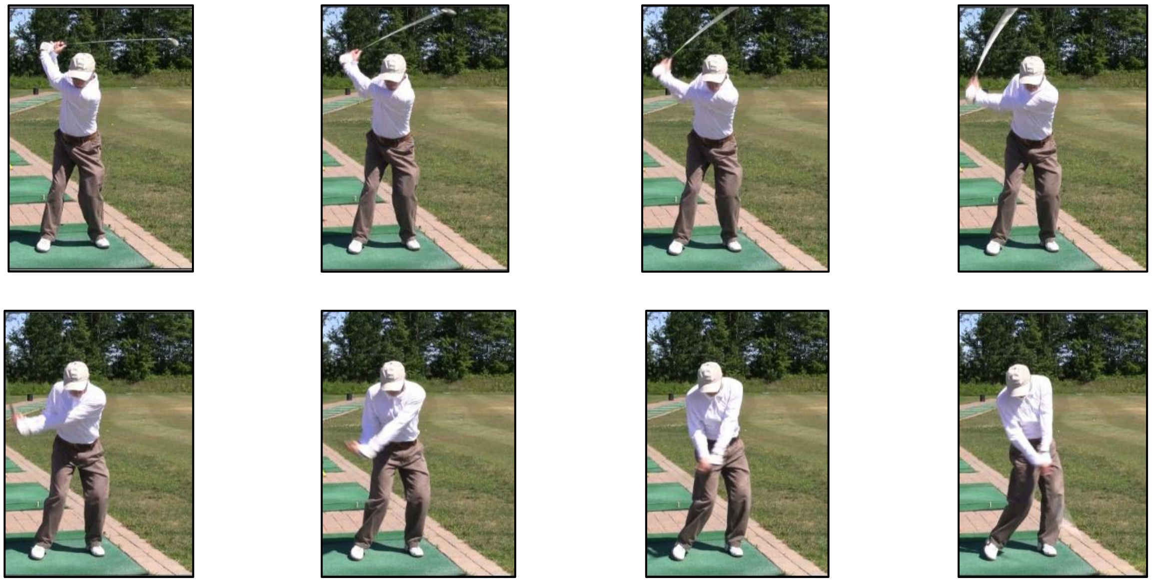
Guide to the Golf Swing



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GUIDE TO THE GOLF SWING

"The nice thing about these (golf) books is that they usually cancel each other out. One book tells you to keep your eye on the ball; the next says not to bother. Personally, in the crowd I play with, a better idea is to keep your eye on your partner." Jim Murray from The Sporting World of Jim Murray

INTRODUCTION

Who to believe? There are lots of ideas about how to swing a golf club: which ideas should you follow?

When someone presents ideas about how to swing a golf club, it is useful to ask why one should believe the ideas. Typically, the reasons for following a particular idea include one or more the following:

- The presenter is one of the best players in the world and presumably must know something about the game.
- The presenter has taught a number of highly successful players and must know something about the game.
- The presenter has studied a large number of successful golf swings and on the basis of this study, has identified common elements that correlate with success.
- The presenter is an older player with experience and on the basis of experience and wisdom, has identified key attributes of the successful swing.
- The presenter is endorsed by organizations such as TV networks, Golf Magazine, Golf Digest, professional golf organizations, and on the basis of these endorsements, must be credible.

With personal opinions playing such a prominent role in the ideas being put forward, it is not surprising that there are a range of views, many of which are contradictory.

The ideas put forward in this Guide are based on science – physics, anatomy, human kinetics, geometry. As we shall see, science provides confirmation about many conventional ideas and explains why they work. It questions some conventional ideas and explains why they may be in error. And it leaves you, the golfer, with some decisions. There is no universally correct golf swing.

As a science-based guide, the Guide follows several principles:

- The golf swing is based on the interaction between human anatomy and physics.

- The golf swing can initially be reduced to specific movements.
- These movements occur because of the contraction and relaxation of muscles.
- It is important to know what muscles are involved to improve the performance of these muscles in the swing and to tailor exercises to improve their functioning.
- Since the purpose of the swing is ultimately to propel the golf ball toward the target, the correct performance of the movement needs to contribute to that purpose.
- Movements that do not contribute to this purpose at best are unnecessary and at worst become a potential source of error; they should be eliminated.
- Each relevant movement in the swing has its own physics.
- Understanding of the physics of the individual movements can lead to an understanding the relative importance of each movement in the overall swing.
- Physics includes measurement, but each player comes with his or her own height, weight, length of legs and arms, golf club length, ability to rotate, etc. This Guide addresses this through modelling based on person-specific parameters.
- Distance ultimately results from carrying out all the movements with speed and precision. Lack of distance results at least in part from not incorporating some movements in the golf swing, not incorporating them effectively and not timing them optimally.
- One should focus on the downswing, since it determines impact. The backswing serves only to position the start of the downswing, and the follow-through is irrelevant in determining what happens to the golf ball.
- Gym exercises to improve the golf swing need to focus on the muscles used in the relevant movements in the swing.

This Guide is for the serious golfer – the golfer who wants to improve his or her game and is prepared to invest time and energy in a methodical and organized process of improvement.

Serious golfers can include beginners. Golf is a difficult game to start playing. Typically, the swings of beginners lack power and the ball goes nowhere, or the swings are mighty but technically flawed and the ball goes everywhere but straight.

While many beginners visit the driving range either occasionally or on a regular basis, serious beginners have gone further. They have probably bought a golf book or two dealing with grip, stance, posture and other details. Most golf books provide few clues about the theory and dynamics of the swing.

Serious beginners have also probably tried a series of lessons from a professional golfer. Like typical golf books, golf professionals deal with the grip, stance, posture and other details. Once these are addressed, they try to get the beginner to start hitting the ball, and then they try to correct faults.

The problem with standard instructional approaches through books and golf professionals is that they try to get the beginner up and going quickly, so the focus is on a few basics. Missing is the basic theory of the swing. Without this theory, beginners do not have a foundation from which to move forward, particularly when on their own.

The problem lies not with the golf professionals; they are just trying to satisfy their client. Nor does it lie with the client; most are in a hurry to get instant success, are satisfied with whatever help they get, and do not realize the need, or have the patience for, a structured, long-term approach. If blame needs to be assigned, blame the golf swing. It is complicated, with multiple movements occurring within a fraction of a second and the involvement muscles all over the body.

To summarize, this Guide is for the serious beginner – one who has read the standard golf books and taken some lessons and is probably already addicted to the game but is looking for a more fundamental understanding of the golf swing and has the patience to work through its underlying theory.

The Guide is also for the serious advanced player who has played a lot and has perhaps played well and who is looking for more. The theory of the swing – the subject of this Guide - is not readily found in conventional golf books. An understanding of the theory and dynamics of the swing may help to coax a few extra yards out of anyone's swing.

This Guide is limited to the full golf swing, and nothing but the full swing. The full swing is only one part of the game of golf. The full swing is important. So too is putting. There are myriad shots requiring less than a full swing (three-quarter and half wedges, chipping, pitching, sand and trouble shots); these are important for a complete game. Not only is it important to be able to execute shots, it is also important to know when to execute shots, where to aim and how to select the right club. For the competitive minded golfer, it is important to know how to play well in competition. For all of us, it helps to manage our game, to keep a good round together for eighteen holes, and to quickly identify and solve problems that could quickly transform a good round into a bad one. Finally, fitness has a role too. General fitness helps manage fatigue and prevent injuries. Fitness targeted specifically at the golf swing can create strength and flexibility and lead to increased power and distance.

This Guide focuses only on the full golf swing. This aspect of golf is not more important than others; it makes up only one part of the fascinating game of golf.

In this Guide:

- Chapter 1 provides an introduction to anatomy, physics and the basic movements in the golf swing.
- Chapters 2 to 9 describe the basic movements, starting with the anatomy of the joint involved and the relationship between anatomy and the golf movement.
- Chapters 10 to 13 address the physics and geometry of the golf swing, leading to a model of the golf swing. The model provides the basis for comments on aspects of the swing.
- Chapter 14 provides some ideas about how to incorporate the movements into your swing.

- Chapter 15 offers some exercise tips related to the movements.

The hope is that it will help you to add thirty or forty yards to your game, and to bring your handicap down by five to ten stokes. The corresponding fear is that it will cause you to obsess about muscles, and to create a path of destruction and lost balls in its wake. Be warned.

This Guide is a total revision to a previous version produced in 2010. Notable changes include the addition of information on the physics of the golf swing, corrections related to the role of the hips and legs in the swing, and the introduction of the spinal tilt as a fundamental part of the swing.

CHAPTER 1: ANATOMY, PHYSICS AND THE SWING'S BASIC MOVEMENTS

Going around in circles

The golf swing works because muscles contract. The contraction of muscles creates rotation. These are the two keys to the golf swing: muscle contraction and rotation.

Let us start with muscle contraction. Muscles and their related tendons are attached to two different bones. Most muscles function as part of a lever system in which rigid rod (a bone) moves on a fixed point called a fulcrum (a joint) when a force (a muscle contraction) is applied. With levers, a heavy load can be moved with less effort than would otherwise be necessary.

Of course, there is more involved than muscle contraction. A specific muscle will pull a body part in only one direction through its contraction. It cannot push the body part to move in the opposite direction. For that movement, another muscle is necessary. Typically, muscles operate in pairs. "Agonists" are the prime movers that provide the main force. "Antagonists" oppose the action of the "agonists". To illustrate, to cause a straight arm to bend at the elbow, the biceps on the top of the upper arm are the "agonists" which contract. To straighten the bent arm, the triceps at the back of the upper arm contract; they are the "antagonists".

Movement will normally involve not only the contraction of the "agonists", but also the relaxation of the "antagonists". Our brains manage the relaxation side of movement automatically so that we rarely notice it. This Guide will focus on muscle contraction.

