Physical Therapist Management of the Golfer

Independent Study Course

Jason M. Stodelle, MSPT, ATC, OCS
Senior Physical Therapist – PGA Tour

CONTINUING PHYSICAL THERAPY EDUCATION

ACADEMY OF
ORTHOPAEDIC
PHYSICAL THERAPY

APTA
American
Physical Therapy
Association

Physical Therapist Management of the Golfer

Guy G. Simoneau, PT, PhD, FAPTA—Editor
Dhinu Jayaseelan, PT, DPT, OCS, FAAOMPT—Associate Editor
Eric Hegedus, PT, DPT—Subject Matter Expert

Cover Illustration by Joseph Kinstler

Dear Colleagues,

I am pleased to welcome you to the Physical Therapist Management of the Golfer monograph written by Jason Stodelle, MSPT, ATC, OCS. This work is part of the Academy of Orthopaedic Physical Therapy Independent Study Course series Physical Therapist Management of Individuals Who Swim, Golf, Throw, and Play Softball.

Jason Stodelle received a bachelor's degree in Health Sciences from the University of Miami in Coral Gables, FL in 1999. He then attended physical therapy school at Washington University in St. Louis, MO, where he received a Master of Science in Physical Therapy in 2001. Upon graduating from physical therapy school, he worked in private practice in the Seattle area (2002-2006), then in Southern California (2006-2008). He then completed a post-professional residency in manual physical therapy and completed the criteria to become an Orthopaedic Clinical Specialist (OCS) in 2008. He is also a certified athletic trainer (ATC). Beginning in 2009, Jason joined the PGA Tour's sports medicine team as a contracted physical therapist. Year 2023 marks his 15th season as a physical therapist with the PGA Tour. His responsibilities with the PGA Tour include traveling as a physical therapist to work with professional golfers at golf tournaments domestically and around the world. Since 2009, he has covered almost 300 tournaments on the PGA Tour, including the major championships and Presidents Cups, and has treated well over 1000 professional golfers at those events. He has had the honor of working as a physical therapist for International Golf Federation at the men's and women's golf events at the last two Summer Olympic Games – Rio de Janeiro in 2016 and Tokyo in 2021. In addition to his work with the PGA Tour, he also treats professional and amateur golfers privately at various golf clubs around Southern California. When he is not on the road, he enjoys working as an orthopedic lab assistant at a local physical therapy school. Jason has also lectured regularly about golf injuries at various academic institutions.

Golf is played by more than 66 million people annually, with female golfers accounting for 24% of total participation. In this monograph, the author first provides an overview of the biomechanics of the golf swing. This is followed by a description of golf-specific injuries and their related evaluation and treatment. The physical examination of the golfer is detailed along with special considerations for the junior, female, and aging golfers. Factors affecting golf performance and injury prevention strategies are also discussed. The monograph is supplemented by extensive figures and videos. The monograph concludes with 3 patient cases, with conditions commonly seen among the golfing population. The first is a 27-year-old professional golfer with low back pain felt primarily at impact and through the finish of the golf swing. The second is a 32-year-old professional golfer with recurrent left hip pain especially at the finish of the golf swing. The final case described the evaluation and treatment of a 19-year-old high-level collegiate golfer with right shoulder pain at the transition point of the golf swing. In each case, the uniqueness of physical therapist care as it relates to golf is highlighted.

My sincere thanks to the author for their contribution to the Physical Therapist Management of Individuals Who Swim, Golf, Throw, and Play Softball series.

Sincerely,

Guy Simoneau, PT, PhD, FAPTA
Editor

TABLE OF CONTENTS

ACRONYM LIST

3D:	three-dimensional
BFR:	blood flow restriction
ECU:	extensor carpi ulnaris
DOMS:	delayed-onset muscle soreness
EMG:	electromyography
ER:	external rotation
FADIR:	flexion, adduction, and internal rotation
FAI:	femoroacetabular impingement
IR:	internal rotation
LBP:	low back pain
LPGA:	Ladies Professional Golfers Association
MRI:	magnetic resonance imaging
OA:	osteoarthritis
PGA:	Professional Golfers Association
PRP:	platelet-rich plasma
ROM:	range of motion
TFCC:	triangular fibrocartilage complex
THA:	total hip arthroplasty
USGA:	United States Golf Association

Opinions expressed by the authors are their own and do not necessarily reflect the view of the Academy of Orthopaedic Physical Therapy. The authors declare no conflict of interest.

The publishers have made every effort to trace the copyright holders for borrowed material. If we have inadvertently overlooked any, we would be willing to correct the situation at the first opportunity.

Course content is not intended for use by participants outside the scope of their license or regulations.

Physical Therapist Management of the Golfer

Jason M. Stodelle, MSPT, ATC, OCS
Senior Physical Therapist – PGA Tour

ABSTRACT

This monograph covers the physical therapist's role in working with golfers of all skill levels. It discusses the biomechanics of the golf swing, golf-specific epidemiology, the most common injuries the physical therapist can expect to encounter when working with the golfer, and evidence-based treatment techniques to address those injuries. The monograph includes a discussion on the physical examination of the golfer. It also reviews the latest methods related to improving performance on the golf course and, finally, ways to mitigate the risk of injury while playing golf. Several photos and videos of the golf swing, examination procedures, and golf-specific interventions are included to enhance the reader's experience. Three real patient examples are presented, each involving a different body region and representing a specific condition commonly seen amongst the golfing population. The first is a 27-year-old professional golfer complaining of low back pain. The second is a 32-year-old professional golfer complaining of pain in his left hip. The last case involves a 19-year-old high-level collegiate golfer complaining of pain in his right shoulder. Each case will include the key history/interview information, examination findings, interventions, and outcomes to guide clinical reasoning and decision-making processes.

Key Words: epidemiology, golf biomechanics, injuries, performance, treatment

LEARNING OBJECTIVES

Upon completion of this monograph, the course participant will be able to:

1. Discuss the epidemiology of golfing injuries and the physical therapist's role in the evaluation and management of golfers.
2. Recognize the terminology required to communicate effectively about the performance and rehabilitation of golfers.
3. Identify the basic biomechanical components of the golf swing.
4. Describe the most common injuries found in golfers, including their underlying causes and contributing factors.
5. Identify the most important components of the physical examination of the golfer.
6. Develop effective treatment programs to address the most common golf-related musculoskeletal injuries.
7. Develop effective golf fitness programs to enhance performance on the golf course and reduce the risk of injury.

INTRODUCTION

Golf has truly arrived as a global sport. Enjoyed by more than 66.6 million people annually, golf is currently played in 209 countries worldwide.[1] After nearly a decade of stagnant growth, golf saw a significant increase in participants, and the total number of rounds played in 2020. Tiger Woods said in his 2022 Open Championship press conference at St. Andrews, "We're in the greatest golf boom ever right now because of COVID. It's allowed us as a sport to get outside and … do some physical activity and get out of the house..." For much of 2020, golf was one of the *only* activities in which individuals could participate outside. This resulted in more than 500 million rounds of golf being played by nearly 25 million Americans (or about 8% of the total population) that year. The total number of rounds represented an increase of 60 million rounds (or 14%) compared to 2019, despite losing several months of play in early 2020 due to COVID-related shutdowns. A record 3 million Americans played golf for the very first time in 2020 (compared to 1.5 million new players in 2011). Female golfers accounted for approximately 24% of the on-course participants in 2020 (up from 20% in 2014). The total number of junior players (those under 18 years old) was relatively steady in 2020 compared to previous years; however, the number of female junior players accounted for 34% of the total, compared to just 15% in 2000.[2] Additionally, another 12.1 million people played in off-golf course venues such as driving ranges, golf simulators, or golf entertainment facilities. Contributing to this growth is the fact that golf is no longer viewed as a sport only to be played by a select few: of the nearly 39,000 golf courses worldwide, more than 75% are open to the public.[3]

Including the game of golf in the last two Summer Olympic Games in 2016 and 2020 (2021) has also contributed to this recent increase in global popularity (**Figure 1**). The International Olympic Committee reintroduced the game in Rio de Janeiro after a 110-year absence. The best male and

Figure 1. The Olympic Rings in Tokyo

female golfers in the world now compete for gold medals on the biggest stage in sports every 4 years. American golfers Xander Schauffele and Nelly Korda won gold medals in the men's and women's events, respectively, at the Tokyo Games in 2021.

Golf is generally classified as a low- to moderate-intensity exercise mode. Evans and Tuttle[4] describe it as "a sport that involves relatively long duration of low-intensity activity interspersed with short bursts of high-intensity activity." As such, golf has been found to provide several health benefits, including improvements in cardiovascular fitness, balance, musculoskeletal strength, and mental health.[5] In 2002, Dobrosielski et al[6] found walking a round of golf to be an effective mode of exercise for individuals with a history of heart disease to improve work capacity and lower resting heart rate.

Many factors can affect how "healthy" a round of golf can be for the participant. For example, walking the golf course versus riding in a cart significantly affects the energy expended during the round. A 2011 study found that golfers carrying their bags over 18 holes walked an average of 5.4 miles (11,200 steps) while burning 1202 kcal and recording an average heart rate of 103 beats per minute (approximately 55% of the golfer's maximum heart rate). This level of activity, the authors concluded, meets "the guidelines set forth by the American College of Sports Medicine for promoting a healthy lifestyle that can lower the risk for hypokinetic diseases in inactive adults."[7] Wolkodoff[8] found that playing golf while using a golf cart burned 411 kcal per 9 holes, while walking with a caddie burned 613 kcal per 9 holes. Those who carried their bag burned 720 kcal over 9 holes.

Other factors that affect energy expenditure while playing golf include sex differences, elevation changes of the golf course, and the layout of the golf course itself – playing on a flatter golf course may result in fewer calories burned than playing on a hillier course. Some golf courses are spread out over a larger area, resulting in greater distance walked over 9 or 18 holes. A study on differences in energy expenditure related to sex found that male golfers burned 926 kcal while females burned 556 kcal.[9] Interestingly, skill level does not affect caloric expenditure as highly skilled low-handicap golfers appear to burn the same number of calories as their high-handicap counterparts.[10,11]

Playing golf 2 to 3 times per week has been found to improve body composition (reduce body weight and decrease waist circumference), improve trunk muscle endurance, and lower HDL cholesterol levels in previously sedentary male golfers.[12] Gao et al[13] found that golfers score significantly higher on two separate balance tests than those in a non-golfing control group, demonstrating better balance control and confidence. Murray et al[5] reported that playing "golf is associated with improving known risk factors for cardiovascular disease, including physical inactivity, blood lipid and insulin-glucose levels, body composition, and aerobic fitness." Brown et al[14] found that older adults who played golf regularly demonstrated improved respiratory function. Finally, a 2009 study in Sweden found a correlation between golf and improved longevity. The authors concluded that golfers had, on average, a 40% lower mortality rate than their non-golfing counterparts, corresponding to an increase in life expectancy of nearly 5 years.[15] Indeed, inactivity as part of a sedentary lifestyle is a global problem that may be counteracted by regular participation in the game of golf.

The Physical Therapist's Role in Golf

As experts in identifying and treating dysfunctional movement, physical therapists are ideally positioned to work with the golfing population. As will be discussed throughout this monograph, musculoskeletal injuries in golf are common, and golfers of all skill levels routinely seek help from physical therapists.[16] All major professional golf tours around the globe employ physical therapists to look after their athletes. These include, among others, the Professional Golfers Association (PGA) and Ladies Professional Golfers Association (LPGA) tours in the United States, the European Tour (now called the DP World Tour) and Ladies European Tour, the Asian and Japan Tours, and the Australian Tour. Physical therapists working in these settings travel to their tour's respective tournaments to evaluate and treat injured professional golfers, assist them with pre- and post-round treatment programs, and help improve performance by designing and implementing conditioning programs. Many of these tours have mobile treatment facilities transported to the tournaments, which the physical therapists and players use daily (**Figure 2**).

Physical therapists working in private practice in the outpatient orthopedic setting are frequently asked to work with injured golfers – both amateur and professional – in their facilities. Specialized clinics are often equipped with hitting bays and cameras for video analysis that can be used to evaluate

Figure 2. Professional Golfers Association (PGA) Tour's Player Performance Center

the golfer's swing mechanics and how those mechanics might relate to specific injuries. Many private golf clubs provide space in their facility for contracted physical therapists to evaluate and treat golf-related injuries sustained by their members. The physical therapist may be a valuable resource to the club and its members in this setting.

Among the fastest-growing areas of participation in golf over the past decade have been what are collectively referred to as golf entertainment facilities. These centers provide a fun, relatively non-competitive setting for participants to enjoy the game. Physical therapists may also provide movement screens and basic exercise programs for interested parties in these facilities. Junior golf programs such as First Tee™ provide instruction and structured programs for children interested in learning the game of golf. Physical therapists in this setting may introduce these young golfers to the idea of using exercise to improve physical performance and decrease the risk of injury.

Finally, much work has been done recently by various organizations, including the United States Golf Association (USGA) and the American Disabled Golfers Association, to assist individuals with physical disabilities to participate in golf. In 2022, the USGA held its inaugural U.S. Adaptive Open, featuring 96 golfers from 11 countries competing in different impairment-related categories (physical, cognitive, and sensory-related). Golfers with spinal cord injuries, amputated limbs, blindness, and other significant disabilities participated in the tournament. Physical therapists are uniquely equipped to work with these incredible athletes to identify permanent physical barriers and create beneficial adaptations that positively affect the individual's ability to swing the golf club.

Regardless of the setting, physical therapists who choose to work with golfers must have a thorough understanding of golf swing biomechanics, the most common injuries they might encounter in this population, and how to effectively treat these injuries so that the golfers with whom they work may return to the golf course playing their best. These topics will be discussed in detail throughout this monograph.

The monograph will begin with a discussion of the important golf-specific nomenclature with which the physical therapist must be familiar. A thorough examination of proper golf swing biomechanics, including the kinematic sequence of the downswing, will follow this discussion. Next, the incidence and prevalence of golf-related injuries and effective treatment strategies for these injuries will be discussed. Then, a description of the physical examination of the golfer, including abnormal findings and patterns commonly observed in the avid golfing population, will be provided. Following that is a discussion of current concepts in golf fitness and considerations for special golfing populations, including the junior golfer, the female golfer, and the aging golfer. Finally, 3 case studies are presented to coalesce all covered concepts. I sincerely appreciate your commitment to obtaining a better understanding of golf as it relates to the physical therapist, and I hope you enjoy this course!

Important Terminology

For physical therapists, understanding golf-specific terminology and concepts is essential for 3 primary reasons: (1) it demonstrates to the golfer some level of expertise in golf, (2) it facilitates communication with the golfer, and (3) it facilitates communication with a golfer's teaching professional or swing coach.

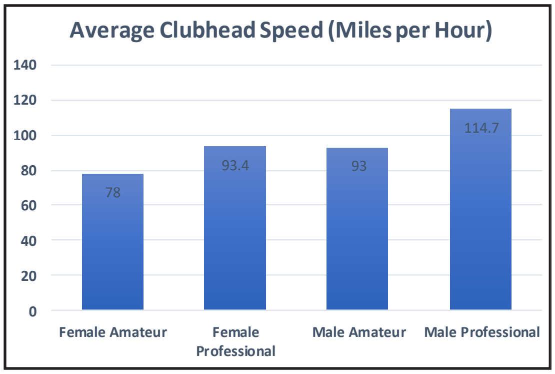
The *swing plane* refers to the club's path throughout the golf swing. The swing plane occurs 3-dimensionally in the frontal, sagittal, and transverse planes and will be discussed in more detail later in this monograph. The *target line* is drawn from the golf ball to the flag stick or point in the fairway the golfer is aiming at. The *clubface* refers to the front surface of the golf club that contacts the golf ball. *Ball flight* refers to the golf ball's trajectory when it leaves the clubface. Ball flight can be straight, or it can veer left or right. For a right-handed golfer, a ball flight that veers unintentionally left is called a *pull* or *hook*, while a ball flight traveling unintentionally to the right is called a *push* or *slice*. More skilled golfers often find it necessary to intentionally curve the golf ball's trajectory around an obstacle to obtain the desired result. For a right-handed golfer, a *cut* is a shot in which the ball begins left of the target and curves to the right at the target; a *draw* starts right and curves to the left at the target.

Ball flight is determined primarily by the angle at which the clubface strikes the golf ball in the frontal plane, the loft of the club being used, and the swing plane in which the club travels. A square clubface is generally ideal for producing a straight ball flight. If the club strikes the ball with the toe ahead of the heel, the clubface is considered *closed,* which usually flights the ball lower and left of the target. Conversely, if the heel is in front of the toe at the ball strike, the clubface is considered *open,* which generally flights the ball higher and right of the target. The *loft* of the golf club refers to the angle of the clubface relative to the ground and is the most important determinant as to how high or low the golf ball's trajectory is as it leaves the clubface (known as the *launch angle*). Shorter clubs have a greater loft, resulting in a higher launch angle. The shortest wedges have loft angles of 60° or more; drivers' loft angles generally range from 7.5 to 11°. On the downswing, the swing plane is often described as *inside* or *outside*. A downswing that approaches the ball from the inside (in which the golfer's hands are closer to their body) tends to produce a counterclockwise rotation of the golf ball in the transverse plane, resulting in a ball flight to the left (hook). Conversely, a downswing that approaches the ball from the outside (where the hands are further away from the body) causes the ball to rotate clockwise and, consequently, curve to the right (slice).

Spine angle is an important concept that describes a golfer's posture at set-up and throughout the golf swing. It refers to the angle of the golfer's spine relative to the ground in the sagittal plane and is also influenced by the flexion angle in both hips (**Figure 3**). The spine angle will differ depending on

Figure 3. Spine Angle

Figure 4. Average Clubhead Speed



the golf club's length. The angle is more acute (greater flexion) when hitting shorter clubs like wedges and irons; the angle is greater (more upright posture) when swinging the driver.[17] Ideally, a golfer's spine angle should remain relatively consistent throughout the golf swing. A significant change in spine angle during the swing will likely result in decreased performance with lost clubhead speed and inconsistent contact with the golf ball and may leave the golfer more prone to pain or injury.

An important parameter that most competitive golfers keep close track of is *clubhead speed*. This is a measure of angular velocity at the point of impact between the clubface and the golf ball. While other factors affect the total distance the golf ball will travel, increased clubhead speed produces longer ball flight and, thus, is an important performance measurement. Balance, lower body strength, and flexibility in the hips and torso are all trainable factors reported to affect clubhead speed positively.[18] It should be noted that clubhead speed is greater with longer clubs: swinging the driver produces the greatest clubhead speed. For perspective, professional golfers on the PGA Tour in 2021 averaged around 114.7 miles per hour of clubhead speed, with the longer hitters exceeding 125 miles per hour. Professional female golfers on the LPGA average approximately 93.4 miles per hour. Amateur male golfers average about 93 miles per hour, while their female counterparts average about 78 miles per hour (**Figure 4**). A negative correlation exists among professional golfers between age and clubhead speed. As a golfer gets older, their golf swing may become less efficient. Perhaps not surprisingly, professional players under 30 demonstrate significantly higher clubhead speed.[19]

Ball speed refers to the velocity of the golf ball as it leaves the clubface. Ball speed is primarily affected by clubhead speed and the equipment being used. The type of material used in the golf ball, the club head, and the club shaft may all affect ball speed. Old clubs with wooden clubfaces produce a lower ball speed than modern clubs manufactured with the latest metal alloys. The ratio of ball speed to clubhead speed is called the *smash factor*. Ideally, ball speed will be approximately 1.5 times greater than clubhead speed (smash factor = 1.5). Smash factor of less than 1.5 may be attributed to faulty or mismatched equipment. For example, a cracked clubface, club shafts that are too stiff, or golf balls that are too dense for the golfer may cause a lower smash factor.

The total distance the ball travels is primarily the result of ball speed but is also affected by spin rate, launch angle, and other factors beyond this monograph's scope. For the 2021 season, tour professional Bryson DeChambeau led the PGA Tour in average driving distance at 323.7 yards, and Rory McIlroy was second at 319.3 yards. Anne van Dam led the LPGA in 2021 with an average driving distance of 290.8 yards. Interestingly, an unpublished analysis by the author of players on the PGA Tour seems to demonstrate that those who average the greatest driving distance earn more prize money than those who are statistically superior putters. Thus, the adage, "Drive for show, putt for dough," may be outdated for this demographic!

BIOMECHANICS OF THE GOLF SWING

The golf swing (**Video 1**) is "a complex and asymmetrical movement that places an emphasis on restricting pelvic turn while increasing thorax rotation during the backswing to generate higher clubhead speeds at impact."[20] As such, it can be analyzed, like most complex movements, by breaking it down into points and phases. The components of the golf swing include set-up, takeaway/back swing, transition, downswing, impact, follow-through, and finish. Set-up, transition, impact, and finish are considered the points in the golf swing, while the backswing, downswing, and follow-through are phases. Many different approaches and techniques have been used to swing the golf club. The discussion of the golf swing in this monograph section will focus on what experts would consider the most "conventional" method. The reader will find a table at the end of this section that summarizes the following discussion (**Table 1**).

Video 1: Golf Swing
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

Table 1. Golf Swing Biomechanics (Right-Handed Golfer)

	Swing Phase						
Body Region	Set-up	Backswing	Transition	Downswing	Impact	Follow-through	Finish
Trail Hip	Neutral rotation; 30° flexion	IR	**Max IR**	Moving toward ER	Moving into ER	Moving into ER	**Max ER, extension**
Lead Hip	Neutral rotation; 30° flexion	ER	**Max ER**	Moving toward IR	Moving into IR	Moving into IR	**Max IR, extension**
Pelvis	Neutral to slight anterior tilt	Increasing anterior tilt	**Max anterior tilt**	Initiate posterior tilt	**Max posterior tilt**	Moving toward anterior tilt	**Max anterior tilt**
Lumbar Spine	Neutral rotation, SB; slight extension	R rotation; L SB	**Max R rotation; Max L SB**	Moving toward L rotation, R SB, flexion	Moving toward L rotation, R SB, extension	**Moving toward L rotation, R SB, extension**	**Max L rotation, Max R SB, Max extension**
Thoracic Spine	Neutral	Moving toward R rotation	**Max R rotation**	Moving toward L rotation	Slight L rotation	**Moving toward L rotation**	**Max L rotation**
Cervical Spine	Neutral	L rotation	**Max L rotation**	Moving toward R rotation	**Max R rotation**	Moving toward neutral	Neutral
Trail Shoulder	Neutral rotation; slight adduction	Horizontal abduction; ER	**Max abduction/ ER**	Moving toward horizontal adduction, IR	Moving toward horizontal adduction, IR	Moving toward horizontal adduction, IR	**Max horizontal adduction/IR**
Lead Shoulder	Neutral rotation; slight adduction	Horizontal adduction; IR	**Max adduction/ IR**	Moving toward horizontal abduction, ER	Moving toward horizontal abduction, ER	Moving toward horizontal abduction, ER	**Max abduction/ ER**

Items in bold indicate points in the golf swing where the particular region reaches its "maximum" range of motion and therefore may be a potential source of pain.

Abbreviations: ER, external rotation; IR, internal rotation; L, left; Max, maximum; R, right; SB, side bending

When analyzing the golf swing, the physical therapist needs to view the golfer from two angles: down-the-line, where the physical therapist (or camera) is positioned directly behind the golfer, looking down the target line, and face-on, where the physical therapist (or camera) is positioned on the opposite side of the golf ball, facing the golfer. When describing aspects of the golf swing, one can identify issues related to the golfer's *lead side* or *trail side*. For example, a deficit in lead hip internal rotation (IR) range of motion (ROM) has been linked to an increased incidence of lower back pain in professional golfers.[21] This finding will be discussed in greater detail later in this monograph. The side of the golfer closest to the target is called the lead side. The side of the golfer facing away from the target is called the trail side. For a right-handed golfer, the lead side is their left; the trail side is their right.

