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Review Article

The lumbar spine and low back pain in golf: a literature review of swing biomechanics and injury prevention

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Abstract

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

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

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

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

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

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

Keywords: Lumbar spine; Low back pain; Injury prevention; Golf swing; Biomechanics

Introduction

The game of golf has come a long way in America since the United States Golfing Association was formed in 1894 [1]. It is a unique sport that has been growing in popularity and can be played and appreciated regardless of age, gender, or athletic ability. In addition, the use of handicapping can allow players of different abilities to compete on a ‘‘level’’ playing field. Between 1970 and 1990, the number of golfers in the U.S. more than doubled to 23 million, and the number of courses increased to over 11,000. By the year 2000, there were over 25 million golfers and over 14,000 courses [2]. The World Golf Foundation expects there to be 55 million participants by the year 2020 [3].

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It is important to note that over 33% of the golfing population in the U.S. is age 50 years of age and above [4]. Given the popularity of golf among seniors and current population demographics, the percentage of older golfers will likely increase in the future. This could potentially create additional health issues because, when combined with degenerative changes in the spine, forces generated by the golf swing can further predispose golfers to injury.

Low back pain (LBP) is one of the most common golf-related symptoms, representing from 26% to 52% of all complaints [5–9]. LBP has long been a major health issue, already costing the nation over $50 billion each year [9]. Understanding how to treat and prevent golf-associated LBP is certainly a worthy endeavor, especially when considering the potential size of the population involved.

Forces on the spine during the golf swing

Although golf may seem less physically demanding than most sports, the golf swing generates a tremendous amount of force. Axial twisting alone has been identified as a risk factor for low back disorders [10,11]. In addition, the lumbar spine is exposed to significant compression, anterior-posterior shearing, torsion, and lateral bending forces during the golf swing [12]. Without knowledge of proper swing mechanics, one may be at increased risk for the development of low back problems.

The primary load-carrying component of the vertebra is cancellous bone, accounting for about 50% of the compressive strength. The nucleus pulposus also serves to absorb compressive shock, and studies have shown that the facet joints resist up to 20% of the spinal compression load [13–21]. Hosea and Gatt estimated forces on the lumbar spine during the golf swing [13,14]. Kinetic data of subjects wearing reflective markers over the T5, T10, L1, and L3 spinous processes, in addition to the wrists, elbows, shoulders, hips, knees, ankles, and fifth metatarsal heads, was captured using four synchronized video cameras with high-speed shutters. Myoelectric data was collected using surface electrodes on the rectus abdominis, external oblique, and paraspinal muscles at the level of L3. Forces around the L3–L4 motion segment were extrapolated from the collected data using an approach similar to one substantiated in previous publications. Compression loads of up to eight times a person's body weight, or about 6,100±2,413 N in amateurs and 7,584±2,422 N in professionals, were found to be produced during the golf swing. A study by the same authors using similar techniques measured lumbar compression forces in Division 1-A college football linemen to be about 8,679±1,965 N when hitting a blocking sled [22]. This demonstrates the significance of compression forces generated by the golf swing, especially when considering that cadaveric studies showed disc prolapse to occur with compressive loads of 5,448 N [23]. In addition, lumbar compression fractures from swinging a golf club have been documented in osteoporotic patients [24].

The facet joints also serve to resist more than 50% of the anterior-posterior shear load [15]. Estimated peak shear loads of 596±514 N have been recorded during the golf swing in amateur golfers, yet similar shear loads of 570±190 N were capable of producing pars interarticularis fractures with cyclic loading in cadaver specimens [14,25,26].

In the lumbar spine, rotation is limited by the annulus anteriorly and the facet joints posteriorly [27]. It allows significant flexion and extension with moderate lateral bending, but relatively little axial rotation secondary to the sagittal orientation of the posterior facet joints [28]. Panjabi described both active and passive stabilizing subsystems of the spine. Flexibility of the passive subsystem accounts for what he characterized as the ''neutral zone,'' or the physiological range of motion within which there is minimal resistance to spinal rotation [29,30]. Research on the neutral zone reveals that it can be variable, based on individual laxity of the spine. It is hypothesized that increased neutral zone magnitude not only correlates with instability, but may also reflect predisposition to injury [31,32].

\In fact, only two or three degrees of intersegmental rotation are required to produce microtrauma in the lumbar facet joints [11,33]. All too often, many teaching aids and instructors put emphasis on loading the lumbar spine, creating tremendous amounts of torque. 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 [34,35].