In the golf swing, muscles operate to cause rotation.

Consider the wheels on a car. The engine rotates a shaft to which the wheel is attached. The surface of the wheel is in contact with the road but is some distance from the rotating shaft. The rotating shaft at the centre of the wheel causes considerable movement at the circumference where the wheel meets the road. One way to look at the golf swing is as a number of rotating shafts, each creating club head movement at the circumference of the circle tracked out by the club head during the swing.

What are these "rotating shafts"?

The eight movements in the golf swing are:

- cocking and uncocking of the wrists;
- rotating the forearms at the elbow;

- moving the lead upper arm in the shoulder socket;
- rotating the upper arms within the shoulder sockets;
- moving the shoulder sockets;
- twisting and untwisting the spine;
- rotating the hips; and
- tilting the spine.

For each movement, the Guide will describe the basic anatomy, outline how anatomy is incorporated into the movement, explain why the movement “works” to provide club head speed, and offer tips to improve performance where warranted.

Let’s look at the individual movements

.

Chapter 2: Cocking and Uncocking the Wrists

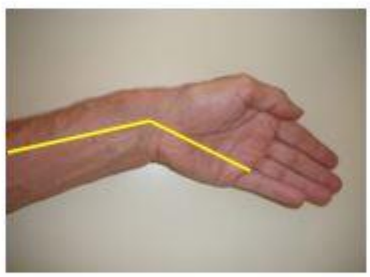
Time to be cocky

Wrist Anatomy

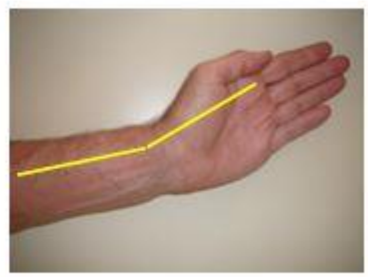
The wrist is the joint between the hand and the forearm. It allows for the positioning of the hand relative to the forearm. Muscle contractions around the wrist allow the hand to be positioned in various ways relative to the forearm. The basic wrist movements include:

- Radial abduction (movement of the hand towards the thumb, or upward);
- Ulnar adduction (movement of the hand towards the little finger, or downward);
- Palmar flexion (tilting of the hand towards the palm, or forward); and
- Dorsi flexion (tilting of the hand towards the back of the hand, or backward).

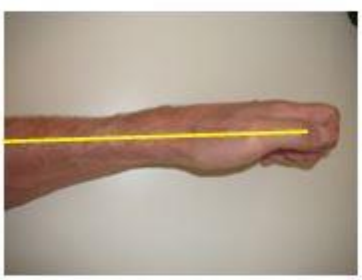
Start Position



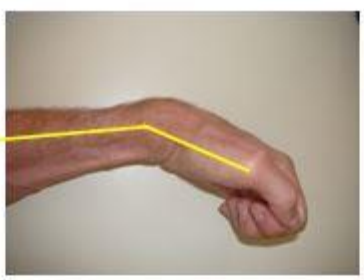
Ulnar Adduction



Radial Abduction



Start Position



Palmar Flexion

Dorsi Flexion

You can isolate the hand movement around the wrist joint by holding your right forearm with your left hand to eliminate forearm movement. Then, start moving your hand forward, backward, upward and downward. Focus on the muscles that you are using in relation to each movement. Rapid repetition, perhaps with a light weight in the hand, will fatigue the specific muscles causing the movement. This fatigue will give you an intuitive sense of the muscles being worked by the movement.

Wrist Anatomy and the Golf Swing

In golf, we are looking for a wrist movement that causes the club to go away from the target on the backswing and toward the target on the downswing. This movement will propel the ball down the fairway toward the target.

Suppose one grips a golf club with both thumbs on top of the shaft when the club face is perpendicular to the target. In this situation, palmar flexion in the lead wrist and dorsi flexion in the trailing list produces a backswing that goes directly away from the target. Dorsi flexion of the lead wrist and palmar flexion of the trailing wrist will move the club directly toward the target.

Suppose one wanted to use radial abduction and ulnar adduction in the swing. With both thumbs on top of the shaft, ulnar adduction in both wrists would lift the club up, and radial adduction would lower the club. The action would not propel a golf ball down the fairway toward the target. Instead, it would drive the ball into the ground.

The only way radial abduction and ulnar adduction will propel the ball down the fairway is to place both thumbs at the side of the shaft when the club face is perpendicular to the target. This position is 90 degrees from the position discussed above. One gets both thumbs at the side of the shaft by rotating the forearms. As we shall see in the next chapter, this setup rotation will eliminate the forearm roll, which is a significant power source in the golf swing.

The two examples above illustrate that wrist movement and grip position on a club whose face is perpendicular to the target need to be considered together.

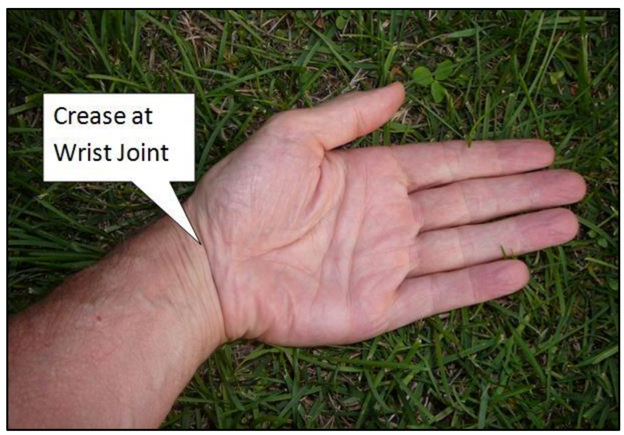
When the club face is pointing toward the target, the standard teaching is to grip the club so that the thumbs are at somewhat at the side of the shaft away from the target. Both thumbs are pointing toward the trailing shoulder. This is considered a “strong” grip.

For beginners, this teaching has some logic. Beginners often lack either the strength or the timing to get the club face perpendicular to the target at impact. The club face is open and the ball typically slices. A “strong” grip is a cheating mechanism that helps beginners to cure their slice.

To propel the ball down the fairway toward the target, this teaching would require the lead wrist to move through a combination of palmar flexion and radial abduction on the backswing to get the club moving directly away from the target, and dorsi flexion and ulnar adduction on the downswing to the club moving toward the target on the downswing. The trailing wrist would execute dorsi flexion and ulnar adduction on the backswing, and a palmar flexion and radial abduction on the downswing.

A better approach is to place both thumbs on top of the shaft when the club face is perpendicular to the target at set up. In the backswing, the lead wrist would execute a palmar flexion on the backswing and dorsi flexion on the downswing, while the trailing wrist would execute a dorsi flexion on the backswing and a palmar flexion on the downswing. This approach is better for these reasons:

- Consistency. With the thumbs always on top of the shaft when the club face is perpendicular to the target, the grip will always be the same. When the thumbs are to some degree at the side of the shaft, it will be difficult to get the thumbs in exactly the same position for each swing, and the risk of inconsistency increases.
- Muscular Simplicity. The recommended approach involves only two wrist movements (dorsi flexion and palmar flexion) and their related muscle groups. The traditional teaching involves four movements and four muscle groups. Muscular simplicity is important because the brain has limited capacity to think about muscle activity during the golf swing. It can manage the involvement of two muscle groups, but not four. To the extent that one wants to bring the golf swing into the consciousness of the brain, muscle simplicity matters.
- Control. When a movement requires a combination of upward and downward movements (ulnar adduction and radial abduction) along with forward and backward movements (palmar flexion and dorsi flexion), it is difficult to get the balance correct. When a golf swing requires only the forward and backward movements (palmar flexion and dorsi flexion), control increases.
- Muscle strength. The muscles controlling dorsi flexion and palmar flexion are more powerful than those controlling the radial abduction and ulnar adduction. One reason for the greater power is that these muscles are more commonly used in daily life. This is illustrated by the fact that the crease in the skin at the wrist is along the axis for the palmar flexion.



- Range of movement. Palmar flexion leads to a range of movement of about 75 degrees relative to the forearm. Dorsi flexion has a range of movement of 45 degrees. When both wrists act together on a gripped club, the smaller range of movement determines the range of movement of the club. The range of movement is therefore 45 degrees in both directions. Ulnar adduction leads to a range of movement relative to the forearm of about 40 degrees while radial abduction produces a range of movement of about 20 degrees. The total range of movement from a combination of radial abduction and ulnar adduction is 60 degrees. Wrist cocking and uncocking will get a larger range of movement when based on palmar flexion and dorsi flexion, than on radial abduction and ulnar adduction.
- Effect on forearm roll. Forearm roll comes from rotating the forearms at the elbow. It is the subject of the next chapter. The forearm roll is an important power source in the golf swing. Placing the thumbs at the side of the shaft so that they are pointing toward the trailing shoulders requires the forearms to rotate in the setup, to accommodate the grip.

This rotation comes at the expense of rotation during the swing. Rotation in the swing creates power.

The bottom line:

- With the club aiming at the target, grip the club with both thumbs on top of the shaft. This puts the lead palm facing way from the target and the trailing palm toward the target.
- With the wrists, perform a backward movement (palmar flexion in the lead wrist and dorsi flexion in the trailing wrist) and forward movement (dorsi flexion in the lead wrist and palmar flexion in the trailing wrist).
- Do not incorporate an upward and downward movement (radial abduction and ulnar adduction) with the wrists.

CHAPTER 3: ROTATING THE FOREARMS AT THE ELBOW

Let the forearms role

ELBOW ANATOMY

Three bones come together at the elbow joint. The humerus is the bone in the upper arm. The radius and ulna are the two bones in the lower arm. Different portions in the elbow joint allow the arm to bend or straighten at the elbow and to rotate clockwise and counter-clockwise at the elbow.