Set-up

A golfer sets up to the golf ball with their lead side pointing toward the target (**Figure 5**). Their feet are approximately shoulder-width apart, with weight evenly distributed over both lower extremities and the toes pointed perpendicular to the target line. The ankles are slightly dorsiflexed, and the knees are slightly flexed. The hips are slightly flexed and in neutral rotation in the transverse plane. When swinging longer clubs, the hip flexion is somewhat less, resulting in a more upright stance in the sagittal lane. Ideally, the thoracolumbar spine is in neutral rotation in the transverse plane. It should be noted that the amount of thoracolumbar spine rotation available may be less when golfers set up with greater thoracic flexion (sometimes called "C-posture"). This limited rotation ROM may predispose these golfers to low back pain (LBP) later in the golf swing compared to those who set up in a more neutral thoracic posture,[22] a finding that will be discussed in greater detail later in this monograph. There is typically slight lateral flexion in the thoracolumbar spine away from the target, primarily due to how the golf club is gripped with the trail hand lower on the grip. This lateral flexion is sometimes referred to as *spinal tilt*. The cervical spine is slightly flexed in the sagittal plane and is in neutral rotation and lateral flexion. The upper extremities should hang in a relaxed position perpendicular to the ground, with the shoulders slightly flexed relative to the torso. Both scapulae are neutrally aligned or slightly protracted, with the trail scapula somewhat depressed due to the grip of the club, with the trail hand being lower on the club than the lead hand. The elbows are slightly flexed, while the forearms are in neutral pronation/supination. Both wrists are in slight radial deviation and neutral flexion/extension. Although these parameters are generally agreed upon as "ideal," variability has been documented in the set-up of high-level and low-level golfers. These variations, it is suggested, will likely result in compensations elsewhere in the golf swing.[23]

Backswing

As the golfer takes the golf club back, their weight gradually shifts onto the trail lower extremity (**Figure 6**). Swing coaches often teach their golfers to feel most of their weight shifting onto the medial aspect of the trail foot, under the first ray. As the club moves away from the target, the pelvis rotates over the hips, resulting in relative IR of the trail hip and external rotation (ER) of the lead hip. The hips should remain in relatively neutral abduction/adduction in the frontal plane. Too much lateral movement away from the target (often referred to as *swaying*) during the backswing may cause inefficiencies, resulting in decreased clubhead speed and inconsistent ball striking.

Approximately halfway into the backswing, the pelvis and hips stop rotating while the torso and shoulders continue to rotate away from the target.[24] This separation creates an elastic coiling effect between the pelvis and torso and is commonly referred to in golf swing parlance as *X-factor*. Compared to

Figure 5. Set-up

Figure 6. Backswing

other biomechanical variables, the X-factor has been reported to be the single greatest variable affecting clubhead speed.[25] The thoracolumbar spine rotates toward the trail lower extremity and laterally flexes toward the golf ball (for a right-handed golfer, that is rotation to the right and lateral flexion to the left). Golfers with reported LBP have been found to demonstrate greater lumbar lateral flexion toward the lead side during the backswing.[22]

It is important to note that the spine angle should remain relatively consistent throughout the golf swing. Low-level amateur golfers have difficulty maintaining a constant spine angle through the takeaway, resulting in relative hip extension and "standing up" at the top of the backswing. Ideally, the golfer keeps their eye on the ball throughout the backswing and keeps the head stable. The stable head results in the torso rotating underneath the head and the cervical spine moving into relative rotation toward the lead shoulder. The trail shoulder abducts and externally rotates, while the lead shoulder horizontally adducts and internally rotates. As the club moves away from the target, the lead scapula protracts away from the spine while the trail scapula retracts.[26] The lead elbow stays relatively extended throughout the backswing. Approximately halfway into the backswing, the trail elbow begins to flex. Supination occurs in the trail forearm while the lead forearm pronates. Both wrists radially deviate with the trail wrist extending, resulting in cocking of the golf club.

The extent to which the club is brought back before it transitions varies greatly among highly skilled and high-handicap golfers. As the golfer ages, degenerative changes in the thoracolumbar spine and/or hips may result in hypomobility in these areas and cause a shortened backswing and other dysfunctional compensations that will be discussed in more detail later in this monograph. Bulbulian and colleagues[27] performed an electromyographic (EMG) analysis on several golfers who swung a golf club with an abbreviated and normal backswing. They concluded that shortening the backswing could reduce the risk of a back injury but might increase the risk of a shoulder injury. Regarding performance, a shorter backswing might make it challenging to generate the same clubhead speed. However, some of the world's top golfers have shown it is possible to generate above average clubhead speed even with an abbreviated backswing.

Transition

The transition is the point at which the backswing is concluded, the moment before the golf club changes direction and begins its downward move toward the ball (**Figure 7**). At this point, most of the golfer's weight has shifted onto the medial right foot of the trail lower extremity. Both hips remain slightly flexed while the lead hip is externally rotated, and the trail hip is internally rotated. It should be noted here that, historically, many high-level golfers previously demonstrated lead hip adduction, resulting in the lead knee sliding behind the golf ball. However, most modern players today tend to keep their lead knee over the lead foot. The pelvis and thoracic spine are fully rotated away from the target, while the lumbar spine is laterally flexed toward the golf ball. In terms of flexion/extension, lumbar spine alignment should change minimally from the angle demonstrated at set-up. A line drawn between the two shoulders (acromion process to acromion process) should point behind the golf ball when viewed from the front. This rotation of the shoulders behind the golf ball indicates that the golfer's X-factor (the separation in rotation between the pelvis and torso) is at its greatest. At the transition, the cervical spine may reach 90° of rotation toward the lead shoulder. The lead shoulder reaches end-range horizontal adduction and IR, while the trail shoulder reaches its greatest amount of abduction and ER. The lead elbow stays close to fully extended while the trail elbow flexes up to 90°. Both wrists are fully radially deviated at the transition, with the trail wrist extended in the cocked position.

Figure 7. Transition

Downswing and the Kinematic Sequence

What initiates the downswing is a controversial topic in many top golf instruction circles. Some swing coaches prefer their students to start the downward movement of the golf club by first shifting their weight onto their lead lower extremity. Some prefer the move downward to be initiated by a posterior tilting of the pelvis (sometimes called "tucking in"). In their EMG study, Bechler et al[28] found that the downswing was initiated by pelvic rotation caused by contraction of the trail hip extensors and abductors and the lead hip adductor magnus muscle.

As the club begins its downward movement toward the golf ball, a kinematic reversal happens in each of the joints discussed with the backswing as the body "unwinds" in preparation for striking the golf ball (**Figure 8**). As weight shifts onto the lead

Figure 8. Downswing

lower extremity, the lead hip begins to move into relative IR while the trail hip externally rotates. The torso begins to move from left lateral flexion and right rotation back toward neutral alignment, then into right lateral flexion and left rotation as the clubface approaches the golf ball. Some tour professionals have demonstrated a total arc upward of 100° of thoracolumbar lateral flexion motion from left lateral flexion at the transition to right lateral flexion at impact. This movement occurs in less than one second and has been hypothesized as a potential source of injury in high-level golfers.[22] The lead scapula retracts toward the spine as the lead shoulder horizontally abducts and externally rotates. Conversely, the trail scapula protracts as the trail shoulder internally rotates and horizontally adducts. The lead elbow should remain in relative extension. Lead elbow flexion occurring before impact with the ball is commonly referred to as "chicken-winging" and will be discussed later in this monograph. The trail elbow begins to extend as the club travels downward. The lead forearm supinates, and the trail forearm pronates toward neutral. Both wrists begin to move out of radial deviation ("uncocking") approximately halfway into the downswing. Still, they should not reach neutral deviation until the clubface impacts the golf ball (or shortly thereafter). The resulting *lag* between the golf club and the wrists enables a greater transfer of force through the clubface at impact.[29] Premature wrist ulnar deviation is another common fault resulting in "casting" or "scooping" that causes the clubhead to reach its peak speed before impacting the golf ball.

Many sports-related movements and other functional endeavors have been studied extensively with three-dimensional (3D) analysis to determine the most ideal and efficient kinematic sequence for the movement. Golf is no different.[20,30-40] Any examination of the golf swing's proper kinematic sequence refers explicitly to the downswing. Hence, it will be discussed in this section.

When a golfer sees a teaching professional for a 3D analysis of their golf swing, markers are placed on various bony landmarks on the body. The relative location between the markers produces a 3D image of any moment during the swing, which allows for the measurement of angular velocity between segments when analyzing successive video frames. Typically, markers are placed at the femoral lateral epicondyles, greater trochanters, the spinous process of C7, acromion processes, humeral lateral epicondyles, ulnar styloid processes, and the clubhead. However, the available literature demonstrates great variability in how many markers are used and how the sequence is recorded. For example, Langdown et al[41] placed 30 markers on their participants' bodies and golf club to collect their data, while Gryc et al[37] used only 14 markers. Regardless of the specific technique used, the primary purpose of this type of analysis is to create a 3D picture of the golf swing and give the golfer insight into areas that may need improvement.

The 3 most important metrics gleaned from this analysis are the peak angular velocity and the rate and timing of deceleration of the various segments. The goal of the downswing, as described by Hume et al,[32] is the "conservation of angular momentum" as the body unwinds. It has been shown that higher-level players demonstrate both greater peak angular velocity and a greater rate of deceleration in each segment than their higher-handicap counterparts. Furthermore, higher-level players demonstrate greater and more consistent peak angular velocities in the various segments, whereas lower-level players demonstrate lower angular velocities with much greater variability.[42] Deceleration during the downswing should happen from the ground up. The pelvis decelerates first, followed by the torso, then the arms. This rapid deceleration is believed to result in a more efficient energy transfer through the kinetic chain, ultimately resulting in peak angular velocity in the clubhead at the point of impact.

Some swing coaches refer to a golfer's "tight" kinematic sequence, meaning that each segment decelerates quickly and in the proper order. The result is a highly efficient, seemingly effortless swing that results in tremendous clubhead speed at impact. Many tour professionals prefer to have video analysis of their golf swing performed at the beginning of the season or when they are playing well. This gives them a "baseline" to compare to subsequent analyses. Disruptions to the kinematic sequence due to injury or fatigue can be identified via 3D video analysis. For example, an injury to the lumbar spine may result in reduced peak angular velocity at the pelvis and a slower rate of deceleration of the pelvis in the downswing.[42]

Impact

The point at which the clubface strikes the golf ball is referred to as impact (**Figure 9**). As has been discussed in this monograph thus far, there tends to be great variation in most aspects of the golf swing. However, most high-level golfers demonstrate little variability at impact. In fact, golf legend Jack Nicklaus once said, "We may all get to impact a little differently, but *at* impact we're all the same – and impact is the bit that

Figure 9. Impact

matters." The golfer's primary goal at impact is to deliver a square clubface to the golf ball. An open clubface at impact may result in a slice or cut (movement of the ball to the right for a right-handed golfer). A closed clubface at impact may result in a hook or draw (movement of the ball to the left for a right-handed golfer). At impact, most of the golfer's body weight has shifted onto the lead lower extremity with the lead ankle stable and in neutral pronation/supination. The lead knee is extended while the trail knee flexes slightly. The hip rotation that began as part of the "unwinding" in the downswing continues through impact. When the clubface strikes the golf ball, the lead hip has gone past neutral rotation and has begun moving into IR while the trail hip moves into ER. The combination of lead hip IR and trail hip ER results in pelvis rotation past neutral and toward the target line at impact. The thoracolumbar spine continues its rotation toward the target line – in the case of the right-handed golfer, that is, left rotation of the thoracolumbar spine – and lateral flexion toward the golf ball (right lateral flexion for the right-handed golfer). The cervical spine is now in relative right rotation as the torso continues its rotation beneath the stable head toward the target. Because the arms and clubhead lag behind the torso on the downswing, the lead shoulder is slightly adducted and internally rotated at impact. The trail shoulder adducts to the side of the torso as it continues to rotate internally. The lead elbow should remain fully extended through impact while the trail elbow remains slightly flexed. The lead forearm remains pronated, and the trail forearm remains supinated. The "uncocking" of the wrists results in the move toward ulnar deviation but both wrists should still be slightly deviated radially at impact.

Follow-through

After the golf ball is struck, the body continues its rotation toward the target as it decelerates into the follow-through (**Figure 10**). Most of the golfer's body weight remains shifted over the lead lower extremity. The lead ankle inverts, and the foot supinates. At the same time, the trail foot pronates while the trail ankle everts and plantar flexes as the trail calcaneus leaves the ground. The lead hip begins to extend and continues to rotate internally as the torso rotates over the lead lower extremity. In contrast, the trail hip extends and continues its move into relative ER. However, because of the trail ankle plantar flexion in the follow-through, the trail hip ER is not as great as the lead hip IR. Therefore, ROM restrictions in trail hip ER may not be as problematic regarding injury or performance. The thoracolumbar spine continues its path into rotation toward the target line and begins a move back toward neutral lateral flexion as it approaches the finish. After impact, the cervical spine follows the ball and begins to rotate toward the target. The lead shoulder horizontally abducts and externally rotates as the lead elbow begins to flex. The trail shoulder horizontally adducts across the body and internally rotates. Trail elbow flexion happens slightly later in the follow-through. Both wrists move past neutral toward ulnar deviation as the golf swing progresses through the follow-through.

Finish

The finish is the final point of the golf swing (**Figure 11**). Here, the lead ankle is slightly inverted while the trail ankle is plantar flexed. The lead knee remains fully extended, and the trail knee is slightly flexed. Both hips are near neutral flexion/extension. The lead hip reaches its greatest amount of IR while the trail hip rotates externally. This results in the rotation of the pelvis toward the target line. Limited lead hip IR ROM at this point may cause undue stress (and possibly pain) in the lower back of professional golfers[21] and amateur golfers.[43] The lumbar spine has returned to neutral lateral flexion and may be slightly extended. During the follow-through, the torso continues

Figure 10. Follow-through

Figure 11. Finish

to rotate past the target line. At the finish, the golfer's chest ideally points past the target line (for a right-handed golfer, that is left of the target), indicating rotation of the thoracic spine well past neutral. The lead shoulder reaches its greatest amount of horizontal abduction and ER, while the trail shoulder is internally rotated and fully adducted horizontally across the golfer's chest. Both elbows flex, and the wrists radially deviate as the golfer "wraps" the club around the back of their shoulders.

EPIDEMIOLOGY OF INJURIES IN GOLF

The golf swing, while not as ballistic of a movement as those required in other sports, still can result in injury to those who play the game. Haddas et al[44] recently described the golf swing as "the sudden explosion of rotation in a flexed posture repeated several hundred times per day [that] exposes the lumbar spine to significant compression, anterior-posterior shearing, torsion, and lateral bending forces…."(p—) Indeed, the lumbar spine is the most common site of injury, but other body regions are also frequently injured. Several investigations into the incidence of injury in golf have been published. Here, I will discuss the most significant of those studies and some of the data from my experience in treating injuries sustained by professional golfers on the PGA Tour.

Current research suggests an annual injury rate of between 15.8 and 40.9 per 100 golfers who play at the amateur level.[5,45] Professional golfers are reportedly injured at a much higher rate (31 to 90% annually), likely due to the increased amount of play and the number of golf swings taken compared to their amateur counterparts.[46,47] Fradkin et al[48] studied 500 high-level female golfers in Australia and found an injury rate of 35.2% over the previous 12 months. More than two-thirds of those injured missed tournaments or practice sessions because of their injury, and 83.7% sought treatment from a healthcare professional (physical therapists were the most common healthcare professional consulted). Investigation into golf-related injuries thus far has focused on two primary causes: overuse and faulty swing mechanics.

Several studies have previously identified overuse (related to the volume of practice and the number of swings) as the most common cause of golf injuries in amateurs and professionals alike.[16,48-50] Pathokinematic swing faults have also been identified as playing a significant role in injuries, particularly in amateur golfers.[50,51] In their retrospective study in 2003, Gosheger et al[49] found that 82.6% of golf-related injuries in both amateur and professional golfers were the result of overuse. Much less common were acute "single trauma events" (for example, an upper extremity injury resulting from the clubhead striking a tree root), accounting for just 17.4% of reported injuries. Like McCarroll,[51] Gosheger et al[49] concluded that faulty swing mechanics affect higher-handicap (less skilled) amateur golfers more frequently than their lower-handicap or professional counterparts. Furthermore, Gosheger et al[49] found that amateurs tend to injure their elbows, back, and shoulders most commonly, while professionals tend to injure their back, wrists, and shoulders. In addition to overuse and faulty swing mechanics, Meira and Brumitt[52] identified a lack of warm-up and poor trunk flexibility and strength as contributing to an increased risk of injury in the golfing population.

GOLF-SPECIFIC INJURIES AND TREATMENT BY BODY REGION

Literature is sparse regarding the prevalence of golf-related injuries by body region, and what is available will be presented in this section. Otherwise, available literature regarding injuries in the general public will be used and related to the golf swing based on the author's experience. According to unpublished data from the PGA Tour, most injury-related interactions between physical therapists and professional golfers are spine-related. About half are related to the lumbar spine; the other half are closely split between the cervical and thoracic spine. Next on the list in terms of frequency of visits are injuries to the hip, elbow/wrist/hand, and shoulder. Therefore, most of the following section will focus on injuries related to these regions. While the physical therapists with the PGA Tour treat golfers with injuries related to the knee, ankle, and foot, these tend to present less often and are typically not golf specific.

Lumbar Spine

All discussions about golf-related musculoskeletal injuries should begin with the spine, and the lumbar region should be at the top of the list. The lumbar spine has been cited as the most frequently injured body region related to golf at the professional and amateur levels.[45,48,53-55] Attempts to predict which golfers are predisposed to LBP have been made with minimal success. For example, it has been reported that body composition[56] and body mass index[57] may be significant predictors of golfers' risk of developing LBP, regardless of skill level. Other causes of back pain may differ between amateurs and professionals, potentially requiring different management approaches. Low back pain in amateur golfers is most frequently attributed to faulty golf swing mechanics.[51] A good starting point when addressing LBP in this group is working closely with a teaching professional to correct the faulty mechanics and ensure properly fitted golf clubs. In contrast, LBP in professional golfers is more often associated with the volume of golf swings taken. While such repetition is an integral part of the professional golfer's daily and weekly routine to maintain an efficient golf swing, it is frequently necessary to alter range sessions and frequency of practice to address LBP in the higher-level golfer effectively.

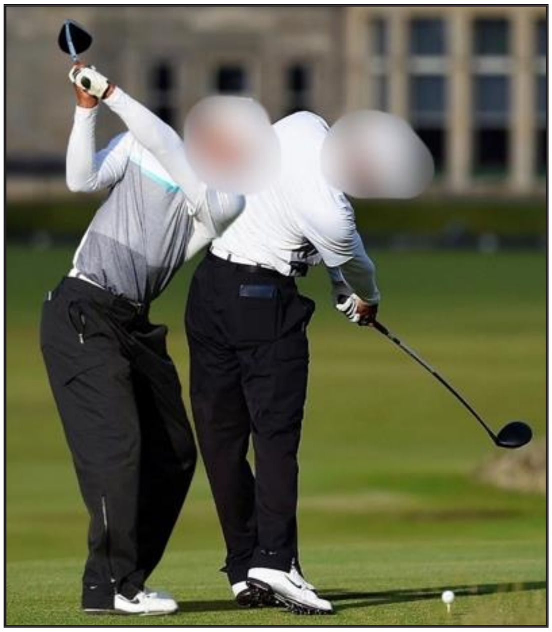
Classifying the types of LBP experienced by golfers is complex and not well-studied. In 2018, Zouzias et al[58] reported that compression loads during the golf swing are as much as 8 times body weight. The forces created during the golf swing and their impact on the lumbar spine have been compared to a football lineman hitting a blocking sled. It has been hypothesized that these excessive forces on the lumbar spine may predispose the golfing population to muscle strains, lumbar disc disease, spondylolysis, and facet joint arthropathy.[59] But, the author of this monograph proposes that identifying the tissue type contributing to the golfer's LBP (disc vs facet vs muscle) may not be as important as identifying and correcting the faulty movement patterns and the underlying physical impairments associated with the golfer's LBP. The more critical impairments include limitations in ROM and strength, reduced muscle length, and reduced motor control. Additionally, monitoring and, if necessary, modifying the training and practice volume may be required to address LBP effectively in the higher-level golfer.

There is evidence that identifying and addressing underlying faulty movement patterns and muscular imbalances may help prevent injuries to the lower back in the golfing population.[60] Although they did not study golfers specifically, Van Dillen et al[61] found that motor skill training in functional activities had a greater effect on people in the general population with LBP (both in the short-term and long-term) compared to strength and flexibility training alone. While further investigation is warranted into the application of this concept to the golfing population, the possibility exists that correcting the faulty or pain-inducing aspects of the golf swing may effectively mitigate the risk of LBP in the golfer. For example, setting up to the golf ball with a rounded thoracolumbar spine has been shown to reduce the amount of available lumbar rotation later in the swing[62] and may contribute to LBP.[22] By training the golfer in a proper set-up position before swinging the golf club and performing functional exercises with an emphasis on maintaining a consistent spine angle, the risk of subsequent LBP may be reduced.

Using Sahrmann's Movement System classification for LBP,[63] the most common golf-related LBP category is lumbar rotation/extension syndrome. The repetitive, single-direction nature of the golf swing likely creates specific segments of the lumbar spine that are relatively hypermobile compared to adjacent regions, including the hips and thoracic spine. Based on my experience, professional golfers' most common segments demonstrating hypermobility are in the lower lumbar area – specifically L4-5 and L5-S1. In the downswing, the combination of left lumbar rotation and right lumbar lateral flexion results in a predictable pain pattern of right-sided LBP in the right-handed golfer. As mentioned in the previous section, the amount of lateral flexion in the thoracolumbar spine from transition to impact is significant and happens quickly (**Figure 12**). This movement from extreme left lateral flexion at the transition to extreme right lateral flexion at impact may create a large amount of compression through the right facet joints of the lower lumbar spine. In my experience, PGA Tour professionals in the prime of their careers routinely demonstrate radiographic evidence of degenerative changes in these segments that are more advanced than anticipated based on their age. These golfers tend to complain of right- (trail-) sided LBP more frequently than left-sided LBP.[54] Attempting to treat the resulting tissue-related impairments without addressing the underlying pathologic movement will most likely not result in long-term improvement in the golfer's LBP.

Accordingly, Evans et al[57] found that asymmetrical performance of the side plank endurance test was a likely predictor of future LBP in young golfers. Typically, the golfer's ability to perform a side plank on the trail side is less than on the lead side. A training program that includes strengthening the trail-side stabilizing musculature to minimize contralateral

Figure 12. Transition From Lumbar Left Lateral Flexion to Right Lateral Flexion



asymmetry in muscle strength may reduce the likelihood that the golfer experiences LBP (**Video 2**). Another study identified the lack of strength in the lumbar extensor musculature as a possible contributing factor to LBP when swinging the golf club.[53] Gluck et al[54] found, in their retrospective study, that strengthening of the transversus abdominus and multifidi muscles should play a part in rehabilitating golfers being treated for lower back pain. There is near-universal agreement among physical therapists and spine surgeons regarding "the importance of the trunk muscles in stabilizing and controlling the loading response [during the weight shift] for maximal power and accuracy in the golfer's swing."[64]

Video 2: Sideplank Progression
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

Trunk strengthening exercises can take many forms. Using a physioball for stability is a favorite of PGA Tour golfers. In **Video 3**, the golfer performs a rhythmic stabilization exercise in which they are asked to maintain neutral alignment in the lumbar spine while performing shoulder movements in the prone position. In **Video 4**, the golfer performs the more advanced modified "Russian Twist," in which the contralateral oblique musculature stabilizes the torso as they rotate with the dumbbell in the opposite direction. Lumbar stability programs often begin with the golfers in the supine position with knees flexed to 90° and feet on the floor, and rightly so. However, when the golfer can sufficiently recruit the desired muscle groups in supine, an effort should be made immediately to advance them into more upright, functional positions. For example, training the golfer to find and maintain neutral lumbopelvic alignment while in the golf set-up posture is more advanced than doing so in the supine position on a mat. The golfer's ability to find and maintain neutral lumbopelvic alignment while in a golf posture is crucial before progressing to dynamic movements such as thoracic rotation exercises. Using kinesiology tape on the lumbar spine may assist the golfer in finding and maintaining neutral lumbopelvic alignment in their set-up. There is evidence of its effectiveness in postural awareness in the non-golfing population with chronic LBP,[65] but additional studies in the golfing population are needed.

Video 3: Rhythmic Stabilization
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

Video 4: Modified Russian Twist
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

Impairments related to the thoracic spine and hips are crucial factors that should not be overlooked when treating the golfer with LBP. There is good evidence that limitations in the mobility of the thoracic spine may contribute to pain in the lumbar spine.[66,67] Likewise, mobility and strength deficits in the hips have been shown to increase the likelihood of LBP in the general population[68] and golfing population alike. In his study of PGA Tour professionals, Vad et al[21] found a correlation between limited mobility in lead hip IR and history of LBP. Addressing deficits in hip extension and rotation mobility should be a central component of the treatment program in the golfer with LBP. This, Sahrmann[63] suggests, will minimize compensatory pelvic and lumbar rotation.

Hip extension deficits may be due to stiffness in the hip capsule or the hip flexors musculature – especially the iliopsoas muscles. Regardless of the cause, hip extension deficits appear to be associated with LBP in the general population.[69] Limitations in hip extension may force the lumbar spine into greater extension – particularly as the golfer moves through impact and into the follow-through. Interventions to improve hip extension ROM should be performed while the lumbar spine remains in neutral alignment and lumbar extension is avoided. Retraining the golfer to extend in the hip, not the lumbar spine, may alleviate extension-biased LBP. It may also potentially improve performance on the golf course and overall function.