Given the limited range of axial rotation in the lumbar spine and the emphasis on torsional loading during the swing, its not surprising that the most frequent cause of acute LBP is thought to be local soft-tissue damage; this includes muscle strain, internal disc disruption, and facet joint capsule trauma [36]. Based on analysis of the forces generated by the golf swing, it is clear how repetitive lumbar spine loads may potentially predispose a golfer to muscle strains, herniated nucleus pulposus, stress fractures of the vertebral body and pars interarticularis, spondylolisthesis, and facet arthropathy [13].

Modern versus classic golf swing

At first glimpse, the golf swing appears to be a relatively simple activity. Perfecting the golf swing, however, is no simple task. There is ample literature and information available on improving one's golf swing. It can be broken up into four basic components: backswing or take away, forward swing, acceleration with ball strike, and follow-through [37–39]. An individual's swing can be as unique as their fingerprint, but there are generally two types of swing styles. These are the ''modern'' golf swing and the ''classic'' golf swing.

The ‘‘modern’’ golf swing emphasizes a large shoulder turn with a restricted hip turn. Reduced hip turn is accomplished by keeping the front foot flat on the ground throughout the swing. This is thought to ‘‘quiet’’ the lower body, and it may better facilitate return of the club face to its starting position and allow more consistent ball striking. Maximizing the hip-shoulder separation angle also increases the torsional load in the spine, and it serves to further stretch the viscoelastic elements. This stores potential energy that contributes to increased rotational velocity, and translates to increased club head speed in an efficient swing.

This separation angle is also known as the ‘‘X-factor’’ due to the ‘‘X’’ made by lines drawn along the axial orientation of the shoulders and hips at the transition between the end of the backswing and start of the forward swing. Lindsay and Horton performed a swing analysis between 12 golfers with and without LBP to look for an association between the ‘‘X-factor’’ and LBP by focusing on trunk rotation. They found no statistically significant difference in rotation between the groups during their golf swing [40]. They did find that LBP golfers consistently exceeded their trunk rotation during their swings when compared with rotation in neutral posture at a controlled speed. This relative ‘‘supramaximal’’ rotation, or ‘‘dynamic X-factor,’’ may represent excessive strain on viscoelastic structures in the spine beyond their physiologic range of flexibility. (Fig. 1).

Fig. 1. Demonstration of static ‘‘X-factor’’ (white lines) and dynamic ‘‘X-factor’’ (black lines). Note increased hip-shoulder separation angle with opening of hips at start of downswing, leading to supramaximal trunk rotation.

Golfers with LBP may lack the muscular and neural control to rotate at increased speeds, but stay within their trunk range of motion measured at lower speeds. This theory is supported in a study where torque and the magnitude of muscle contraction during isokinetic axial rotation were analyzed at various rates of speed using previously validated methods [41]. The study showed decreasing torques with increasing rotational speeds, despite maximal EMG recordings in active rotational muscles at all speeds. The authors concluded that as forceful rotary motion velocities increase, more muscle force is absorbed in deforming connective tissues. This allows for increased rotation, but also illustrates how the safety of viscoelastic soft tissues is jeopardized. Acutely, this may lead to pain secondary to microtrauma. Over time, this repetitive trauma may lead to decreased effectiveness of passive stabilizing structures through their deformation.

The modern golf swing can also be problematic because of increased lateral bending, or ‘‘crunch factor,’’ and exaggerated hyperextension on follow-through, known as the ‘‘reverse C’’ position [12,13] (see Fig. 2).

Although the ‘‘reverse C’’ and ‘‘crunch factor’’ components may be removed from the modern swing to reduce compressive forces on the spine, it still incorporates a large hip-shoulder separation angle.

Increased lateral bending towards the trailing side during the forward swing is thought to put more force behind the ball at impact. The amount of lateral bending can be measured both directly and through the ‘‘crunch factor.’’ Its clinical application is controversial because of lack of supporting evidence, but it is defined as the product of the lumbar lateral bending angle and axial rotation velocity. The ‘‘crunch factor’’ was developed as a tool to analyze dynamic lateral bending in the golf swing by Morgan et al., based on their analysis of asymmetric spinal motion in collegiate golfers [42]. An epidemiologic and radiographic study of elite golfers by Sugaya et al. further supports the importance of swing symmetry and the ‘‘crunch factor.’’ They surveyed Japanese tour professionals at four different tournaments and found 55% to have a history of LBP. Over half of the symptomatic golfers complained of localized pain in their trailing side. They then performed radiographic analysis on 26 of those golfers and found significantly greater trailing side vertebral body and facet joint arthritis when compared with age-matched controls [43]. Additional radiographic studies on the lumbar spines of golfers could not be found, however there are studies on radiographic findings in athletes of other sports. In general, it is accepted that athletes have a greater amount of disc degeneration on MRI when compared with the normal population [44,45]. The location and extent of these changes have also been correlated with the type of sport and intensity of training [46–48]. These radiographic findings, however, did not always correlate with LBP. Certainly, disc degeneration is not an uncommon finding in asymptomatic individuals [49].

