



Artículo especial

ARTÍCULO EN INGLÉS

Spinal musculoskeletal disorders in golf players

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ABSTRACT

Low back pain is one of the most common golf related symptoms, representing from 26% to 52% of all complaints and older golfers who take up the game later in life are potentially the most at risk because the forces generated by the golf swing are combined with degenerative changes in the spine. The aim of the present study has been to analyse mechanisms responsible for low back pain and discuss how this musculoskeletal disorder might be reduced. In the orthodox swing it is apparent that as regards the spine the most stressful part of the swing is the start of the downswing where the upper and lower body move in different directions increasing the relative twist between the shoulders and the hips combined with right-side bending. This twist might be reduced if the golfer would rotate feet, hips and shoulder 7-10 degrees to the right of the target line at the start of the swing and dispense with the sharp hip slide to the left when beginning the downswing. Many studies show the medical consequences of a bad performance but there is no research oriented to find a real solution. Future research should be oriented to find empirical support for alternative techniques.

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RESUMEN

Trastornos musculoesqueléticos de la columna vertebral en golfistas

Las lesiones en la columna lumbar son las más comunes en el golf. Representan de un 26% a un 52% de todas las molestias. Los golfistas mayores que empiezan a jugar con cierta edad son los que potencialmente se encuentran en mayor riesgo, debido a la combinación de las fuerzas generadas por el *swing* de golf y los cambios degenerativos de la columna. El objetivo del presente estudio ha sido analizar los mecanismos responsables de las lesiones en la columna lumbar y discutir cómo podrían reducirse dichos problemas musculoesqueléticos. En el *swing* ortodoxo, en cuanto se refiere a la columna, la parte más estresante es el inicio del *downswing*, porque el tren superior e inferior se mueven en diferentes direcciones, con aumento de la torsión entre los hombros y las caderas en combinación con una inclinación lateral hacia la derecha. Esta torsión podría reducirse si el golfista rotase pies, caderas y hombros unos 7 a 10 grados hacia la derecha de la línea de tiro en el comienzo del *swing* y prescindiera del deslizamiento de cadera hacia la izquierda tan agudo en el *downswing*. Muchos estudios muestran las consecuencias médicas de una mala ejecución pero no hay ninguna investigación orientada a encontrar una solución real. Los trabajos futuros deberían orientarse a encontrar resultados empíricos de técnicas alternativas.

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Introduction

Although golf may seem less physically demanding than most sports, the golf swing can exert tremendous forces on the body. It is a complex movement involving the whole body and is used to develop momentum that is transferred to the golf ball to propel it towards the target. This movement pattern requires a coordinated sequence of muscle activity to efficiently transfer the energy generated by the swing. Without knowledge of proper swing mechanics, one may be at increased risk of development of musculoskeletal disorders.

Low back pain is one of the most common golf related symptoms, representing from 26% to 52% of all complaints. Older golfers who take up the game later in life are potentially the most at risk because the forces generated by the golf swing are combined with degenerative changes in the spine¹⁻⁴. Over 28% of the golfing population in Spain is 50 years of age and above and this percentage is higher in the rest of Europe.

The purpose of this paper is to analyse mechanisms responsible for low back pain and discuss how this musculoskeletal disorder might be reduced.

Biomechanics of the orthodox golf swing

Golf has traditionally been perceived as a low-impact sport, however the stresses placed on the body during the performance of the swing have been linked to numerous acute and overuse injuries⁵⁻¹⁵.

An understanding of the biomechanics of the golf swing will facilitate appropriate knowledge of the etiology of the injury, thereby improving its management. At first glimpse, the golf swing appears to be a relatively simple activity: it can be defined simply as the process of swinging a club to hit a stationary ball. However, it is a complex series of integrated motions, which involve most of the major muscles and joints in the body. It is a closed-chain, multi-variate feedback activity that transfers power from the feet firmly planted on the ground, through core musculature to the upper extremity. The swing can be broken down into 4 specific phases¹⁶⁻¹⁸:

- 1) Setup or address: the initial starting and stable position.
- 2) Backswing: ball address to top of the backswing. The initial movement is called the takeaway.
- 3) Downswing: top of swing to impact. It can be divided into two sub-phases:
 - transition: top of swing to left arm just past horizontal, plane flattened, left arm-shaft plane pointing at the ball and at the target
 - acceleration: clubhead increasing to maximum radius at impact.
- 4) Follow through: impact to completion of swing. It is divided into two sub-phases:
 - early follow through: impact to club horizontal.
 - late follow through: horizontal to completion of swing.