It is common practice for the physical therapists on the PGA Tour to address faulty movement patterns and impairments in the thoracic spine and hips before addressing lumbar-specific impairments. In my experience, professional golfers who report LBP while swinging the golf club and who demonstrate weakness or capsular stiffness in the hip often report a reduction in LBP when the hip ROM restriction and weakness are addressed through manual interventions and exercise. One preferred exercise utilized by professional golfers on the PGA Tour is the combination of resisted hip abduction and ipsilateral thoracic rotation (**Video 5**). This exercise likely engages the gluteal musculature, which seems to alleviate pain in the lumbar spine when actively rotating. It is, therefore, a great approach to reintroduce active rotation to the golfer's exercise routine following a lower back injury. This exercise should progress to being performed in a golf posture once the golfer is proficient in the side-lying position. The author of this monograph has found these interventions that provide immediate relief of LBP invaluable for the highest-level golfers playing in the biggest tournaments.

Video 5: Resisted Hip Abduction with Ipsilateral Thoracic Rotation in Sidelying
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

Surgical intervention is an option when conservative management of the golfer's LBP does not lead to satisfactory results. Common surgical interventions for this demographic include lumbar discectomy, laminectomy, or fusion, depending on the structures involved and the severity of the condition. Several professional golfers have returned to play following discectomy and laminectomy surgery. However, only one golfer has returned to play and eventually won multiple tournaments on the PGA Tour following lumbar fusion surgery. A study of amateur golfers who underwent lumbar fusion surgery found that only about 50% returned to playing golf within a year.[70] Rehabilitation and return-to-play parameters vary greatly, depending on the procedure performed.

Post-surgical rehabilitation following lumbar surgery should be a collaborative effort between the golfer, the physical therapist, and the surgeon. Additionally, after postoperative precautions allow it, faulty movement patterns should be addressed early in the rehabilitation process. Focus is placed on retraining rotational movement that occurs through the hips and thoracic spine while maintaining stability in the lumbar spine. Because of the amount of force a professional golfer generates while swinging a golf club, many surgeons recommend that this demographic does not attempt to swing a golf club for a minimum of 12 weeks post lumbar discectomy or laminectomy; and possibly 6-12 months following lumbar fusion.[70] Generally, it is appropriate to begin with chipping and putting for short periods. Returning to full swings with progressively longer clubs occurs only when the golfer can chip and putt pain-free.

Thoracic Spine and Ribs

Considering the frequency with which professional golfers seek treatment from the PGA Tour's physical therapists, golf-related thoracic spine and rib injuries have been under-investigated. According to the PGA Tour data, the frequency with which professional golfers seek treatment for injuries related to the thoracic spine is second only to the lumbar spine. As discussed in previous sections, mobility in the thoracic spine is vital to a smooth, powerful golf swing (**Figure 13**). A stiff, immobile thoracic spine often results in swing changes that may affect performance and cause injury elsewhere. Thoracic dysfunction in the form of decreased mobility and faulty posture has been linked to increased incidence of LBP,[71] neck pain,[72] and shoulder pain[73] in the general population. Anatomically, the thoracic vertebrae and adjacent ribs permit greater rotation ROM than the lumbar vertebrae. Also, high-level golfers tend to demonstrate slightly greater thoracic rotation ROM toward the lead direction. This greater motion is necessary to properly finish the golf swing with the torso rotating well past the target line. Thoracic rotation ROM should be about 45° in each direction when in neutral flexion or extension.[74] However, when the thoracic spine flexes away from neutral, its rotation ability decreases. This concept is important when the golfer addresses the golf ball in their set-up. A rounded thoracic spine at set-up (C-posture) will most likely result in decreased thoracic spine mobility elsewhere in the golf swing.[20] Compensations in other segments, including the cervical spine, shoulder, and lumbar spine, may result in pain syndromes in those segments.

Figure 13. Thoracic Mobility in the Backswing

If limited thoracic spine rotation ROM is detected in either direction, the physical therapist may implement one or more manual techniques to improve motion. Limitations due to muscular stiffness may require soft tissue mobilization. Improving length in the thoracic paraspinal musculature, specifically multifidus and longissimus thoracis, may result in short-term improvement in ROM. Joint mobilization or manipulation may be necessary if the restriction is due to joint-related stiffness. Several joint mobilization and manipulation techniques may be effective for increasing thoracic rotation ROM. Physical therapists on the PGA Tour often use a technique described by Kaltenborn[76] to manipulate the thoracic spine. For this technique, the golfer is side-lying with the fingers interlaced behind the cervical spine. The therapist stands to the side of the golfer and reaches around the golfer's torso to palpate the spinous process of the segment to be manipulated with the mobilizing hand. Using an L-shape hand/index/thumb position, the therapist contacts the spinous process and deviates their wrist ulnarly. Maintaining this point of contact, the therapist rolls the golfer into a supine position using the golfer's elbows as a guide. Using the golfer's elbows, the therapist flexes the thoracic spine to the segment to be manipulated. A low-amplitude thrust is applied through the golfer's elbows in the anterior to posterior direction (**Figure 14**). Alternatively, a wedge may be used in place of the therapist's mobilizing hand. Additionally, if the golfer complains of shoulder pain with this position, the therapist may have the golfer wrap their arms around their torso. The direction of force remains the same. Whether muscular or joint limitations restrict ROM, it is essential to perform active and resisted exercises through the recently gained ROM immediately following the performance of the manual techniques. Active thoracic rotation exercises can be performed from several positions, including quadruped, side-lying, half-kneeling, lunge, standing, and golf posture (**Video 6**).

Video 6: Resisted Thoracic Rotation in Side Lunge
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

Injuries to the ribs and their articulations with the thoracic spine can occur due to swinging the golf club. Rib injuries are more often the result of chronic overuse and are less likely to occur from a single swing. The most common golf-related rib injury reported in the literature is a stress fracture.[77,78] Rib stress fractures in golfers are most often reported in ribs 4 to 6 and may occur on either the lead or trail side.[78,79] In the author's experience, they tend to occur more frequently on the professional golfer's lead side. They can be challenging to diagnose in the clinic, often being mistaken for an intercostal or paraspinal muscle strain. Diagnosis is usually confirmed via plain-film radiograph but may require magnetic resonance imaging for more accuracy.[80]

Figure 14. Thoracic Manipulation

Clinically, the golfer complains of pain in the posterolateral aspect of the ribcage. Specific, local tenderness on the rib (as opposed to in between the ribs) is often present. Local pain upon deep inhalation may be present in more severe cases as the expansion of the ribcage stresses the injury site. The golfer complains of painful lateral flexion in either direction because compression or traction at the injury site is bothersome. This makes it likely that the golfer experiences pain throughout the golf swing – transition, impact, and finish. It is thought that rib stress fractures are related to recent increases in training intensity and fatigue in the serratus anterior muscle, but this hypothesis requires further investigation.[78,79] These injuries can be difficult to manage and may require significant time away from the game due to recurring aggravation when swinging the golf club.[81] Golfers on the PGA Tour are instructed to avoid swinging the golf club for at least 4 weeks. When the golfer improves over time, keeping them away from the golf course may be difficult when most other activities of daily living are completed without pain. However, swinging the golf club at this point may result in re-injury. As the golfer progresses toward a return to play, there is a gradual reintroduction of strength and mobility exercises. Care should be taken to avoid loaded lateral flexion exercises initially because this may overload the healing tissue. Multi-planar rotational exercises are added when single-plane exercises can be performed without pain (**Figure 15**). At this point, the golfer may begin chipping and putting in pain-free ranges of motion. A gradual, disciplined return to full swings is progressed as symptoms allow.

Despite a dearth of literature regarding rib joint injuries related to the golf swing, physical therapists on the PGA Tour frequently encounter rib injuries in their golfers. The costovertebral and costotransverse joints are the posterior articulations of the ribs with their corresponding thoracic vertebrae.[82] These synovial joints can be sprained acutely by overswinging the golf club or attempting to hit the ball out of thick rough. However, they are more likely to be sprained chronically during an increased volume of practice or competition. Usually, the injury is unilateral and isolated to a single rib articulation. As with stress fractures, costovertebral injuries typically occur in the middle portion of the ribcage (ribs 6-8).

Clinically, palpation of the involved articulation is painful. Rotation in the ipsilateral or contralateral direction may be problematic, and lateral flexion is typically less pain-inducing than rotation. The sprained costovertebral joint is often accompanied by a hypomobile thoracic facet joint at the same level. As with rib fractures, costovertebral and costotransverse joint sprains result in a painful golf swing from transition to finish. The golfer often reports shortening the backswing or cutting off the finish early to avoid pain at these extreme ranges.

Figure 15. Thoracic Rotation Stretch in Half-Kneeling

Treatment of costovertebral and costotransverse joints includes ice and other electrophysical agents in the acute stage. Mobilization or manipulation of the adjacent hypomobile thoracic facet joint may provide immediate, short-term pain relief. Strengthening exercises should target the serratus anterior, serratus posterior inferior, and the posterior scapulothoracic musculature (rhomboids, middle and lower trapezius). Rotational exercises are reintroduced as the golfer progresses through their rehabilitation program. When the golfer returns to play, the volume of swings taken during practice sessions is adjusted as symptoms permit. Faulty swing mechanics are addressed before the golfer is allowed to take full swings in their practice session. For example, setting up to the golf ball with a neutrally aligned thoracic spine (as opposed to thoracic kyphosis) should allow greater thoracic rotation ROM. Evaluating hip mobility in all golfers with rib injuries, including costovertebral joint sprains, is essential. It is possible that swinging a golf club with limited hip rotation may require greater thoracic rotation, thereby applying more stress to the thoracic spine and costovertebral joints. Despite this pattern of compensation being seen clinically, this relationship should be investigated more thoroughly.

Finally, golfers occasionally sustain injuries to the costochondral joints in the anteroinferior aspect of the ribcage. The upper ribs (ribs 2-7) attach directly to the sternum, while the 8-10th ribs articulate with the sternum via a thick band of cartilage.[83] As with other golf-related rib injuries, costochondral joint injuries mainly occur on the lead side to the mid/lower ribs (ribs 6-9). The spectrum of injuries to the costochondral joint ranges from costochondritis, which is a mild irritation or sprain of the joint, to a costochondral tear.[80] Costochondral joint injuries in golfers can be very stubborn to respond to treatment as the cartilaginous tissue is slow to heal and the golf swing's rotational component may prevent timely healing. Occasionally, high-level golfers engage in a swing drill in which they set up to the golf ball with a closed stance (feet and hips pointing behind the golf ball) and make full swings to feel more rotation through the torso on the follow-through. This drill is the likely culprit in costochondral joint injuries sustained by several high-profile players on the PGA Tour and should be avoided. A referral for a computerized tomography scan may be indicated to determine the severity of the injury and the most effective treatment options.

Costochondral joint injuries are treated based on their severity. A period of rest for 4 weeks, followed by a gradual return to full swings as described previously, is typically sufficient for less significant injuries. Manual techniques directed at the costochondral joint are usually avoided as these tend to exacerbate the symptoms. A progressive strengthening program like the one described for other rib injuries is appropriate. Still, progression will likely be slower when compared to costovertebral joint sprains or even rib stress fractures. More severe sprains or partial tears may require a corticosteroid injection. Platelet-rich plasma (PRP) therapy has been used to treat costochondral injuries,[84] but its effectiveness in the golfing population has yet to be formally studied.

Cervical Spine

The incidence of neck pain in the general population has been reported to be around 18%.[85] Cervical spine injuries and neck pain related to golf have been studied much less than in the lumbar spine. However, injury to the cervical spine is one of the most frequent reasons professional golfers seek physical therapy on the PGA Tour, trailing only the lumbar and thoracic spines. The cause of neck pain in high-level golfers is often faulty posture coupled with an excessive volume of play. For example, when golfers practice their putting while in excessive thoracic kyphotic flexion for several hours, there may be a compensatory effect of increased lordosis in the upper cervical spine. The resulting approximation of cervical facet joints may limit cervical rotation ROM in either direction.

As noted, up to 90° of cervical rotation ROM toward the lead side is necessary when swinging longer clubs. This motion ensures that the golfer maintains visual contact with the golf ball throughout the swing. Suppose cervical rotation ROM over the lead shoulder is limited. In that case, the golfer may attempt to compensate by abbreviating the backswing or excessively flexing the torso laterally toward the target to avoid losing sight of the golf ball. Either compensation will change the kinematics of the golf swing and may negatively affect performance.

Isolated neck pain resulting from the repetitive microtrauma of the golf swing may result in irritation of the facet joints in the lower cervical spine. Typically, cervical extension and lateral flexion toward the painful side reproduce the golfer's pain. The golfer often stands with a forward head posture, resulting in lower cervical flexion and compensatory extension in the upper cervical segments. Hypertonic cervical paraspinal musculature will likely be tender. Exercises focused on pain-free movement, including upper cervical flexion and lateral flexion in the opposite direction, should be included initially and progressed as appropriate. The golfer may find it helpful to perform a slight chin tuck while in their set-up before initiating the golf swing. Gently flexing the upper cervical segments away from extension and toward neutral alignment may increase the rotation ROM available during the golf swing. Assessment of intervertebral accessory motion may reveal hypermobility at the involved segment and possibly hypomobility of the adjacent segments. In this case, joint mobilization or manipulation of the hypomobile cervical segments may result in short-term pain relief.[86] Although rare, there are reported risks of and contraindications to cervical manipulation of which the physical therapist must be aware, and the golfer must be informed.[87] Contraindications for cervical manipulation include fracture, dislocation, ligamentous rupture, instability, tumor, infection, myelopathy, recent surgery, acute soft tissue injury, osteoporosis, ankylosing spondylitis, rheumatoid arthritis, vascular disease, vertebral artery abnormalities, connective tissue disease, and current use of anticoagulant therapy.[88]

If the golfer is experiencing severe neck pain and guarding that makes movement and manual interventions directed at the cervical spine difficult, there may be some value in initially addressing hypomobile segments in the upper thoracic spine and ribs.[72,89] Manipulation of the upper thoracic spine has been shown to improve cervical ROM and decrease cervical pain.[90,91] Additionally, educating the golfer in self-mobilization techniques using a high-density foam roller or mobilization wedge may relieve neck pain (**Figure 16**).[92] Regardless of the technique, improving joint mobility in the upper thoracic spine and ribs may reduce strain on the injured lower cervical segments, providing at least short-term relief of the golfer's neck pain.

Figure 16. Thoracic Self-mobilization With Foam Roller

Over time, repeated lower cervical stresses may result in degenerative changes of the articular cartilage, resulting in cervical osteoarthritis (OA) or foraminal stenosis. In advanced stages, foraminal stenosis in the lower cervical spine may cause radiculopathy (pain, numbness/tingling, weakness) into the upper extremities in a dermatomal/myotomal pattern reflective of the cervical level involved. Clinically, cervical extension and ipsilateral rotation and/or side bending will reproduce the golfer's neck pain and/or radicular symptoms. Prolonged sitting in a slouched posture may also produce pain as the upper cervical spine is forced into greater extension. Exercises directed at pain-free ROM in the direction of flexion may reduce symptoms.[93] With a forward head position, the deep cervical flexors, paraspinal and scapulothoracic musculature will typically be lengthened and weak while the pectoralis minor and suboccipital muscles will be shortened. Addressing muscle balance impairments and postural correction should be implemented early in rehabilitation. Mechanical or manual cervical distraction to unload the compressed segment may be helpful in the short term.[94] In more advanced cases, a corticosteroid injection may be necessary to provide relief and allow the golfer to regain ROM and functional use of their cervical spine.[95]

Less common but still prevalent is cervical disc pathology. It is thought that the repetitive rotation of the cervical spine during the golf swing may weaken the annulus, eventually resulting in the tearing of the annulus and possible protrusion of the nucleus into the vertebral foramen. Even if the protruding disc is not physically compressing the adjacent nerve root, the presence of inflammatory cytokines may irritate the adjacent nerve root.[96] Like foraminal stenosis, advanced cervical disc protrusion may result in nerve root compression and radicular symptoms into the upper extremity in a dermatomal or myotomal pattern. However, movements directed toward flexion (versus extension, as with foraminal stenosis) seem more problematic, resulting in increased pressure on the disc anteriorly, facilitating posterolateral protrusion. In the case of disc-related cervical pain and radiculopathy, movements in the direction of cervical extension and lateral flexion toward the side of pain tend to be more tolerable. They may contribute to centralizing the disc protrusion.[97] Again, identifying the faulty or pain-inducing movement is key to successfully treating certain types of cervical pain and, in the author's experience, is more effective than simply treating the affected tissue.

Golfers with advanced cervical disc injuries may choose cervical disc arthroplasty, a surgery in which the injured disc is replaced with a prosthesis designed to simulate normal cervical motion.[98] Because the involved cervical segment is designed to move, cervical disc arthroplasty may be preferable to fusion for high-level golfers. Several tour professionals have undergone this procedure with good results, including immediate relief of the radicular pain and eventual return to playing competitive golf at a high level within 2 or 3 months. Although promising, this procedure is relatively new, and its ultimate long-term outcome for the golfer remains unknown.

Hip

As stated several times in this monograph, the hips play a paramount role in the golf swing. Mobility and strength in both hips are required to produce a stable but dynamic base around which the torso can rotate. Therefore, hip dysfunction can negatively impact the golfers' swing at all levels. The most common hip pathologies associated with golf and management strategies are discussed here.

Femoroacetabular impingement (FAI) is well studied in the general population, but less so in golfers. It is defined as an early pathologic contact during hip joint motion between skeletal prominences of the acetabulum and the femur that limits the physiologic hip ROM, typically flexion and internal rotation which may ultimately lead to damage of the articular cartilage and acetabular labrum and become painful.[99] Pun et al[100] describe 3 types of FAI:

(1) Cam impingement, in which thickening of the femoral neck causes early contact with the acetabulum.
(2) Pincer impingement, in which the acetabulum projects around the femoral head and causes early contact with the femoral neck.
(3) Mixed, which is a combination of cam and pincer impingement.

Most studies have found cam impingement to be the most common.[101-103] The cause of FAI is generally not well known. Some authors believe a genetic component exists, while others think it is acquired when the growing skeleton is exposed to specific repetitive movements.[104-106] Either way, it is a prevalent disorder that can alter performance on the golf course and cause disability in everyday life.

According to the Warwick agreement in 2016, the diagnosis of FAI should be made based on the combined presence of symptoms (deep pain in the groin related to specific movement), clinical signs (positive hip impingement tests and limited hip IR ROM), and findings on diagnostic imaging (plain-film radiographs or magnetic resonance imaging [MRI]).[107] Clinically, a golfer with symptomatic FAI tends to be younger (< 40 years old) and demonstrates pain with combined hip flexion, adduction, and IR (FADIR sign). Hip IR ROM tends to be limited compared to ER.[108,109] This pattern of limitation could be due to the presence of femoral retroversion, a significant structural anomaly in the hip joint. However, its prevalence in golf has never been formally studied. Femoral retroversion can severely limit the amount of IR available in the hip and may leave the golfer predisposed to FAI. Femoral retroversion can be determined via plain film radiograph, but a couple of clinical tools have shown good reliability in detecting its presence as well. First, the Craig test is an easy and reliable clinical test to determine the neutral position of the femoral head in the acetabulum.[110] If the neutral position occurs when the hip is externally rotated, femoral retroversion is suspected. Second, when measuring hip rotation ROM, a moderate correlation has suggested that a difference of greater than 20° between unilateral ER and IR (for example, left hip ER is 60° while left hip IR is 25°) may be indicative of femoral version. If hip ER is greater, femoral retroversion may be present; if hip IR is greater, femoral anteversion may be present.[110] Weakness throughout the hip is also associated with FAI. In their EMG study on patients with symptomatic FAI, Casartelli et al[111] found significant weakness in the hip abductors, adductors, flexors, and external rotators.

With FAI, the golfer may ambulate with decreased hip flexion and extension throughout the gait cycle,[112,113] and deep squatting (required when reading putts) may become painful.[114] In the golf swing, FAI in the lead hip tends to produce pain in the follow-through phase. As the pelvis rotates over the lead hip, the hip moves into relative IR and adduction, which may cause the premature approximation of the femur and acetabulum described previously. The golfer often compensates by "hanging back" during the downswing to avoid pain in the lead hip. Instead of shifting body weight onto their lead side, it stays on the trail side. This lack of weight shift may lead to decreased clubhead speed and inconsistent ball striking. Conversely, but for the same reason, FAI in the trail hip tends to be problematic in the backswing as the club approaches the transition. Similarly, an inability to load onto the trail leg because of pain may result in an abbreviated backswing or other compensations that ultimately affect performance.

While there is no published evidence on the effectiveness of conservative management of FAI in the golfer, studies of the general population suggest flexibility training, hip strengthening, and movement pattern retraining may be of some benefit in symptom reduction, delaying the onset of hip OA[115-117] and lowering reaction forces through the hip joint.[118] Golfers with symptomatic FAI in their lead hip may benefit from setting up to the golf ball with the lead hip slightly rotated externally (foot pointed more toward the target). This ER in the set up may result in less stress on the hip by "adding" IR ROM available during the follow-through.

Physical therapists on the PGA Tour have successfully treated professional golfers with FAI with a combination of flexibility, strength, and functional training. Exercises performed in the quadruped or half-kneeling position are often an effective way to improve pain-free hip flexion ROM early in rehabilitation. One exercise used by players on the PGA Tour to improve hip IR mobility is performed in half-kneeling with the inside of the back leg against a stable surface. The golfer then rotates their pelvis toward the back leg until they feel a comfortable stretch deep in the hip (**Figure 17**). This stretch may be aggressive for some individuals; therefore, it should be cautiously performed and progressed slowly.

A strength program specifically targeting the gluteus maximus, gluteus medius, and deep hip external rotator musculature seems particularly effective for managing FAI. The strength program can be initiated on the mat in open- and closed-chain positions using bands or manually applied resistance without causing pain in the hip. Bridges performed with bilateral or unilateral support can be performed with external resistance in the form of resistive bands (**Figure 18**). As the golfer progresses toward their goals, closed-chain lower extremity strengthening exercises in full weight bearing like squats and lunges may be beneficial. Still, care should be taken to avoid squatting deeply into the range of hip flexion motion that induces pain. Starting the squat with the hips in slight ER may increase the depth with which the golfer can perform these exercises without pain. An external load from a kettlebell, barbell, or medicine ball should only be added when the golfer can perform the exercise without pain and demonstrate good form with appropriate depth using only their body weight. Stretching the hip flexors – particularly the iliopsoas – through a pain-free ROM is helpful. Additionally, joint mobilization may be indicated if the physical therapist notices restriction in the hip capsule.[117] Specifically, the author of this monograph finds that the posterior/inferior aspect of the hip capsule tends to be most restricted in golfers with FAI. Addressing this restriction with specific manual techniques may allow the head of the femur to glide inferiorly more easily as the hip internally

Figure 17. Hip Internal Rotation Stretch in Half-Kneeling

Figure 18. Bridge Progression with Resistance

A, Bilateral. B, Unilateral.

rotates, thus limiting the early approximation of the femur on the acetabulum.

If conservative management of FAI is not satisfactory, arthroscopic hip surgery is a reasonable option for the golfer. Hip arthroscopy for FAI typically involves debriding or repairing the labrum in addition to "recontouring" the anatomic abnormality via femoral (cam) or acetabular (pincer) osteochondroplasty.[100] A 2016 study of 20 professional golfers who underwent arthroscopic hip surgery for FAI found that all 20 players returned to play at an average of 4.7 months post-op.[119] However, the golfers' longer-term outcomes were not followed in this study, and whether they were able to regain and maintain their performance on the golf course over time was not reported.

As the golfer gets older, the anatomical abnormalities associated with FAI may eventually result in hip OA.[120-123] Hip OA is a common condition in the general population as well, with a prevalence of up to 27%[124,125] that continues to increase as the population gets older.[126,127] Like FAI in the younger golfer, the impairments and dysfunctional movement related to hip OA in the older golfer can significantly impact performance on the golf course. Clinically, hip OA presents similarly to FAI. Weakness throughout the hip musculature, including gluteal muscles and deep hip external rotators, is a common finding, and the Scour test may reproduce the golfer's pain.[128] The American College of Rheumatology has developed clinical criteria to determine the presence of hip OA.[129] These include pain in the hip, hip flexion less than 115°, hip IR less than 15°, and age greater than 50 years old. Range of motion deficits, especially in hip flexion, adduction, and IR, are likely due to the combination of anatomical changes in the joint and stiffness in the hip capsule. Deep squatting is difficult due to pain and limited mobility in the hip joint. Pain from prolonged walking can make it challenging to complete a round of golf without a golf cart.