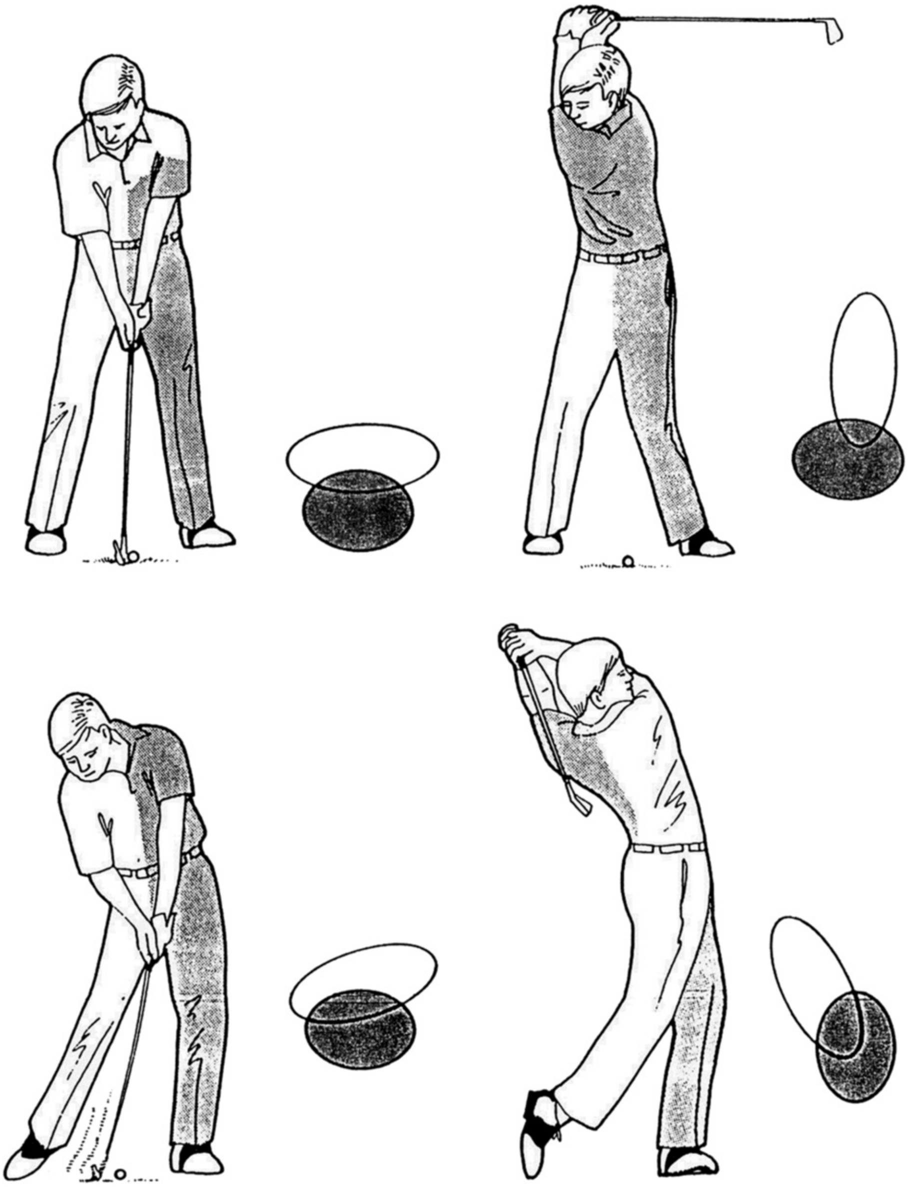

Fig. 2. Modern golf swing. Note the restricted hip turn. (unshaded oval represents shoulder position; shaded oval represents hip position) [12].

