THE EFFECTS OF THE BIOMECHANICS OF THE DYNAMIC GOLF SWING ON SPINAL HEALTH

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ABSTRACT

Background: The dynamic golf swing is a complex movement that involves placing incredible stresses on a player's spine. These stresses, combined with the repetitive nature of the sport, create an injury prone environment. The most popular injuries amongst golfers are back injuries because the loads created on the back, during the golf swing, predispose the entire golfing population to muscle strains, ligament sprains, discogenic lower back pain, spondylolysis, and arthritis. The direct cause of these back injuries has not yet been identified, though several hypotheses have been examined. Preventative measures have also been discussed, but most efforts typically focus on strengthening and flexibility exercises and not on the biomechanics of the golf swing itself.

Objective: The objectives of this article were to review peer-reviewed journal and international magazine publications to determine the effects of the biomechanics of the dynamic golf swing on spinal health.

Data Source: A search of the current literature from 1985 to present through EBSCO, ICL, Pubmed and Mantis was performed without constraints. Search terms used included: *golf, golf swing, biomechanics, spine, rehabilitation.*

Conclusion: Golf is an alluring sport because there are many different ways for an individual to create good, effective golf swing biomechanics. Education is the primary mechanism to prevent injury and reinjury in the golfing population. Using proper mechanics, golfers can achieve better results and relatively lower spinal loads, only secondarily to greater efficiency.

Key Indexing Terms: *golf, golf swing, biomechanics, spine, spinal health, rehabilitation, low back pain, stress.*

INTRODUCTION

Golf is a popular sport that crosses all age groups, races and sex. The increase in popularity of the sport brings with it an increase in the number of injuries attributed to it. The golf swing is a very complex movement that involves a considerable amount of trunk rotation and powerful muscle contractions. On the golf course, physical exertion is intermittent. A golfer could attempt approximately 50-70 violent swings every five minutes or so while playing 18 holes. The average amateur will swing their club at 80-100 miles per hour (1). This dynamic swing tends to put a great deal of stress on the spine, often leading to problems. Low back pain has been identified as the most common musculoskeletal problem affecting amateur and professional or elite golfers. Surveys have shown that 63% of injuries sustained by professional golfers were to the low back area, as compared with 36% for amateur golfers. Development of such pain in amateur golfers is attributed to poor swing mechanics, excessive practice and poor physical conditioning (2). Professional golfers tend to exhibit more consistent swing mechanics than amateurs, but are susceptible to overuse resulting from long practice sessions and repetitive play. Overuse, in association with the asymmetrical nature of the dynamic golf swing may create repetitive abnormal stresses on the spine, which may lead to injury and pain.

The basic rules of golf are the same, however, the biomechanics of the golf swing differ in everybody. Biomechanics refers to the way we move our body. Posture is an important component in our body's biomechanics. Good posture generally means the spine is in a neutral or resting position. The four normal curves in our spine are natural. This position our spines are in, is not fixed or static, which means it can change. It is also personalized and individual, with no two being the same. Each persons neutral spine is one in which the position is comfortably supported and maintained by the bones, discs and ligaments.

The spine is an articulation of bony segments called vertebrae, which increase in size and load-carrying capabilities from the cervical area to the lumbar area. The primary load-carrying component of the vertebra is the cancellous or trabecular bone. The cancellous bone accounts for approximately 50% of the compressive strength while the cortical bone only contributes about 10% of the overall strength in compression (3). Between the vertebral bodies are the intervertebral discs. Each disc is composed of two distinct structures, the annulus fibrosis and the nucleus pulposus. The annulus is composed of laminated collagen fibers; with each layer oriented approximately 120 deg from each other, or 30 deg off the horizontal axis (4). Because the collagen fibers orientation they can increase the resistance to rotation. The other load-sharing structures of the spine are the facet joints. They work together with the intervertebral discs in the support of loads.