Radiologists use the Kellgren and Lawrence grading system to classify hip OA. It uses a scale from 0-4, with 0 being no radiographic evidence of hip OA and 4 being the most severe.[130] Conservative treatment for hip OA seems to be most effective for those individuals on the lower end of the scale. Conservative treatment should include a comprehensive exercise program consisting of strength and flexibility exercises like those described in the previous discussion on FAI.[131] In the author's experience, exercises performed in the quadruped position are particularly effective in improving hip flexion ROM in golfers with less-advanced OA. The golfer is instructed to rock their buttocks back toward their heels as far as they can comfortably, thereby increasing hip flexion (**Figure 19**). If necessary, the golfer may start with a slight hip ER (by crossing one foot over the other) before initiating the rock backward. If capsular stiffness is detected, joint mobilization may be indicated and has been shown to improve hip function.[132-134] Manual interventions used for older professional golfers on the PGA Tour Champions include joint mobilization into long-axis distraction and inferior and posterior-anterior glides.

Figure 19. Hip Flexion Stretch in Quadruped

As hip OA advances and joint space is lost, and non-surgical interventions have failed to manage symptoms or improve function, total hip arthroplasty (THA) becomes the most effective treatment option. There are several examples of professional golfers on the PGA Tour Champions who have returned to competitive golf at a very high level following THA, with some players even winning several tournaments. However, one recent study found that less than 75% of amateur golfers returned to playing golf within one year following THA.[135]

Shoulder

The shoulder is a common site of golf-related injuries.[58,136,137] Although golf is not considered to be an "overhead sport" like tennis or baseball, the extreme ROM placed on the shoulder throughout the swing is thought to leave the shoulder susceptible to subacromial impingement, glenohumeral joint instability, glenoid labrum pathology, and rotator cuff tendinopathy and tear (**Figure 20**).[138] Several special tests have been described in the literature to differentiate between these conditions clinically. The Apprehension test, Jobe Relocation test, Surprise test, and Crank test help detect the presence of anterior instability. In contrast, the Neer and Hawkins-Kennedy tests may help detect the presence of shoulder impingement.[139,140]

As noted previously, the glenohumeral joint of the lead shoulder reaches maximum horizontal adduction at the transition point of the golf swing. This may contribute to instability and result in mechanical impingement of the rotator cuff between the humeral head and the anterior labrum or acromion. When the golfer initiates the downswing, the contraction of the posterior rotator cuff musculature from a significantly lengthened position may predispose this tissue to tendinopathy and eventual tearing. As the golfer moves through the follow-through phase and into the finish position, the lead glenohumeral joint ER and abduction may cause

Figure 20. Lead Shoulder Horizontal Adduction and Internal Rotation in the Backswing

mechanical impingement of the rotator cuff against the glenoid and posterior labrum,[58] sometimes referred to as "internal impingement." When determining the most effective treatment for shoulder impingement, it is imperative to identify where the golfer is experiencing the pain in the golf swing.

As mentioned, shoulder injuries in amateurs often result from faulty swing mechanics. Correcting the faulty swing sequence should be a central component of successfully treating injuries in this population. Furthermore, it has been found that individuals who stand in greater thoracic kyphosis may have a greater susceptibility to developing shoulder impingement.[141] When the thoracic spine flexes away from its neutral position (kyphotic posture), its ability to rotate is lessened and the scapulae internally rotate, thus requiring greater compensatory movement in the glenohumeral joint. High-level golfers who often spend hours practicing on the putting green may predispose themselves to shoulder impingement later when they attempt to take full swings because of the rounded posture throughout the thoracic spine associated with putting. Those golfers on the PGA Tour are advised to break up their practice sessions to limit their time in this rounded posture. Additionally, manual techniques for improving thoracic mobility have been shown to be effective in reducing pain in individuals with subacromial impingement.[142] It is possible that increased mobility in the thoracic spine results in less stress on the shoulder complex at the extreme ranges of the golf swing (transition and finish). However, this concept and its application to the golfer warrants further investigation.

The role played by the scapulothoracic joint must be considered in the discussion of shoulder pain and the golf swing. Sequential coordination between the scapula and the humerus is essential when swinging the golf club. It has been suggested that approximately one-third of the ROM necessary to raise the arm overhead should come from motion at the scapulothoracic joint. In contrast, the remaining two-thirds should come from the glenohumeral joint.[143] As described in the biomechanics section, the scapulae move in 3 planes when the golfer swings the golf club. Insufficient upward rotation and/or protraction of the scapula in the lead shoulder girdle during the backswing phase of the golf swing may contribute to subacromial impingement and rotator cuff injury described previously. This pattern is classified as shoulder medial rotation syndrome by Sahrmann[63] and is probably the most common shoulder-related movement impairment category found in the golfing population.

Assessment of scapular movement during the golf swing and strength and length of individual muscles is critical to identifying the contribution of the scapulothoracic joint to the golfer's shoulder pain. If the physical therapist detects weakness in the golfer's middle/lower trapezii and serratus anterior, strengthening of these muscles should be a primary focus. Additionally, the length of the pectoralis minor muscle should be assessed. The insertion of the pectoralis minor on the scapula's coracoid process may produce an anterior tilting and IR of the scapula at rest and during movement. Komati et al[144] found that weakness in the lower portion of the trapezius combined with a short pectoralis minor can create a muscle imbalance that prevents the scapula from sufficiently rotating upwardly while performing a dynamic movement of the upper extremity. It should be noted that these authors did not study the shoulder as it relates specifically to golf. However, this concept can be easily applied to the golf swing.

Typically, exercises begin in the quadruped position and progress to performance while the golfer is in their golf posture. With the golfer in the quadruped position, they are instructed to allow the thoracic spine to relax toward neutral alignment. This creates adduction of the scapulae and may position the humeral head more centrally in the glenoid. Different movements of the upper extremity may be added from this position as the golfer progresses. Next, the golfer may stand with their back against the wall and perform active shoulder movements while focusing on upwardly rotating the scapula and maintaining a stable thoracic spine. Finally, the golfer may perform retraction of the trail scapula using a resistive band while in set-up posture and the trail shoulder in abduction and ER (**Video 7**). This type of functional exercise promotes proper maintenance of the spine angle during movement while increasing strength and stability in the shoulder girdle.

Video 7: Scapular Strengthening Progression in Golf Posture
https://www.orthptlearn.org/mod/vimeo/view.php?id=____)

With anterior glenohumeral instability, especially in the acute stage, care should be taken to avoid end ranges of shoulder ER because this often results in pain-inducing stress on the anterior capsule. Strengthening exercises for the glenohumeral joint internal rotators (especially the subscapularis) should begin in neutral rotation and move into IR. This promotes centralization of the humeral head in the glenoid, resulting in less pain as the stress on the anterior capsule is diminished. As the pain subsides and shoulder ROM improves, the exercise may be progressed toward greater shoulder ER. Anterior instability in the golfer's trail shoulder is often accompanied by hypomobility in the posterior aspect of the glenohumeral joint capsule. In addition to functionally shortening the anterior capsule through IR exercises, the golfer may benefit from manual techniques to improve flexibility in the posterior capsule. An anterior-posterior glide of the glenohumeral joint will also promote a more centralized resting position of the head of the humerus in the glenoid at rest and during movement.[145]

Elbow

The repetitive nature of the golf swing may result in microtrauma and pain in various structures of the elbow. Kohn[146] found that up to 24% of amateur golfers and 7% of professional golfers sustain injuries to the elbow. In the amateur population, he identified playing 3 or more rounds per week as a threshold, after which complaints of elbow pain began to rise. More recently, Qureshi et al[147] found the elbow the most frequently injured joint among amateur golfers. Lateral elbow tendinopathy (also known as tennis elbow) has been cited as the most common pathologic condition of the elbow in the general population[148] and in the golfing population.[50,149] Interestingly, tennis elbow is much more common in the golfing population than golfer's elbow (medial elbow tendinopathy) by a ratio of 5:1.[50]

Lateral elbow tendinopathy in golfers may result from repetitive overuse or, in the case of low-level amateur players, faulty swing mechanics. Occasionally, it may result from a single traumatic event, such as striking a tree root with the clubface at impact. A common pathological component of the golf swing is known as "chicken winging" and involves not keeping the lead elbow in extension through the impact of the golf swing. It is theorized that striking a golf ball with a flexed lead elbow puts the structures of the lateral elbow at a mechanical disadvantage that may lead to inflammation, pain, weakness, and other symptoms commonly associated with tendinopathies. Therefore, working with a teaching professional to correct the amateur golfer's faulty swing mechanics is crucial in treating lateral elbow tendinopathy.

Lateral elbow tendinopathy most often involves the extensor carpi radialis brevis tendon but can also affect the extensor digitorum tendon. Pain at the lateral epicondyle of the elbow with resisted wrist extension (Cozen's test) or resisted third-digit extension (Maudsley's test) seems to be a sufficient clinical finding to make this diagnosis.[150] However, diagnostic ultrasound may provide a more specific picture of the extent of involvement of the common extensor tendon.[151]

Medial elbow tendinopathy affects the wrist flexor and the pronator teres muscles.[148] A detailed examination can differentiate it clinically from other medial-sided elbow conditions (for example, pronator teres syndrome, cubital tunnel syndrome or ulnar neuritis). Local tenderness with palpation of the medial epicondyle is the classic sign, but symptoms may begin more distally in the belly of the common flexor tendon in the medial forearm. Like lateral elbow tendinopathy, its medially located cousin is more commonly associated with overuse and/or changes in the golfer's grip rather than an acute, single-event injury. For example, gripping the club with the trail forearm more supinated (known as a stronger grip – more on that in the next section) may expose the medial aspect of the trail elbow to the repetitive trauma associated with the golf swing. For this reason, in the author's experience, medial elbow tendinopathy may happen more frequently in the trail elbow than in the lead elbow.

Treatment of lateral or medial elbow tendinopathy should begin with conservative management, including rest, the application of ice for inflammation or pain modulation in the short term, stretching of the wrist extensors (for lateral elbow tendinopathy) or wrist flexors (for medial elbow tendinopathy), and progressive loading through graduated resistance exercises. Additionally, it may be necessary to adjust the golfer's grip to redistribute the forces that occur through the elbow during the golf swing. Golfers who experience lateral elbow tendinopathy may benefit from changing to a stronger grip, and conversely, golfers with medial elbow tendinopathy may benefit from a weaker grip. Global strengthening of the entire upper extremity effectively treats lateral elbow tendinopathy.[152] Strength exercises that involve musculature from the shoulder girdle to the wrist and performed in golf-specific positions are effective.

Physical therapists working with golfers on the PGA Tour have found that blood flow restriction (BFR) therapy helps load the affected musculature early in rehabilitation. While no research in this area is specifically dedicated to golf, some literature demonstrates the effectiveness of BFR in general for muscular hypertrophy.[153,154] For this technique, the occlusion cuff is placed around the brachium, beginning with inflation of 100-160 mmHg (the parameter most often described in the literature[153]) (**Figure 21**). Using this technique to address lateral elbow tendinopathy, resisted wrist extension is performed with a low load (usually 5 to 8 lbs) and repetition to fatigue (usually 20 or more repetitions per set). When fatigue is reached, the

Figure 21. Blood Flow Restriction to Treat Lateral Elbow Tendinopathy

golfer rests for one minute, then repeats the process (up to 4 sets). For those with medial elbow tendinopathy, a similar protocol is performed with resisted wrist flexion replacing wrist extension. Either way, this technique aims to achieve muscular fatigue before the golfer experiences pain. If pain is elicited first, the physical therapist may increase the cuff pressure, decrease the load, or both. Often, it is necessary to inflate the cuff to 250 mmHg or greater to achieve the desired muscular fatigue. It should be noted that significant muscular hypertrophy is not usually a desirable outcome for high-level golfers in most circumstances because of the risk of loss of flexibility due to increased muscular stiffness. Therefore, this type of BFR training has thus far been selectively performed only for treating lateral and medial elbow tendinopathy. Application of BFR for other conditions may be possible but requires further investigation.

For chronic cases of lateral and medial elbow tendinopathy not responding to other approaches, the physical therapists on the PGA Tour occasionally employ dry needling. Blood flow may be increased to the area by using a higher-gauge needle to create localized microtrauma in the affected tissue. Or the physical therapist may choose to use a filiform needle to penetrate trigger points, thereby reducing strain on the tendon and may provide at least short-term relief of the elbow pain attributed to elbow tendinopathies.[155,156] When performing dry needling techniques on the medial aspect of the elbow, great care is taken to avoid the ulnar nerve as it passes superficially through the ulnar tunnel of the medial elbow, between the medial epicondyle and olecranon. Additionally, because dry needling may result in increased soreness in the short term, it is typically avoided in the days immediately preceding a tournament.

If conservative management does not provide satisfactory results, an injection of corticosteroid may be indicated.[157] However, long-term corticosteroid use may eventually lead to the weakening of the injected tissue. There is evidence that other types of injections, including PRP therapy, may help treat more advanced cases of lateral elbow tendinopathy.[158] While the evidence of the effectiveness of PRP injections in the golfing population is sparse, the author of this monograph has found them to be a good adjunct to other treatment techniques for the most stubborn cases of chronic lateral elbow tendinopathy in some, but not all, professional golfers on the PGA Tour. Interestingly, recent research indicates a possible genetic link to the effectiveness of PRP injections in the elbow. Niemiec et al found[159] that the presence of a particular gene appears to predict whether PRP will be an effective treatment for lateral elbow tendinopathy and concluded that identifying this gene may be a helpful diagnostic tool while assessing patients for PRP therapy. This may account for PRP therapy's effectiveness in some golfers with lateral elbow tendinopathy but not others. Open surgical debridement of the pathologic tissue may be an option in extreme cases that do not resolve with more conservative measures. However, knowledge is limited about the long-term outcomes of this procedure in golfers.

Wrist and Hand

Hand and wrist injuries are common in golf,[160] but there is a discrepancy between what is reported in the literature and what the physical therapists on the PGA Tour see. Gosheger et al[49] list the wrist as the second likeliest site of injury sustained by professional golfers at 16% of total injuries, exceeded only by injuries to the lower back. On the PGA Tour, the number of treatments devoted to wrist injuries is well down the list at just 5% of the total. Spine, shoulder, and hip injuries are reported much more frequently. This discrepancy is likely explained by the fact that injuries reported to the PGA Tour medical staff occur only when the golfer plays in the tournament that week. Hand and wrist injuries can be devastating for a professional golfer. If the golfer sustains an injury that precludes them from playing, that injury may go unrecorded in the PGA Tour's injury tracking system. Significant injuries to the wrist that need surgery may require weeks or months at home, during which the golfer cannot play tournament golf.

Golf-related hand and wrist injuries occur in both wrists (lead and trail), but injuries to the lead wrist are much more common. Hawkes et al[161] reported that injuries to the lead wrist account for about two-thirds of wrist injuries in professional golfers. These injuries tend to be chronic and can be related to the golfer's style of gripping the golf club. A *strong grip* is one in which the thumb of the lead wrist points away from the target (more pronated), while a *weak grip* is one in which the thumb of the lead hand is pointed more toward the target (more supinated). A stronger grip tends to expose the structures on the ulnar aspect of the lead wrist to greater forces – especially eccentric forces as the club decelerates. Furthermore, some players are taught to “bow” (or flex) their lead wrist from the takeaway through impact (**Figure 22**). While this helps with consistency in maintaining a square clubface at impact, the flexed lead wrist may add to the exposure of increased loads on the ulnar side of the wrist throughout the golf swing.

Striking the ball out of thick rough with a strong grip and bowed wrist predisposes many of the world’s top players to wrist pathology. Tournaments with notoriously thick rough, such as the US Open Championship, often cause an uptick in wrist and elbow injuries in professional golfers. A recent change in grip (weak to strong or strong to weak) or a switch to practicing on a range with artificial turf mats (especially for amateur golfers) may be enough to induce a wrist injury. When evaluating the golfer’s wrist injury, the physical therapist should inquire about any recent changes in practice habits or how the golfer grips the golf club.

Hand and wrist injuries can be effectively divided into radial-sided and ulnar-sided injuries. For the reasons just described, ulnar-sided injuries tend to occur more frequently in golfers than radial-sided injuries,[162] so this monograph will focus on ulnar-sided injuries. Common injuries on the wrist’s ulnar side include hamate fractures, extensor carpi ulnaris (ECU) tendinopathies or tears, and tears in the triangular fibrocartilage complex (TFCC).

Figure 22. Bowed Lead Wrist at the Transition

The hamate is a carpal bone on the ulnar side of the wrist that may be fractured when the clubhead strikes a hard surface, such as a rock or tree root (**Figure 23**). The abrupt deceleration is thought to transmit force through the end of the club grip, which tends to rest on the hook of the hamate of the lead wrist, resulting in a direct blow to the bone and causing a fracture.[163] Hamate fractures resulting from the golf swing occur almost exclusively in the lead wrist. The golfer can usually identify a specific swing that caused the injury.

Clinically, the golfer presents with sharp pain in the ulnar/palmar aspect of the lead wrist. Wrist flexion, extension, and ulnar deviation may be painful at the end range. Plain film radiographs confirm the diagnosis. However, radiographs taken immediately after the injury may not identify a nondisplaced

Figure 23. Striking a Tree Root May Cause a Hamate Fracture

fracture. These injuries are typically treated with immobilization and rest for 6 to 8 weeks. Because of poor vascularization of the hook of the hamate, displaced fractures that do not heal as expected may require surgery to remove the fractured hook, with golfers usually regaining full functional use of the wrist.[164,165]

Injuries to the ECU tendon are quite common in the golfer's lead wrist. It is theorized that the insertion of the ECU on the base of the fifth metacarpal may expose the ECU to significant eccentric forces throughout the golf swing.[166] If the clubhead decelerates quickly, as when it strikes thick rough, or a tree root, eccentric loading of the ECU tendon may result in microtearing and injury. Hawkes et al[161] describe a spectrum of golf-related ECU injuries ranging from mild tenosynovitis to full tendon subluxation that may require surgery.

In the case of ECU tenosynovitis and tendinopathy, the golfer typically describes an insidious onset of ulnar-sided wrist pain that worsens with the repetitive swinging of the golf club. Clinically, the golfer demonstrates pain with contracting or lengthening the ECU. Crepitus within the synovial sheath may be present with passive and active radial deviation of the wrist. Because the tendon lies superficially on the dorsal/ulnar aspect of the wrist, pain with palpation and swelling around the tendon may be easily appreciated. In its reactive stage, ECU tendinopathy requires a period of rest and possible immobilization in a splint. As the injury improves from the acute phase, the treatment program may add stretching through pain-free ROM and progressive loading. The well-timed introduction of progressive loading of the injured tendon has been shown to produce superior outcomes when compared to rest alone.[167] Additionally, golfers who choose to play with ongoing pain related to ECU tendinopathy may benefit from applying kinesiology tape to support the injured tendon. However, published literature on this topic is sparse regarding its effectiveness for golf-related injuries. Finally, stubborn cases of ECU tendinopathy that do not respond to conservative measures may be treated with PRP injections with good effect.[168]

In the case of the subluxated ECU tendon, the physical therapist can palpate the unstable tendon (and subsequent "pop") as it translates away from its normal position with active movement of the wrist. Chronic instability may require surgical intervention.[169,170] Diagnostic imaging, including ultrasound or MRI, can confirm the physical therapist's suspicion of a subluxated ECU tendon.[171]

Injuries to the TFCC are less common in golf but can be tricky to manage conservatively. The TFCC is a meniscal-type structure that absorbs load through the ulnar side of the wrist between the lunate, triquetrum, and distal ulna. Repetitive compressive forces may result in degenerative injuries to the TFCC. Such compression occurs when the lead wrist travels from end-range radial deviation at the transition to end-range ulnar deviation in the follow-through. Because of this, it has been suggested that a weaker golf grip may expose the TFCC to injury.[166]

Clinically, the golfer complains of ulnar-sided wrist pain and a feeling of instability frequently associated with audible "popping" during active movement. Identifying the specific location of the "pop" will help the physical therapist differentiate between a torn TFCC and a subluxated ECU tendon, although the two conditions are often present concurrently. Several special tests, which have varying degrees of specificity and sensitivity, have been suggested. The piano key test requires the golfer to place the palms of both hands on the exam table with the wrists extended. A prominent ulnar styloid on the injured side suggests instability indicative of a TFCC tear. The TFCC grind (or compression) test is done with the physical therapist first applying compression, then a shearing force through the ulnar aspect of the wrist. Pain, instability, or popping may indicate pathology to the TFCC.[172] Palpation of the ulnar styloid may be painful. The golfer frequently demonstrates decreased grip strength; weakness and pain may also be detected with resisted pronation and supination. Diagnostic ultrasound or MRI with gadolinium contrast may help in making a diagnosis.

Conservative interventions are moderately effective in treating TFCC injuries in the general population.[173] These measures include rest and progressive wrist strengthening as tolerated. Emphasis is placed on eccentric strengthening of the ECU, flexor carpi ulnaris, pronator teres, and supinator muscles. Circumferential wrist taping may help to stabilize the wrist while playing golf. An unsatisfactory response to conservative management may require a corticosteroid injection and eventual surgical repair or debridement of the injured tissue.[174,175]

PHYSICAL EXAMINATION OF THE GOLFER

Interview and History

Completing a thorough interview and history with the golfer, combined with the knowledge of golf-related injuries discussed in the previous section, should lead the physical therapist to a solid hypothesis about what injury the golfer may have even before the physical examination begins. When taking the golfer's history, it is essential to ask specific questions related to recent changes in the golfer's habits or patterns in their practice, training, and play. Such questions should lead to investigating recent changes in the frequency of practice or play that may have precipitated the injury. For example, an increase in the number of balls struck during a typical practice session in preparation for an upcoming tournament may be one factor accounting for the golfer's LBP. Switching from practicing on a natural turf range to hitting off mats may contribute to their recent elbow pain. Similarly, asking the golfer about any recent changes in equipment (for example, switching to heavier clubs or clubs with longer shafts) is vital because answers may indicate a potential contribution to their injury. Questions about the chronicity of the golfer's injury are helpful as well. Did the pain just recently start, or has it been bothering them for a longer period? Did the golfer begin noticing pain immediately after a specific swing (indicative of a traumatic injury), or did they experience a gradual onset of pain over perhaps several weeks (indicative of an injury related to repetitive microtrauma)?

Finally, a question about recent changes in the golf swing itself may help direct the examination. A golfer who recently changed swing coaches may be working on a new aspect of their golf swing (eg, bowing the lead wrist at the transition to square up the clubface). This swing change may be contributing to the injury.

Visual Inspection

The following is a discussion of the most common features the physical therapists on the PGA Tour observe when examining the golfer. Ideally, the examination is conducted with the golfer barefoot, wearing shorts and no shirt (or wearing shorts and a sports bra for female golfers). The physical examination typically begins with visually inspecting the golfer's posture, although postural asymmetries should only be interpreted as "abnormal" in light of other examination findings. Posture should be observed with the golfer standing normally, and in the set-up position while holding a mid-iron (5-7 iron). As part of the examination process, the physical therapist attempts to identify any asymmetries resulting from the repetitive nature of the golf swing or contributing to any painful conditions the golfer might be experiencing. Golf is an asymmetrical sport; therefore, physical therapists on the PGA Tour observe recurring patterns of asymmetry resulting from the volume of swings taken, etc. These asymmetries differ from what is seen in the general population. Although some of these asymmetries may be considered "normal" for a golfer, in my opinion, asymmetries that are good for the golf swing may not always be good in terms of predisposing the golfer to injury. An example we see almost every day is the golfer who presents, after playing a round of golf, in lateral flexion toward the trail side (asymmetry) with LBP on the trail side. Performing exercises moving toward the lead side reduces the pain. This probably does not make them "more symmetrical" in the long term, but it may help with pain. Whether these asymmetries could or should be addressed with the goal of making the golfer "more symmetrical" in the long term is a difficult question unanswered at this time because it may potentially negatively impact performance.

The visual inspection begins with an appraisal of the feet and ankles. Here, the physical therapist notes the mid- and rear-foot position, specifically identifying excessive pronation or supination. Moving upward, the knees are examined for malalignment primarily in the frontal plane – genu valgus or genu varus. Next, hip alignment in standing is observed. The physical therapist notes if the golfer stands in relative hip internal or external rotation and if there is an asymmetry between the two sides. Next, the therapist looks at pelvic alignment, noting pelvic tilt (anterior or posterior). It was previously thought that anterior pelvic tilt predisposes the lumbar spine to move into extension. However, recent research suggests that it may not.[176] Pelvic rotation in the transverse plane is common among higher-level golfers. The most common abnormal finding is left rotation (for a right-handed golfer) of the pelvis relative to the hips. Regarding bony landmarks, the right posterior superior iliac spine often appears superior and forward to that on the left. Similarly, the right anterior superior iliac spine seems to be inferior to that on the left.