The classic golf swing emphasizes reducing the ''X-factor.'' This is accomplished by raising the front heel during the backswing to increase hip turn, shortening the backswing, or a combination of the two. This reduces the magnitude of the hip-shoulder separation angle, and it decreases the torque on the lumbar spine. This swing also emphasizes balanced, upright form that may also serve to reduce the ''crunch factor.'' It is characterized by an erect ''I'' finish with balanced shoulders [12,13] (see Fig. 3).

Although one study has shown that a short backswing reduces forces on the trunk and the spine without having a detrimental effect on either club head velocity or ball-contact accuracy, it was also found that shoulder muscle activation increased substantially. This may increase the risk for shoulder injury. The authors of the study hypothesized that this increased activation was because of overcompensation, and that golfers could be trained to reduce involvement of the shoulder [50]. Some doctors advocate wearing a corset to encourage a shorter, more compact swing, but research has not been done to prove the effectiveness of this method [51].

In general, a more upright stance in which the golfer is closer to the ball has been shown to prevent LBP in case reports [52]. This may be beneficial because of a decrease in anterior-posterior shear forces on the spine through decreased spine flexion. Increased shear forces on the spine during rotation in a flexed position have been demonstrated by Kumar and Narayan [53]. Using EMG, they demonstrated an exponential increase in trunk muscle activation, and subsequently torque, with isometric rotation while flexing and extending when compared with a more upright

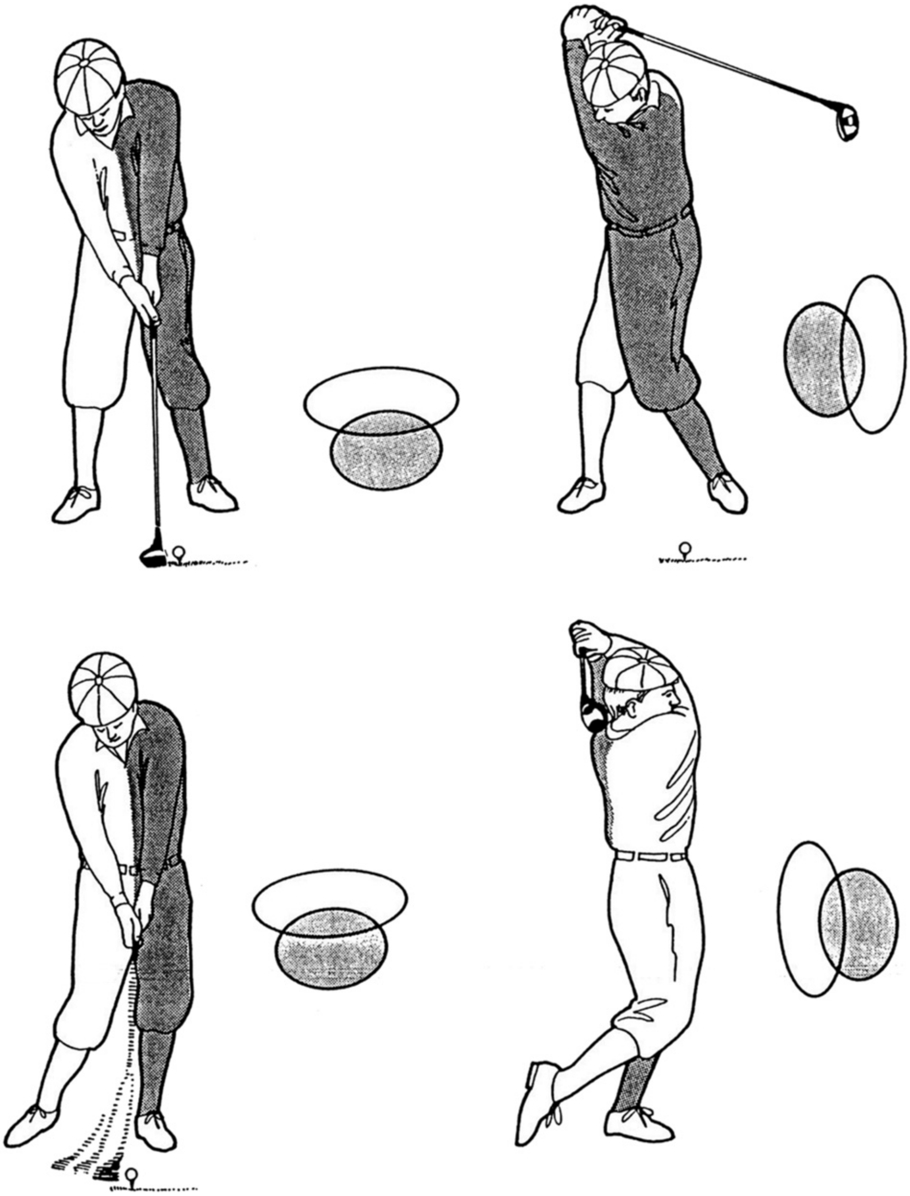

Fig. 3. Classic golf swing. Note the large hip and shoulder turn. (unshaded oval represents shoulder position; shaded oval represents hip position) [12].

