back

The biomechanical forces provoking the back were studied in four professional- and four amateur golfers. The forces calculated were; lateral bending, shear compression, and torsion forces at the L3-L4 motion segment. Among amateurs, the forces were found to be greater and the standard deviations larger, owing to the greater variation in the amateurs' swing patterns. The professionals had smaller standard deviations in this study, indicating similar swing patterns. The torsion force patterns are closely related to the twisting motions of the trunk during the golf swing. A small peak occurred at the top of the backswing, with a rapid change in the direction of the torsion force in the forward swing. The peak loads occurred during the forward swing, and acceleration phase. The professionals' compressive loading patterns consisted of two peaks, one at the top of the backswing, and one during the follow-through. Amateurs exhibited a different timing, but a similar two-peak pattern.

Compressions of eight times the body weight, shear 560N, lateral bending 960N and a peak torque of 85.2Nm were the peak forces on the amateur golfers back. While for professionals, the forces of compression were eight times the body weight, shear 329N, lateral bending 530N and a peak torque of 56.8Nm. Thus, all peak forces, except compressions, were much greater among amateurs than among professionals. The authors explained this by the amateurs' poor swing mechanics generating greater forces to the body.

For comparison, rowing generates compression on the spine of seven times the body weight, and a peak shear load of 848N; and running generates a compression of three times the body weight (Hosea et al., 1990; Hosea et al., 1994).

4.2 Injuries to the Trunk

4.2.1 Injuries to the Lower Back

The most common problem among golfers seems to be lower back pain, especially among men. The reasons for this according to Hosea et al. are most likely the twisting of the lumbar spine in the back swing, and the hyperextension, together with a rotation during the follow-through (Hosea et al., 1994). Back pain in golf can be mechanic, discogenic, spondylogenic, or related to the facet joints. The forces in the golf swing are of the same nature as those causing degenerative changes in the facet joints (Hosea and Gatt, 1996).

Three cases of postmenopausal patients with acute compression fractures of the vertebrae that had occurred while playing golf have been reported. All women had fractures in the lower back region, and were found to have osteoporosis (Ekin and Sinaki, 1993).

4.2.2 Injuries to the Ribs

During a time period of seven and a half-year, 19 cases of stress fractures in the ribs of golfers were reported from three medical institutions. Six were women and 13 men, with ages ranging from 29 to 51. Eighteen of them were beginners, and had been playing golf for an average of eight weeks. Fifteen golfers sustained rib fractures in the leading side of the trunk, all on the posteriolateral side, and most commonly involving the 4th to 6th ribs. According to the authors the serratus anterior muscle is the source of much of the force applied to the ribs. The leading side's serratus anterior constant activity throughout the entire golf swing indicated that the muscle is particularly susceptible to fatigue (Kao et al. 1995). Consequently, fatigue of the serratus anterior may lead to stress fracture of the ribs (Lord et al., 1996).

5 SHOULDER

5.1 Biomechanics of the Shoulder

The shoulder girdle includes the clavicle, and the shoulder bone, and four articulations; the sternoclavicular, acromioclavicular, glenohumeral and scapulothoracic joint. The golf swing affects the shoulder in different ways during the swing's phase. At the top of the backswing, the right shoulder is posterior retracted resulting in an anterior stress in the sternoclavicular joint. In the power phase during the downswing, the right acromioclavicular joint ligaments are laterally stretched as the scapula is externally rotated. During the golf swing, three of the rotator cuff muscles, subscapularis, infraspinatus, and teres minor, counteract anterior displacement of the humeral head in glenohumeral joint (Andrews and Whiteside, 1994).

The electromyographic (EMG) activities were studied in the shoulder muscles bilaterally during a golf swing. Seven female and six male right-handed golf professionals were examined. The muscles recorded were; supraspinatus, subscapularis, infraspinatus, latissimus dorsi, pectoralis major, and the anterior, middle and posterior deltoid. They divided the swing into the same five phases as Jobe et al., takeaway, forward swing, acceleration, early follow-through, and late follow-through.

During takeaway the muscle activity recorded were more than 20%MMT in the supraspinatus bilaterally, the trailing side's infraspinatus, and in the target side's subscapularis, and pectoralis major.