A number of papers have investigated the mechanics of the golf swing¹⁹⁻³⁰. Surface electrodes were used to collect muscle activity data. Before conduction of the golf swings, a peak one second EMG signal during manual muscle strength testing (MMT) was selected as a normalising value (100%) for each muscle tested¹⁹.

The findings are presented in the following paragraphs.

Setup

The golf swing is predicated upon developing a stable stance. The orthodox set-up aligns the golfer (feet, hips and shoulders) with the target, establishing a static but poised balance to execute the golf swing.

Backswing

The backswing is the action of moving the club away from the direction of intended ball flight on a wide radius so that at the top the hands are as far as possible from the ball with the club shaft aiming at the target.

It begins with the upper body coiling on the pelvis toward the trailing hand, placing strain on the lumbar facets, L5-S1 junction, and sacroiliac joints 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 across the chest, loading the acromioclavicular joint and placing the shoulder in a position that promotes impingement.

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 the upper (52% MMT) and middle (37% MMT) trapezius on the right, and the subscapularis (33% MMT) and serratus anterior (30% MMT) on the left.

At the top of the backswing, the wrists are in radial deviation, with the right wrist also displaying submaximal extension.

Transfer of weight toward the right leg increases force upon the lateral compartment of the knee and fifth metatarsal, due to supination of the foot.

The most active muscle in the lower body is the semimembranosus and the long head of the biceps femoris on the right side (28% MMT and 27% MMT). On the left side, the most active muscle is the erector piniae (26% MMT) and the abdominal oblique (24% MMT).

Downswing

The downswing phase starts from the top of the backswing and involves the clubhead returning along a shorter radius and a slightly flatter plane to the backswing in preparation to hit the ball.

Power is developed during this phase of the swing, and while flexibility is certainly necessary, muscular strength clearly is the most important variable. It begins at the end of the backswing and continues until club makes contact with the ball. Although intuitively reversing the above events, there are important differences and unique biomechanical forces that must be discussed.

In fact as far as the study of injuries is concerned it is important to realise that the forward swing or downswing starts first in the lower body before the arms and the club stop at the top of the backswing. About 0.1 seconds before the club stops at the top, the hips start moving, first laterally towards the target and then turning, increasing the relative twist between the shoulders and the hips. So, the motion begins with contraction of the left leg adductor magnus (63% MMT). Momentum is continued as the right leg hip extensors and abductors (upper and lower gluteus maximus [100% MMT and 98% MMT] with the biceps femoris [78% MMT] add to rotation of the pelvis.

In this 'transition' period weight is transferred dynamically from the right foot to the left with the right foot sometimes being almost dragged along the ground. The right leg remains slightly flexed and in a good swing is not allowed to straighten during the backswing.

In the first part of the downswing the hands start to move almost vertically downwards as the hips move laterally to the left. As the shoulders then rotate to face the ball they clearly try to force the hands closer to the target line but with good golfers this is resisted and the top of the left arm is tight across the chest. At this point the spine is bent forward and bent to the right with the lower half twisted towards the target. This puts large direct compressive and shear forces on the lower lumbar discs. These forces can peak sharply if the golfer jerks into the start of the downswing rather than starting smoothly. The club head during this period loops slightly backward away from the ball as the plane between the left arm and club shaft flattens off to point at the ball and at the target. This looping is more apparent with very 'upright' golf swings but is a feature of all good golf swings.

Further acceleration for the upper body is provided by contraction of the transverse abdominal and oblique muscles (59% MMT), while the erector spinae stabilizes the core. 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. The left shoulder is abducted from the position of impingement by the deltoid muscles, while the right shoulder is adducted and internally rotated by the pectoralis major (64% MMT during forward swing, 93% MMT during the acceleration). The muscles involved in scapular movement are also active. On the left side, the rhomboid (68% MMT) and middle trapezius (51% MMT) during forward swing and the levator scapulae to aid scapular tilting during acceleration (62% MMT). On the right the upper serratus contracts (58% MMT during forward swing, 69% MMT during acceleration) to assist scapular protraction.

During the second part of the downswing the golfer squats down a little as the club and arms increase in speed and move outwards away from the centre of rotation of the swing. The rotational speed of the body decreases here partly due to the conservation of angular momentum and partly due to the body-arm torque reaction. In this second part, in a good golf swing, from the point at which the club shaft points directly at the ball, the plane formed by the left arm and the club shaft remains in-plane with the ball until close to impact and this is important in allowing the accelerating forces to be applied efficiently to promote high club head speed. If this does not happen the swing is weak and usually off-line.