We shall discuss bending and straightening the arm at the elbow in Chapter 5. The more important movement is the rotation of the forearms clockwise and counter-clockwise at the elbow.

The rotational movement is caused by muscles near the top of the forearm. One end attaches to the bone in the upper arm (the humerus) and the other to the two bones (ulna and radius) in the forearm. They operate “across” the arm, so that their contraction causes the rotation.

You can observe the clockwise and counter-clockwise rotation if you hold your upper arm stationary with one hand to immobilize it, and then rotate the forearm. You should observe that your wrist can rotate from facing up to facing down. This is a rotation of almost 160 degrees. See the pictures below for the right arm.

Start Position

Rotation Outward

Rotation Inward

Note that this rotation is separate and independent from cocking and uncocking the wrists, as the pictures illustrate.

By rotating your lower arm clockwise and counter-clockwise quickly for a while, you will fatigue the muscles whose contractions are causing the movement and will get an intuitive feel of the muscles involved.

Without Wrist Cock

With Wrist Cock

Elbow Anatomy and the Golf Swing

Grip a golf club in both hands, hold it in front of you, and try to rotate the right and left forearms clockwise without involving other movements such as cocking and uncocking the wrists, or moving the upper arm in the shoulder socket, or rotating the upper arm in the shoulder socket. Then, rotate the club counter-clockwise. You should observe considerable movement of the club face. It is this movement that generates club head speed and distance in the golf swing. We call this movement the forearm roll.

Some advisers recommend against the forearm roll, but as we shall see in Chapter 12 on modeling the golf swing, the forearm roll, properly executed, is a significant power source that should not be ignored.

The angle between the club head and the forearms can range from about 90 degrees to about 180 degrees. There is considerably more movement in the club head when the angle between the forearm and the club shaft approaches 90 degrees and less movement when the angle approaches 180 degrees. When the angle is 180 degrees, rotating the forearm rotates the club face, but does not cause the shaft of the club to move. Maximum movement occurs at 90 degrees.

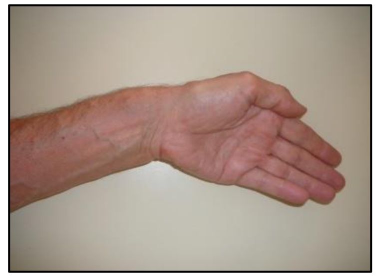
The angle of the gripped club to the club shaft makes a difference. This angle is determined by:

- The way you position the hands relative to the forearms at setup, and
- The way you grip the club.

In terms of the position of the hands relative to the forearms, we saw in the previous chapter that the muscles in the forearm can pull the hand towards the radius bone (radial abduction –

movement toward the thumb) or toward the ulnar bone (ulnar adduction – movement toward the little finger).

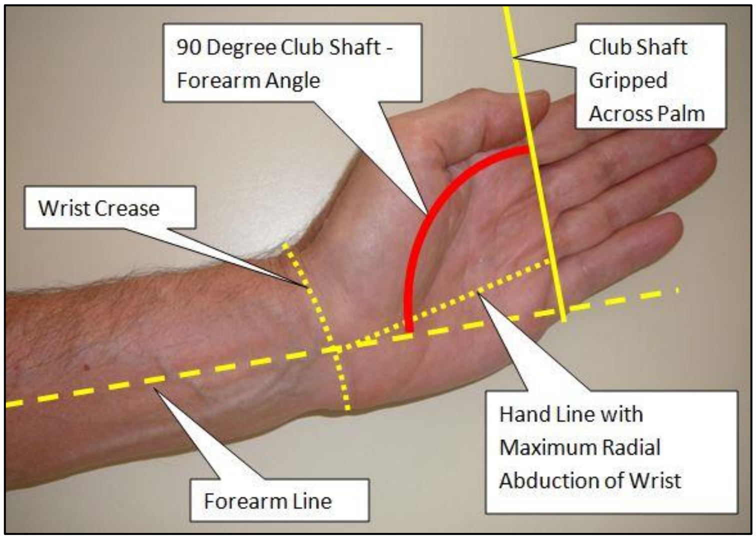




Neutral Start Position Radial Abduction Ulnar Adduction

Radial abduction will increase the angle between the forearm and the shaft of the golf club, and enhance the effect of the forearm roll. Conversely, ulnar adduction will decrease the angle between the forearm and the shaft of the club and detract from forearm roll. Whatever the extent of radial abduction or ulnar adduction, it is important to maintain a constant amount throughout the swing.


The other factor that affects the angle between the forearm and the club shaft is the grip in the lead hand, specifically whether one grips the club along the finger line, as in the left picture or in palm, as in the right picture.



For any amount of radial abduction, the two different grips positions can change the angle between the forearm and the club shaft by 10 degrees.

If one grips the club along the finger line and at the same time maximizes radial abduction of the wrist joint, the angle between the forearm and the club can approach 90 degrees.

A 90-degree angle between the forearms and the club shaft is a problem in several respects:

- The geometry does not put the golf club on the ground at setup. Imagine a player who sets up with arms hanging vertically from the shoulders. A 90-degree angle between the arms and the club shaft puts the club horizontal to the ground. We need an angle that puts the club on the ground, not horizontal to it.
- Maximum radial abduction would make it more difficult to cock and uncock the wrists. Try to cock and uncock the wrists (dorsi flexion and palmar flexion) starting in the maximum radial abduction position. You will find a diminished range of movement in the wrist cocking and uncocking. Avoid maximum radial abduction to ensure efficient wrist cocking and uncocking (palmar flexion and dorsi flexion).

Our golf model, discussed in Chapter 12, observes that an angle of 120 degrees gives slightly more distance than 130 degrees, which in turn gives noticeably more distance than 140 degrees.

Experiment with lowering the angle between your forearms and club shaft to the 120- to 130-degree range, by adjusting both your grip and your hand positions relative to the forearm.

Note that to make different angles work, you will likely need to make modest adjustments to the amount of knee bend, the degree to which you bend forward at the hips, the distance between your feet and the ball, and the angle between your upper arms and the spine at the start of your swing.

The bottom line:

- Do the forearm roll (despite occasional professional advice to the contrary), as it is a significant power source.
- Execute the forearm roll by using the muscles around your elbows to rotate your forearms at the elbows clockwise and counter-clockwise.
- Experiment with lowering the angle between your club shaft and your forearms to the 120- to 130-degree range, by gripping the club across the finger line in the lead hand rather than across the palm, and by getting a modest degree of radial abduction of the wrists.
- Keep the degree of radial abduction of the wrists constant through the swing.
- Adjust the amount of knee bend, the degree to which one bends forward at the hips, the distance between the feet and the ball, and the angle between the upper arms and the spine at the start of the swing to make the improved angle work.

Chapter 4: Moving the Upper Arms in the Shoulder Sockets

Arms and the Swing

Shoulder Anatomy – Part I

The shoulder consists of three bones: the collar bone or clavicle; the shoulder blade or scapula, and the upper arm or humerus. The term "shoulder joint" usually refers to the joint where the upper arm attaches to the shoulder blade (scapula).

This joint is a "ball and socket" joint. The ball is the rounded end of the humerus, while the socket is a dish-shaped structure in the shoulder blade (scapula).

This ball and socket joint allows the upper arm to move in a number of directions, limited by the socket and the flexibility of the muscles holding the bone in the socket. Two movements are singled out here: up and down, and toward and away from the body centre.

One can get a sense of up-and down movement by starting by standing erect with the arm vertical to the ground at one's side, then moving the arm up to the front till it is horizontal to the ground, and continuing to move it until it is vertical to the ground. This movement encompasses about 180 degrees.

One can get a sense of the movement toward and away from the centre of the body by standing erect and holding the upper arm straight out in front horizontal to the ground, moving the upper arm on the same horizontal plane as far as it will go to the centre of the body, then moving the upper arm on the same plane away from the centre of the body as far as it will go.

When the arm is straight out in front horizontal to the ground, the movement of the upper arm to the centre of the body from the start position should be about 70 degrees. The movement from the start position away from the centre of the body can be almost 90 degrees.

Arm Elevation Relative to the Spine	Range of Movement from Straight Out Inward to the Centre of the Body
90 degrees	70 degrees
60 degrees	60 degrees
45 degrees	45 degrees
30 degrees	30 degrees
0 degrees	0 degrees

In carrying out this movement, take care not to move your shoulder socket forward or backward. Moving the shoulder socket forward and backward is another movement to be discussed in Chapter 6.

Now, instead of starting with the arm horizontal to the ground, lower the arm a few degrees and retry the movement toward and away from the centre of the body on the same level. Continue to retry the movement, each time lowering the level a few degrees. Note that as you go to lower levels, the range of movement to the centre of the body decreases, as the chest and upper body get in the way.

You can get an intuitive sense of which muscles are performing this movement by executing a number of repetitions, perhaps with a light weight, and feeling where the burning sensation occurs.

Essentially, muscles attached on the one hand to the upper arm and on the other hand to the scapula and other bones contract to move the arm in the various directions.