During the forward swing a muscle activity over 40%MMT were noted in both sides' latissimus dorsi, and in the trailing side's subscapularis, and pectoralis major.

An activity above 40%MMT were recorded in both sides' subscapularis, and in the trailing side's latissimus dorsi during the acceleration phase. The highest activity recorded in this study was by the pectoralis, which showed a MMT of 93% during this phase.

During the early follow-through the activity were above 30%MMT in the following muscles; both sides' latissimus dorsi, and pectoralis major; target side's infraspinatus, and trailing side's subscapularis.

In the late follow-through both sides' subscapularis and pectoralis showed an activity above 30%MMT as did the target side's infraspinatus.

From this analysis Pink et al. found specific roles for the different muscles. At the endmost of shoulder motions in the golf swing the infraspinatus, and supraspinatus acted as external rotators, abductors, and stabilisers. The golf swing does not require extremes of strength or range of motion but it is a rapid movement, and to protect the glenohumeral complex the rotator cuff muscles must be well co-ordinated. The latissimus dorsi, and pectoralis major were the powerdrive muscles of the shoulder. Of all muscles tested the pectoralis major contributed to the most activity during the acceleration phase when the arm was rotated and adducted. The subscapularis was the most active while assisting the internal rotation of the trailing arm during the acceleration phase. The posterior and middle deltoid showed low levels of activity and no significant differences in activity in either side. The anterior deltoid was most active as it was lifting and flexing the arm during the takeaway and follow-through phases (Pink et al., 1990).

The muscle activity in, the levator scapulae, the rhomboid, the lower, middle and upper trapezius, and the lower and upper serratus anterior were analysed in 15 male competitive golfers with handicaps of 5 or less.

During takeaway an activity of 20%MMT or more were recorded in all parts of the target side's serratus anterior, and in the trailing side's levator scapulae, rhomboid, and all parts of the trapezius.

In the rhomboids bilaterally, the trailing side's upper serratus, and in the target side's levator scapulae, and middle and lower trapezius a muscle activity over 40% were noted during the forward swing.

Activities over 40%MMT were recorded in the trailing side's serratus anterior, and the target side's levator scapulae, rhomboid, and upper trapezius during the acceleration phase.

As the swing went into early follow-through the activity in all of the target side's muscles tested were 20-40%MMT. In the trailing side's serratus anterior the activity was over 40%MMT, and in the levator scapulae below 15%MMT.

During the late follow-through the activity in the target side's muscles stayed in the same interval as during early follow-through, while in the trailing side's muscles the activity decreased below 15%MMT, except the serratus anterior, which had an activity of 40%MMT (Kao et al., 1995).

The firing patterns of the scapular rotator muscles were described by Kao et al. They found that a linked biscapular motion were present throughout the golf swing. During the takeaway, the scapula rotated clockwise around the chest wall, and counter-clockwise during the remainder of the swing for a right handed player. This complex movement does not require maximum muscle activity, but rather a synchronous muscle balance. According to the authors the medial scapular retractor muscles and the protractor muscles work as a common force couples in order to rotate, elevate, protract, and retract the scapula. All parts of the trapezius worked together to retract the scapula. The activity of the trapezius of the trailing side was primarily during takeaway while in the target side it was during acceleration. The levator scapulae and rhomboid muscles also assisted in the scapular retraction, elevation, and stabilisation. Upper and lower serratus anterior acts as scapular protractors, and continuous moderate activity was recorded in the target side throughout the swing, which may cause this muscle susceptible to fatigue. The activity of the serratus anterior in the trailing side was primarily during acceleration and early follow-through (Kao et al., 1995).

The difference in muscle firing patterns between men and women professionals has been studied by Jobe et al. No significant difference ($p=0.05$) was found but men tended to have slightly more activity during acceleration, and follow-through, while women had a tendency to have more activity during takeaway, and forward swing. However this study did not compare the relative strength of men and women (Jobe et al., 1989).

To achieve greater distance according to Jobe et al. the golfer should strengthen the rotator cuff, latissimus dorsi, and the pectoralis major bilaterally (Jobe et al., 1986).