It has been reported that alterations in trunk movement patterns occur as a result of muscular insufficiencies and deficiencies, leading to an inability of the spine to withstand repetitive stresses. The soft tissues of the spine, including muscles, ligaments, tendons and discs, may experience abnormal stress from inappropriate muscle recruitment, which increases the likelihood of developing injuries to the back. The golf swing is a very complex movement that involves a considerable amount of spinal rotation and powerful muscular contractions. Now, the spine is composed of two basic biologic tissue types, bone and soft tissue. The biomechanical properties of biologic tissue are directly related to the orientation of the specimen and the application of the load (5). Another characteristic is viscoelasticity, which allows the mechanical property of a material to change with the rate of load application. For example, the intervertebral disc uses a hydraulic mechanism by squeezing water out under pressure with increasing load. However, cyclic or continuous loading activities (the golf swing) will negate this mechanism by effectively squeezing out all of the hydraulic fluid (6). By adding this stress, the spine is the area most vulnerable to injury during the golf swing.

A lot has been written over the years about the dynamic golf swing. The object of any golf swing is to hit the ball in the proper direction and for the proper distance with the most efficient motion. Now that golf injuries are in the forefront, proper swing biomechanics should be discussed, to achieve maximum efficiency and minimize risk of injury. The purpose of this literature review is to look at the biomechanics of the golf swing and its effects on spinal health, and most importantly the low back. Although injuries to the shoulder, elbow, wrist, and knee are common, injuries to the low back appear to be the most prevalent amongst all golfers. The most common cause of injury in golfers is believed to be the repetitive swing motion and poor swing mechanics.

There are three fundamental causes of golf injuries: poor posture, lack of flexibility and poor swing mechanics. Medical and golf experts have long suspected that back pain in the game of golf is as much related to swing-imposed on the spine as it is to poor mechanics (7-10). White and Punjabi have suggested that disc failure in low back pain is due to combined torsion and bending loads at the joint. Facet and disc injury contribute to torsional injury and pain. In addition to torsional and bending loads, the low back must contend with significant lateral bending, shear and compression forces generate eight times the body weight in golfers (11). To add to that, this loading, combined with swing repetition, and poor swing biomechanics, may exacerbate any preexisting back injury. The loads on the spine, especially the lumbar spine, during a golf swing may also predispose a golfer to muscle strains, herniated discs, fractures and arthritis. The root cause of poor mechanics is often a result of a physical restriction or mechanical dysfunction, which may be alleviated through chiropractic procedures.

Moving on from the causes of injuries, we can talk about ways to prevent them. Most efforts typically focus on strengthening and flexibility exercises and not on the biomechanics of the golf swing itself. Such golf exercise programs may allow the back to better withstand the biomechanical stress of the dynamic golf swing, however the potential for injury still exists because it is the execution of each of the phases of the swing that induce injuries. Flexibility is certainly a key to maintaining normal arc of motion and an injury-free spine. Spine stability allows the extremes of range of motion as well as the synchrony of timing in muscle firing as the spine travels through the arc and the club meets the ball (12).

DISCUSSION

The golf swing can be broken down to a very general four phases: the grip, setup, backswing, and downswing. The golf grip is a very important aspect for success in golf, but not so important for its effects on spinal health. We will also consider the follow through as a part of the downswing.

SETUP

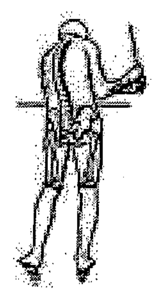
Proper setup or posture in golf provides the platform from which stressors during the swing will be initiated. Because the setup phase is the first and most important phase in the golf swing, its potential contribution to pathology deserves attention and investigation. The first angle created during the setup phase, the primary spinal angle, is accomplished by hinging the hips to flex the trunk forward. The hip joints serve as the axis of rotation, while the midtrunk and thigh lines serve as the lever arms to form the angle. Many golfers, however, incorrectly utilize a spinal flexion movement to achieve this angle.