Shoulder Anatomy and the Golf Swing

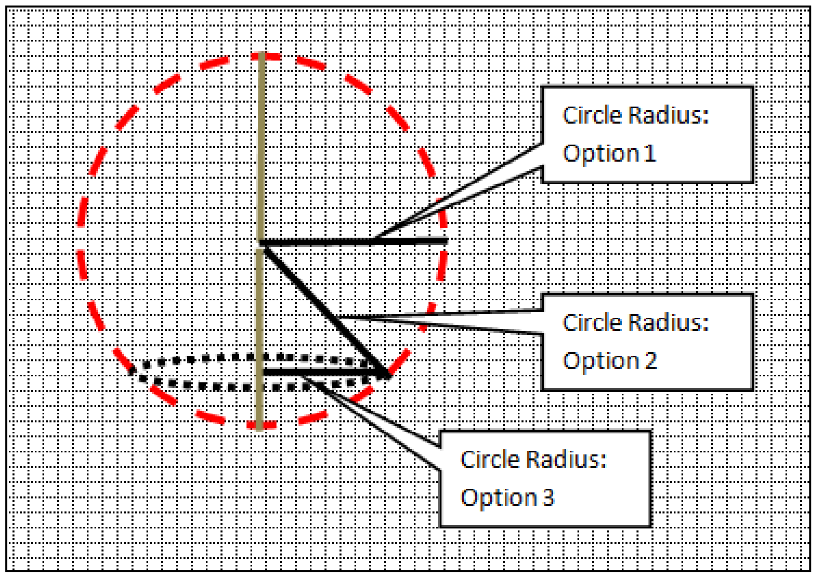
In the golf swing, the lead upper arm is our focus. It provides the power and direction to the golf club. The trailing upper arm primarily moves to accommodate the actions of the lead arm.

Consider the shoulder socket on the lead arm as the centre of a circle. Because the shoulder joint is a ball and socket joint, the lead arm can move around the shoulder socket in a variety of circles. Let us consider some possibilities:

- Option 1: Start from a position where one is standing erect and the lead arm is extended straight out perpendicular to the spine at the level of the shoulder socket. Move the lead around in a circle at that elevation. In this scenario, the muscles which cause the arm to go up or down would retain whatever contraction they started with (to manage gravity), but would neither contract nor relax further as the arm rotates around the circle. The active muscles would be those that cause the lead arm to move toward the body centre during the backswing and away from the body centre in the downswing. When the arm moves from the start position across the body toward the centre, the range of movement is about 70 degrees.
- Option 2: Start from a position where one is standing erect and the lead arm is extended some degrees below perpendicular to the spine so that the hand is lower than the shoulder socket. Move the lead arm around a circle in which the low point in the circle would occur at the start position. The lead arm would move both across the body toward the centre of the body and up on the backswing. Then, it would move away from the centre of the body in the opposite direction and down on the downswing to the start and impact position. After impact, the lead arm would move away from the centre of the body and up. The active muscles would be both those on the top and bottom of the shoulder socket that cause the arm to go up and down, as well as those at the front and back of the shoulder socket that cause the arm to move across the body toward and away from the body centre. In comparison with Option 1, Option 2 is more complex from a muscular perspective. The range of movement across the body is more restricted than Option 1, as

the lower elevation allows the body to restrict the arm movement, but the movement upward is not restricted. On balance, there is a range of movement approximately the same as in Option 1.

- Option 3: Start from a position where the one is standing erect and the lead arm is extended some degrees lower than perpendicular to the spine (as in Option 2). Move the lead arm around a circle at the same elevation as at the start position (as in Option 1). In this option, the muscles that control the up and down movement of the shoulder remain inactive. The active muscles are those that move the upper arm toward to the centre of the body on the backswing and away from the body centre on the downswing and follow-through. The range of movement across the body is less than in Option 1, because the body intrudes on the upper arm movement to a greater extent.



The picture illustrates the three options. The vertical line is the spine. In Option 1, the movement of the upper arm causes the hand/club to trace out a circle. The plane of the circle is perpendicular to the spine. In Option 2, the upper arm is below perpendicular to the spine, but the movement of the upper arm continues to allow the hand/club to trace out a circle. The radius is the same as in Option 1. The plane of the circle follows the radius and is at an angle less than perpendicular to the spine. If one imagines the elevation of the hand/club as it moves around the circle circumference, the track of the club/hand will have an up and down component. In Option 3, the radius of the circle traced out by the hand/club is less than in both Option 1 and 2. The elevation of the hand/club remains constant as the upper arm moves in the shoulder socket.

With Option 1, when one moves from standing erect to the golf swing setup where the spine is tilted forward, it would be technically difficult, if not impossible, to get the club on the ground at address, as one is unlikely to find a configuration of knee bend, forward lean, angle between the club shaft and the forearm, and club length that would end up with the club on the ground. Option 1 was introduced to demonstrate the concept of a muscularly simple movement.

Option 2, when incorporated into the golf swing, is complicated from a muscular perspective, since more muscle groups are involved. It involves getting the right combination of movements across and away from the body centre and up and down. However, when perfected, it will produce power and distance, because the radius of the circle traced out by the hand/club is maximized. This is a good option for the skilled player.

Option 3 is conceptually simple to incorporate into the golf swing. Option 3 requires that the arm stay at the same elevation relative to the spine. In Option 3, the mental thoughts should include keeping the club at the same elevation relative to the spine and not contracting the muscles that move the upper arm up and down. One needs to think only of moving the upper arm across the body toward the body centre on the backswing, and back to the start position and beyond on the downswing. However, there will be a loss of distance off the maximum because of the small rotation circle radius. The loss in distance may be offset by better contact from a simpler swing. The miss-hits should diminish and the average distance should go up. This is a good option for beginners and high handicap players.

The problem with the movement of the upper arm in the shoulder socket is the flexibility inherent in the ball and socket shoulder joint. The upper arm can go in a variety of direction.

One solution to the problem is Option 3. In this option, focus on moving the lead arm across the body toward the body centre on the backswing and away from the body centre on the downswing and follow-through. Avoid trying to move the lead arm up (particularly on the backswing) or down.

If one opts to pursue Option 2, the issue is more complex

In the golf swing where the spine is tilting forward because of the forward lean, the challenge is to get the upper arm to trace out a circle which moves the club head directly away from the target on the backswing, back to the start position at impact, and directly toward the target on the follow through. Getting the correct circle involves getting the correct balance of movements across and away from the body centre on the one hand, and up and down on the other.

One way to get the correct movement in the swing is to assume one’s normal setup position, and without a club, swing the lead arm directly away from the target in the backswing and toward the target in the downswing and follow-through. Use your eyes and brain to tell you whether the club is on the correct path. Place the trailing hand on the lead shoulder socket to immobilize it; make sure the lead shoulder socket does not move. Note the range of movement in the backswing; it should be restricted as the upper body impedes the movement. When you feel the restriction, the movement toward the body centre should end. Note the position of the lead arm relative to one’s chest; it should be across the chest. Note the position of the lead arm relative to the chin; the lead arm should not be getting up to the chin. Try to get a sense of the balance between the across-the-body and up movements in the backswing.

Now, retry the movement, this time holding a golf club in the lead hand. At the driving range, try to hit the ball straight toward the target from your swing setup position with a one arm movement. Do not incorporate any other movements in the swing; use only the lead arm. Hit a number of balls. If you have problems at first, after you get some skill in the movement, you will start to hit the ball better. At this point, note whether your balls are straight on target, or to the left or right. The ball flight will tell you whether the plane of your swing circle is going directly down the target line. As you continue to hit balls, try to get a sense of the balance between movements across and away from the body centre and up and down, and the limits to your range of movement.

Many players over-swing. In the interest of getting more power and distance, they move the lead arm too much in the up direction and not enough in the across-the-body direction. In some cases, they begin with the proper across-the-body movement, but when they come to the end of their range of movement, rather than stopping the backswing and starting the downswing, they continue the backswing by moving the lead arm up in an effort to get more power. As indicated in the section on shoulder anatomy, there is no practical limit on the range of movement in the up direction, but there are limits on the across-the-body movement. The up and across-the-body movements become unbalanced in the up direction, and the club moves off the desired circular path.

The typical result is a club path that goes from outside the target line before impact to inside the target line after impact (i.e. an outside to inside swing). The corresponding ball flights are a pull hook (closed club face at impact), a straight pull (club face square to the ball path at impact), or slice (club face open to the ball path at impact). Monitor the flight paths of your balls to determine whether you may be over-swinging.

One way to test for over-swinging is to put an object (tee, towel, etc.) in the lead armpit during the swing. If the item falls to the ground in the backswing, the lead arm is separating from the body as it goes too far up on the backswing. This test also becomes a drill to correct the fault.

Another correction technique is to simply realize that if you hold golf club and perform an up-down movement of the lead arm without going across the body, the result will not be the coveted extra distance, but a golf ball driven into the ground. The mental note that going up too much does not add distance should reduce the temptation to over-swing.

A third technique is to monitor the position of the lead arm relative to the chin. If the lead arm rises to the level of the chin, you are probably over-swinging.

The Bottom Line:

- Think about the movement in terms of a circular plane around your lead shoulder socket.
- For experienced players, pursue Option 2. Try to move the lead arm directly away from the target on the backswing and directly toward the target on the follow-through by getting the right balance of up and down, and across-the-body movements of the upper arm in the shoulder socket.

- Practice this movement using just the lead arm, to get a sense of the movement. Subsequently, try hitting a number of golf balls one-armed using the lead arm. Monitor the path taken by the ball, with objective of getting a path directly toward the target.
- For beginners, pursue Option 3. Try to move the lead arm across the body to the body centre but not up on the backswing and away from the centre but not down on the downswing. Try to keep the lead arm on the same vertical plane through the swing by eliminated the up and down movements.
- Monitor whether you are over-swinging, by (1) monitoring the flight path of your balls; (2) using the “object in the lead armpit” to test whether your lead arm is moving up, and (3) noting the position of your lead arm relative to your chin.

Chapter 5: Rotating the Upper Arms in the Shoulder Socket

Going Around in Circles

Shoulder Anatomy – Part 2

In the previous chapter, we addressed the movement of the lead upper arm in the shoulder socket. Now we'll talk about the rotation of both upper arms in their shoulder sockets.