position. They concluded that such rapid increases in tissue stress with asymmetric axial rotation could increase injury potential. In addition, they also found statistically significant increases in flexion angles at ball address in golfers with LBP. These findings, coupled with studies showing increased lumbar disc pressure in flexion, further implicate increased stance-to-ball distance as a factor in golf-related LBP [40,54].

Despite problems with accuracy and consistency, most golfers tend to focus more on power and distance. This mindset makes the ‘‘modern’’ swing more popular among both amateurs and professionals. Mainstream golf publications often advocate coiling the shoulders against a stable lower body to increase the ‘‘X-factor’’ and achieve maximum power and distance [55]. In addition, the ‘‘reverse C’’ finish commonly pictured in these publications has been shown to result in maximal extensor muscle contraction, further increasing compressive force on the spine [56]. Furthermore, microtrauma to the hyperlordotic spine secondary to repetitive hyperextension activities has been implicated in the etiology of spondylolysis [57]. For these reasons, some feel that ‘‘modern’’ swing mechanics are a potential cause of golf-associated LBP [58,59].

Amateurs versus professionals

Although swing style may be an underlying problem, injury mechanisms can differ. Professionals practice constantly and develop a consistent swing, but have problems because of overuse. Amateurs do not play as frequently and often have multiple inconsistencies in their swing, leading to back pain as a result of poor swing mechanics [58,60]. This has been substantiated by studies on differences in the swing between professionals and amateurs [14]. While trying to compensate for swing irregularities, there is increased muscle activation and force generation. Amateurs, who generally have more swing irregularities, generate approximately 80% greater peak lateral bending and shear loads than professionals. Amateurs were also found to generate 50% greater swing torques, and they reached a greater percentage of their peak trunk muscle activity than professionals while swinging a golf club [6,13,61,62].

Kumar has written extensively on overexertion and cumulative load theory, which applies in varying degrees to both amateurs and professionals. Muscle strains and ligament sprains are common in athletics, and often represent a single episode where demands exceed those tolerated by the system. This represents the overexertion model of injury. Cumulative load considers total stress placed on the system over time. Kumar found a statistically significant difference between LBP workers and those who were pain free when looking at the total number of hours worked. LBP workers were found to consistently have worked for more hours over their lifetimes, supporting the cumulative load theory [63]. This is no different for golf, where high repetition and high force activity increases the risk of LBP acutely through overexertion and over time through cumulative load.

Other commonly sustained injuries apart from LBP occurred mainly in the upper extremities and were more common in professionals and female golfers. These included medial epicondylitis (golfer's elbow) in the trailing arm, lateral epicondylitis in the leading arm, hook of hamate fractures, tenosynovitis of the extensor pollicis brevis and abductor pollicis longus common tendon sheath (De Quervain's disease), and rotator cuff pathology [5,6,8].

Trunk muscle rotation and stabilization

To further understand the biomechanics of the golf swing, to provide a basis for therapy and conditioning programs, EMG analysis on the trunk musculature of golfers and subjects performing axial rotations has been performed.

Studies were identified that analyzed muscle activation during both pure rotation and the golf swing in healthy subjects that were free from LBP. Muscles included in these studies were the erector spinae (ES), rectus abdominis, external obliques (EO), internal obliques (IO), latissimus dorsi, quadratus lumborum, psoas major, pectoralis, and gluteus maximus (GM) [10,37,38,64]. Although not specifically isolated in these rotational studies, the transversus abdominus (TA) and multifidi (MF) are key stabilizers of the lumbar spine that deserve mention and will be discussed in the therapy section [65].

Studies on axial twisting showed the highest amount of activity in the contralateral EO and ipsilateral IO and latissimus dorsi, with the ES, quadratus lumborum, and RA providing the most stabilization.[10,40,66,67]. Two studies were found that focused specifically on trunk muscle activity patterns in different phases of the golf swing [37,38]. Muscles analyzed in these studies were the ES, GM, EO, IO, and RA. The takeaway phase was found to have the lowest muscle activity, and the forward swing and acceleration were found to have the highest muscle activity. The GM was found to play an important role in hip stabilization and the generation of power. The ES was more involved with counteracting gravity, especially during the forward swing [37,38,68]. Differences between the left and right trunk muscles were also seen during the golf swing. Without proper conditioning, imbalances in trunk muscle strength can develop on either side. This may potentially cause back pain.