5.2 Shoulder Injuries

A tournament professional may perform over 2000 shoulder revolutions per week, by this volume of repetitions the tissues will break down faster than they can be repaired; consequently overuse is definitely a risk (Jobe and Pink, 1996).

Factors for shoulder injuries are according to Andrews and Whiteside poor strength and/or flexibility, inadequate warm up, improper technique, excessive play or overuse. Overuse is considered to be the major reason of shoulder stress pathology and results in microtrauma with an inflammatory response. Postinflammatory changes as bursitis, synovitis or tendinitis may results in a less active shoulder motion, muscle weakness and may lead to an atrophy of the rotator cuff muscles. This is called a pain-weakness-atrophy sequence and may if untreated lead to rotator cuff tears (Andrew and Whiteside, 1994).

Instability is the most significant predisposing factor for glenohumeral dysfunction in the athletic shoulder. In the golf swing there is a risk of anterior dislocation of the leading arm during the follow-through, as the arm is externally rotated, abducted, and extended. Hyperelastic joints or glenohumeral instability also decreases the shoulder function and may lead to impingement syndromes (Andrew and Whiteside, 1994).

Shoulder problems most often occurred among older players and most frequently in the left, target side. The pain may be related to impingement when it occurs at the top of the back swing, where the arm is maximally elevated, and there is a remarkable eccentric load on the shoulder muscles (McCaroll and Mallon, 1994).

The degenerating process of the rotator cuff in elderly people may be the reason to the higher frequency of shoulder injuries among older golf players (Jobe et al., 1989).

Acromiclavicular joint injuries are due to the stresses of the ligaments when the arms cross the body during the golf swing (Andrew and Whiteside, 1994).

A case of acromioclavicular degeneration in a 64-year old male golf professional has been reported. In addition the patient had a supraspinatus impingement due to spur formation under the distal clavicle. The main cause to this injury was, according to the authors, the repetitious horizontal adduction of the arms at the top of the backswing and at the end of the follow-through (Jobe and Pink, 1996).

A case of stress fracture of the acromion in a golf player has been reported. A 42-year old woman felt a sudden pain in her target side's shoulder while hitting the ball from tee. Radiography showed a linear fracture at the base of the acromion extending into the spine of the scapula. The mechanics were probably a contraction of the posterior deltoid muscle and repeatedly stress as the club head strikes the ground over a period of time (Hall and Calvert, 1995).

Posterior shoulder pain at the top of the backswing may be posterior capsulitis (Jobe and Pink, 1996).

6 FOREARM AND WRIST

6.1 Biomechanics of the Forearm and Wrist

The strains on the forearm muscles of a right-handed player were described by Stannish et al. As the club changes direction at the top of the backswing the trailing side's wrist is dorsiflexed and the elbow's common flexor muscles are stretched. In the downswing many golfers attempt to decelerate their swing prior to impact. This manoeuvre puts a lot of strain on the trailing side's common flexor tendons. Just after impact the club decelerates because of divot or ball contact. This requires significant counteracting forearm muscle action to maintain control of the club. Consequently the majority of elbow injuries will take place during impact (Stannish et al., 1994).

An electromyographic analysis of the common flexors and extensor muscles of the right forearm in 16 male golf players indicated that the flexor muscles at impact produced a bust of activity (90.77%MMT). The extensor muscles' activity was recorded and ranged from 33.59% MMT at address to 58.77% MMT at impact. There were no significant difference (P=0.6357) in mean EMG activity between subjects neither with low or high handicap nor in total swing time (Glazebrook et al., 1994).

Wrist "uncocking" is wrist adduction (ulnar deviation) from an abducted (radial deviated) position (McLaughlin and Best, 1994). This uncocking is according to Rettig the result of forearm rotation, which creates an illusion of uncocking (Rettig, 1994). Stannish et al. says that an active uncocking of the wrist increases the stresses of impact at the elbows (Stannish et al., 1994).

The arcs of motion were measured in the wrists during a golf swing. The target side's wrist used a mean range of motion of 35 degrees in the sagittal plane (flexion-extension) and 36 degrees in the frontal plane (ulnar-radial deviation.). The trailing side's wrist used a mean range of motion of 103 degrees in the sagittal plane, and 31 degrees in the frontal plane. The ulnar deviation of the left wrist at impact had a mean of 23 degrees (Calahan et al., 1991).