To understand this rotation, start by holding your right upper arm straight out in front, make a 90-degree bend between your upper and your lower arm, and point your lower arm upward so that it is vertical to the ground. Loosely grab your upper arm with your left hand to hold it in one place, without impinging on its movement. Now, rotate your lower arm inward toward the centre of your body, then back to the start position, and then outward to the extent possible.

This movement occurs because your upper arm is rotating in its shoulder sockets. You can see this rotation if you focus on your elbow. Out the outset, it is pointing down. When you rotate your lower arm inward, your elbow points outward away from the body.

You should be able to rotate your lower arm inward about 90 degrees from the start position (lower arm up, elbow down) to the finish position (lower arm horizontal, elbows out).

Return to the start position (lower arm vertical, elbow down) and try to rotate your lower arms away from the centre of the body. You should experience relatively little movement outward.

The total rotation from moving the lower arms inward and outward is about 90 degrees. Most of this occurs when the forearm is rotated inward so that the elbow points outward.

The ability to rotate the upper arm in the shoulder socket arises from the fact that the shoulder joint is a ball and socket joint. This ability is the result of muscles contracting around the shoulder joint.

You can get a feel for which muscles are involved by allow your upper arms to hang vertically at your side from a standing or sitting position, and rotating your upper arm quickly and repeatedly clockwise and counter-clockwise. In time, you should begin to feel the burn as the muscles around your shoulders fatigue. If you do not feel this burn, hold a light weight and repeat the exercise.

Upper Arm Rotation in the Shoulder Socket and the Golf Swing

In the golf swing, grip your club in front of you with the thumbs on top of the shaft. Both elbows will be pointing down. The lead upper arm can rotate about 90 degrees, with the elbow moving from down to outward in the backswing, and outward to down in the downswing.

This rotation adds to the forearm rotation discussed in Chapter 3. In that Chapter, we noted that forearm rotation adds power to the golf swing. The rotation of the upper lead arm in the shoulder socket adds to the forearm rotation.

To support the rotation of the lead upper arm in the shoulder socket, one would want the trailing arm to rotate in the same direction. However, the trailing arm starts initially in a position that is essentially down; it cannot rotate inward to any significant degree. As such, it does not supplement the rotation of the trailing forearm at the elbow. Since the lead and trailing arms are linked through the grip and work together, the lack of rotation in the trailing arm limits the rotational effect of the lead arm to less than the 90 degrees that it could achieve on its own. The overall rotation of the golf club from the rotation of the lead upper arm in the shoulder socket combined with the lack of rotation of the trailing upper arm in the shoulder socket is approximately 45 degrees.

We have noted that at setup, the thumb on the trailing arm is located on top of the shaft of the club. This puts the trailing elbow substantially, but not necessarily fully, at the limit of its inward rotation. To simplify the golf swing, it is useful to rotate the trailing upper arm inward to the limits of its movement in the setup, and keep it there throughout the backswing, rather than allow some inward rotation inward during the swing.

Golf analysts in books, videos or television on occasion discuss the trailing elbow. They usually make the point that the trailing elbow should be pointed toward the ground at the top of the backswing, and not pointed outward. When the elbow points outward, it is sometimes characterized as a “flying” elbow. A trailing elbow pointed outward at the top of the backswing can affect:

- Direction. The club head will likely follow a path from outside the line of flight prior to hitting the ball, to inside the line of flight after contact. Depending on the angle of the club face at impact, the ball will slice if club is open at impact, go straight offline in a pull if the club face is square, and experience a pull-hook or duck hook if the club face is closed.
- Distance. When the trailing elbow is pointing outward, there will be a loss of distance. The reason is that the rotation of the trailing elbow nullifies the rotation of the forearm arms. As noted in Chapter 3, the forearms are a power source.

The proper rotation of the trailing upper arm in the shoulder socket does not add much to the backswing, but faulty rotation in the wrong direction can do damage.

A test of faulty rotation is to place an object in the armpit of the trailing arm. If the object falls to the ground during the backswing, then there is separation between the upper body and the trailing upper arm caused by the outward rotation, and the object will fall to the ground. As a practice drill, swing with the object in the armpit, and make every effort not to let the object fall to the ground until after impact.

The rotation of the lead upper arm in the shoulder socket should be clockwise for the right-hand golfer on the backswing, and counter-clockwise on the downswing. For the trailing upper arm, if one starts at the limit of clockwise rotation, then there is no rotation on the backswing, but counter-clockwise rotation on the downswing. Just past impact, the counter-clockwise rotation of the lead upper arm stops as it reaches the limit of its range of movement.

Golf analysts occasionally talk about the direction of the clubface at the top of the backswing in a good golf swing. The possibilities are open, square and closed. The definitions of "open", "square" and "closed" generally seem imprecise, but are directly related to the extent of upper arm rotation in the shoulder socket and forearm rotation. A lot of clockwise rotation for a right hander can be associated with an "open" club face, and minimal rotation or counter clockwise rotation associated with a "closed" club face. "Open" is more powerful.

An Aside on the Lead Elbow

What about bending and straightening the lead arm at the elbow? The modern golf swing typically involves keeping the lead arm straight. In theory, bending the lead arm offers the potential to add another movement to the golf swing, to invoke another set of muscles, and ultimately to increase distance. Yet successful modern golfers do not bend the lead elbow. It is a technique that has evolved out of the game, presumably because it does not work; the loss of accuracy and control is not worth the additional distance. The conclusion is: keep the lead elbow straight till after impact

The bending and straightening of the lead arm at the elbow is caused primarily by muscles in the upper arm. These muscles attach to the lower part of the bone in the upper arm (the humerus) and to the upper part of the two bones in the forearm (the ulna and radius). Contracting the biceps on the top of upper arm causes the arm to bend at the elbow. Contracting the triceps on the back of the upper arm causes the arm to straighten. To keep the lead arm straight, maintain the contraction of the triceps in the back of the lead upper arm from the start of the swing until after impact.

An Aside on the Trailing Elbow

In the backswing, the lower and upper portions of the trailing arm bend at the elbow because of a contraction of the biceps. During the downswing, the trailing arm straightens because of the contraction of the triceps. Is this movement a power source in the golf swing?

The answer is no. If one assumes the setup position, and contracts the biceps of the trailing arm, the forearm moves upward. Contracting the triceps causes the forearm to move downward. The up and down movement in the golf swing does not propel the ball forward, and as such, is not a power source. The trailing arm bends to accommodate other movements in the golf swing.

The Bottom Line

- Rotate the lead upper arm in the shoulder socket in the same direction as the forearm roll, to give added effect to the forearm roll. For a right-hand golfer, the rotation would be clockwise on the backswing, and counter-clockwise on the downswing. For lefties, the opposite would apply.

- At setup, rotate the trailing upper arm in the shoulder socket to the limit of its inward range of movement, and keep this position throughout the backswing.
- Do not, under any circumstances, rotate the trailing arm in the opposite direction during the backswing, i.e. for the right-hand golfer, counter-clockwise on the backswing and the opposite for a left-hand golfer. This will cause problems with both direction and distance.
- Put an object in the armpit of the trailing arm and see if it drops during the backswing. This is a sign of a faulty rotation. As a drill to correct this faulty rotation, practice with the object in the armpit and do not let it fall until after impact.
- In the downswing, rotate both arms in the shoulder socket to reinforce the forearm roll.
- Do not bend the lead elbow in the golf swing. Use the triceps to keep the lead arm straight during the backswing and till after impact.

Chapter 6: Moving the Shoulder Sockets

Socket it to me

Shoulder Socket Anatomy

In each shoulder, the scapula and clavicle make up a bone structure which holds the shoulder socket. This bone structure is held in place by muscles attached to the body's core. The bone structure can move around. Each shoulder socket can move upward (as in a shrug), downward, forward and backward, and points in between.

One can raise and lower the scapula and clavicle. This occurs through the contraction of muscles attached to the bone structure, and the spine, neck and skull. The contraction of these muscles pulls the bone structure up. Muscles attached to the bone structure and the ribs can contract to pull the bone structure down (although when standing, gravity also works).

One can also move the bone structure forward and backward. The forward movement comes by contracting muscles which connect the bone structure to the front ribs. The backward movement comes by contracting the trapezius, which attaches the bone structure to the various vertebrae in the upper part of the spine, and the rhomboids, which attach the bone structure to vertebrae in the middle of the spine.

To get a sense of the potential effects of this movement, sit in a chair with a low back that does not impede the movement of your shoulder, immobilize all joints but the shoulder socket, and move the shoulder socket forward and backward. You will notice that you can move your shoulder socket forward by about three inches, and backward by the same amount. The extent of the movement is illustrated in the following pictures, with the ear as a reference point.

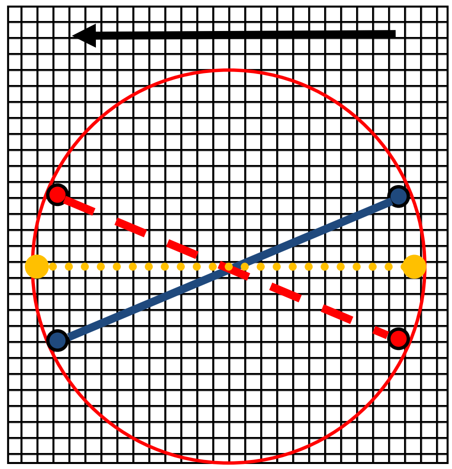
Socket Start Position   Socket Forward   Socket Backward

The Shoulder Socket and the Golf Swing

In the golf swing, the "up and down" movement of the shoulder socket does not add distance in the golf swing. You can visualize this by gripping a golf club and executing the up and down movement. The movement does not propel a golf ball forward.

Moving the lead shoulder socket forward toward the front centre of the body and the trailing shoulder socket backward away from the front centre on the backswing, and reversing the movements on the downswing, create a rotation around the spinal column that can add distance to the golf swing.