The trunk muscles transmit forces through the thoracolumbar fascia between the spine, pelvis, legs, and arms. This assists in rotating the trunk while simultaneously stabilizing the lumbar spine [69]. It is through this fascia that the abdominal muscles are able to transmit stabilizing forces that reduce stress at the intervertebral joint [70]. The importance of trunk muscle stabilizing ability can be seen in studies of healthy individuals whose trunk muscle activity at neutral posture shows baseline trunk flexor-extensor co-activation [71]. Studies also showed delayed onset of these stabilizing trunk muscles in patients with LBP while performing trunk rotations, further supporting the importance of muscular stabilization of the spine [65,72–74]. It has been noted that up to 30% or more of touring professionals are playing while injured at any one time [59]. It is also not uncommon for amateurs to play through a sore back. This can be problematic because it has been shown that patients experiencing LBP undergo increased trunk muscle contraction with rotation in an effort to increase spinal stability. In one study, large-array surface EMG of the low back musculature was able to distinguish between normal subjects and those with LBP when looking at patterns of muscle activity [75]. Studies have also shown that there is reduced trunk muscle coordination, and therefore stabilization, with LBP and fatigue [61,62,64,65,72,76,77,78].

Solomonow et al. [79,80] published a series of experiments designed to analyze reflexive muscular stabilization of the multifidus muscles in vivo using anesthetized cats. The study was able to document loss of reflexive stabilization after cyclic loading of the feline lumbar spine, along with marginal recovery despite allowing a rest period of up to 2 hours. It also showed that creep, and subsequent laxity, caused by loading the viscoelastic ligaments, discs, and joint capsules of the spine desensitized mechanoreceptors. This resulted in decreased reflexive protection. Resetting the experimental construct to offset creep restored the reflexive response. This illustrates how increased laxity can lead to more flexibility, but also greater potential for injury if voluntary muscle contractions are not coordinated. In the setting of pain and fatigue, it is apparent how the spine becomes more susceptible to injury.

Treatment and prevention strategies

Exercise is the standard form of treatment in the prevention of LBP and injury [36,81]. Ice, rest, and nonsteroidal anti-inflammatory medication are the best forms of treatment for acute soft-tissue injuries, such as a muscle strain. Based on EMG studies and golf swing analysis, certain measures have been proposed to improve the golfer's back and prevent injury.

Two studies were identified that proposed programs specifically for the rehabilitation of golfers suffering from LBP. The first was a case report by Grimshaw and Burden on the reduction of LBP in a professional golfer [52]. Trunk motion and paraspinal muscle activity were used to assess the effect of a 3-month rehabilitation program. Muscle conditioning consisted of dynamic stabilization exercises involving the TA and MF. The TA was exercised with light contractions while lying supine with the knees bent. The MF was exercised in both the prone and quadruped positions through alternating forward flexion of one shoulder and extension of the opposite hip simultaneously. These exercises were done 3 to 4 times each day. Each session consisted of 10 repetitions for each exercise, holding initially for 5 seconds and gradually building up to 20 to 30 seconds. Swing coaching served to move the ball closer to the golfer to create a more upright posture. In addition, hip-shoulder separation angle was reduced by increasing the hip turn and decreasing the shoulder turn during the backswing. Lying and seated rotational spinal stretches were also incorporated twice per day and 3 to 4 times per week with eight to 10 repetitions holding for about 30 seconds in each stretch. At the end of the treatment period, the player had decreased EMG signal intensities throughout his swing in the paraspinal muscles and was able to resume golfing without LBP.

The second study was retrospective, nonrandomized, and involved a group of 145 golfers treated through a multidisciplinary golf rehabilitation program [60]. The group characteristics were as follows: 95% were amateur golfers, 80% were male, mean age was 55.7 years, and low back injuries were present in about 45% of the study group (49% of the men and 28% of the women). The most common swing modification was change to a ''classic'' golf swing through a front heel raise and shortened backswing. Swing modification was used in 83% of the subjects, along with flexibility training and physical therapy. Specific discussion on the training methods used, length of treatment period, and percentage of those with back pain who responded to the ''classic'' swing modification were not included. The authors reported a 98% success rate in return to golf participation and the absence of new golf-related injuries within the first year after completion of the program.