The second "angle" is created with a combination of lateral bending to the right (for a right-handed golfer) in the spinal segments and slight depression and downward rotation of the arm and scapula, and is termed the secondary spinal angle. This position results from hand placement on the club grip, whereby the right hand is placed lower than the left. High-speed video analysis of professional golfers indicates that at setup the average primary angle is approximately 45°, while the average secondary angle measures 16° (13). The proper posture would be to begin by standing straight up. The weight should be on the balls of the feet, not on the toes or the heels, with the feet shoulder width apart. The knees should be slightly flexed, bending forward slightly at the hips, keeping the back straight. The buttocks will move backwards to help maintain balance at setup and throughout the golf swing. A key element of posture is spine angle. Bending at the hips, as opposed to the waist will support the spine in a more stable position. Key stressors on the spine during the golf swing can be limited by concentrating on maintaining the proper lumbar lordosis at setup.

There is two basic moves of the golf swing itself: the backswing, which is necessary to build kinetic energy, and the downswing, the release of kinetic energy. These phases require an unrestricted ability of the spine to bend laterally, rotate and extend. The backswing is where many of the problems begin regarding injury. It consists of rotation, lateral and vertical tension-producing motion, with a whole host of joints on which to apply pressure. In a right-handed golfer, rotatory motion occurs when the body coils to the right, on the backswing. This loads most of the weight onto the front of the right foot. As the golfer is coiling and loading the weight on the right side, the head will drift to the right as well. This is important, as it will allow the spine to stay perpendicular with the ground. If the head stays totally immobile, then the spine must tilt to the left on the backswing, and the other direction on the through swing. This creates the dreaded "reverse c" that does nothing but create trouble for the spine. Allowing the body to coil around the spine on the backswing is important, as well as allowing the spine to stay vertical and drift to the right.

To begin the downswing, the lower body begins to turn and rotate toward the target. The uncoiling, created in the backswing, creates the speed. Initiation of the downswing begins when the legs drive the coiled energy directly toward the intended target.

BACKSWING



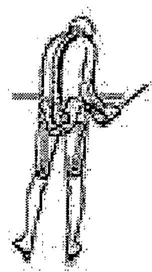
In order for the golfer's center of rotation to remain stable during the ensuing swing, both spinal angles at the top of the backswing should be maintained as close to the original angles as possible (14,15). Maintaining both spine angles and achieving a full 90°-shoulder turn and a 45° hip turn with minimal lateral weight shift requires the golfer to have excellent hip, shoulder, and trunk flexibility. In addition, keeping the secondary spine angle stable during the backswing allows for a natural and uninhibited path during the downswing because it effectively prevents the body from getting in the way of the arms and club during the downswing. By contrast, losing the secondary spine angle (reverse pivot) will require a very complicated and stressful maneuver during the downswing to get the body "out of the way."

Observation of many of today's professional golfers will reveal a great deal of variance with regard to backswing length. Anatomically, the available range of motion in the left shoulder, combined with the amount of spinal rotation, will be the deciding factor in determining the height of any one particular golfer's backswing. Additionally, there is currently no scientific research supporting the idea that "parallel with the ground" is the ideal position for the end of the backswing.

The most common position seen at the top of the backswing is one in which the hips and legs move laterally and the secondary spine angle is lost, or even inverted-a reverse weight shift. Rather than rotating the pelvis to the right in synchronization with the rotating shoulders, many amateur golfers mistakenly attempt to laterally shift the lower body in an effort to increase club head speed on the downswing. The end result in this scenario is that the golfer places the majority of his weight on the front foot, rather than the back foot, and loses the secondary spine angle-hence the term "reverse weight shift," or "reverse pivot."

Regardless of ability, golfers who lose their secondary spine angle will be forced to attempt to get their upper torso behind the ball (reestablishing the secondary spine angle) before impact in order to make contact with the ball. From this position the golfer must reverse his/her trunk inclination in the early part of the downswing by aggressively sliding the hips back laterally toward the target. In a chain reaction, this forces the spine to flex laterally to the right in order to reestablish the original spine and torso inclination. Keep in mind that as this violent loss and reestablishment of the spine angle is occurring, the spine is also undergoing significant rotational and shear forces, and the combination can potentially result in a tremendous hyperextension force on the spine during the latter stages of the swing (follow-through). The degree of hyperextension that occurs is a direct result of the amount of movement required to reestablish the secondary spine angle.