Next, the therapist assesses the lumbar spine position in standing. Ideally, the golfer stands with the lumbar spine in neutral alignment. Demonstrating a decreased lordosis (lumbar flexion) or increased lordosis (lumbar extension) would be considered abnormal. Assessment of the lumbar spine in the sagittal plane may reveal scoliosis typically toward the lead side (convexity to the left for a right-handed golfer), most likely resulting from asymmetrical hypertrophy of the overdeveloped trail-side lumbar paraspinal musculature. The thoracic spine may have a slight compensatory curve in the opposite direction. Rotation of the thoracic spine in the transverse plane is noted as well. A common observed abnormal finding here is a slight rotation toward the lead side. Thoracic position in the sagittal plane might reveal a rounded posture with increased thoracic kyphosis. Scapular position is observed next. Ideally, the medial border of the scapulae should rest approximately two inches from the midline. The root of the scapular spine should align with the second thoracic vertebra, while the inferior angle should align with the eighth thoracic vertebra.[63] Observation may reveal relative scapular depression or elevation, abduction or adduction, or excessive upward or downward rotation. Common abnormal findings in the golfing population include depressed, abducted, downwardly rotated scapulae, slightly more pronounced on the trail side than on the lead side. Next, cervical spine alignment is noted. Any deviation from neutral rotation is considered abnormal. In the sagittal plane, forward head posture is a common finding in which excessive flexion in the lower cervical segments is coupled with a compensatory extension of the upper cervical segments. Shoulder alignment is observed next. Rounded, forward, and internally rotated shoulders are a common abnormal finding. Finally, the therapist assesses the alignment of the elbows and wrists, noting any excessive forearm pronation/supination.

Range of Motion

"Normal" ROM in the golfer is not well established in the literature. With a few exceptions that will be addressed here, ROM can be considered normal if it is consistent with the guidelines proposed by Moromizato.[177] As with the visual observation of posture, it is vital to interpret asymmetries in ROM as part of a comprehensive examination.

Rotation ROM in the hips and thoracic spine is particularly important as it relates to golf. As noted previously, deficits in hip IR ROM, for example, have been correlated to increased risk of LBP in professional golfers.[21] Hip rotation ROM can be measured with the golfer prone with the hip extended and knee flexed 90° or supine with the hip and knee in the 90-90 position. When working with golfers on the PGA Tour, the physical therapists often assess hip rotation in both positions. When measuring hip rotation in prone, the hip is relatively more extended (compared to the 90-90 position in supine), and a short tensor fascia latae may limit ER. To account for this, abducting the hip slightly before measuring may be helpful. When measuring hip rotation in supine, the hip is flexed to 90°. In this position, the gluteal musculature can limit hip ER. Again, slightly abducting the hips before measuring should control for this. Generally, 45° of hip internal and external rotation is considered normal. However, there do appear to be significant sex differences amongst golfers, with female golfers demonstrating greater hip rotation ROM overall and especially in the direction of IR.[178] Increased hip IR may be accounted for by the presence of femoral version, as discussed in the previous section.

Thoracic rotation ROM can be reliably measured with the golfer seated with a dowel, bar, or golf club placed behind them, tucked under both elbows.[179] The golfer rotates in one direction, and the therapist measures the ROM from above. Care is taken to avoid protracting the contralateral scapula because this substitution may appear to increase thoracic rotation ROM. Forty-five degrees of rotation in each direction is preferred. In the author's experience, professional golfers tend to demonstrate greater thoracic rotation to the lead side than the trail side, likely due to the physical requirement of torso rotation past the target line at the finish, as noted previously. While no published evidence supports this theory, the author of this monograph believes some composite amount of rotation may be necessary between the thoracic spine and hips. Increasing thoracic spine rotation ROM may compensate for deficits in hip rotation ROM and vice versa. For example, right-handed golfers with limited left hip IR might have greater-than-expected left thoracic rotation, allowing them to successfully complete the golf swing through the finish. Identifying the presence of such a relationship would be a valuable topic for future study.

Strength

Manual muscle testing can help identify weaknesses in individual muscles that may leave the golfer unable to perform at their best or, worse, predispose them to injury. Based on the available literature already discussed, assessment of the strength of the middle and lower trapezius muscles, the rotator cuff musculature, the lower abdominal muscles (obliques and transversus abdominis), the erector spinae, the gluteal musculature (especially the posterior portion of the gluteus medius), and the deep hip external rotators is of particular importance. The physical therapists on the PGA Tour use the manual muscle testing techniques suggested by Kendall.[180]

Muscle Length

Deficits in the length of specific muscles may contribute to some faulty movement patterns discussed throughout this monograph. Physical therapists should specifically investigate the length of the iliopsoas, tensor fascia latae, and pectoralis minor muscles. Iliopsoas length can be assessed clinically with the Thomas test.[181] A short or stiff iliopsoas muscle will limit hip extension and may predispose the pelvis to tilt anteriorly. It is common for the high-level golfer to demonstrate asymmetry in iliopsoas length, with the trail-side iliopsoas testing shorter than that on the lead side. Tensor fascia latae length can be assessed using Ober's test.[182] A short or stiff tensor fascia latae may suggest its dominance as a hip abductor over the gluteus medius and may limit the hip's ability to rotate externally, especially when the hip is extended.[63] Finally, assessing pectoralis minor muscle length using the method described by Borstad[183] can be performed to determine this muscle's contribution to faulty posture and dysfunction in the shoulder girdle. A short or stiff pectoralis minor will tilt the scapula anteriorly and internally and may limit the ability of the scapula to rotate upward during the golf club swing. It may also contribute to a rounded posture in the golfer's set-up ("C-posture") along with weakness in the scapulothoracic musculature.

Functional Testing

First, observe the golfer's swing! Much information can be obtained by watching the golfer swing the golf club. If possible, watch the golfer take full swings at full speed. Some deficiencies may not be evident at slower speeds. Ideally, the golfer can identify where their pain is most noticeable in the swing. As noted previously, the phase or point in the golf swing in which the golfer experiences pain may provide clues as to the source of pain.

Several studies attempt to use specific functional tests to identify golfers at risk for developing LBP. Lower scores on the Star Excursion Balance Test, for example, were found to be associated with golfers who reported chronic LBP.[184] Cook et al[185] used a functional movement screen consisting of, among other tests, the overhead squat, hurdle step, and in-line lunge, to identify impairments and functional limitations that may leave the individual predisposed to injury. Rose and Philips at the Titleist Performance Institute have adapted this screen specifically for golfers.[186] The functional movement screen may reveal asymmetries and deficits that can negatively affect performance on the golf course and leave the golfer prone to injury.[187]

SPECIAL CONSIDERATIONS FOR SPECIFIC DEMOGRAPHICS

Considerations for the Junior Golfer

The increase in popularity in the game of golf has not only affected adult players. The growth in competitive programs for junior players over the past two years has been unprecedented. It is now possible for golfers as young as 5 to play competitively in golf tournaments. Not surprisingly, the growth in popularity globally has resulted in added pressure on younger players to play well. Like in other sports, it is becoming more common for these younger players to play and practice several hours daily, several days weekly. In my experience working with several of the top golfers in the world, a common theme in these golfers' upbringing is that almost all participated in multiple sports throughout their childhoods, not focusing exclusively on golf until well into their teenage years. While the risk of burnout and injury has not been studied in junior golfers specifically, it has been studied in young athletes participating in other sports. A retrospective study by Russell[188] found that early specialization by young athletes resulted in less time spent participating in their sport as adults. Jayanthi et al[189] concluded that early specialization might result in higher rates of injury, increased psychological stress, and quitting sports at a young age. As discussed previously, vigorous training before apophyseal plates have fully fused may result in significant injuries like FAI in young athletes.[106] While a specific age has not been identified as to when a young golfer should begin specializing only in golf, care should be taken to ensure they continue to enjoy the game pain-free throughout their childhood. Such care might include maintaining a low emphasis on competition among the youngest golfers, monitoring the daily and weekly amount of time spent on the range, and regular participation in alternative physical activity.

Most modern instructors place a greater emphasis on teaching their junior players how to generate speed and power in their golf swing before they focus on accuracy. This can be summed up by the adage, "Learn how to hit it far first, then learn how to hit it straight." This focus on distance may result in less success in tournaments at the junior level but more success later in their careers. The junior golfer's fitness program also emphasizes strength and power. There is strong evidence of the positive effect of strength and conditioning programs of varying types for this demographic. For example, Coughlan et al[190] found that exposing junior golfers (ages 12-17) to resistance training one day per week for 12 weeks improved ball speed, indicating that this population can benefit from resistance training like their older counterparts (**Figure 24**). Bliss et al[191] found plyometric training useful in improving clubhead speed in younger golfers. In a smaller study of junior golfers (average age: 16.77 years old), Redondo et al[192] found that completing a conditioning program before playing golf resulted in better performance on the golf course.

Figure 24. Functional Resistance Exercise for the Junior Golfer

As with strength training for any junior-level athlete, emphasis should always be placed on the proper form of the exercise before any significant load is added. In most circumstances, resistive bands can provide more than enough resistance to achieve improved strength while keeping the risk of injury relatively low in this population compared to lifting large weights. Exposing young golfers to this type of training early in their journey results in a positive association between physical conditioning and improved performance on the golf course. Most top college golf teams today employ full-time trainers, physical therapists, or strength coaches who create effective conditioning programs for their student-athletes long before they become professional. The fact that young players are achieving greater physical prowess earlier in their collegiate careers may be one reason they are finding immediate success when they reach the PGA Tour and is likely contributing to the steady decrease in the average age of the top PGA Tour professionals over the past decade.[193]

Considerations for the Female Golfer

As stated, the number of female junior golfers as a percentage of junior players has more than doubled since 2000. Young female golfers have more opportunities to play golf in college and compete in big tournaments than ever before. Even before the overall growth of participation in golf attributed to COVID shutdowns, the number of women playing in college was growing substantially. A report by the NCAA found a 26% increase in female golfer participation in the 10 years from 2009 to 2019.[194] Therefore, the opportunities for physical therapists to work with these female athletes continue to grow as well.

One study of high-level female golfers in Australia found that golfers who did not warm up before playing were more likely to report an injury.[48] Horan et al[195] studied the differences between the swings of male and female golfers. Female golfers demonstrated significantly higher variability in thoracolumbar rotation during the downswing, possibly indicating decreased stability and control of the torso. A training program focusing on improving the strength of the lower abdominal muscles and pelvic stability from transition to impact may be an effective way to improve female golfers' performance on the golf course.

As the female golfer reaches menopause, age-related conditions like osteoporosis may become problematic, leaving the female golfer at increased risk of fracture. Regular performance of a resistance training program and weight-bearing exercise (like walking a round of golf) may promote increased bone mineral density and lower the risk of fracture in older female golfers.[196,197] The physical therapist would be wise to include a weight-bearing resistance training component to this demographic's golf fitness routine, the specifics of which will be discussed in the next section.

Considerations for the Aging Golfer

Older players enjoy the game of golf and can excel at the highest level. Jack Nicklaus won the Masters Tournament at the age of 46. In 2009, Tom Watson lost the Open Championship in a playoff at 59. After turning 50, Phil Mickelson became the oldest player to win a major tournament when he won the PGA Championship in 2021. These examples aside, key performance measures begin to decrease as a professional golfer ages. Brown et al[198] studied the statistics published by the PGA Tour and found that scoring average, driving distance, driving accuracy, and greens hit in regulation all begin to decline when a professional golfer reaches the mid-40s. To the author's knowledge, scant literature identifies age-related differences in injuries between older and younger golfers.

It is worth noting that two of the prominent professional men's golf tours in the United States (PGA Tour and PGA Tour Champions) are covered by a staff of physical therapists. These physical therapists collect data for every visit to the Player Performance Center at the tournament site. The PGA Tour is open to any players who qualify, with the average age of the top 20 players worldwide as of this writing being 28.7 years. Golfers must be at least 50 to compete on the PGA Tour Champions; some are 70 or older. As one might expect, the unpublished data collected by the physical therapists who work with the professional golfers on the PGA Tour and PGA Tour Champions suggest significant differences between treatment sought by body region between the younger golfers on the PGA Tour and their older counterparts on the PGA Tour Champions.

When viewed as a percentage of the total number of visits, younger professional players seek treatment much more frequently for injuries related to the thoracic spine and ribs than older professional players. While treatment of injuries related to the lumbar spine is far and away the most common reason golfers on both tours seek help from physical therapists, Champions-level players seek treatment for LBP at a higher rate than those on the PGA Tour. It is hypothesized that chronic, degenerative changes in the lumbar spine that worsen with age can account for some of the difference. Furthermore, loss of hip rotation ROM with age may result in added stress to the lumbar spine in older golfers. As stated earlier, these are conclusions drawn from the physical therapists' experience and warrant further investigation. However, regardless of the dearth of literature on this topic, most would agree that a fitness program focusing on strength and flexibility in the hips and lower back should play an increasingly important role as the golfer gets older.

Golf is an effective mode of exercise to address other conditions commonly associated with the aging population. For example, Bliss and Church[199] studied individuals with Parkinson's disease who played golf and concluded that a movement as complex as the golf swing improves balance and reduces the risk of falls in this population. As referenced previously, the study by Gao et al[13] indicates that older individuals who play golf regularly demonstrate improved scoring on key balance tests that predict an increased risk of falls (**Figure 25**). Therefore, one may reasonably conclude that playing golf regularly could

Figure 25. Weighted Ball Exercise for Dynamic Balance in an Older Golfer

mitigate fall risks in the aging population. For those individuals at risk of cardiovascular disease, walking a round of golf regularly meets the recommended physical activity requirement and, therefore, may reduce the risk of cardiovascular disease in the older golfer.[200]

CURRENT CONCEPTS IN GOLF FITNESS AND PERFORMANCE TRAINING

The idea of employing fitness and working out to enhance one's performance on the golf course is relatively new. Before Tiger Woods emerged as one of the all-time great players, most golfers viewed fitness (especially resistance training) as potentially harmful to the golf swing. Tiger Woods' approach to the game in the late 1990s was paradigm-shifting in terms of golf fitness. Today, the number of professional golfers working out before and after competitive rounds continues to increase. Well over two-thirds of the field at a given PGA Tour event visit the on-site Player Performance Center each week.

Two primary goals should be considered when designing a comprehensive fitness program for a golfer: improving performance on the golf course and mitigating the risk of injury while playing the game.[52,201] Because clubhead speed is such a critical measurement of golf performance, exercises designed to improve clubhead speed should be central to the program. Training programs for golfers should be comprehensive to incorporate exercises that address the following areas: strength, cardiovascular fitness, mobility/flexibility, power/speed, and balance.

Strength and Power Training

The effects of strength training on performance on the golf course are well documented.[52,202,203] The type of strength training that is best for golf performance is debatable. In their retrospective study, Uthoff et al[204] found that an 8-week program consisting of 3 or 4 sets of 5 to 15 repetitions of golf-specific strength exercises increased clubhead speed and driving distance. Oranchuk et al[205] studied collegiate golfers and found that Olympic-style lifting consisting of back squats, power cleans, and deadlifts improved clubhead speed and driving distance. Smith et al[203] reviewed 13 studies regarding golf strengthening programs that used various modes of resistance (bands, machines, medicine balls, and free weights) and found that all improved clubhead speed. Because multiple strength training approaches result in improved clubhead speed, an individualized exercise approach may be best. The physical therapist should help each golfer determine their most suitable type of training.

Most likely, early in the strength-building process, a resistance program consisting of simpler movements may be more effective. As the golfer improves their strength, progression to more complex movements like those required in Olympic-style lifting is appropriate. In most cases, the golfer should avoid attempting to lift anywhere near their one-rep max when performing Olympic movements. The risk does not surpass the possible reward for this style of resistance training as it pertains to golf. While this seems intuitive, it is worth mentioning because the physical therapists on the PGA Tour have spent countless hours working with their athletes to rehabilitate training injuries sustained while lifting too heavy a weight with poor form. Regardless of the type of exercise or mode of resistance, a strength routine following the American College of Sports Medicine's guidelines should result in improved performance on the golf course.[206] These guidelines include (1) multi-joint exercises, (2) performing these exercises with a sub-maximal resistance (2 or 3 sets of 8 to 12 repetitions), (3) a frequency of 2 or 3 times per week, (4) performing this program over 8 weeks or more. Because of the possibility of delayed-onset muscle soreness (DOMS) following a strength workout, it is recommended to avoid heavy lifting immediately before playing in a big tournament. Golfers on the PGA Tour often perform a heavier resistance workout either during an off-week or earlier during a tournament week to have time to recover from DOMS before beginning the competition on Thursday.

Power training also appears to improve clubhead speed and, therefore, positively affect performance on the golf course. Lewis et al[207] found that clubhead speed positively correlates with squat jump height and rotational medicine ball throw length. In their study of junior golfers, Coughlan et al[208] similarly found improvements in clubhead speed with power training using "upper-, lower-, and full-body concentric dominant power exercises," suggesting that power training should be a central part of a comprehensive golf fitness program at the junior level as well. The ideal frequency for performing a power routine related to golf is not well studied. As a general guideline, most professional golfers do not exceed one power workout per week during the season, and for the amateur golfer, perhaps once every two weeks is sufficient.

Periodization and Load Management

Some professional golfers on the PGA Tour have reported to the medical staff that they make upward of 50,000 golf swings over a season. While no injury-inducing "magic threshold" related to the volume of swings has been identified in the literature, proactive management of the high-level golfer's workout and recovery program is paramount to keeping them healthy on the golf course and playing their best. Additionally, the "offseason" is very short for professional golfers. With the PGA Tour's "wrap-around season," play begins in January and runs through the summer. The playoffs end in August, and the new season begins a week or two later and runs until late November. This schedule makes load management throughout the season even more important.

For most professional golfers on the PGA Tour, their performance focuses on the major championships and bigger tournaments that happen approximately once every month from March to August. Therefore, the professional golfer's fitness routine is periodized to reach peak performance the week of major tournaments. *Periodization*, defined as "the planned manipulation of training variables (load, sets, and repetitions) to maximize training adaptations and to prevent the onset of overtraining syndrome,"[209] has not been well-studied as it relates to golf. However, it is an effective approach to training for athletes competing in other sports.[210,211] An example of periodization in golf is tapering of the strength and power aspects of the golfer's fitness routine during the week of a major tournament and focusing instead on other aspects such as functional mobility and dynamic stabilization. While it might be challenging to convince a professional golfer to limit their practice time during a major week, the physical therapists on the PGA Tour encourage their golfers to take days off from the golf course periodically during other weeks and focus on recovery throughout the season. Practice sessions are encouraged to be shorter during non-major weeks. The golfer's treatment and workout programs are designed with load in mind, focusing on limiting repetition and improving recovery between practice sessions during the non-major weeks with the goal of increasing the likelihood that the golfer stays healthy, performs at their peak, and avoids injury later in the season. While well-studied in other sports like professional soccer and baseball, this type of load management warrants further investigation as it relates to golf.

Pre-Round Warm-up

An effective pre-round warm-up routine may be one of the most valuable and performance-enhancing aspects of a golf-specific fitness program. Ehlert et al[212] define warm-ups as "protocols designed to prepare the body physically for subsequent activity." The primary goal of a pre-round warm-up routine is for the golfer to be ready to perform at their best on the first tee. It should eliminate the need to play several holes before "feeling loose." Indeed, professional golfers do not have the luxury of hitting their stride on the fourth or fifth hole. By that point, the tournament may be over for them.

A good routine has been found to include a combination of active and dynamic activities[213] with some type of functional resistance.[214] Conversely, passive stretching before a round of golf has been found to decrease clubhead speed in the short term.[212] The pre-round exercises should be performed primarily in golf posture. For example, performing hip exercises in golf posture with light resistance seems to have a positive neuromuscular effect that can be carried over onto the practice range and golf course (**Video 8**). Most of the top golfers on the PGA Tour have a consistent routine that they perform before every practice session or competitive round. To this point, when recently asked if they had to choose between preparing for a tournament round by hitting golf balls on the range or performing their gym-based warm-up, one professional golfer chose the gym warm-up without hesitating.

Video 8: Resisted Hip Extension in Golf Posture
https://www.orthptlearn.org/mod/vimeo/view.php?id=_____)

The physical therapist should design a warm-up routine for the golfer based on the examination results and related to the client's goals. For example, a golfer demonstrating muscular stiffness in the hip gluteal musculature and limited rotation ROM in the thoracic spine should address these impairments during their pre-round warm-up. Most exercises in the warm-up do not necessarily require machines or other equipment. Therefore, the golfer should be able to perform most aspects of their routine on the practice range or in the locker room before teeing off. Because no single pre-round routine is best for every golfer, it may take some time to figure out what combination is best for their performance. When the golfer does find the right combination of pre-round exercises, they should be encouraged to make it a habit to perform the routine consistently before every round.

Post-Round Recovery

The fastest-growing aspect of fitness on the PGA Tour is what the medical staff refers to as "recovery." It is important to note that research on this aspect of fitness is not very well established. However, professional golfers are implementing post-round recovery measures more than ever before. Several different modalities can aid the golfer in post-round recovery. These include vasopneumatic compression, cupping, sports massage, flexibility/stretch training, and cryotherapy (**Figure 26**). There is some indication that BFR training may aid in lessening post-activity muscle soreness.[215] However, the literature on this topic remains sparse at this point.

A typical post-round recovery program for a professional golfer on the PGA Tour includes 8 to 10 minutes of low-resistance cycling, then active stretching of the lower back and hips, then 20 to 30 minutes of vasopneumatic compression. It is understood that most amateur golfers will likely not commit to 45 to 60 minutes of recovery following their rounds. This demographic may have more success adhering to a post-round stretching routine lasting 10 to 15 minutes and consisting of 5 or 6 exercises to target the primary muscles discussed previously.

Of all factors affecting recovery and resulting performance, none seems more important than sleep.[216] Consistent, regular sleep is crucial to recovery as measured by performance and post-activity soreness.[217] Conversely, irregular sleep has been associated with decreased motor performance, reaction times, and inconsistent mood states, all significant factors that may affect the high-level golfer's performance on the golf course.[218] Sleep hygiene is a field of growing interest as it relates to athletic performance. Many sports teams now employ "sleep specialists" to assist their athletes in developing good sleep habits. It is

Figure 26. Post-round Recovery in the Professional Golfers Association (PGA) Tour's Player Performance Center

generally agreed that most individuals require 7 to 9 hours of sleep each night. For professional golfers, frequent travel across multiple time zones, early tee times, and the pressure to perform make maintaining regular sleep habits difficult. Furthermore, sleep requirements likely change as the professional season progresses. Golfers playing multiple tournaments in a row late in the season may require more sleep and may be better served napping regularly instead of performing another strength workout.[219]

Injury Prevention

The most controversial and understudied aspect of golf fitness is injury prevention. It has been studied in other populations of athletes, but not so much in golf. Baroni and Costa[220] found that most studies on preventing hamstring injuries in athletes focused on a single session to identify risk factors. They suggested that such screenings should happen regularly throughout the season to be more effective because certain modifiable risk factors might change for this population. While the incidence of hamstring injury is low in the golfing population, it is reasonable to implement a similar construct in golf. Frequently screening the golfer throughout the season for faulty movement patterns (eg, excessive lateral flexion of the lumbar spine in the backswing) or impairments like those discussed throughout this monograph (eg, limited hip IR ROM, weakness in the erector spinae musculature) may very well allow the physical therapist to identify and address these issues before they affect performance or induce injuries. As mentioned previously, many professional golfers undergo 3D swing analysis during the offseason to produce a "baseline swing" to which they might compare future swings later in the season. A faulty swing pattern identified on video may also cue the physical therapist to further examine specific areas of concern before they become a problem.

One aspect of injury prevention that has been studied related to golf is the effectiveness of a pre-round warm-up. The previous section discussed the pre-round warm-up as an effective means to improve performance. However, such a program has also been found to mitigate (not eliminate) the risk of injury.[52] Again, active, dynamic, and functional exercises that specifically target the thoracolumbar spine and hips seem to be most effective at limiting the risk of injury on the golf course. Unsurprisingly, Ehlert et al[212] found that golfers who are more highly skilled are more likely to perform a consistent warm-up routine. Conversely, a lower-skilled golfer who demonstrates poor mechanics and does not perform a warm-up is more likely to get injured. While the "perfect" warm-up routine does not exist for every golfer, the physical therapist can serve their golfing clients by designing an effective routine that the golfer can perform consistently before every round.