The coaching of a more ''classic'' swing, combined with trunk muscle conditioning and flexibility exercises, was a common modification in both of the articles mentioned. Unfortunately, one cannot say to what extent swing modifications contributed to the reduction of LBP. It is reasonable to conclude that forces on the lumbar spine may be reduced through those swing modifications mentioned previously, and that this force reduction could reduce LBP. It is also possible that LBP subjects would be able to load their lumbar spines using a ''modern'' golf swing and be free of pain, provided they increased their flexibility and conditioned their lumbar stabilization muscles to protect against increased forces. A study of 42 male professional golfers found a statistically significant correlation between decreased internal rotation and flexion–abduction–external rotation in the leading hip and LBP. It is argued that this decreased hip flexibility requires golfers to further load the lumbar spine during the swing to achieve the same rotation [82]. Theoretically, this increased torque could not only be decreased by increasing hip flexibility, but also by adopting a ''classic'' swing. Conclusive statements on the benefits of switching to a ''classic'' swing can not be made unless controlled studies that isolate the effects of those swing modifications from muscle conditioning and stretching are done. It is accepted, however, that strength and flexibility training have a place in any sport—this includes golf [83]. Muscle conditioning and flexibility exercises for the trunk muscles are important, and should include all of the muscles shown to be active during the golf swing. Stretching is especially important for seniors, as it slows the loss of flexibility and associated degenerative joint disease that are a hallmark of aging [4,84,85]. Physical rehabilitation research has shown that focus should first be placed on strengthening the core trunk muscles through dynamic lumbar stabilization exercises in patients with LBP. Stabilization exercises focus specifically on the MF and TA.

The MF has distinct superficial and deep fibers that originate from the spinous process and lamina of each lumbar vertebra. The superficial fibers serve to control extension of the lumbar spine and maintain lumbar lordosis. The deep fibers stabilize the spine via compression, and they protect it from intervertebral shear and torsion [86]. Research looking at MF cross-sectional area using ultrasound has shown a correlation between unilateral LBP and ipsilateral atrophy of the MF. Additionally, resolution of acute back pain does not correlate with reversal of MF wasting, possibly contributing to a high rate of recurrence of LBP in those who do not rehabilitate their MF [87,88].

The TA runs horizontally around the abdomen. It attaches to the transverse processes of each lumbar vertebra via the thoracolumbar fascia, and it is thought to play an integral role in stabilizing the lumbar spine and the sacroiliac joints [89,90]. It can be strengthened by slowly pulling the umbilicus towards the spine without contracting the rectus abdominus. Significant contraction delays in the TA of subjects with LBP have been identified, suggesting that this muscle is clinically important for spinal stabilization [89].

The effectiveness of stabilization exercises in LBP patients has been shown through multiple prospective, randomized studies. These techniques have been shown to reduce the recurrence of LBP in subjects presenting with their first episode of LBP [91]. They have also been shown to be superior to other commonly used exercise techniques, such as flexion-extension training and general trunk strengthening, in the nonoperative management of low-grade spondylolisthesis [92] and for postoperative rehabilitation after lumbar microdiscectomy [93]. Once patients master these stabilization contractions, it is important to incorporate dynamic components such as extending the hip and forward flexing the contralateral shoulder simultaneously from a quadruped position. These maneuvers have been shown to increase the cross-sectional area of the paravertebral muscles significantly more than stabilization exercises alone [94]. Further information describing lumbar stabilization exercises and approximate spinal compression loads because of specific dynamic positions can be found in the literature [95,96]. Warming up before playing a round of golf is also important for injury prevention. Gosheger et al. [97] published a retrospective study of 703 golfers. The purpose of the study was to perform an epidemiologic assessment of the musculoskeletal problems that develop in golfers, and to identify variables associated with increased risk of injury. They found a statistically significant decrease in injury by about 60% in golfers who stretched and warmed up for at least 10 minutes before playing. Unfortunately, one study of over 1,000 amateur golfers during a 3-week period also found that only about half performed some form of warm-up activity [98]. Gosheger et al.'s study also found that golfers who carried their bag on a regular basis suffered significantly more injuries to the lower back, shoulder, and ankle. When warming up, referenced sources advocate an activity such as jumping jacks to elevate body temperature, followed by a period of stretching and swinging with a club [4,13,84,99]. Some also suggest hitting balls on the range after stretching before play [13,100].