DOWNSWING



A common theory in golf teaching circles is that the larger muscles of the legs, buttocks, and torso perform most of the work, and therefore provide most of the club head speed during the down swing (16). This theory is accompanied by the notion that using the entire body for power and endurance will reduce the demand and stresses placed on the smaller muscles and bones of the upper extremities. However, golfers who follow this theory tend to have too much lateral movement in their base of support and rotary movement in their downswings. The result is a tendency to produce a reverse-c swing pattern in the follow-through position. In fact, the greater the lateral weight shift, the greater the extent of the reverse-c position. Prolonged exposure to this position can generate significant hyperextension stresses on the vertebrae, discs, and soft tissues of the spine.

Increasingly, teachers are becoming convinced that shoulder and arm actions are responsible for a majority of the club head speed, and that the lower body segments and trunk merely initiate the movement and serve as the base of support. Keeping the lower body balanced and stable provides the arms and club an opportunity to accurately maintain the backswing and downswing planes with minimal interference. Unfortunately, this also places greater physical demands on the anatomical structures of the shoulders, arms, and hands. In general, golfers with a greater degree of rotational motion in their swing require greater shoulder, upper back, and arm strength and control, while golfers with more lateral movement require greater abdominal and lower back strength and stability (15).

As the hands and club approach the impact position, the arms, hands, and club should approximate their initial starting positions. It is generally believed that the wrists should remain cocked until the last possible instant if maximum speed is to be achieved, in effect creating a lag. It has been suggested that premature uncocking of the wrists (often referred to as "casting" the club) dismantles the "two-lever, one-hinge" system and creates a "one-lever, no-hinge" system. This action effectively decelerates the golfer's arm speed, therefore decreasing the angular speed of the entire swing (16). The force that is created during a live swing will cause both wrists to deviate slightly in the ulnar direction, and the left wrist to "bow" into flexion as the hands near the contact zone. Lateral epicondylitis ("golfers' elbow") of the left elbow is often the result of this "bowing" of the left wrist and forearm during the preimpact phase, much like the action of the right elbow extensor muscle (tennis elbow) during the backhand stroke in tennis. The hand and wrist units are the last links in the kinetic chain and are ultimately responsible for transferring speed and kinetic energy from other body segments and natural laws of physics into the club. The demand placed on the small bones and soft tissues of the hand and wrist during this process, added to the forces absorbed by these small parts when the club head contacts a semi yielding surface (grass, turf, dirt) at high speeds, makes them very susceptible to injury (17-19).

During the short time from pre- to post impact, the trunk and spine undergo increased stresses as a result of simultaneous and multidirectional movements. At impact, the average amount of secondary spine angle has been found to be 28° (compared to 16° at setup), while the primary spine angle averaged 34° (compared to 45° at setup) (13). The change in magnitude of both primary and secondary angles from setup to impact (about 10° to 12° each) indicates a significant change in spine angle position. The spine angle changes that occur are actually opposite and equal reactionary movements that are produced by the forces created during the high-speed, 3D motion of the downswing. The same data show that shoulder and hip rotation at impact averaged -27° and -43°, respectively (13). The negative numbers indicate that the hips and shoulders rotate beyond the imaginary target line, or are open; while the difference in amount represents a continued torsional stress to the trunk and spinal elements.

Although the knee joint forces generated during the golf swing are not large enough to be considered high-risk for traumatic knee injury, the downswing phase can place significant stresses on a lead knee that may be vulnerable (20). The dynamic work by Gatt et al (20), found that the back of the knee could sustain anterior shear forces of up to 10% of body weight at an approximate knee flexion angle of 33°. This is of clinical significance for ACL patients when one considers the similarity of the peak forces in this position with those found in side-to-side cutting and open kinetic chain movements, and with the increasing quadriceps activity found with this flexion/extension moment. The authors also found the internal tibial rotation moments and average flexion angles during these peak rotation moments (23°) of the trailing knee to be similar-and as detrimental-to those found in a newly reconstructed knee, or as troublesome for an ACL-deficient knee as a side-cut maneuver. As in the trailing knee, the forces in the lead knee are greatest during the downswing and, with the exception of peak posterior forces, are greater than the forces measured in the trailing knee. With great speed the left knee is simultaneously undergoing hyperextension, lateral rotation, and varus stresses that can place undue strain on the vulnerable joint. These multidirectional stresses are a result of the rapid lateral weight transfer and trunk rotation that take place in a closed chain position (21).