To complete the complex picture; at impact almost all the weight is on the left foot, the hips are usually turned away from the target line, the shoulders are square to it or slightly open and the left arm and club shaft form a straight line (viewed from the front) with the hands slightly higher than at address (viewed from behind) due to the exertion of the large centripetal force required on the club (often 500 N or more). The club head rotates from open to closed through impact as the hands pass the centre of the body (being square at impact of course) and during this period the hands can exert little influence on this. However, some top class golfers often try to keep the face square after impact.

At the top of the backswing, the wrists remain in a position that is termed 'cocked'. During the downswing the left forearm extensors pull the wrist into slightly dorsiflexion and ulnar deviation, while the right arm flexor mass brings that wrist into a more neutral position (the 'uncocking' of the wrists).

Follow-through

The early follow-through of the golf swing occurs after ball impact and is the phase where deceleration of trunk rotation occurs. Abdominal

muscles begin eccentric contraction, to slow rotation of the trunk, while the facet and sacroiliac joints absorb the stress. Pressure inside the intervertebral disc once again increases, as the annulus is torqued in the opposite direction. Similar to the acromioclavicular joint, this is a more violent application of force, which slows momentum of the rotating trunk.

The 'rolling' of the forearms at impact is continued into the early follow-through and this results in left arm supination and right arm pronation followed by left arm external rotation and right arm internal rotation. The most active muscle during the early follow through is the pectoralis major bilaterally (74% MMT), followed by the right subscapularis (64% MMT) and the infraspinatus on the left (61% MMT). The leading shoulder is abducted to slightly less than 90° and externally rotated, which places it in a position of anterior impingement. The left wrist continues dorsiflexion and ulnar deviation, while the right side undergoes radial deviation and palmar flexion.

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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 (40% MMT) in this phase as it aids in the protraction of the scapular around the trunk.

As stated above, from before the top of the backswing position weight is transferred from the right leg to the left. This transfer loads the medial compartment and fifth metatarsal, as the ankle inverts and arch supinates. Some golfers raise the trailing heel in the follow through, but that doesn't seem to affect their mechanics significantly. The most active muscle in the lower body during the early follow through is the left long head of biceps femoris (79% MMT), and left vastus lateralis (59% MMT). The right gluteus medius (59% MMT) is the most active right sided muscle, followed by the abdominal oblique (51% MMT).

Spine injury

The spine is exposed to significant compression, anterior-posterior shearing, torsion, and lateral bending forces during the golf swing¹³¹. Axial twisting alone has been identified as a risk factor for low back disorders^{32,33}.

Hosea and Gatt estimated forces around the L3-L4 motion segment. Compression loads of up to eight times a person's body weight were found to be produced during the golf swing. Cadaveric studies have shown disc prolapse to occur with compressive loads of 5,448 N^{34,35}. Although data derived from cadaveric studies may not represent an *in vivo* condition, this estimated value demonstrates the significance of compression forces generated by the golf swing.

It is believed that maximizing torso-pelvic separation will contribute to increased ball velocity and driving distance. The "X-factor stretch" has been described as the maximum torso-pelvic separation that occurs during the downswing and is suggested to result from initiation of the downswing with the pelvis rotating back towards the impact position while the upper torso is still rotating towards the top of the backswing, creating maximum separation between the segments³⁶⁻³⁹. Burden and colleagues⁴⁰ demonstrated that skilled golfers (sub-10 handicap) perform this countermovement of the pelvis and upper torso at the start of the downswing. They further describe how the countermovement of the pelvis and upper torso create a summation of speed that ultimately

results in greater force being applied by the club to the ball at impact.

In the lumbar spine, rotation is limited by the annulus anteriorly and the facet joints posteriorly⁴¹. It allows significant flexion and extension with moderate lateral bending, but relatively little axial rotation secondary to the sagittal orientation of the posterior facet joints⁴². In fact, only two or three degrees of intersegmental rotation are required to produce microtrauma in the lumbar facet joints^{33,43}.

It has been shown that the most common cause of disc herniation in a healthy disc was lateral bending combined with compression and torsion, all of which are significant components of the golf swing^{44,45}.

Amateur golfers are more subject to back injury, because poor mechanics in the golf swing lead to 80% more torque and shear load and lateral stress^{17,46}. Another predisposing factor is the inherently poor core muscle stability most amateur athletes demonstrate.

The sacroiliac joint is particularly susceptible to injury, because it serves as a critical link in the kinetic chain, between the power generated above it and the stability provided below. There also is a transfer of weight from one leg to the other at a critical phase of the swing, when the sacroiliac joint undergoes maximal rotation. Sacroiliac dysfunction and pelvic instability are said to be responsible for 40% of injuries to the low back, and one would expect the incidence to at least equal that among golfers⁴⁷.