Golf after back surgery

No focused research studies exist on when patients can safely return to playing golf after surgery on the lumbar spine. Most surgeons have different recommendations based on their experiences, comfort levels, and fundamental concepts in bony and soft-tissue healing. In general, activity limitations and length of recovery are based on the preoperative condition of the patient and the type of surgery performed. Lumbar discectomy and fusion are two commonly performed procedures that differ significantly in recovery time. They will be discussed here.

Lumbar discectomy serves to decompress the neural structures by removing the herniated component of the nucleus pulposus. A small laminotomy provides access to the spinal canal, and there is usually very little trauma to the paraspinal musculature during the approach. Patients recover fairly quickly, and can begin physical therapy approximately 4 weeks postoperatively. Spine Universe, an online patient resource written by physicians, presents the opinions of a few spinal surgeons who work with golfers [101,102]. Contributing physicians allow their patients to start swinging a club between 6 and 12 weeks after surgery, depending on their level of skill and progress with low back flexibility and strength training. One small animal study showed that iatrogenic canine lumbar anulus lesions took 12 weeks to stabilize histologically, with mesothelial cells lining the inner lesion and a fibrous tissue cap covering the peripheral portion [103]. A more recent study measured the strength of a lumbar disc after an iatrogenic lesion over a period of 6 weeks in sheep [104]. This study cited a previously substantiated method that used maximum attainable intradiscal pressures as a measure of disc strength [105]. At 2 weeks, injured discs reached only 15% to 35% of control strength, depending on the type of lesion. At 6 weeks, injured discs reached only 60% to 65% of control strength. Although disc strength most likely never reached 100% of control strength after injury, it would have been ideal if this study had been carried out over a total of 12 weeks. Extrapolating animal data to humans is a limiting factor, but it seems as though 6 weeks may be a gray area for disc recovery, and 12 weeks may be required for reliable fibrocartilagenous repair to occur. Indeed, connective tissue healing takes time, and some surgeons advocate waiting at least 12 weeks before starting to swing so that scar tissue may adequately reduce the risk of reherniation or chemical radiculitis from extrusion of nuclear fluid.

Gradual reintroduction to the game is recommended after having completed a strengthening and flexibility routine for the lower back. This reintroduction includes swinging short irons at an easy pace, practicing on the driving range, playing nine holes as a trial before a full round of 18, not taking shots from the sand, angled lies, or deep rough, and walking with a pull cart for exercise instead of riding. Patients should always warm-up and stretch before playing, and they should stop playing for at least 4 weeks if symptoms return.

Lumbar fusion is a more substantial surgery, and paraspinal muscle dissection is more extensive. Patients may require both anterior and posterior approaches to the spine, depending on the surgeon's preference and indications for fusion. In addition, patients require bony healing to occur. Extension bracing is often used for 2 to 3 months after surgery, and activity is limited to walking only. Physical therapy is implemented after radiographic evidence of fusion, and most surgeons interviewed keep their fusion patients from swinging a club until at least 6 to 12 months postoperatively. Once the patient is cleared to resume golfing, the same precautions used for discectomy patients can be applied to fusion patients. Unlike simple discectomy, however, spinal fusion removes all intervertebral support at the pathologic level and redistributes force to the adjacent discs. This is important because adjacent segment degeneration is a known long-term complication of spinal fusion, and golf may serve to accelerate this process.

Conclusions

Perhaps the most important goal to address for low back injury prevention in golf is to dispel common misconceptions about the game. Many people view golf as a benign sport that is not usually associated with injury. They also do not understand the risks that golf poses to the lower back, in addition to other areas of the body. As a result, some individuals attempt to learn the game without proper research or coaching with a United States Golfing Association-certified instructor. People often play without warming up and stretching. In addition, many subscribe to mainstream publications that focus unnecessarily on power and distance.

By studying the biomechanics of the golf swing in relation to the lumbar spine, it is understandable how both acute and chronic injury can occur. Although the human body may not be designed to handle the forces generated by swinging a golf club, there are measures one can take to prevent injury in the lower back when doing so. Strength training with a focus on dynamic lumbar stabilization techniques, rotational flexibility training, assuming a more upright stance, and warming up have all been shown to be beneficial. Although the adoption of a ''classic'' swing style has not been shown to significantly reduce the incidence of LBP, it has been incorporated as a treatment modality into the specific rehabilitation studies identified in this article. When considering this and the biomechanics of the lumbar spine, these therapies and swing modifications are all reasonable recommendations to consider in a patient suffering from golf-associated LBP.

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