These stresses continue until the downswing is completed but reach their highest levels during the impact-to-post impact time period. Studies on vertical compression levels during the golf swing indicate that more than 80% of a right-handed golfer's body weight is on the left side during impact, and this value can go up to 85% in early follow-through (20). When compression and rotational torque forces are produced at high speeds, a great deal of stability and strength is required to withstand the potentially detrimental forces generated. Golfers with ligamentous and cartilage injuries are very aware of the stresses placed on the spine during an otherwise innocuous activity like swinging a golf club.

Hosea et al evaluated the golf swings of amateur and professional players and the stresses placed on their L3-L4 motion segments while swinging a five-iron (22). The authors found that professional golfers were generating 34% greater club-head speed, yet the amateurs were producing significantly greater spinal forces and 50% greater trunk muscle activity (22). Compared to professional golfers, amateurs produced 80% greater peak lateral bending and shear loads (560 N versus 329 N), and 34% greater rotary torque forces. The study also found that both groups of golfers generated compressive loads in the spine of up to eight times body weight, similar to spinal loads seen in more vigorous activities that produce up to 4000 N of force.

The loads produced in the lumbar spine of a golfer may predispose him or her to muscle strains, herniated nucleus pulposus, spondylolysis, and facet arthropathy with associated spinal stenosis. Failure to maintain the secondary spinal angle during the backswing is the primary factor responsible for producing these dramatic levels of stress in the lumbar spine of amateur golfers. Remember, the more of the secondary spine angle that is lost, the more lateral movement is required to reestablish the position during the downswing. This chain reaction produces greater shear, lateral bending, and rotary torque forces and requires greater muscular effort to produce the movement. The work of Hosea and Gatt supports the idea that professional golfers have more efficient swings than amateurs, and that amateurs experience higher forces that contribute to the development of injury and pathology (22).

PREVENTION

Getting in good physical condition will decrease the risk of back injury. Lose weight if you are overweight, perform regular aerobic exercise, such as riding a cycle, walking or running on a treadmill, using a Stairmaster, etc. 30 minutes of aerobic exercise at least twice per week is recommended. Stretching should be done on a daily basis, with emphasis on the hamstrings and other hip muscles. Engage in moderate weight training exercises to strengthen your abdominal, back, shoulder, forearm, and other muscles, esp. those involved in golf. 2 to 4 times per week is probably best. Perform some balance exercises as part of your routine, such as using a wobble board, as this helps you develop a smooth, coordinated swing.

Maintain proper posture while being bent over to strike the ball, putt, and even when bending down to pick your ball up. Keep your normal lordosis (backwards curvature) by bending at the hips rather than at the spine. When putting, think of maintaining the hollow in your back and avoid hunching over the ball. When bending down to pick up your ball or clubs, bend with the knees and use your legs rather than your back Warm up with some light movement and stretching prior to your round. When you go to the driving range, start with your shorter clubs (such as your nine iron) that you tend to take shorter and easier swings with. Start with some easy half swings and work up to a full swing. Gradually work up to your long irons and woods.

Use a pull cart rather than carrying your clubs (23). Carts are not as professional, but they avoid the spinal compression associated with strapping your clubs to your back for four or five hours. Walking with a cart is good exercise and is preferred over riding in an electric cart. Sitting and bumping up and down over the bumps of the course in a cart may not be the best thing for your back. Take some swings in the opposite direction every few holes to even out the stresses to your spine. Consider using a long putter as this avoids the bent over position in conventional putting that is so stressful on the back. When bending over your putts, bend at the hips and not at the spine. That is, do not hunch over and round your back.