SUMMARY

The recent increase in popularity of golf has resulted in greater opportunities for physical therapists to work with golfers of all skill levels. To effectively treat this demographic and their golf-specific injuries, the physical therapist needs to understand the biomechanics of the golf swing. Examination of the injured golfer should include specific tests and measures to identify underlying dysfunctional movements and their related impairments. The physical therapist should also consider the direct and indirect contributions that other related body regions may have on the golf-specific pain syndromes discussed throughout this monograph. Likewise, treatment of the injured golfer should include activity-specific interventions designed to target these impairments to eliminate the pain syndrome and enhance performance on the golf course. Finally, a fitness program should include a pre-round warm-up designed for the golfer's specific strengths and weaknesses. This will likely improve performance and mitigate the risk of further injury.

CASE STUDIES

Case #1 – Low Back Pain

History

The patient was a 27-year-old male right-handed professional golfer complaining of LBP. He turned professional at 17 and reported previous episodes of LBP throughout his career. The most recent episode of LBP began during the previous week's tournament, his fourth tournament in a row. He had been playing more frequently than usual at this point in the season because he was trying to keep his status as a full member of the PGA Tour for next season. The pain was reported to be on the lower right side of his lumbar spine. He noticed it primarily at impact and through the finish of his golf swing. He also noticed it during his warm-up while performing "scorpions" (combined lumbar extension and rotation in prone). He reported cutting his finish short to avoid reproducing the pain. He recently changed to a new swing coach, who was attempting to get him to "stay down on the ball longer" through impact. His past medical history was insignificant for any other medical comorbidities. He occasionally took a low-dose nonsteroidal anti-inflammatory as needed and had received physical therapy for this back injury at various points "when it gets really bad." He had never had diagnostic imaging for this condition.

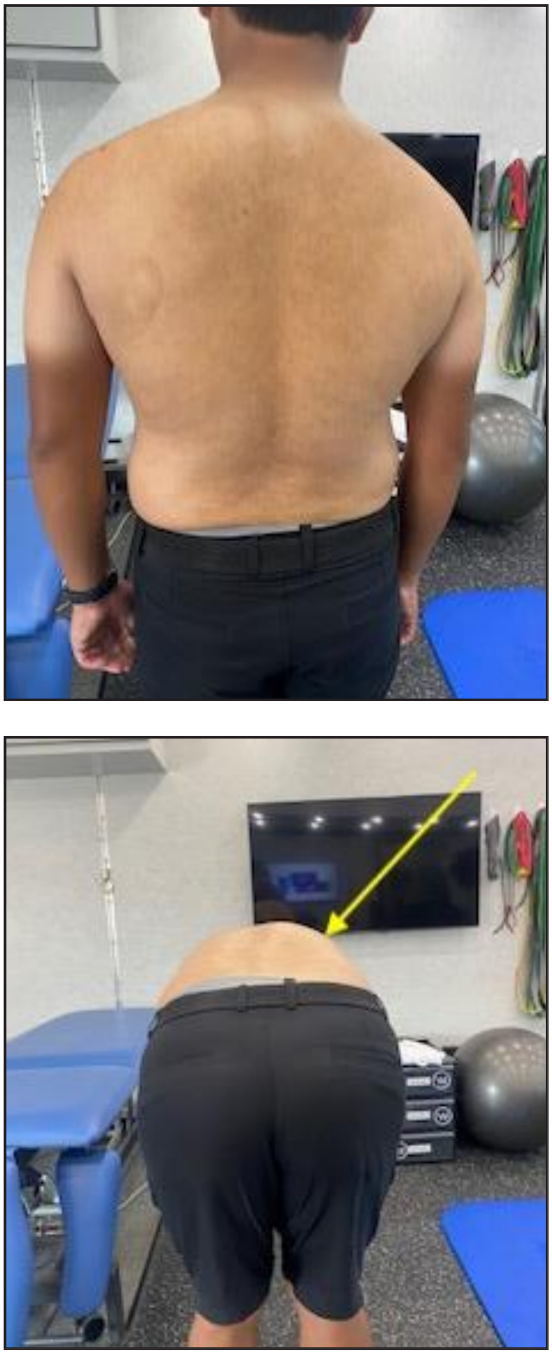
Examination

Physical examination revealed asymmetrically hypertrophied lumbar paraspinal musculature on the right. The golfer stood in excessive lumbar lordosis, with the right iliac crest resting higher than the left (**Figure 27**). The pain was reported with active lumbar extension, right rotation, and right lateral flexion approximately halfway into the available range of each direction. Flexion, left rotation, and left lateral flexion were normal and pain-free. Passive hip ROM was recorded as follows: Hip IR - 30° on the left with a capsular end feel and no pain; right hip IR was 35°; hip ER was 45° bilaterally. Active thoracic rotation was 45° bilaterally and pain free. Strength was graded as follows: left gluteus medius: 4/5, gluteus maximus: 5-/5, tensor fascia latae: 5/5; right gluteus medius: 3+/5, gluteus maximus: 4+/5, tensor fascia latae: 5/5; lower abdominals: 4-/5, erector spinae: 4+/5. Muscle length testing revealed short iliopsoas on the right (positive Thomas test); otherwise, muscle length was normal. Joint accessory motion of the lumbar spine demonstrated hypermobility and pain with a unilateral PA glide of the right L5 transverse process. Otherwise, the lumbar joint accessory motion was normal.

A neuromuscular examination revealed normal deep tendon reflexes and sensation to light touch throughout both lower extremities. Myotomal testing was normal and symmetrical. The lumbar quadrant test (combined extension, lateral flexion) was positive for pain in the right side of his lumbar spine. Straight leg raise and slump tests were negative for symptom provocation bilaterally.

Functional testing revealed difficulty maintaining single-leg balance in golf posture on the right due to the same pain in the right side of his lower back. Forward lunge was normal on the left; unstable (golfer also reported "it feels weaker") on the right. The side plank test revealed fatigue after 20 seconds on the right while on the left side, 30 seconds was done without difficulty. Video analysis of the golf swing from the previous week's tournament revealed excessive right lumbar lateral flexion at impact and during the follow-through (**Figure 28**).

Figure 27. Examination



A, Standing. B, Forward-bending.

Diagnosis

The golfer was diagnosed with right lumbar rotation/extension syndrome. It was determined that he could continue to play competitively while undergoing treatment for this condition. His primary impairments were hypermobility of the right L5/S1 segment, decreased left hip IR ROM, weakness in the right gluteus medius, gluteus maximus, and lower abdominal musculature, painful lumbar ROM into extension and right rotation and lateral flexion, and limited left hip IR passive ROM. Given his age, motivation, and overall health,

Figure 28. Right-sided Low Back Pain Reported at the Finish

his prognosis to recover from this injury and regain pain-free performance on the golf course was considered excellent.

Interventions

A treatment program was initiated immediately to include lumbar spine stabilization exercises focusing on the lower abdominal and gluteal musculature. Planking exercises were performed on the trail side with gradual progression to dynamic side planks with rotation using resistive bands. Hip extension exercises were performed in prone, then progressed to quadruped and standing with care taken to maintain neutral alignment of the lumbar spine and avoid lumbar extension or rotation (**Figure 29**). The strengthening program progressed to include exercises performed in golf posture with resistive bands (**Figure 30**). Additionally, his pre-round warm-up was modified to include these exercises while eliminating the pain-inducing ones.

Figure 29. Hip Extension in Quadruped

Figure 30. Backswing Stretch with Resisted Hip Abduction

Outcomes

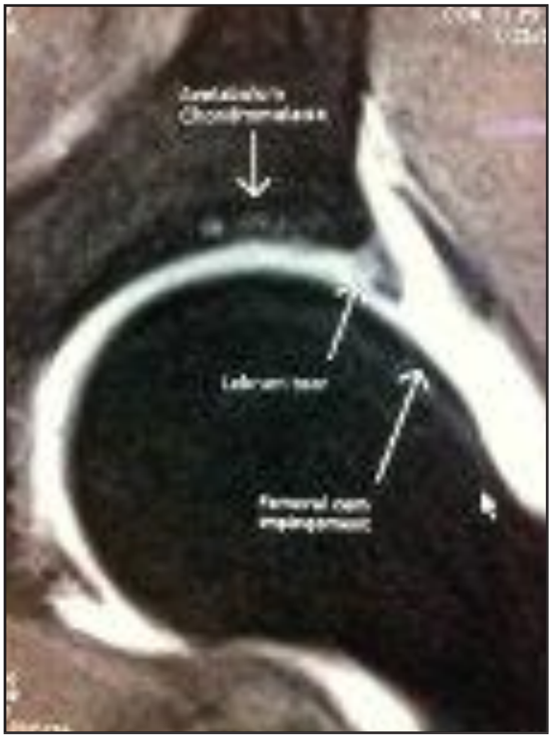
The golfer reported decreased LBP almost immediately upon initiating the stability program and modifying his current warm-up. He continued to play successfully and advanced well into the playoffs at the end of the season. He was encouraged to continue with this protocol preemptively to prevent a recurrence.

Case #2 – Hip Pain

History

The patient was a 32-year-old male right-handed professional golfer complaining of left hip pain for 3 weeks. He reported a history of on-again, off-again left hip pain throughout his career. This current injury was attributed to a recent increase in playing schedule, during which he has played eight of the previous nine weeks. The pain was reported as a sharp "pinching" in the anteromedial aspect of his left hip. He reported a recent decrease in clubhead speed corresponding to the onset of symptoms. He also said his coach told him he was not transferring his weight onto his left side at impact. The pain was most noticeable at the finish of his golf swing when he attempted to post on his left (lead) side. Diagnostic imaging performed two weeks prior revealed cam impingement in the left hip, a small labrum tear, and mild degenerative changes of the articular cartilage on both the femoral head and the acetabulum (**Figure 31**). Past medical history was remarkable for a diagnosis of Legg-Calve-Perthes disease in the left hip as a child.

Figure 31. Initial Image of Golfer's Lead Hip Injury



Examination

Physical examination revealed normal thoracolumbar alignment in standing. Both hips were slightly externally rotated. Active lumbar flexion ROM was limited by hip pain at end-range; otherwise, all lumbar ROM was normal. Passive ROM of the left hip was measured as follows: hip IR: 5° with pain and capsular end feel (right IR was 35° and pain-free), ER: 60° (right ER was 65°), flexion: 110° with "pinching" in the anteromedial hip, extension:15°. Strength testing revealed weakness in the left deep hip external rotators (4/5), gluteus medius (4-/5), and gluteus maximus (4/5) compared to the uninvolved right hip (5/5 throughout). Muscle length testing revealed a short tensor fascia latae on the left (positive Ober test). The FADIR test was positive on the left for reproducing the golfer's pain, and Craig's test was positive for left hip retroversion. Gait analysis revealed slightly decreased left stance time with premature heel-off at terminal stance.

Functional testing revealed pain with deep squatting. Single-leg stance on the left lower extremity was limited by poor balance compared to the right but was not painful. A forward lunge on the left revealed weakness and decreased stability but was also not painful.

Diagnosis

The golfer was diagnosed with left FAI (cam-type). His primary impairments were limited hip flexion and IR ROM, gluteus medius and maximus muscle weakness, and an antalgic gait pattern. Despite favorable factors such as age and overall good health, the golfer's prognosis to recover from this injury was downgraded from excellent to good, based primarily on significant negative factors, including his history of Legg-Calve-Perthes disease as a child and the current clinical and recent MRI findings. He was deemed able to continue competing on the PGA Tour while concurrently undergoing treatment. It was suggested that he makes a slight modification to his swing by slightly turning his left foot toward the target (approximately 10°).

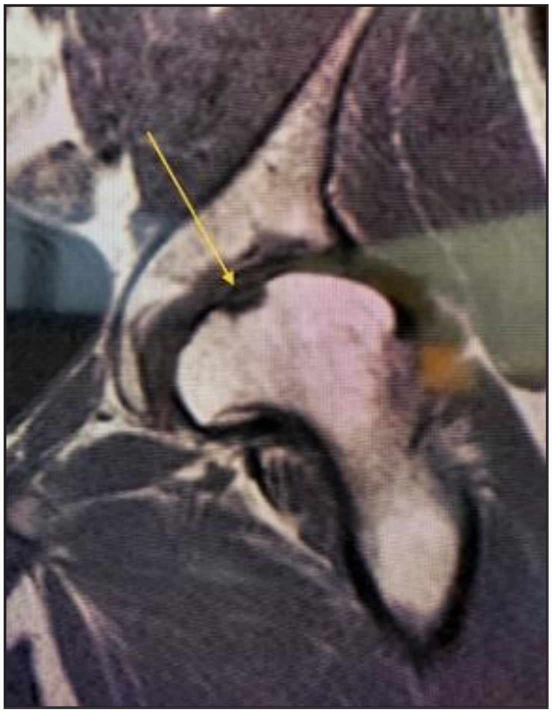
Interventions

Initially, the golfer's treatment program consisted of left hip joint mobilization, including long-axis distraction and caudal glides performed at end-range flexion. This provided him with immediate, moderate relief of the hip pain and temporarily eliminated the "pinching" sensation previously reported at end-range flexion and IR. However, this symptom tended to return following practice sessions and competitive play. A hip strengthening program was also initiated, consisting of exercises like those described in the previous case. Hip ER strengthening exercises were initially performed supine with a resistive band, and the hip and knee flexed to 90°. Open-chain hip abduction and ER were performed with the golfer sidelying against the wall. Hip flexion in quadruped was performed in a pain-free range, with his ability to flex the hips in this position improved following the manual interventions just described.

Outcomes

The athlete completed the season with moderate success related to the pain in his left hip. During the offseason (approximately 8 months after the examination), he began experiencing a worsening of symptoms. He reported that his gait pattern worsened, and he could not swing a golf club or perform most gym exercises due to hip pain. Activities requiring a single-leg stance suddenly became difficult. Unfortunately, an additional MRI revealed avascular necrosis of the left femoral head (**Figure 32**). The golfer elected to undergo hip arthroscopy for femoral head resurfacing, cam debridement, and labrum repair, followed by post-surgical rehabilitation. He is currently on a medical exemption as he rehabilitates and works toward returning to the PGA Tour.

Figure 32. Follow-up Image of Golfer's Lead Hip Injury



Case #3 – Shoulder Pain

History

The patient was a 19-year-old male right-handed collegiate golfer who sought help from the physical therapist for his right shoulder pain. He reported that he injured his shoulder while working out in the gym with his team the previous week. He was performing a single-arm overhead snatch with a kettlebell and felt a "pull" in the anterior aspect of his right shoulder. After that, he had difficulty swinging the golf club, reporting sharp pain in the right shoulder at the transition point of his golf swing. His coach noticed that the golfer was abbreviating his backswing, which contributed to poor performance in their final tournament of the season the previous weekend. He denied clicking or popping in the shoulder. Past medical history was unremarkable. The golfer reported that he had never experienced an injury like this and had not undergone any diagnostic imaging for this condition.

Examination

Physical examination revealed the golfer standing with a forward shoulders posture. Both scapulae were depressed, slightly abducted, and downwardly rotated (right more pronounced than left). The thoracic spine was slightly more kyphotic than normal. Passive ROM was as follows: bilateral shoulder flexion, abduction: normal and pain-free, right shoulder ER: 105° with pain and guarding at end-range (left was 95° and pain-free), IR: 75° (left was 70° and pain-free). Active thoracic rotation while sitting was measured at 30˚ to the right and 45˚ to the left. Strength testing was as follows: right supraspinatus: 4-/5 with pain (left: 5/5), infraspinatus/teres minor: 5/5 bilaterally, right subscapularis: 4-/5 with pain (left: 5/5), serratus anterior: 5/5 bilaterally, deltoid: 5/5 bilaterally, and middle/lower trapezius: 4/5 bilaterally. Glenohumeral joint accessory motion assessment of the right shoulder indicated hypermobility in the anterior direction and hypomobility in the posterior direction. Muscle length testing revealed equally short pectoralis minor muscles bilaterally (acromion approximately 8 cm from the table). Special testing for the right shoulder was recorded as follows: (+) Empty can test; (-) Hawkins-Kennedy impingement test; (+) Anterior apprehension test; (-) Jobe relocation test; (-) Crank test.

Functional testing revealed an abnormal overhead squat where the golfer rotated toward his painful side (**Figure 33**). Attempts to correct his alignment caused increased pain in the right shoulder.

Diagnosis

Following the examination, the golfer was diagnosed with a strain of the rotator cuff (subscapularis and supraspinatus) and glenohumeral joint anterior instability. His primary impairments included glenohumeral joint hypermobility in the anterior direction, weakness in the rotator cuff (supraspinatus and subscapularis muscles) and scapulothoracic musculature (middle and lower trapezius muscles), short pectoralis minor muscle, and poor posture. His prognosis was judged to be excellent given his age, motivation, and lack of previous injury.

Figure 33. Poorly Performed Overhead Squat

Figure 34. Overhead Squat Performed Against the Wall

Interventions

A treatment program was initiated immediately. Because the golfer was in his offseason, he was instructed to refrain from swinging the golf club for 2 weeks while undergoing treatment. Treatment initially consisted of postural education (he was instructed to avoid slouching while sitting to study, etc), stretching exercises for the pectoralis minor and thoracic spine, and a scapular strengthening program performed in the prone position with no external resistance. Rotator cuff strengthening exercises were initiated in neutral positions and performed isometrically first, then isotonically with light resistance as the golfer progressed. Glenohumeral joint mobilization was performed in the anterior-posterior direction to address the hypomobile posterior capsule. Additionally, thoracic mobilization was performed to address the limited ROM in the left thoracic rotation.

As the golfer progressed, he was permitted to begin chipping and putting and several new exercises were added to his program. The overhead squat was performed against the wall, and the golfer was instructed to press his right upper extremity into the wall (**Figure 34**). He was able to perform this movement without pain. The rotator cuff strengthening exercises were progressed to be performed with the shoulder in increasing degrees of abduction. Finally, a weight training regimen focusing on sub-90° strengthening exercises was added. One example is the resisted chop performed in a staggered stance (**Figure 35**). The golfer stood with his right side toward the cable machine and his right leg forward in a partial lunge. He grasped the handle with both hands close to his right shoulder and pulled it downward across his body (toward the arrow).

Outcomes

Following two weeks of physical therapy, the golfer reported no pain in the right shoulder and was allowed to resume taking full swings. His pre-round routine was adjusted to include several of the exercises just described. He spent the summer gradually returning to a full volume of practice and was expected to return to competition with his college team soon.

ACKNOWLEDGEMENTS

I would like to thank my colleagues (and friends) on the PGA Tour Sports Medicine Team including Tom Hospel, MD, Daniel Chelette, DPT, Digby Watt, PT, Paul Schueren, PT, Corey Hug, PT, Jonny Eichner, DPT, Tim Dunlavey, ATC, and Tom LaFountain, DC, for their support and feedback throughout the process of writing this monograph. We eat, sleep, and breathe all things related to the orthopedic management of the golfer. Our many conversations in the trailers have shaped my clinical practice and contributed immensely to the contents of this monograph.

Thanks to Dr. Shirley Sahrmann, PT, PhD, FAPTA, for her long-standing mentorship and invaluable thoughts on the

Figure 35. Resisted Chop in Staggered Stance

movement science component of the monograph. Thanks to my close friend, Dr. Christopher Ivey, PT, MPT, ATC, MS, EdD, for his thoughts on the monograph's organization and content development. Special thanks to Dr. Ioannis (John) Zouzias, MD, and Dr. Robert Watkins, IV, MD, for providing a physician's viewpoint on many of the topics discussed throughout the monograph.

Thanks to the late Dr. Frank Jobe, MD, whose vision for a mobile sports medicine program for the PGA Tour came to fruition over 30 years ago. His pioneering foresight was truly ahead of its time.

Thanks to the many professional golfers, especially Jason Dufner, James Hahn, Charley Hoffman, Brendan Steele, and Adam Scott, for the deep conversations we have had over the years about swing theory, workout routines, and injury rehabilitation. Finally, thanks to the hundreds of professional golfers on the PGA Tour and PGA Tour Champions who have entrusted their care to the PGA Tour's staff of physical therapists and athletic trainers. Over the 30+ years of our program's existence, their participation has turned the PGA Tour Player Performance Center into a kind of working laboratory to help our staff figure out what works and what does not when treating the best golfers in the world!

REFERENCES

1. Record numbers now playing golf worldwide. The R&A. December 14, 2021. Accessed April 22, 2023. https://www.randa.org/articles/record-numbers-now-playing-golf-worldwide
2. 2021 National Golf Foundation report. Accessed May 4, 2023. www.nationalgolffoundation.com
3. 2019 Royal and Ancient Report. Accessed May 4, 2023. www.randa.org
4. Evans K, Tuttle N. Improving performance in golf: current research and implications from a clinical perspective. *Braz J Phys Ther*. 2015;19(5):381-389. doi:10.1590/bjpt-rbf.2014.0122
5. Murray AD, Daines L, Archibald D, et al. The relationships between golf and health: a scoping review. *Br J Sports Med*. 2017;51(1):12-19. doi:10.1136/bjsports-2016-096625
6. Dobrosielski DA, Brubaker PH, Berry MJ, Ayabe M, Miller HS. The metabolic demand of golf in patients with heart disease and in healthy adults. *J Cardiopulm Rehabil*. 2002;22(2):96-104. doi:10.1097/00008483-200203000-00008
7. Gabellieri JM. *The Physiological Demands of Walking During Golf.* Dissertation. University of Rhode Island. ProQuest Dissertations Publishing; 2011.
8. Pennington, B. How many calories do you burn in Golf? Colorado Center for Health and Sports Science blog. August 8, 2010. Accessed April 22, 2023. https://cochss.com/howmanycaloriesdoyouburningolf/
9. Zunzer SC, von Duvillard SP, Tschakert G, Mangus B, Hofmann P. Energy expenditure and sex differences of golf playing. *J Sports Sci*; 2013;31(10):1045-1053. doi:10.1080/02640414.2013.764465
10. Burkett LN, von Heijne-Fisher U. Heart rate and calorie expenditure in golfers carrying their clubs and walking flat and hilly golf courses. *Int Sports J.* 1998;2(2):78-85.
11. Lampley JH, Lampley PM, Howley ET. Caloric cost of playing golf. *Res Q.* 1977;48:637-639.
12. Parkkari J, Natri A, Kannus P, et al. A controlled trial of health benefits of regular walking on a golf course. *Am J Med*. 2000;109(2):102-108. doi:10.1016/s0002-9343(00)00455-1
13. Gao KL, Hui-Chan CWY, Tsang WWN. Golfers have better balance control and confidence than healthy controls. *Eur J Appl Physiol*. 2011;111(11):2805-2812. doi:10.1007/s00421-011-1910-7
14. Brown S, Samuel D, Agyapong-Badu S, et al. Age-related differences in lung function between female recreational golfers and less active. Paper presented at: World Scientific Congress of Golf VII; July 18-22, 2016; St Andrews, UK. *Int J Golf Sci.*2016;*5*(Suppl 1): S69. Accessed April 23, 2023. https://www.golfsciencejournal.org/article/4973-world-scientific-congress-of-golf-2016