To understand where the distance comes from, picture the shoulder sockets as two points on the circumference of a circle, for which the centre is the spinal column. In the illustration, the yellow dotted line depicts the line between the two shoulder sockets at the start of the swing. The red dashed line depicts the position of the shoulder sockets in the backswing, with the lead socket moving forward and the trailing shoulder moving backward. In the downswing, the shoulder sockets would move back to the start position and then go beyond in the follow through, as depicted by the blue solid line.



How important is this rotation? If shoulder sockets are 13 inches apart, and each shoulder socket can move forward and backward a straight-line distance of 3 inches, then the shoulder socket movement will create a rotation of 26.7 degrees.

In addition to the rotational effect, the forward movement of the shoulder socket in the backswing is important because it allows a fuller range of movement of the lead upper arm in the shoulder socket. The previous chapter noted that the body and chest can impede the range of movement of the upper arm in the shoulder socket. Moving the shoulder socket forward creates more room for the upper arm to clear the chest and upper body. This enables a wider range of movement for this arm.

For many golfers, the movement of the lead shoulder socket forward toward the chest occurs unconsciously in the backswing while the golfer is moving the lead upper arm toward a full backswing. What some players miss are, on the downswing, the rotation of the lead shoulder socket from the forward position to the backward position and the corresponding rotation of the trailing shoulder socket from the backward position to the forward position. This is a missed opportunity for power and distance. Next time on the course, test to see whether you are achieving rotation with your shoulder sockets.

In some golf swings, the lead shoulder socket moves upward toward the neck, rather than backward, in the downswing. A sign of this movement is a high, rather than low, follow-through. This movement in essence stops the rotation, and causes a loss of distance.

Watch the practice and ball-striking swings of professional golfers, particularly on short iron shots. The follow-through actions are very low, and typically look as if the professionals are purposely focusing on moving the lead shoulder socket backward.

The Bottom Line:

- Move your lead shoulder forward on the backswing and backward on the downswing and your trailing shoulder backward on the backswing and forward on the downswing, to give extra rotation, power and distance.
- Concentrate on the downswing rotation, and make sure that the lead shoulder socket moves backward and not upward. This movement is a potential power source that many players do not take full advantage.

Chapter 7: Twisting and Untwisting the Spine

Let's twist again, like we did last summer.

Spinal Anatomy

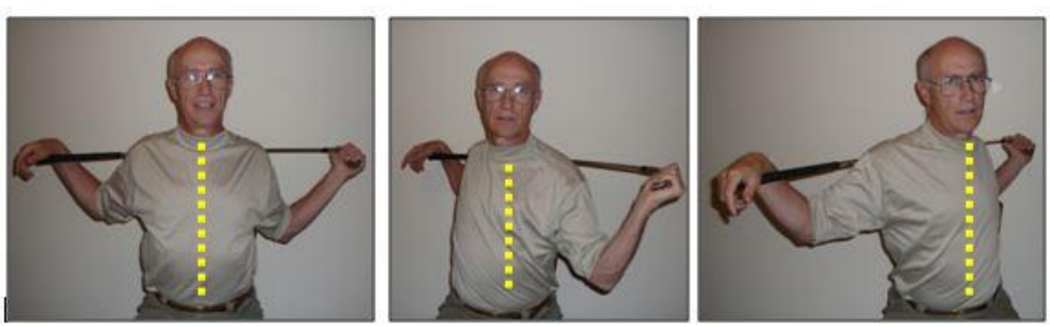
The spine includes thirty-three vertebrae. A vertabra is a bone structures that include a cylindrical front part, with two bones sticking out on either side at the back. The bones at the back intertwine to create a canal to house and protect the spinal cord. Nerves leave the spinal cord through small openings between the bones at the back of the vertebra.

Of the thirty-three vertebrae, nine at the bottom are fused and do not move; however, twenty-four at the top are separated by disks, which are like cushions. These cushions allow each vertebra to move slightly relative to the vertabra above and below.

Cumulatively, these small movements between individual vertebrae allow the spine to bend forward, bend backward, tilt to the left, tilt to the right, and twist clockwise and counter-clockwise.

Muscles contractions cause the movements in the spine. Muscles at the front of the body in the abdomen and chest contract to pull the top of the spine forward, causing the forward bend in the spine. Muscles at the back of the spine contract to cause the top of the spine to end backward, although the spine does not bend readily in this direction. Muscles at the side of the body contract to pull the top of the spine to the left or right. These movements are relatively straight forward. The spinal twist is less so.

To get an intuitive feel of the spinal twist, sit on a bench or chair in front of a mirror, rest a club across your upper back below your shoulders (to ensure you are not moving your shoulder sockets), hold it in place with your two hands, and gently rotate your shoulders clockwise and counter-clockwise. Keep the club parallel to the ground to ensure that you are rotating your shoulders. Sitting in a chair ensures that your hips are stationary so that all rotation occurs in the



Start Position Twist Right Twist Left

spine between the hips and the shoulders. The club that you see in the mirror should be on the horizontal plane throughout.

Several muscles groups are involved:

- One set of muscles is attached to the upper ribs at the one end and various bones in the lower abdomen. To rotate the lower spine clockwise, the contraction of these muscles on the left side shortens the distance between the left ribs and the lower abdomen, contributing to clockwise rotation.

- Another set is attached to the lower ribs and the front top of the hip. To rotate the lower spine clockwise, the contraction of these muscles on the right side pulls the lower right ribs toward the right hip, further contributing to the clockwise rotation.

- A third set of muscles is attached to the back of the hip and the upper lumbar vertebrae and the last rib at the back. To rotate the lower spine clockwise, the contraction of these muscles on the right side shortens the distance between the right rib at the back and the right hip. This contributes further to the clockwise rotation.

Note that the spinal twist is a relatively simple motion controlled by large muscles in the abdomen and back with relatively few opportunities for mistake. Unlike movements that use ball and socket joints, it is relatively easy to get the spinal twist right.

How much can you twist your spine? The first consideration should be your health; you certainly do not want to injure your back by overdoing the spinal twist. However, there is much you can do to increase your ability to both twist your spine and protect spinal health.

In a normal, healthy person who has warmed up the spinal muscles, a spinal twist of 120 degrees (60 degrees in clockwise and counter-clockwise directions) should be attainable without assistance. If you use hands and arms to assist in the twist, you should be able to rotate up 160 degrees in total, or 80 degrees in clockwise and counter-clockwise directions. For most people, the primary constraint on spinal twists is muscle weakness, not inflexibility in the spine.

Spinal health is important. Muscles pulls occur frequently. There are a number of muscles tied to the spine; they function among other things to protect the spine. Muscles pulls can be reduced through proper warm up, stretching exercises, and good swing techniques.

Disk damage is a major concern. The disks separating the vertebrae can withstand a lot of pressure. The spinal twist should put equal pressure on all parts of the disk. Bending forward, or backward, or to either side, would focus pressure on one side to which the bending takes place. Intuitively, twisting would appear to be healthier than bending. Also, intuitively, the combination of twisting and bending could be problematic, since a bend would put additional pressure on the side of a disk that would already be slightly stressed from the twisting.

Spinal Twist and the Golf Swing – Part 1

The "spinal twist" is different from a "spinal tilt". The "spinal tilt" occurs through the contraction of muscles on your sides. The spinal tilt will be the subject of Chapter 9. The focus here is the spinal twist.

Expert studies of the golf swing have noted that players who hit the ball the farthest frequently do so because of greater "spinal twist". One way to look at the golf swing is a twist to coil the spine on the backswing, followed by a fast twist in the opposite direction to uncoil the spine on the downswing.

To get a sense of the impact the spinal twist can have within the golf swing, remain seated in front of the mirror, grip the club as you would in a golf swing, hold it out in front of you, ensure that your shoulders and arms remain stationary, twist the spine, and observe the range of movement in the club head from the spinal twist.

We noted above that the unassisted spine can twist about 120 degrees. Of this, 60 degrees occurs in the backswing and the downswing to the start position. In the modern swing, the spine has typically rotated perhaps 10 degrees beyond the start position at the point of impact. Thus, the total rotation in the downswing would be about 70 degrees. This rotation at the centre of your swing creates considerable movement of the club head.

Because the spinal twist occurs with the spine bent forward at the hips, the shoulders do not remain parallel to the ground within the swing. In the backswing, the trailing shoulder will be higher than the lead shoulder because the spine is bent forward. When you look at someone else's swing, or observe videos of your own swing, you need to look closely to see the spinal twist.

Because the shoulders appear to change elevation during the swing, a common swing problem is that golfers tilt the spine to get the change in shoulder elevation during the swing, rather than twisting it. As we shall see in Chapter 9, the spinal tilt has a role to play in the golf swing, but if done at all, it should be done with, not instead of, the spinal twist.

You can work on your spinal twist away from the golf course. Simply sit in a chair, put a club across the back of your shoulders, rotate clockwise and counter-clockwise, and concentrate on the contraction of the three major muscles involved. Then, insert this muscle awareness into your golf swing.

Take your backswing and hold your position at the top of the swing. You should feel the contraction of the three muscle groups. If you don't feel the contraction of all three muscles, you may not be turning to your maximum potential. Now take a slow downswing and follow through. Again, feel the muscle groups being used.

As a final note, the spinal twist is a potential source of power in the golf swing. The long hitters are obviously tapping into this source. If you are not a long hitter, ask yourself whether you are fully using the spinal twist in your golf swing.

The Bottom Line

- Become aware of the three muscle groups that cause the lower spine to twist.
- Take care of the health of your spine by warming up before twisting the spine, and by working to increase flexibility with assisted and unassisted stretching.
- Sit in front of a mirror, put a club or similar object across the back of your shoulders, rotate your spine clockwise and counter-clockwise, and make sure the club remains horizontal to the ground. This is the movement you want to use in your swing.
- Incorporate this movement into your swing.
- Recognize that when you lean forward from the hips, the spinal twist will appear to put shoulders at different elevations during the swing. You are looking for rotation perpendicular to a forward leaning spine, not horizontal to the ground.