THE 10-MINUTE WARM-UP

The 10-minute warm-up consists of four activities. The first is stretching, which should be done for at least two minutes. Before swinging a club, stretching will increase flexibility and blood flow to the muscles, thus decreasing the chances of strain. Five stretches should be performed for at least twenty seconds each. Neck rotations: Tilt your head to the right and hold. Go far enough to feel the stretch but no so far as to elicit pain. This exercise should be repeated on the left side. Shoulder stretch: Hold the golf club with both hands and raise it over your head and hold, place the club behind your back, and extend the shoulders and hold. Then grasp each elbow across the body. Trunk side bends (lateral flexion): With hands on the hips bend to each side and hold. Trunk rotation: Assume the address (setup) position with arms crossed over the chest and hands resting on the opposite shoulders rotate the shoulders (not the hips) and hold. Toe touches (flexion): Standing erect, bend forward at the waist and touch toes; rise slowly. For those with preexisting back problems, this should be performed sitting on a bench and leaning forward.

The second part of the 10-muinute warm-up is driving range practice, done for at least three minutes. Hit shots with the sand wedge, five iron and driver, spending at least one minute with each club. Concentrate on tempo and use a half swing with only the sand wedge, three quarter swing with the five iron, and a full swing with the driver. Focus on proper position and swing biomechanics while avoiding over rotation of the shoulders.

Putting is the third phase of the warm-up, and should be done for at least four minutes. Spend two minutes putting back and forth across the green, getting a feel for speed of the green. Following the long put, spend two minutes concentrating on straight and breaking three-foot putts. Not only will this give you feel for the greens, but will warm up those muscles responsible for the putting stroke.

Waiting to tee off is the last part of the ten-minute warm-up. Spend thirty seconds making practice swings with the club you plan to use on the first tee. Concentrate on tempo, a low takeaway, balance, a full turn on backswing, clearing the hips on downswing, and a full finish. Swing slowly, concentrating on rhythm and balance. Then spend the next thirty seconds relaxing and visualizing your drive (24).

CONCLUSION

Golf is an alluring sport because there are many different ways for an individual to create good, effective golf swing biomechanics. The key is to design good swings that are not physically debilitating. The human body certainly was not designed with the game of golf in mind. Because the golf swing is not a natural activity for the human body, and because it does not fit the model of sound body mechanics in many ways, golfers of all abilities and experience should be aware of the potential risks involved in playing the game. It is important to remember that there are many different combinations of anatomical functioning possible in all types of bodies, and so there are many different and equally effective ways to swing a golf club. The combination of these variables will dictate the relative levels of success and physical stresses produced in each individual golfer.

Education is the primary mechanism to prevent injury and reinjury in the golfing population. Improving swing mechanics (thus diminishing the loads affecting the lumbar spine) is imperative. The limitation of hip rotation with maximal shoulder rotation, thus increasing the resultant torque, should be avoided. A smooth, flowing, upright golf swing with a decreased ratio of shoulder and hip rotation is encouraged as well as proper body mechanics on the golf course for such activities as teeing, or marking a golf ball, and picking a ball out of a hole.

Each individual golfer must realistically assess his or her physical capabilities including physical strength and flexibility. In addition to striving to improve the trunk, buttock, and lower extremity strength and flexibility, the golfer must also play within his or her own capability. Aerobic conditioning is also important in the prevention of injury because it delays the onset of fatigue. Walking should be encouraged whenever possible, but especially on the golf course; golf cart uses should be limited. As stated earlier, a pull cart, though not professional would be the best option of limiting spinal stress, while aiding in aerobic exercise.

Finally, the golfer must make time for an appropriate warm-up prior to commencing play and must allow at least ten minutes prior to beginning a round for warm-up preparation, although 45 minutes would be optimal (25).

The golf swing subjects the spine to rapid, complex, and intense loads. The amateurs develop higher loads compared with professionals as a result of poor swing biomechanics. Using proper mechanics, professionals achieve better results and relatively lower spinal loads, only secondarily to greater efficiency. Nevertheless, the loads on the back predispose the entire golfing population to muscle strains, ligament sprains, discogenic lower back pain, spondylolysis, and arthritis. It is imperative for all golfers to warm up properly before play, to consider practice warm-up patterns carefully, and strive to improve their swing biomechanics. This will limit the damaging effects of the biomechanics of the dynamic golf swing on a golfers spinal health.

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