15. Farahmand B, Broman G, de Faire U, Vågerö D, Ahlbom A. Golf: a game of life and death – reduced mortality in Swedish golf players. *Scand J Med Sci Sports*. 2009;19(3):419-424. doi:10.1111/j.1600-0838.2008.00814.x
16. Fradkin AJ, Cameron PA, Gabbe BJ. Golf injuries – common and potentially avoidable. *J Sci Med Sport*. 2005;8(2):163-170. doi:10.1016/s1440-2440(05)80007-6
17. Lindsay DM, Horton JF, Paley RD. Trunk motion of male professional golfers using two different golf clubs. *J Applied Biomech*. 2002:18(4);366-373. doi:10.1123/jab.18.4.366
18. Sheehan WB, Bower RG, Watsford ML. Physical determinants of golf swing performance: a review. *J Strength Cond Res*. 2022;36(1):289-297. doi:10.1519/JSC.0000000000003411
19. Lewis AL, Ward N, Bishop C, Maloney S, Turner AN. Determinants of club head speed in PGA professional golfers. *J Strength Cond Res*. 2016;30(8):2266-227.
20. Cole MH, Grimshaw PN. The biomechanics of the modern golf swing: implications for lower back injuries. *Sports Med*. 2016;46(3):339-351. doi:10.1007/s40279-015-0429-1
21. Vad VB, Bhat AL, Basrai D, Gebeh A, Aspergren DD, Andrews JR. Low back pain in professional golfers: the role of associated hip and low back range of motion deficits. *Am J Sports Med*. 2004;32(2):494-497. doi:10.1177/0363546503261729
22. Lindsay D, Horton J. Comparison of spine motion in elite golfers with and without low back pain. *J Sports Sci*. 2002;20(8):599-605. doi:10.1080/026404102320183158
23. Langdown BL, Bridge MW, Li FX. Address position variability in golfers of differing skill level. *Int J Golf Sci*. 2013;2:1-9.
24. Myers J, Lephart S, Tsai YS, Sell T, Smoliga J, Jolly J. The role of upper torso and pelvis rotation in driving performance during the golf swing. *J Sports Sci*. 2008;26(2):181-188. doi:10.1080/02640410701373543
25. Joyce C. The most important "factor" in producing clubhead speed in golf. *Hum Mov Sci*. 2017;55:138-144. doi:10.1016/j.humov.2017.08.007
26. Kao JT, Pink M, Jobe FW, Perry J: Electromyographic analysis of the scapular muscles during a golf swing. *Am J Sports Med*. 1995;23(1):19-23. doi:10.1177/036354659502300104
27. Bulbulian R, Ball KA, Seaman DR. The short golf backswing: effects of performance and spinal health implications. *J Manip Phys Ther*. 2001;24(9):569-575. doi:10.1067/mmt.2001.118982
28. Bechler JR, Jobe FW, Pink M, Perry J, Ruwe PA. Electromyographic analysis of the hips and knees during the golf swing. *Clin J Sport Med*. 1995;5(3):162-166. doi:10.1097/00042752-199507000-00005
29. Betzler NF, Monk SA, Wallace ES, Otto SR. Effects of golf shaft stiffness on strain, clubhead presentation and wrist kinematics. *Sports Biomech*. 2012;11(2):223-238. doi:10.1080/14763141.2012.681796
30. Marsan T, Thoreux P, Bourgain M, Rouillon O, Rouch P, Sauret C. Biomechanical analysis of the golf swing: methodological effect of angular velocity component on the identification of the kinematic sequence. *Acta Bioeng Biomech*. 2019;21(2):115-120.
31. Han KH, Como C, Kim J, Hung CJ, Hasan M, Kwon YH. Effects of pelvis-shoulders torsional separation style on kinematic sequence in golf driving. *Sports Biomech*. 2019;18(6):663-685. doi:10.1080/14763141.2019.1629617
32. Hume P, Keogh J, Reid D. The role of biomechanics in maximizing distance and accuracy of golf shots. *Sports Med*. 2005;35(5):429-449. doi:10.2165/00007256-200535050-00005
33. Tinmark F, Hellstrom J, Halvorsen K, Thorstensson A. Elite golfers' kinematic sequence in full-swing and partial-swing shots. *Sports Biomech*. 2010;9(4):236-244. doi:10.1080/14763141.2010.535842
34. Langdown BL, Bridge M, Li FX. Movement variability in the golf swing. *Sports Biomech*. 2012;11(2):273-287. doi:10.1080/14763141.2011.650187
35. Callaway S, Glaws K, Mitchell M, Scerbo H, Voight M, Sells P. An analysis of peak pelvic rotation speed, gluteus maximus and medius strength in high versus low handicap golfers during the golf swing. *Int J Sports Phys Ther*. 2012;7(3):288-295.
36. Gryc T, Zahalka F, Maly T, Mala L, Hrasky P. Movement's analysis and weight transfer during the golf swing. *J Phys Ed Sport*. 2015;15(4):781-787. doi:10.7752/jpes.2015.04119
37. Burden A, Grimshaw P, Wallace E. Hip and shoulder rotations during the golf swing of sub-10 handicap players. *J Sports Sci*. 1998;16(2):165-176. doi:10.1080/026404198366876
38. Nesbit SM. A three-dimensional kinematic and kinetic study of the golf swing. *J Sports Sci Med*. 2005;4(4):499-519.
39. Myers J, Lephart S, Tsai YS, Sell T, Smoliga J, Jolly J. The role of upper torso and pelvis rotation in driving performance during the golf swing. *J Sports Sci*. 2008;26(2):181-188. doi:10.1080/02640410701373543
40. Choi A, Joo SB, Mun JH. Kinematic evaluation of movement smoothness in golf: relationship between the normalized jerk cost of body joints and the clubhead. *Biomed Eng*. 2014;13(1):20. doi:10.1186/1475-925X-13-20
41. Langdown B, Bridge M, Li FX. Address position variability in golfers of differing skill level. *Internat J Golf Sci*. 2013;2:1-9.
42. Steele KM, Roh EY, Mahtani G, Meister DW, Ladd AL, Rose J. Golf swing rotational velocity: the essential follow-through. *Ann Rehabil Med*. 2018;42(5):713-721. doi:10.5535/arm.2018.42.5.713
43. Murray E, Birley E, Twycross-Lewis R, Morrissey D. The relationship between hip rotation range of movement and low back pain prevalence in amateur golfers: an observational study. *Phys Ther Sport*. 2009;10(4):131-135. doi:10.1016/j.ptsp.2009.08.002
44. Haddas R, Pipkin W, Hellman D, Voronov L, Kwon YH, Guyer R. Is golf a contact sport? Protection of the spine and return to play after lumbar surgery. *Global Spine J*. 2022;12(2):298-307. doi:10.1177/2192568220983291
45. McHardy AJ, Pollard HP, Luo K. Golf-related lower back injuries: an epidemiological survey. *J Chiropr Med*. 2007;6(1):20-26. doi:10.1016/j.jcme.2007.02.010
46. Theriault G, Lachance P. Golf injuries. An overview. *Sports Med*. 1998;26(1):43-57. doi:10.2165/00007256-199826010-00004
47. Barclay C, West S, Shoaib Q, Morrissey D, Langdown B. Injuries patterns among professional golfers: an international survey. *Br J Sports Med*. 2011;45(2). doi:10.1136/bjsm.2010.081554.12
48. Fradkin AJ, Windley TC, Myers JB, Sell TC, Lephart SM. Describing the epidemiology and associated age, gender, and handicap comparisons of golfing injuries. *Int J Inj Cont Safety Prom*. 2007;14(4):264-266. doi:10.1080/17457300701722585
49. Gosheger G, Liem D, Ludwig K, Greshake O, Winkelmann W. Injuries and overuse syndromes in golf. *Am J Sports Med*. 2003;31(3):438-443. doi:10.1177/03635465030310031901
50. McCarroll J, Rettig A, Shelbourne K. Injuries in the amateur golfer. *Phys Sportsmed*. 1990;18(3):122-126. doi:10.1080/00913847.1990.11709999

51. McCarroll J. The frequency of golf injuries. *Clin Sports Med*. 1996;15(1):1-7.
52. Meira EP, Brumitt J. Minimizing injuries and enhancing performance in golf through training programs. *Sports Health*. 2010;2(4):337-344. doi:10.1177/1941738110365129
53. Tsai YS, Sell TC, Smoliga JM, Myers JB, Learman KE, Lephart SM. A comparison of physical characteristics and swing mechanics between golfers with and without a history of low back pain. *J Orthop Sports Phys Ther*. 2010;40(7):430-438. doi:10.2519/jospt.2010.3152
54. Gluck GS, Bendo JA, Spivak JM. The lumbar spine and low back pain in golf: A literature review of swing biomechanics and injury prevention. *Spine J*. 2008;8(5):778-788. doi:10.1016/j.spinee.2007.07.388
55. Smith JA, Hawkins, A, Grant-Beuttler M, Beuttler R, Lee SP. Risk factors with low back pain in golfers: a systematic review and meta-analysis. *Sports Health*. 2018;10(6):538-546. doi:10.1177/1941738118795425
56. Nicholas JJ, Reidy M, Oleske DM. An epidemiologic survey of injury in golfers. *J Sport Rehabil*. 1998;7(2):112-121. doi:10.1123/JSR.7.2.112
57. Evans K, Refshauge KM, Adams R, Aliprandi L. Predictors of low back pain in young elite golfers: a preliminary study. *Phys Ther Sport*. 2005;6:122-130. doi:10.1016/j.ptsp.2005.05.003
58. Zouzias I, Hendra J, Stodelle J, Limpisvasti O. Golf injuries: epidemiology, pathophysiology, and treatment. *J Am Acad Orthop Surg*. 2018;26(4):116-123. doi:10.5435/JAAOS-D-15-00433
59. Hosea TM, Gatt CJ Jr. Back pain in golf. *Clin Sports Med*. 1996;15(1):37-53.
60. Finn C. Rehabilitation of low back pain in golfers: diagnosis to return to sport. *Sports Health*. 2013;5(4):313-319. doi:10.1177/1941738113479893
61. Van Dillen L, Lanier VM, Steger-May K, et al. Effect of motor skill training in functional activities vs strength and flexibility exercise on function in people with chronic low back pain: a randomized clinical trial [published correction appears in *JAMA Neurol*. 2021 Jan 19]. *JAMA Neurol*. 2021;78(4):385-395. doi:10.1001/jamaneurol.2020.4821
62. Burnett A, O'Sullivan P, Ankarberg L, et al. Lower lumbar spine axial rotation is reduced in end-range sagittal postures when compared to a neutral spine posture. *Man Ther*. 2008;13(4):300-306. doi:10.1016/j.math.2007.01.016
63. Sahrmann S. *Diagnosis and Treatment of Movement Impairment Syndromes*. Mosby; 2002.
64. Watkins RG, Uppal GS, Perry J, Pink M, Dinsay JM. Dynamic electromyographic analysis of trunk musculature in professional golfers. *Am J Sports Med*. 1996;24(4):535-538. doi:10.1177/036354659602400420
65. Bae SH, Lee JH, Oh KA, Kim KY. The effects of kinesio taping on potential in chronic low back pain patients anticipatory postural control and cerebral cortex. *J Phys Ther Sci*. 2013;25(11):1367-1371. doi:10.1589/jpts.25.1367
66. Ko TS, Jung HB, Kim JA. The effects of thoracic mobilization on pain, disability index and spinal mobility in chronic low back pain patients. *J Spec Edu Rehabil Sci*. 2009;48(2):115–137.
67. Yang SR, Kim K, Park SJ, Kim K. The effect of thoracic spine mobilization and stabilization exercise on the muscular strength and flexibility of the trunk of chronic low back pain patients. *J Phys Ther Sci*. 2015;27(12):3851-3854. doi:10.1589/jpts.27.3851
68. Zafereo J, Devanna R, Mulligan E, Wang-Price S. Hip stiffness patterns in lumbar flexion- or extension-based movement syndromes. *Arch Phys Med Rehabil*. 2015;96(2):292-297. doi:10.1016/j.apmr.2014.09.023
69. Roach SM, San Juan JG, Suprak DN, Lyda M, Bies AJ, Boydston CR. Passive hip range of motion is reduced in active subjects with chronic low back pain compared to controls [published correction appears in *Int J Sports Phys Ther*. 2015;10(4):572]. *Int J Sports Phys Ther*. 2015;10(1):13-20.
70. Shifflett GD, Hellman MD, Louie PK, Mikhail C, Park KU, Phillips FM. Return to golf after lumbar fusion. *Sports Health*. 2017;9(3):280-284. doi:10.1177/1941738116680200
71. Kostadinovic S, Milovanovic N, Jovanović J, Tomašević-Todorović S. Efficacy of the lumbar stabilization and thoracic mobilization exercise program on pain intensity and functional disability reduction in chronic low back pain patients with lumbar radiculopathy: a randomized controlled trial. *J Back Musculoskel Rehabil*. 2020;33(6):897-907. doi:10.3233/BMR-201843
72. Masaracchio M, Kirker K, States R, Hanney WJ, Liu X, Kolber M. Thoracic spine manipulation for the management of mechanical neck pain: A systematic review and meta-analysis. *PLoS One*. 2019;14(2):e0211877. doi:10.1371/journal.pone.0211877
73. Hunter DJ, Rivett DA, McKeirnan S, Smith L, Snodgrass SJ. Relationship between shoulder impingement syndrome and thoracic posture. *Phys Ther*. 2020;100(4):677-686. doi:10.1093/ptj/pzz182
74. Hwang D, Lee JH, Moon S, Park SW, Woo J, Kim C. The reliability of nonradiologic measures of thoracic spine rotation in healthy adults. *Phys Ther Rehabil Sci*. 2017;6:65-70. doi:10.14474/ptrs.2017.6.2.65
75. Johnson KD, Kim KM, Yu BK, Saliba SA, Grindstaff TL. Reliability of thoracic spine rotation range of motion measurements in healthy adults. *J Athl Train*. 2012;47(1):52-60. doi:10.4085/1062-6050-47.1.52
76. Kaltenborn F. *Manual Mobilization of the Joints, Volume II: The Spine*. 7th ed. Orthopedic Physical Therapy Products; 2018.
77. Lee AD. Golf-related stress fractures: a structured review of the literature. *J Can Chiropr Assoc*. 2009;53(4):290-299.
78. Lord MJ, Ha KI, Song KS. Stress fractures of the ribs in golfers. *Am J Sports Med*. 1996;24(1):118-122. doi:10.1177/036354659602400121
79. Orava S, Kallinen M, Aito H, Alén M. Stress fracture of the ribs in golfers: a report of five cases. *Scan J Med Sci Sports*. 1994;4(2):155-158. doi:10.1111/j.1600-0838.1994.tb00420.x
80. Zhang T, Wu J, Chen YC, Wu X, Lu L, Mao C. Magnetic resonance imaging has better accuracy in detecting new-onset rib fractures as compared to computed tomography. *Med Sci Monit*. 2021;27: e928463-1–e928463-7. doi:10.12659/MSM.928463
81. Lin HC, Chou CS, Hsu TC. Stress fractures of the ribs in amateur golf players. *Zhonghua Yi Xue Zhi (Taipei)*. 1994;54(1):33-37.
82. Bryan GJ. *Skeletal Anatomy*. 3rd ed. Churchill Livingstone; 1996.
83. Ontell FK, Moore EH, Shepard JA, Shelton DK. The costal cartilages in health and disease. *Radiographics*. 1997;17(3):571-577. doi:10.1148/radiographics.17.3.9153697
84. Nguyen RT, Borg-Stein J, McInnis K. Applications of platelet-rich plasma in musculoskeletal and sports medicine: an evidence-based approach. *PM R*. 2011;3(3):226-250. doi:10.1016/j.pmrj.2010.11.007
85. Croft PR, Lewis M, Papageorgiou AC, et al. Risk factors for neck pain: a longitudinal study in the general population. *Pain*. 2001;93(3):317-325. doi:10.1016/S0304-3959(01)00334-7
86. Puentedura EJ, Cleland JA, Landers MR, Mintken PE, Louw A, Fernández-de-Las-Peñas C. Development of a clinical

prediction rule to identify patients with neck pain likely to benefit from thrust joint manipulation to the cervical spine. *J Orthop Sports Phys Ther*. 2012;42(7):577-592. doi:10.2519/jospt.2012.4243

87. Swait G, Finch R. What are the risks of manual treatment of the spine? A scoping review for clinicians. *Chiropr Man Ther*. 2017;25:37. doi:10.1186/s12998-017-0168-5
88. Puentedura EL, March J, Anders J, et al. Safety of cervical spine manipulation: Are adverse events preventable and are manipulations being performed appropriately? A review of 134 case reports. *J Man Manip Ther*. 2012;20(2):66. doi:10.1179/2042618611Y.0000000022
89. Koppenhaver SL, Morel T, Dredge G, et al. The validity of the cervical rotation lateral flexion test in predicting benefit after manipulation treatment to the first and second rib. *Musculoskelet Sci Pract*. 2022;62:102629. doi:10.1016/j.msksp.2022.102629
90. Krauss J, Creighton D, Ely JD, Podlewska-Ely J. The immediate effects of upper thoracic translatoric spinal manipulation on cervical pain and range of motion: a randomized clinical trial. *J Man Manip Ther*. 2008;16(2):93-99. doi:10.1179/106698108790818530
91. Cross KM, Kuenze CK, Grindstaff TL, Hertel J. Thoracic spine thrust manipulation improves pain, range of motion, and self-reported function in patients with mechanical neck pain: a systematic review. *J Orthop Sports Phys Ther*. 2011;41(9):633-642. doi:10.2519/jospt.2011.3670
92. Oh HT, Hwangpo G. The effect of short-term upper thoracic self-mobilization using a Kaltenborn wedge on pain and cervical dysfunction in patients with neck pain. *J Phys Ther Sci*. 2018;30(4):486-489. doi:10.1589/jpts.30.486
93. Childress MA, Becker BA. Nonoperative management of cervical radiculopathy. *Am Fam Physician*. 2016;93(9):746-754.
94. Romeo A, Vanti C, Boldrini V, et al. Cervical radiculopathy: effectiveness of adding traction to physical therapy – a systematic review and meta-analysis of randomized controlled trials [published correction appears in *Phys Ther*. 2018 Aug 1;98(8):727]. *Phys Ther*. 2018;98(4):231-242. doi:10.1093/physth/pzy001
95. Eubanks JD. Cervical radiculopathy: nonoperative management of neck pain and radicular symptoms. *Am Fam Physician*. 2010;81(1):33-40.
96. Woods BI, Hilibrand AS. Cervical radiculopathy: epidemiology, etiology, diagnosis, and treatment. *J Spinal Disord Tech*. 2015;28(5):E251-259. doi:10.1097/BSD.0000000000000284
97. Wu SK, Chen HY, You JY, Bau JG, Lin YC, Kuo LC. Outcomes of active cervical therapeutic exercise on dynamic intervertebral foramen changes in neck pain patients with disc herniation. *BMC Musculoskel Disorders*. 2022;23:728. doi:10.1186/s12891-022-05670-6
98. Steinberger J, Qureshi S. Cervical disc replacement. *Neurosurg Clin N Am*. 2020;31(1):73-79. doi:10.1016/j.nec.2019.08.009
99. Casta A. Femoroacetabular impingement. *Current Sports Med Reports*. 2015;14(4):276-277. doi:10.1249/JSR.0000000000000177
100. Pun S, Kumar D, Lane NE. Femoroacetabular impingement. *Arthritis Rheumatol*. 2015;67(1):17-27. doi:10.1002/art.38887
101. Nardo L, Parimi N, Liu F, et al. Femoroacetabular impingement: prevalent and often asymptomatic in older men: the osteoporotic fractures in men study. *Clin Othop Relat Res.* 2015;473(8):2578-2586. doi:10.1007/s11999-015-4222-0
102. Clohisy JC, Baca G, Beaulé PE, et al. Descriptive epidemiology of femoroacetabular impingement: a North American cohort of patients undergoing surgery. *Am J Sports Med.* 2014;41(6):1348–1356. doi:10.1177/0363546513488861
103. Agricola R, Heijboer MP, Bierma-Zeinstra SM, Verhaar JA, Weinans H, Waarsing JH. Cam impingement causes osteoarthritis of the hip: a nationwide prospective cohort study (CHECK). *Ann Rheum Dis*. 2013;72(6):918-923. doi:10.1136/annrheumdis-2012-201643
104. Wensaas A, Gunderson RB, Svenningsen S, Terjesen T. Femoroacetabular impingement after slipped upper femoral epiphysis: the radiological diagnosis and clinical outcome at long-term follow-up. *J Bone Joint Surg Br.* 2012;94(11):1487–1493. doi:10.1302/0301-620X.94B11.29569
105. Fraitzl CR, Kafer W, Nelitz M, Reichel H. Radiological evidence of femoroacetabular impingement in mild slipped capital femoral epiphysis: a mean follow-up of 14.4 years after pinning in situ. *J Bone Joint Surg Br.* 2007;89(12):1592–1596. doi:10.1302/0301-620X.89B12.19637
106. Siebenrock KA, Ferner F, Noble PC, Santore RF, Werlen S, Mamisch TC. The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. *Clin Orthop Relat Res.* 2011;469(11):3229–3240. doi:10.1007/s11999-011-1945-4
107. Griffin DR, Dickenson EJ, O'Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI): an international consensus statement. *Br J Sports Med*. 2016;50(19):1169-1176. doi:10.1136/bjsports-2016-096743
108. Ejnisman L, Philippon MJ, Lertwanich P, Lertwanich P, et al. Relationship between femoral anteversion and findings in hips with femoroacetabular impingement. *Orthopedics.* 2013;36:e293–e300. doi:10.3928/01477447-20130222-17
109. Wyss TF, Clark JM, Weishaupt D, Notzli HP. Correlation between internal rotation and bony anatomy in the hip. *Clin Orthop Relat Res.* 2007;460:152–158. doi:10.1097/BLO.0b013e3180399430
110. Uding A, Bloom NJ, Commean PK, et al. Clinical tests to determine femoral version category in people with chronic hip joint pain and asymptomatic controls. *Musculoskelet Sci Pract*. 2019;39:115-122. doi:10.1016/j.msksp.2018.12.003
111. Casartelli NC, Maffiuletti NA, Item-Glatthorn JF, et al. Hip muscle weakness in patients with symptomatic femoroacetabular impingement. *Osteoarthr Cartil.* 2011;19(7):816–821. doi:10.1016/j.joca.2011.04.001
112. Hunt MA, Guenther JR, Gilbart MK. Kinematic and kinetic differences during walking in patients with and without symptomatic femoroacetabular impingement. *Clin Biomech.* 2013;28(5):519–523. doi:10.1016/j.clinbiomech.2013.05.002
113. Freke MD, Kemp, J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med*. 2016;50(19):1180. doi:10.1136/bjsports-2016-096152
114. Lamontagne M, Kennedy MJ, Beaulé PE. The effect of cam FAI on hip and pelvic motion during maximum squat. *Clin Orthop Relat Res.* 2009;467(3):645–650. doi:10.1007/s11999-008-0620-x
115. Wall PD, Fernandez M, Griffin DR, Foster NE. Nonoperative treatment for femoroacetabular impingement: a systematic review of the literature. *PM R.* 2013;5(5):418–426. doi:10.1016/j.pmrj.2013.02.005
116. Emara K, Samir W, Motasem H, Ghafar KA. Conservative treatment for mild femoroacetabular impingement. *J Orthop Surg (Hong Kong).* 2011;19(1):41–45. doi:10.1177/230949901101900109
117. Enseki K, Harris-Hayes M, White DM, et al. Non-arthritic hip pain. *J Orthop Sports Phys Ther*. 2014;44(6):A1-A32. doi:10.2519/jospt.2014.0302