CHAPTER 8: MOVING THE "HIPS"

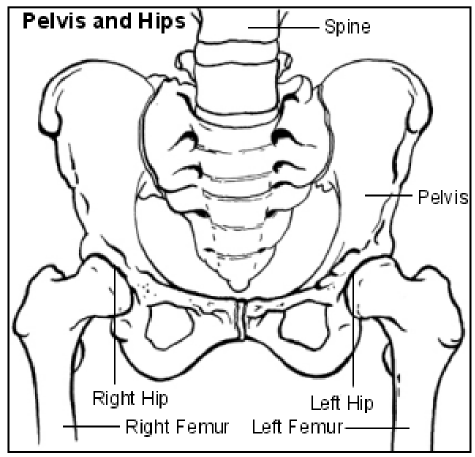
It's not hip. (It's ankles.)

"HIP" ANATOMY

In this chapter, "hips" refer primarily to the hip, knee and ankle joints. Anatomically, hips, knees and ankles are separate entities, but in golf, they work as a system with the ultimate goal of moving (primarily rotating) the spinal column that sits above it.

Think of the hips in terms of a bone structure. The upper part of this structure provides the base for the spinal column. The lower part of the structure provides the ball and socket joint for the upper leg (femur).

The hip joints are inside the periphery of the bone structure. That is because the upper leg (femur) is L shaped. The upper leg (femur) has a long straight vertical component leading to a ball-like structure called the trochanter. The upper leg then has a horizontal component with a ball at the end. The ball fits into a socket within the bone structure



Because the joint between the bone structure and the femur is a ball and socket joint, each femur can move in a variety of directions relative to the bone structure: toward the front, toward the back, away from the body centre, toward the body centre and a variety of positions in between. It can also rotate within the hip joint. You can get a sense of this rotation by sitting in a chair, and turning the knee clockwise and counter-clockwise.

Muscles attach to various points on the femur and the bone structure. Their contraction and relaxation cause these movements.

The muscles around the hip joint control the tilt of the bone structure relative to the upper leg. For example, contracting the muscles around the hip joint to bring the upper leg forward effectively tilts the bone structure forward. This in turn tilts the spinal column forward.

Apart from the tilting of the bone structure, the bone structure goes where the hip joints take it. If the hip joints tilt so that one is higher than the other, the bone structure tilts too. If the hip joints move to the left or right, the bone structure and spinal column follow and move to the left or right. If the hip joints rotate, the bone structure and spinal column rotate.

The base of the spine comes out of the bone structure. It goes where the bone structure takes it. Moving the bone structure requires movement of the hip joints. Movement of the hip joints depends on the workings of joints below it, namely the knee and the ankle joints.

The knee joint is a hinge joint between the upper leg (femur) and the two bones in the lower leg bones (tibia and fibula). In the absence of gravity, when muscles attached to the front of the lower and upper leg bones (quadriceps) contract, they cause a bent leg to straighten. When muscles attached to the back of the lower and upper leg bones contract, they cause a straight leg to bend behind.

When gravity is involved (for example in bending the knee from a standing position), bending the knee will come from relaxing the contraction of the quadriceps.

The knee joint does not allow the two bones in the lower leg to rotate relative to the upper leg. To get a sense of this, sit in a chair, straighten the knee out in front, hold your upper leg to immobilize it, and try turning your lower leg (not your ankle) left or right. You will not find much movement.

The ankle is where the foot and the two bones in the lower leg meet. It includes three joints that collectively allow the foot to move in a variety of directions. One can:

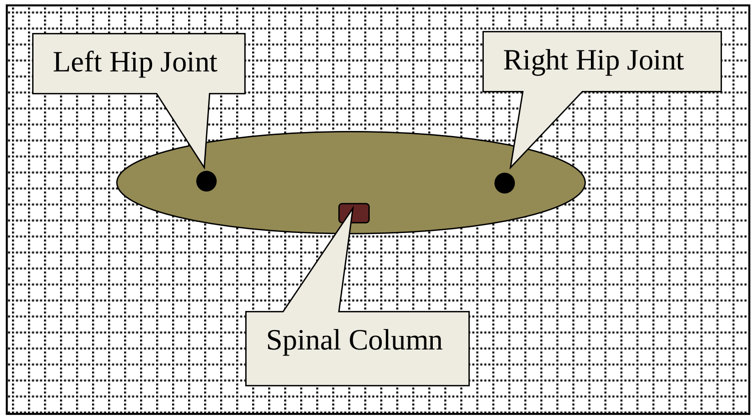
- Pull the foot up toward the shin (dorsi flexion) using the muscles of the front part of the lower legs or push the foot down away from the head (plantar flexion) using the muscles in the back of the lower legs.
- Rotate the toe relative to the heel either inward (pronation) or outward (supination).
- Turn the entire sole or the foot either outward away from the centre of the body (eversion) or inward toward the centre of the body (inversion).

Test all these movements by sitting in a chair, moving the foot in the aforementioned directions, and sensing which muscles are involved.

Observe the movement of the toe relative to the heel. If you start with your foot perpendicular to the ground, you should be able to rotate your foot inward toward the body centre (pronation) about 10 degrees, and rotate your foot outward (supination) about 60 degrees.

“Hip” Anatomy and the Golf Swing

The “hips” are important in the golf swing. One way to get a sense of their importance is to immobilize them by sitting in a chair, and then to try to hit golf balls. Alternatively, place your butt against the back of a chair, and hit golf balls while keeping your butt in contact with the chair. You should be able to feel the importance of the “hips” by noting the loss of power when they are immobilized during the golf swing.



The diagram provides a top down caricature of the bone structure. The spinal column is located in the middle and at the back. The two hips joints are toward but slightly inside both ends of the bone structure.

There are two ways golfers can use this bone structure to create power in the golf swing.

- Rotate it.
- Move it laterally toward the target.

On moving the bone structure laterally toward the target, we make these observations:

- By the end of the golf swing, the bone structure has moved toward the target and rotated. Good golfers will invariably finish their swing with the bone structure facing the target and moved forward so the centre of gravity is over the lead foot. Much of this movement occurs after impact, and as such has little relevance.
- Moving the bone structure toward the target only makes a difference in the absence of spinal-tilting away from the target. Moving the bone structure toward the target in the downswing moves the base of the spine toward the target, but if the spinal column tilts away from the target, the upper spine, shoulders, and arms do not move, and the net distance effect of the bone structure movement is zero. The head is a good indicator of the position of the upper spine. Many great golfers keep their head behind the ball until after impact.
- Even if the head, upper spine, shoulders, and arms move forward with the lower spine and bone structure, the distance effect of this lateral movement is small. A lateral movement of a few inches in the downswing of a fraction of second does not translate into a lot of miles per hour in club speed. Chapters 11 and 12 will illustrate this point.
- Moving the bone structure toward the target requires both hip joints to shift from an initial position toward the target. Since both feet are essentially planted on the ground, the physical action that will shift the bone structure toward the target is rolling the sole of the lead foot inward (ankle inversion), which moves the lead leg and hip joint outward, and the sole of the trailing foot outward (ankle eversion), which moves the trailing leg and hip joint inward.
- Moving the bone structure (and spinal column) forward changes the centre of gravity. Depending on the extent, this change can put the golfer off balance. The typical response is to tilt the spine away from the target to maintain the centre of gravity and balance. This negates the distance effect of the movement.

- The knee joint cannot contribute to the movement. Bending or straightening the knee changes the elevation of the bone structure but does not move it forward.
- The hip joint cannot contribute to the movement of the bone structure, since the positioning of the hip joint is determined by events at the knees and ankles. However, there may be some rotation of the upper leg in the hip joint to manage balance and stability.

On rotating the bone structure, we make these observations:

- Rotation will amplify the rotation from the spinal twist. We saw in Chapter 7 that the spinal twist can provide considerable power in the golf swing, and bone structure rotation can add to this power.
- There are two ways to rotate the bone structure:
  - *Pure Rotation*; and
  - *Push and Clear* (for lack of a better term).

Pure Rotation

To get a sense of *Pure Rotation*, stand erect with spine vertical to the ground with your feet directly below your hip joints, lock your knees, keep both feet flat on the floor, put your weight on the instep of each foot (by eversion at both ankles i.e. rolling both ankles outward), and then turn your hips clockwise and counter-clockwise while keeping your weight on the step of both feet. If you start with your hips in a neutral initial position, you will be able to turn about 45 degrees in each direction.

The 45-degree rotation in both directions occurs even though one can only rotate each foot inward by about 10 degrees and outward by about 60 degrees. The explanation for the seemingly contradictory numbers is a combination of the effects of plantar flexion of one ankle and dorsi flexion of the other, and vice versa, as well as rotation of the upper leg in the hip socket.

A key to the movement is keeping the head and spine in the same place. Performing the movement in front of a mirror allows you to monitor how you are doing. If you find your head and spine have moved, chances are you are allowing one or both ankles to roll. Inversion of one ankle and eversion of the other, taken alone, will move the bone structure laterally.

In the golf swing, the hips normally lead the swing, so that at impact, the hips have moved beyond the start position. Consequently, the downswing rotation of the “hips” is likely to be about 10 degrees more than the backswing rotation.

Consider what happens to your weight in *Pure Rotation* when done properly without eversion or inversion of the ankles. Your centre of gravity and the location of your weight will generally sit in the middle of your stance, not toward your heels or toes, or toward one foot or another. You can check the purity of your rotation by doing the *Pure Rotation* movement on a balance aid such as a BOSU ball or balance board or a mirror.