In addition to the lumbar discs the cervical discs are also under threat: to hit straight, the golfer is often encouraged to 'drive the right shoulder down and under' through impact, rather than allow it to spin around to the left, and this maintains the right side bending of the spine and forces the base of the neck to bend sharply as he watches the impact and the subsequent path of the ball. Damage to the cervical discs can occur during this period.

Stress fracture of the ribs, thought to be related to weakness of the serratus anterior, has been observed in golfers¹⁴. These injuries typically occur on the nondominant side. As for spine injury, treatment includes relative rest until symptoms abate followed by progressive rehabilitation.

Discussion

In the orthodox swing described above and in the literature it is apparent that as regards the spine the most stressful part of the swing is the start of the downswing where the upper and lower body move in different directions increasing the relative twist between the shoulders and the hips combined with right-side bending. This 'weight transfer' part is arguably the most difficult part of the swing to master – and was called the 'Magic Move' by Pennick⁴⁸ and the 'Transition' by Mann and Griffin⁴⁹. Although coaches recommend that the golfer keep his back flat at the set-up so that the spine is straight, most people do not do this; the back is often bent forward and during the transition period, as the hips move left and rotate and the inside and right hand sides of the lower lumbar discs experience sudden heavy compressive and shear loads.

An interesting question to ask is, "why does the golfer slide or drive the hips left at the start of the downswing anyway?" This movement involves large, heavy body parts and although it is a big factor in tempo and rhythm it is done to get the right hip out of the way of the hands descending into the correct impact position. It is the result of a set-up position where the feet are set parallel to the target line.

If this sideways hip movement and weight transfer is not performed adequately (and it is undeniably the most frequent swing fault dealt

with by golf coaches) the golfer's hands start down on a path that is too close to the target line: he is unable to drop the hands vertically downwards enough and he 'comes over the top' in golfing parlance. Here the downswing path of the hands and the club head is inevitably obliquely across the target line to the left and the ball is 'pulled' left following which the ball flies straight left if the clubface is square to the club head path or starts left then slices to the right if the clubface is open and facing the target, the most common ball trajectory in golf. The evidence for this is in the path of the divots on virtually every short hole in the world: 90% of them point well left of the target and although it may be argued that some of this is the result of the curved club head path even with a straight hit, most divots are clearly the result of an out-to-in swing.

Many older golfers are unable to perform this hip slide left and it could be recommended medically that they shouldn't do it: they could simply aim to the right and allow for the "fault" – in addition they should play the ball further out from the body than usual. In the modified swing (fig. 1) they would take up a stance with the feet, hips and shoulders aiming some 7 to 10 degrees to the right of the target line (the right hand side of the fairway for example) with the ball positioned on the left toe and deliberately pull it across the aiming line - straight at the target, keeping the club face square to the club head path.

At the start of the downswing the golfer simply turns the body, dropping the hands vertically as much as he can, with little or no weight shift to the left. He will require as much hip turn as possible to prevent the club face from turning over through impact but this will require no right-side bending, it will keep the weight central and with the back flat it will only exert a twisting or shear loading on the discs. Only as the arms and club move into the follow-through will the weight transfer to the left foot.

This modified swing is similar to the baseball swing, which is well documented, in which the hitter sets his left foot out in front, keeps his weight fairly central and has no sideways weight transfer: it is a turning action alone with the hips still turning the trunk so that they are well open at impact, as happens with most good golfers. It seems that the golfer's troubles stem from the fact that the ball is on the ground whereas in baseball it is between knee and shoulder height – and the baseball player's right hip does not get in the way of the hands as he twists towards impact.

Conclusion

The golf swing has been widely studied and many different models have been designed to define 'the proper swing', always with a common objective: to get a longer and straighter hit. Many studies show the medical consequences of a bad performance but there is no research oriented to

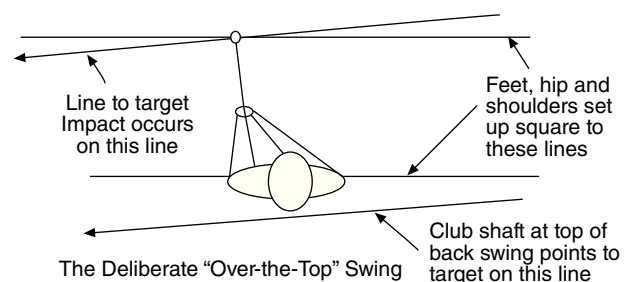


Fig. 1. A modified golf swing.

find a real solution. However, future research should be oriented to find empirical support for alternative techniques to avoid the above-mentioned musculoskeletal disorders.

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