6.2 Injuries

6.2.1 Elbow injuries

Overuse, age, swing mechanics, conditioning, warm-up, equipment, and pathology are the factors for elbow injuries according to Kohn et al. If the swing involves a lot of compensatory movements to get the club back in the proper plane, it may lead to an elbow injury. God strength and flexibility of the wrist, forearm, and shoulder will decrease the possibility of getting an elbow injury. Graphite-shaft reduces the vibrations and the risk of getting overuse injuries to the arm. Pathology includes reversible inflammation, microscopic changes, tendon degeneration and disruption. Occasionally loose bodies and degenerative spurs with symptoms of locking and catching will be seen in golfers' elbows. Up to 20% of medial epicondylitis are associated with ulnar nerve symptoms (Kohn, 1996).

The torque created by the club, and the high stress placed on the wrists at the beginning of the downswing, as well as at impact, combines to make tendinitis a very common problem in the elbow. Injuries in the elbow are probably caused by a poor swing that results in an even higher stress on the tendons and the muscles in the forearm (Stannish et al., 1994). This theory is supported by McCaroll et al. who found that amateurs injured their elbow more frequently than professionals, and that the cause of injury were poor swing mechanics (McCaroll et al., 1990).

The electromyographic activity was analysed in the forearm's muscles in a group of 16 male golfers of which 8 had medial epicondylitis. They found that the recorded activity of the mean flexor muscles' from the symptomatic subjects was significantly higher than for the non-affected subjects both at address and swing phases (Glazebrook et al., 1994).

6.2.2 Wrist Injuries

The wrist motions of 45 golfers were analysed; 20 had hand, wrist, or forearm pain and 25 had no pain at all. The group with pain used a greater arc of motion in the left, target side's wrist during the golf swing than the control group did. In the frontal plane range of motion the affected group had a mean of 68 degrees, versus 36 degrees for the normal group. In the frontal plane motion, clinically, the group with pain had less arc of motion with a mean range of motion of 61 degrees, versus 75 degrees for the non-affected group. The group with pain ranged from 56% to 84% of the strength of the normal group. Because the study group had less strength the authors believed that they did not have the strength to resist the forces that the wrists are exposed to in the golf swing and therefore, the excessive motion occurred (Calahan et al., 1991).

De Quervain tenosynovitis is an inflammation of the abductor pollicis longus and extensor pollicis brevis tendons. It gives a swelling and tenderness of the first dorsal compartment of the wrist caused by the ulnar deviated position the left wrist gains during the golf swing, or a too tight grip of the club (Plancher, 1996).

7 LOWER EXTREMITY

7.1 Biomechanics of the Foot

A study of the shoe-ground reactions found that the shoes had different movement patterns during a golf swing. At address, the golfer's weight was nearly symmetrically distributed with the centre of pressure closer to the heel and the medial side, in both shoes. During the backswing the target side shoe rotated 15 degrees towards the target. The pressure shifted anteriorly from a centre closer to the heel at address and the weight shifted towards the trailing side's shoe. The trailing shoe's centre of pressure shifted slightly towards the heel during the weight transfer in the backswing.

In the downswing, the weight shifted back to the target side's shoe and the pressure shifted towards the heel but in a lateral direction. Before impact the pressure returned towards the medial side while it continued towards the heel. The trailing shoe's centre of pressure shifted rapidly to the toe during the rapid transfer of weight towards the other shoe. At impact the shoe rotated, raised and rolled.

The more skilled players (hcp 0-7) in this study made a greater weight transfer to the trailing side foot during the back swing. They also kept their centres of pressure more to the heels and to the medial side than the less skilled players (Koenig et al., 1994).

The golf player were able to generate greater forces while using a driver while wearing spiked shoes compared to when wearing rubber moulded soles (Wallace et al., 1994).

7.2 Lower Extremity Injuries

Hip injuries are uncommon. However, the rotation of the hip or walking in uneven terrain may lead to trochanter bursitis, this problem is most often seen in the female golfer (McCaroll, 1994).