118. Gaffney BMM, Harris-Hayes M, Clohisy JC, Harris MD. Effect of simulated rehabilitation on hip joint loading during single-leg squat in patients with hip dysplasia. *J Biomech*. 2021;116:110183. doi:10.1016/j.jbiomech.2020.110183
119. Newman JT, Saroki AJ, Briggs KK, Philippon MJ. Return to elite level of play and performance in professional golfers after arthroscopic hip surgery. *Orthop J Sports Med.* 2016;4(4):2325967116643532. doi:10.1177/2325967116643532
120. Harris M, Shepherd MC, Song K, et al. The biomechanical disadvantage of dysplastic hips. *J Orthop Res*. 2022;40(6):1387-1396. doi:10.1002/jor.25165
121. Harris-Hayes M, Royer NK. The relationship of acetabular dysplasia and femoroacetabular impingement to hip osteoarthritis: a focused review. *PM R.* 2011;3(11):1055-1067. doi:10.1016/j.pmrj.2011.08.533
122. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;417:112–120. doi:10.1097/01.blo.0000096804.78689.c2
123. Stelzeneder D, Mamisch TC, Kress I, et al. Patterns of joint damage seen on MRI in early hip osteoarthritis due to structural hip deformities. *Osteoarthr Cartil*. 2012;20(7):661–669. doi:10.1016/j.joca.2012.03.014
124. Cibulka MT, White DM, Enseki KR, Macdonald CW, Woehrle J, McDonough CM. Hip pain and mobility deficits – hip osteoarthritis. *J Orthop Sports Phys Ther*. 2009;39(4):A1-A25. doi:10.2519/jospt.2017.0301
125. Kim C, Linsenmeyer KD, Vlad SC, et al. Prevalence of radiographic and symptomatic hip osteoarthritis in an urban United States community: the Framingham osteoarthritis study. *Arthritis Rheumatol.* 2014;66(11):3013–3017. doi:10.1002/art.38795
126. Fu M, Zhou H, Li Y, Jin H, Liu X. Global, regional, and national burdens of hip osteoarthritis from 1990 to 2019: estimates from the 2019 Global Burden of Disease Study. *Arthritis Res Ther*. 2022;24:8. doi:10.1186/s13075-021-02705-6
127. Jordan JM, Helmick CG, Renner JB, et al. Prevalence of hip symptoms and radiographic and symptomatic hip osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. *J Rheumatol.* 2009;36(4):809–815. doi:10.3899/jrheum.080677
128. Sutlive TG, Lopez HP, Schnitker DE, et al. Development of a clinical prediction rule for diagnosing hip osteoarthritis in individuals with unilateral hip pain. *J Orthop Sports Phys Ther*. 2008;38(9):542-550. doi:10.2519/jospt.2008.2753
129. Altman R, Alarcón G, Appelrouth D, et al. The American College of Rheumatology criteria for the classification and reporting of osteoarthritis of the hip. *Arthritis Rheum*. 1991;34(5):505-514. doi:10.1002/art.1780340502
130. Murphy NJ, Eyles JP, Hunter DJ. Hip osteoarthritis: etiopathogenesis and implications for management. *Adv Ther*. 2016;33(11):1921-1946. doi:10.1007/s12325-016-0409-3
131. Nguyen C, Lefevre-Colau MM, Poiraudeau S, Rannou F. Rehabilitation (exercise and strength training) and osteoarthritis: a critical narrative review. *Ann Phys Rehabil Med.* 2016;59(3):190–195. doi:10.1016/j.rehab.2016.02.010
132. Pfluegler G, Borkovec M, Kasper J, McLean S. The immediate effects of passive hip joint mobilization on hip abductor/external rotator muscle strength in patients with anterior knee pain and impaired hip function. A randomized placebo-controlled crossover trial. *J Man Manip Ther*. 2021;29(1):14-22. doi:10.1080/10669817.2020.1765625
133. Brun A, Sandrey MA. The effect of hip mobilizations using a mobilization belt on hip range of motion and functional outcomes. *J Sport Rehabil*. 2020;30(4):559-567. doi:10.1123/jsr.2019-0544
134. Cibulka MT, Bloom NJ, Enseki KR, Macdonald CW, Woehrle J, McDonough CM. Hip pain and mobility deficits – hip osteoarthritis: revision 2017. *J Orthop Sport Phys Ther*. 2017;47(6):A1-A37. doi:10.2519/jospt.2017.0301
135. Robinson PG, Khan S, MacDonald D, Murray IR, Macpherson GJ, Clement ND. Golfers have a greater improvement in their hip specific function compared to non-golfers after total hip arthroplasty, but less than three-quarters returned to golf. *Bone Joint Open*. 2022;3(2):145-151. doi:10.1302/2633-1462.32.BJO-2022-0002.R1
136. Kim DH, Millett PJ, Warner JJ, Jobe FW. Shoulder injuries in golf. *Am J Sports Med*. 2004;32(5):1324-1330. doi:10.1177/0363546504267346
137. Kao JT, Pink M, Jobe FW, Perry J. Electromyographic analysis of the scapular muscles during a golf swing. *Am J Sports Med*. 1995;23(1):19-23. doi:10.1177/036354659502300104
138. Liem D, Gosheger G, Schmidt C. Schulterverletzungen im golfsport [Shoulder injuries in golf]. *Orthopade*. 2014;43(3):244-248. doi:10.1007/s00132-013-2147-4
139. Hegedus EJ, Goode A, Campbell S, et al. Physical examination tests of the shoulder: a systematic review with meta-analysis of individual tests. *Br J Sports Med*. 2008;42(2):80-92. doi:10.1136/bjsm.2007.038406
140. Tennent TD, Beach WR, Meyers JF. A review of the special tests associated with shoulder examination. Part II: laxity, instability, and superior labral anterior and posterior (SLAP) lesions. *Am J Sports Med*. 2003;31(2):301-307. doi:10.1177/03635465030310022601
141. Hunter DJ, Rivett DA, McKeirnan S, Smith L, Snodgrass SJ. Relationship between shoulder impingement syndrome and thoracic posture. *Phys Ther*. 2020;100(4);677-686. doi:10.1093/ptj/pzz182
142. Park SJ, Kim SH, Kim SH. Effects of thoracic mobilization and extension exercise on thoracic alignment and shoulder function in patients with subacromial impingement syndrome: a randomized controlled pilot study. *Healthcare* (Basel). 2020;8(3):316. doi:10.3390/healthcare8030316
143. McClure PW, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. *J Shoulder Elbow Surg*. 2001;10(3):269-277. doi:10.1067/mse.2001.112954
144. Komati M, Korkie FE, Becker P. Pectoralis minor length measurements in three different scapula positions. *S Afr J Physiother*. 2020;76(1):1487. doi:10.4102/sajp.v76i1.1487
145. Rosa DP, Borstad JD, Ferreira JK, Gava V, Santos RV, Camargo PR. Comparison of specific and non-specific treatment approaches for individuals with posterior capsule tightness and shoulder impingement symptoms: A randomized control trial. *Braz J Phys Ther*. 2021;25(5):648-658. doi:10.1016/j.bjpt.2021.04.003
146. Kohn HS. Prevention and treatment of elbow injuries in golf. *Clin Sports Med*. 1996;15(1):65-83.
147. Qureshi AI, Khan MN, Saeed H. Injuries associated with golf: a qualitative study. *Ann Med Surg (London).* 2022;78:103899. doi:10.1016/j.amsu.2022.103899
148. Shiri R, Varonen H, Heliövaara M. Prevalence and determinants of lateral and medial epicondylitis: a population study. *Am J Epidemiol*. 2006:164(11):1065-1074. doi:10.1093/aje/kwj325
149. Field LD, Savoie FH. Common elbow injuries in sport. *Sports Med.* 1998;26:193–205. doi:10.2165/00007256-199826030-00005

150. Yoon SK, Thiese MS, Ott U, et al. The role of elbow tender point examination in the diagnosis of lateral epicondylitis. *J Occup Environ Med*. 2019;61(2):126-131. doi:10.1097/JOM.0000000000001496
151. Dones VC, Grimmer K, Thoirs K, Suarez CG, Luker J. The diagnostic validity of musculoskeletal ultrasound in lateral epicondylalgia: a systematic review. *BMC Imaging*. 2014;14:10. doi:10.1186/1471-2342-14-10
152. Alizadehkhaiyat O, Fisher AC, Kemp GJ, Vishwanathan K, Frostick SP. Upper limb muscle imbalance in tennis elbow: a functional and eletromyographic assessment. *J Orthop Res*. 2007;25(12):1651-1657. doi:10.1002/jor.20458
153. Yasuda T, Ogasawara R, Sakamaki M, Ozaki H, Sato Y, Abe T. Combined effects of low-intensity blood flow restriction training and high-intensity resistance training on muscle strength and size. *Eur J Appl Physiol*. 2011;111(10):2525-2533. doi:10.1007/s00421-011-1873-8
154. Pearson S, Hussain S. A review on the mechanisms of blood flow restriction resistance training-induced muscle hypertrophy. *Sports Med*. 2015;45(2):187-200. doi:10.1007/s40279-014-0264-9
155. Sukumar S, Mathias L, Rai S. Early effects of dry needling and low level laser therapy in chronic tennis elbow – an experimental study. *Int J Health Sci Res*. 2015;5(1):187-196.
156. Navarro-Santana MJ, Sanchez-Infante J, Gómez-Chiguano GF, et al. Effects of trigger point dry needling on lateral epicondylalgia of musculoskeletal origin: a systematic review and meta-analysis. *Clin Rehabil*. 2020;34(11):1327-1340. doi:10.1177/0269215520937468
157. Calfee RP, Patel A, DaSilva MF, Akelman E. Management of lateral epicondylitis: current concepts. *J Am Acad Orthop Surg*. 2008;16(1):19-29. doi:10.5435/00124635-200801000-00004
158. Hastie G, Soufi M, Wilson J, Roy B. Platelet rich plasma injections for lateral epicondylitis of the elbow reduce the need for surgical intervention. *J Orthop*. 2018;15(1):239-241. doi:10.1016/j.jor.2018.01.046
159. Niemiec P, Szyluk K, Balcerzyk A, et al. Why PRP works only on certain patients with tennis elbow? Is PDGFB gene a key for PRP therapy effectiveness? A prospective cohort study. *BMC Musculoskelet Disord*. 2021;22(1):710. doi:10.1186/s12891-021-04593-y
160. Rettig AC. Epidemiology of hand and wrist injuries in sports. *Clin Sports Med*. 1998;17(3):401-406. doi:10.1016/s0278-5919(05)70092-2
161. Hawkes R, O'Connor P, Campbell D. The prevalence, variety, and impact of wrist problems in elite professional golfers on the European Tour. *Br J Sports Med*. 2013;47(17):1075-1079. doi:10.1136/bjsports-2012-091917
162. Murray PM, Cooney WP. Golf-induced injuries of the wrist. *Clin Sports Med*. 1996;15(1):85-109.
163. Tan KH, Chew N, Chew KT, Peh WC. Clinics in diagnostic imaging (156). Golf-induced hamate hook fracture. *Singapore Med J*. 2014;55(10):517-521. doi:10.11622/smedj.2014133
164. Aldridge JM, Mallon WJ. Hook of hamate fractures in competitive golfers: Results of treatment by excision of the fractured hook of the hamate. *Orthopedics*. 2003;26(7):717-719. doi:10.3928/0147-7447-20030701-17
165. Gill N, Rendeiro DG. Hook of the hamate fracture. *J Orthop Sports Phys Ther*. 2010;40(5):325. doi:10.2519/jospt.2010.0408
166. O'Brien C. Leading wrist injuries in a golfing population: golf swing biomechanics a significant cause of pathology. In: Taiar R, ed. *Contemporary Advances in Sports Science*. InTech Open; 2021. Accessed April 25, 2023. https://www.intechopen.com/chapters/75940
167. Cook JL, Purdam CR. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. *Br J Sports Med*. 2009;43(6):409-416. doi:10.1136/bjsm.2008.051193
168. Darrow M, Shaw B, Boeger G, Raspa S. The effect of platelet-rich plasma therapy on unresolved wrist pain. *Orthop Muscular Syst*. 2019;8:1. doi:10.4172/2161-0533.1000268
169. Allende C, Le Viet D. Extensor carpi ulnaris problems at the wrist – classification, surgical treatment and results. *J Hand Surg Br*. 2005;30(3):265-272. doi:10.1016/j.jhsb.2004.12.007
170. Kim BS, Yoon, HG, Kim HT, Park KH, Kim CG, Song HS. Subluxation of the extensor carpi ulnaris tendon associated with the extensor digitorum tendon subluxation of the long finger. *Clin Orthop Surg*. 2013;5(1):82-86. doi:10.4055/cios.2013.5.1.82
171. Campbell D, Campbell R, O'Connor P, Hawkes R. Sports-related extensor carpi ulnaris pathology: a review of functional anatomy, sports injury, and management. *Br J Sports Med*. 2013;47(17):1105-1111. doi:10.1136/bjsports-2013-092835
172. Casadei J, Kiel J. Triangular Fibrocartilage Complex. In: *StatPearls*. Statpearls Publishing; August 22, 2022.
173. Lee JK, Hwang JY, Lee SY, Kwon BC. What is the natural history of the triangular fibrocartilage complex tear without distal radioulnar joint instability? *Clin Orthop Relat Res*. 2019;477(2):442-449. doi:10.1097/CORR.0000000000000533
174. Seo JB, Kim JP, Yi HS, Park KH. The outcomes of arthroscopic repair versus debridement for chronic unstable triangular fibrocartilage complex tears in patients undergoing ulnar-shortening osteotomy. *J Hand Surg Am*. 2016;41(5):615-23. doi:10.1016/j.jhsa.2016.02.009
175. Jawed A, Ansari MT, Gupta V. TFCC injuries: How we treat? *J Clin Orthop Trauma*. 2020;11(4):570-579. doi:10.1016/j.jcot.2020.06.001
176. Preece SJ, Tan YF, Alghamdi TDA, Arnall FA. Comparison of pelvic tilt before and after hip flexor stretching in healthy adults. *J Manipulative Physiol Ther*. 2021;44(4):289-294. doi:10.1016/j.jmpt.2020.09.006
177. Moromizato K, Kimura R, Fukase H, Yamaguchi K, Ishida H. Whole-body patterns of the range of joint motion in young adults: masculine type and feminine type. *J Physiol Anthropol*. 2016;35:23. doi:10.1186/s40101-016-0112-8
178. Gulgin H, Armstrong C, Gribble P. Weight-bearing hip rotation range of motion in female golfers. *N Am J Sports Phys Ther*. 2010;5(2):55-62.
179. Johnson KD, Kim KM, Yu BK, Saliba SA, Grindstaff TL. Reliability of thoracic spine rotation range of motion measurements in healthy adults. *J Athl Training*. 2012;47(1):52-60. doi:10.4085/1062-6050-47.1.52
180. Kendall F, McCreary EK, Provance PG, Rodgers MM. *Muscles: Testing and Function with Posture and Pain*. 5th ed. Lippincott Williams & Wilkins; 2005.
181. Peeler J, Anderson JE. Reliability of the Thomas test for assessing range of motion about the hip. *Phys Ther Sport*. 2009;8(1):14-21. doi:10.1016/j.ptsp.2006.09.023
182. Adkins SB, Figler RA. Hip pain in athletes. *Am Fam Physician*. 2000;61(7):2109-2118.
183. Borstad JD. Measurement of pectoralis minor muscle length: validation and clinical application. *J Ortho Sports Phys Ther*. 2008;38(4):169-174. doi:10.2519/jospt.2008.2723
184. Peng YC, Hsu CY, Tang WT. Deficits in the star excursion balance test and golf performance in elite golfers with chronic low back pain. *J Sports Sci Med*. 2021;20(2):229-236. doi:10.52082/jssm.2021.229

185. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function – part 1. *Int J Sports Phys Ther*. 2014;9(3):396-409.
186. Advanced 3D: biomechanics of golf. Titleist Performance Institute. 2023. Accessed April 25, 2023. mytpi.com/shop/online-courses/advanced-3d-biomechanics-of-golf
187. Speariett S, Armstrong R. The relationship between the golf-specific movement screen and golf performance. *J Sport Rehabil*. 2019;29(4):425-435. doi:10.1123/jsr.2018-0441
188. Russell WD. The relationship between youth sport specialization, reasons for participation, and youth sport participation motivations: a retrospective study. *J Sport Behav*. 2014;37(3):286-305.
189. Jayanthi N, Pinkham C, Dugas L, Patrick B, Labella C. Sports Specialization in young athletes. *Sports Health*. 2013;5(3):251-257. doi:10.1177/1941738112464626
190. Coughlan D, Taylor MJD, Wayland W, Brooks D, Jackson J. The effect of a 12-week strength and conditioning programme on youth golf performance. *Int J Golf Sci*. 2020;8(1).
191. Bliss A, McCulloch H, Maxwell N. The effects of an eight-week plyometric training program on golf swing performance characteristics in skilled adolescent golfers. *Int J Golf Sci*. 2015;4(2):120-135.
192. Redondo JC, de Benito AM, Izquierdo JM. Effect of concurrent training on trainability performance factors in youth elite golfers. *Peer J*. 2020;8:e9963. doi:10.7717/peerj.9963
193. Rappaport D. The real reasons golf is getting younger. Golf Digest. February 2, 2022. Accessed April 26, 2023. golfdigest.com/story/the-real-reasons-golf-is-getting-younger-
194. Williams J. NCAA research shows major growth in number of women's college golf teams since 2009. Golfweek. December 27, 2019. Accessed April 25, 2023. golfweek.usatoday.com/2019/12/27/ncaa-research-womens-college-golf-teams-growth/
195. Horan SA, Evans K, Kavanagh JJ. Movement variability in the golf swing of male and female skilled golfers. *Med Sci Sports Exerc*. 2011;43(8):1474-1483. doi:10.1249/MSS.0b013e318210fe03
196. Zhao R, Zhao M, Xu Z. The effects of differing resistance training modes on the preservation of bone mineral density in postmenopausal women: a meta-analysis. *Osteoporos Int*. 2015;26(5):1605-1618. doi:10.1007/s00198-015-3034-0
197. Martyn-St James M, Carroll S. Meta-analysis of walking for preservation of bone mineral density in postmenopausal women. *Bone*. 2008;43(3):521-531. doi:10.1016/j.bone.2008.05.012
198. Baker J, Deakin J, Horton S, Pearce GW. Maintenance of skilled performance with age: a descriptive examination of professional golfers. *J Aging Phys Act*. 2007;15(3):300-317. doi:10.1123/japa.15.3.300
199. Bliss RR, Church FC. Golf as a physical activity to potentially reduce the risk of falls in older adults with Parkinson's Disease. *Sports*. 2021;9(6):72. doi:10.3390/sports9060072
200. Broman G, Johnsson L, Kaijser L. Golf: a high intensity interval activity for elderly men. *Aging Clin Exp Res*. 2004;16(5):375-381. doi:10.1007/BF03324567
201. Lehman GJ. Resistance training for performance and injury prevention in golf. *J Can Chiropr Assoc*. 2006;50(1):27-42.
202. Torres-Ronda L, Sanchez-Medina L, Gonzalez-Badillo JJ. Muscle strength and golf performance: a critical review. *J Sports Sci Med*. 2011;10(1):9-18.
203. Smith CJ, Callister R, Lubans DR. A systematic review of strength and conditioning programmes designed to improve fitness characteristics in golfers. *J Sports Sci*. 2011;29(9):933-943. doi:10.1080/02640414.2011.571273
204. Uthoff A, Sommerfield LM, Pichardo AW. Effects of resistance training methods on golf clubhead speed and hitting distance: a systematic review. *J Strength Cond Res*. 2021;35(9):2651-2660. doi:10.1519/JSC.0000000000004085
205. Oranchuk DJ, Mannerberg JM, Robinson TL, Nelson MC. Eight weeks of strength and power training improves club head speed in collegiate golfers. *J Strength Cond Res*. 2020;34(8):2205-2213. doi:10.1519/JSC.0000000000002505
206. Fiataraone SM, Hackett D, Schoenfeld B, Vincent HK, Wescott W. ACSM guidelines for strength training. American College of Sports Medicine. July 31, 2019. Accessed April 25, 2023. acsm.org/blog-detail/acsm-certified-blog/2019/07/31/acsm-guidelines-for-strength-training-featured-download
207. Lewis AL, Ward N, Bishop C, Maloney S, Turner AN. Determinants of club head speed in PGA professional golfers. *J Strength Cond Res*. 2016;30(8):2266-2270. doi:10.1519/JSC.0000000000001362
208. Coughlan D, Taylor MJD, Jackson J, Ward N, Beardsley C. Physical characteristics of youth elite golfers and their relationship with driver clubhead speed. *J Strength Cond Res*. 2020;34(1):212-217. doi:10.1519/JSC.0000000000002300
209. Lorenz DS, Morrison S. Current concepts in periodization of strength and conditioning for the sports physical therapist. *Int J Sports Phys Ther*. 2015;10(6):734-747.
210. Mujika I, Halson S, Burke LM, Balagué G, Farrow D. An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *Int J Sports Perform.* 2018;13(5):538-561. doi:10.1123/ijspp.2018-0093
211. Lorenz DS, Reiman MP, Walker JC. Periodization: current review and suggested implementation for athletic rehabilitation. *Sports Health*. 2010;2(6):509-518. doi:10.1177/1941738110375910
212. Ehlert A, Wilson PB. A systematic review of golf warm-ups: behaviors, injury, and performance. *J Strength Cond Research*. 2019;33(12):3444-3462. doi:10.1519/JSC.0000000000003329
213. McGowan CJ, Pyne DB, Thompson KG, Rattray B. Warm-up strategies for sport and exercise: mechanisms and applications. *Sports Med*. 2015;45(11):1523-1546. doi:10.1007/s40279-015-0376-x
214. Tilley NR, Macfarlane A. Effects of different warm-up programs on golf performance in elite male golfers. *Int J Sports Phys Ther*. 2012;7(4):388-395.
215. Page W, Swan R, Patterson SD. The effect of intermittent lower limb occlusion on recovery following exercise-induced muscle damage: a randomized controlled trial. *J Sci Med Sport*. 2017;20:729–733. doi:10.1016/j.jsams.2016.11.015
216. Vitale KC, Owens R, Hopkins SR, Malhotra A. Sleep hygiene for optimizing recovery in athletes: review and recommendations. *Int J Sports Med*. 2019;40(8):535-543. doi:10.1055/a-0905-3103
217. Bird S. Sleep, recovery, and athletic performance – a brief review and recommendations. *J Strength Cond*. 2013;35(5):43-47.
218. Walters PH. Sleep, the athlete, and performance. *J Strength Cond*. 2002;24(2):17-24.
219. Halson SL. Nutrition, sleep, and recovery. *Eur J Sport Sci*. 2008;8(2):119-126. doi:10.1080/17461390801954794
220. Baroni BM, Oliveira Pena Costa L. Evidence-based prevention of sports injuries: is the sports medicine community on the right track? *J Orthop Sports Phys Ther*. 2021;51(3):91-93. doi:10.2519/jospt.2021.0104

REVIEW QUESTIONS

1. How is *spine angle* defined in the down-the-line view?

   a. Angle formed between the golfer's spine and the ground.
   b. Angle formed between the golfer's spine and their shoulders.
   c. Angle formed between the golfer's spine and their hips.
   d. Angle formed between the golfer's spine and their golf club.

2. Which of the following movements initiates the *downswing* phase of the golf swing?

   a. Weight shift onto the trail lower extremity.
   b. Posterior pelvic tilt of the pelvis.
   c. Rotation of the thoracic spine toward the target.
   d. Lateral flexion of the lumbar spine away from the target.

3. Which of the following most accurately describes the term *X-factor* as it relates to the golf swing?

   a. The difference between the rotation of the shoulders and the rotation of the thoracic spine at impact.
   b. The difference between the rotation of the shoulders and the rotation of the pelvis at the finish.
   c. The difference between the rotation of the shoulders and the rotation of the pelvis at the transition.
   d. The difference between the rotation of the shoulders and the rotation of the knees at the transition.

4. A golfer enters your clinic complaining of "pain in his side," which has made playing golf difficult over the past 6 weeks. You are the first health care provider to examine them. The condition began gradually after they increased their normal practice schedule to prepare for an upcoming tournament. Physical examination reveals local tenderness on the posterolateral aspect of the left fifth and sixth ribs. Lateral flexion in either direction is painful in the same area. What should be your next course of action?

   a. Perform a high-velocity thrust of the thoracic spine and "see what happens."
   b. Initiate a rotational strength program to stabilize the injured area.
   c. Refer them for further diagnostic testing to rule out a rib stress fracture.
   d. Modify their golf swing so they can continue playing through the pain.

5. The head professional from your local golf club is referred to your clinic for evaluation and treatment of acute neck and left arm pain. You suspect cervical radiculopathy caused by a protruding disc at C5-C6. Which of the following movements are most likely to *centralize* this golfer's symptoms?

   a. Cervical flexion; cervical rotation toward the painful side.
   b. Cervical extension; cervical lateral flexion toward the painful side.
   c. Cervical flexion; cervical lateral flexion away from the painful side.
   d. Cervical extension; cervical rotation away from the painful side.

6. The patient from the previous question has completed 3 weeks of therapy with good success. However, currently, they are limited in rotation to the left (45°). At which point of their golf swing will they most likely notice this impairment?

   a. Set-up.
   b. Transition.
   c. Impact.
   d. Finish.

7. Which of the following muscle imbalances is most likely present in a golfer with significant *C-posture* in their set-up?

   a. Short iliopsoas and tensor fascia latae; weak and lengthened pectoralis and lower abdominals.
   b. Short pectoralis; weak and lengthened middle and lower trapezius.
   c. Short pectoralis; weak and lengthened lower abdominals.
   d. Short middle and lower trapezius; weak and lengthened pectoralis.

8. A member at your country club comes to your office with pain, weakness, and occasional "popping" on the ulnar side of their left wrist that began when they struck a tree root with their 6 iron four weeks ago. So far, symptoms have been unresponsive to rest and other conservative measures. Which of the following conditions do you suspect is possibly causing these symptoms?

a. Scaphoid fracture.
b. Carpal tunnel syndrome.
c. Extensor carpi radialis longus tendinopathy.
d. Triangular fibrocartilage complex (TFCC) tear.

9. A golfer is referred to you to evaluate pain in their left (lead) hip. While taking the history, the golfer mentions that they experience pain and stiffness in the lead hip at the finish of the golf swing. A pinching pain is also present in the left hip when in a deep squat to read the green. Which of the following impairments are most likely to be present?

a. Decreased left thoracic rotation range of motion; decreased left hip internal rotation range of motion.
b. Decreased right thoracic rotation range of motion; decreased left hip external rotation range of motion.
c. Decreased right thoracic rotation range of motion; weakness of left gluteus medius.
d. Decreased left thoracic rotation range of motion; decreased left hip external rotation range of motion.

10. Which of the following is true about the kinematic sequence of the golf swing?

a. It is a picture of what is happening during the golfer's backswing.
b. Amateurs demonstrate slower deceleration rates and greater peak angular velocity than their professional counterparts.
c. Tour professionals demonstrate greater peak angular velocity and faster deceleration rates than their amateur counterparts.
d. Abnormalities in the golfer's kinematic sequence have strong positive predictive value in diagnosing lumbar spine pathology.

ANSWERS

1. a
2. b
3. c
4. c
5. b
6. b
7. b
8. d
9. a
10. c