Of 35 golfing knee injuries, most of them were found to be overuse injuries and not acute trauma. Fifteen persons had target side problems, 17 had trailing side problems, and 3 had bilateral problems. The most common cause of injury was torn medial meniscus (49%), followed by osteoarthritis (29%). Other diagnoses were torn lateral meniscus, chondromalacia of the patella, and loose bodies in the knee. Fifteen patients had previous meniscectomies and had developed their pain while beginning to play golf. According to Guten, the post meniscectomy knee does not tolerate the powerful stress in the golf swing. The spiked shoe locks the foot to the ground and holds the left tibia in an internal rotation in the follow-through, and adds a lot of stress to the medial target side's knee during the knee-flexion position. Only seven of the patients were women. The author discusses the probability that the female knee, having a greater flexibility, may tolerate the spiked shoes better (Guten, 1996).

Patellofemoral problems are seen in the lower extremity of golfers. According to McCaroll large Q-angles and pronation of the feet increase the stress on the patellofemoral joint during the golf swing when valgus forces are applied to the knee. Other knee problems can result from overuse of tight hamstrings, tight heel cords, or foot pronation (McCaroll, 1994).

A case of osteochondral fracture of the patella has been reported in a golf player. During the follow-through phase in a golf swing, the patella dislocated in the right knee due to the internal rotation of the tibia (Isaac et al., 1992).

In a normal bone, the forces in the tibia during a golf swing are unlikely to cause a fracture, but Gregori reported two cases of left tibial stress fractures in professional golfers. The previous symptoms of these cases were persistent shin pain and should, according to the report, be regarded as due to stress fractures, which often only involve the cortex, however with repeated torsion of the tibia complete fracture may follow, as it did in this case (Gregori, 1994).

Pietrocarlo described in a report different foot problems in golf such as blisters, contact dermatitis, tinea pedis, lesser toe deformities, Morton's neuroma, hallux rigidis and valgus, plantar fascitis, Haglund's deformity, Achilles tendinitis, and ligament injuries of the ankle (Pietrocarlo, 1996).

8 CONCLUDING REMARKS

There are some differences in the patterns of injury between men and women, professionals and amateurs, and older and younger players according to the studies presented in this paper. The lower back is most commonly injured among male professional golf players. Professional women most often injure their left wrist, followed by the lower back. The studies on amateur players show different patterns of injuries but the wrist, back, and elbow are the three most commonly injured sites of the body. Although the back is one of the most commonly injured site golf couldn't be proved to be a strong independent risk factor according to a Dutch study. Older amateur players tend to injure their shoulders more often than younger players do. Overall the target side was most commonly injured for all groups.

The incidence of injury, according to McCaroll et al., was approximately 60% for amateurs, with an average of 1.28 injuries per player, and that professionals suffered from an average of two injuries during their career with an incidence of injury of 81% for men and 88% for women. Among professional players neither the players age nor the number of years on the tour were related to the incidence of injuries. Though it is worth noting that all studies in this paper concerning incidence of injuries used questionnaires, they all had a poor response rate and they may also contain a high degree of nonsampling errors.

Overuse is without question the most common cause of injury. The acute injuries occurred most often at impact when the club strikes another object such as a root or a rock rather than the ball. Some serious head injuries have been reported in children who had been struck with a club when watching another player's swing. Those injuries did not take place on a golf course.

The golf swing is a very complex body motion. The forces on the spine are extremely high and the angular velocities in the upper extremity joints are high. The amateurs tended to generate greater forces to their body than professionals did.

The muscle activity recorded shows that the muscles around the spine work as stabilisers and the abdominal muscles works as rotators during the golf swing. To generate more power in the swing, a player should strengthen her or his rotatorcuff, latissimus dorsi, and the pectoralis major bilaterally.

No significant differences in muscle activity between men and women have been reported among professionals. Professionals and amateurs do not have the same swing pattern according to the analysis presented in this review. Amateurs tend to expose the body to greater forces than professionals do, though professionals generate higher club head speed at the impact phase of the swing.

As the most common cause of injury is overuse it should be concluded that most of the injuries could be related to the golf swing.

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