Try this exercise again, but this time, try to discern which muscles cause the hip rotation. Do the exercise clockwise and counter-clockwise until you begin to fatigue the muscles. You will discover that it is the muscles around your ankles that are causing the rotation.

Let us look more closely at what is happening in *Pure Rotation*. The hip joints rotate in a circle around a centre point between them. This point is close to the base of the spine. To rotate in a golf swing that starts at the neutral address position, the lead hip joint would move toward the ball and away from the target on the backswing, while the trailing hip joint would move toward the target and away from the ball on the backswing. In the downswing, the hip joints would return to the neutral start position, after which the lead hip joint would move away from the ball and target, while the trailing hip joint would move toward the ball and target. The table below summarizes how ankle and knee joint movements in one leg will move the related hip joint.

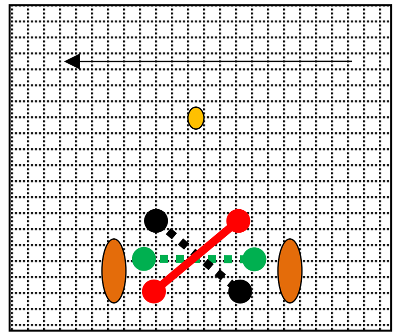
Ankle and Knee Joint Movement	**Related Hip Joint Movement In the Golf Swing**
Moving the foot up toward to the shin (dorsi flexion of the ankle)	Moves the hip joint toward the ball.
Moving the foot down away from the head (plantar flexion of the ankle)	Moves the hip joint away from the ball
Rotating the toe relative to the heel inward toward the centre of the body (pronation of the ankle)	Rotates the leg in the hip joint inward
Rotating the toe relative to the heel outward away from the centre of the body (supination of the ankle)	Rotates the leg in the hip joint outward
Turning the entire sole of the foot inward toward the centre of the body (inversion of the ankle)	Moves the hip joint laterally away from the outside of the foot
Turning the entire sole of the foot outward away from the centre of the body (eversion of the ankle)	Moves the hip joint laterally toward the outside of the foot
Increasing the bend of one leg at the knee (without changing the angle between the foot and the lower leg)	Moves the hip joint away from the ball and decreases the elevation of the hip joint.
Decreasing the bend of the leg at the knee (without changing the angle between the foot and the lower leg)	Moves the hip joint toward the ball and increases the elevation of the hip joint.

Here is how the muscles work through the three phases of the golf swing in *Pure Rotation*.

Golf Swing Phase	**Lead Leg**	**Trailing Leg**
Start Position to Top of Backswing	Dorsi flexion and pronation of the ankle, causing the lead hip to move toward the ball and away from the target.	Plantar flexion and supination of the ankle, causing the trailing hip to move away from the ball and toward the target
Top of Backswing Back to Start Position	Plantar flexion and supination of the ankle to the neutral position, causing the lead hip to move away from the ball and toward the target	Dorsi flexion and pronation of the ankle to the neutral position, causing the trailing hip to move toward the ball and away from the target
Start Position to Impact	Plantar flexion and supination of the ankle, causing the lead hip to move away from the ball and away from the target.	Dorsi flexion and pronation, causing the lead hip to move toward the ball and toward the target.

For knees to contribute *Pure Rotation*, the lead knee would need to straighten from the start position to the top of the backswing to move the lead hip forward toward the ball, and bend from impact to the finish to move the lead hip away from the ball. The trailing knee would need to bend in the backswing to move the trailing hip away from the ball, and straighten from impact to the finish to move the lead hip toward the ball.

Although use of the knees in this way is a theoretical possibility, they are not part of an effective golf swing for several reasons. First, successful golfers do not swing this way. In fact, if they change the bend in their knees at all, they do exactly the opposite. Second, knee bending is another movement and every movement carries the risk of error. Third, the combination increasing and decreasing the bend in the knees throughout the swing will lead to different elevations in the bone structure, and will ultimately cause the spine angle to change. Fourth, to get a *Pure Rotation*, there needs to be a balance between the amount of movement toward and away from the ball, and toward and away from the target. One can get adequate balance without changing the bend in the knees, with the result that knee bends can destabilize the swing.



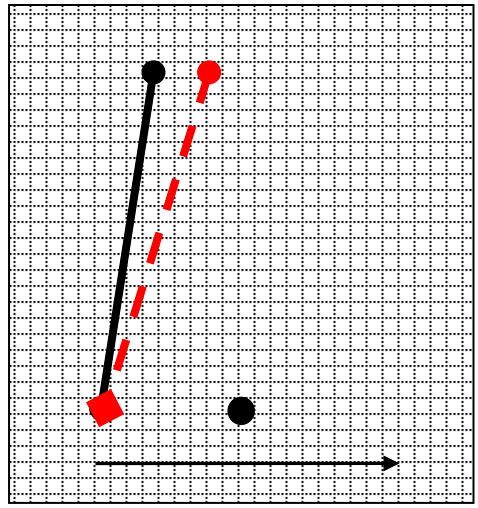
The diagram illustrates *Pure Rotation*. The balls at the end of the lines indicate the hip joint positions. The green dotted line denotes the start position. The black dotted line shows the rotation for a right-handed golfer on the backswing. The red line indicates the hip joint position at impact (i.e. slightly beyond the start position). Both hip joints are moving around the circumference of a circle (more or less).

The hip joints are typically about 32 inches from the ankle (ground). A change of a few degrees in the angle between the ankle and leg will end up moving one hip joint several inches. The two hip joints are about 7 inches apart. Moving both the lead and trailing hip joints a few inches around a circle when they are relatively close can translate into considerable rotation at the base of the spine.

If you want to experiment with *Pure Rotation*, here are some ideas:

- Stand vertically rather than leaning forward, to the extent possible. Leaning forward complicates *Pure Rotation*, as we shall see in the next chapter.
- Maximum rotation occurs when the legs are vertical, so the feet should be placed directly under the balls at the top of the femur.
- Your weight shift should be minimal, since the centre of gravity should not change. If your centre of gravity is changing, chances are you are rolling your ankles (eversion and inversion).
- Check out your ability to rotate without changing the centre of gravity by using balance aids such as a BOSU ball, balance board or mirror.
- Do not change the bend in your knee in the backswing and downswing in *Pure Rotation*.
- The lead leg may straighten in the follow through, but should not straighten before impact. Straightening the lead leg by contracting the quadriceps in the downswing prior to impact pulls the lead hip joint toward the ball and dampens the rotation.
- Tiger Woods has suggested that to get power, he used to slam his lead knee back away from the ball. While it is hard to argue with success, the movement occurring before impact is counterproductive, and at worst, could cause hyperextension injuries in the knee joint.
- The key to power is the ankles. The muscles at the back in the lead ankle need to contract to point the toe away from the body i.e. plantar flexion (and the lower leg and hip away from the ball)). Bubba Watson executes this move with such force that he sometimes appears to push himself off the ground.
- A bulging calf muscle in the lead leg is an indicator of the plantar flexion that is moving the toe away from the head. Video your calf muscle, to see how you're your calf bulges.

Push and Clear



Push and Clear works. The "push" movement lengthens the trailing leg during the downswing. The "push" comes from pointing the toe and straightening the leg at the knee. The "clear" movement gets the lead hip joint out of the way.

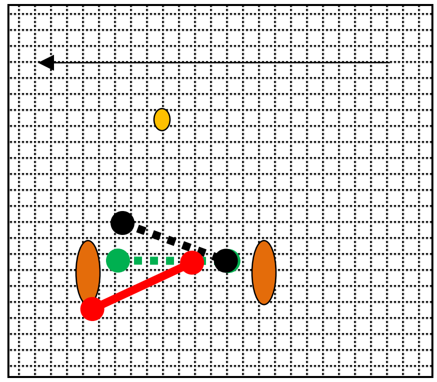
The diagram illustrates what happens with the trailing leg during the "push". The solid black line depicts the front view at the top of the backswing for a right-hand player. The diamond at the bottom of the line depicts the foot, while the ball at the top depicts the trailing hip joint. The line is in fact the line from the foot to the hip joint. Because the femur has a right-angle bend at the top, the line does not depict the actual leg. Note that the line is slanted, because in normal circumstances the foot would be placed at shoulder width and the hip joint would lie inside the shoulder width. The dashed red line shows what happens at impact to the line when the trailing leg is lengthened and the hip joint elevation remains constant. The trailing hip joint moves in the direction of the target.

You can figure out how much you can lengthen your leg by standing next to a wall, with knees bent as in a normal set up. Measure the elevation of the hip joint on the wall. As we shall see, this is the effective length of your leg at set up and at the top of the backswing, because we suggest the leg should not move in the backswing. Now, straighten the bend in the knee and stand on your toe. Measure the elevation of the hip joint on the wall. Compare the two measurements, to determine how much you lengthened your leg.

To get an accurate determination of the movement of the hip joint in the downswing, you would have to apply some geometry to account for the angles involved, and you would have to take into account how much leg lengthening occurs up to impact. The geometry is addressed in Chapter 10 and 11. Regardless of the specific measurements, our purpose here is to show where the power comes into the golf swing.

As indicated above, lengthening the trailing leg involves straightening the bend at the knee using the quadriceps, combined with moving the toe away from one's head (plantar flexion). Lengthening the leg by itself is not sufficient to create power in the swing. The leg lengthening has to be in the direction of the target. This requires:

- Turning the trailing ankle outward (eversion). Turning the ankle outward with the foot planted on the ground points the trailing knee inward and toward the target.
- Ensuring a position at the top of the backswing that will allow the push forward. This position is best achieved by ensuring that the trailing hip joint, and the knee and ankle joints below it, do not move in the backswing. If one allows them to move laterally away from the target, or to rotate away from the target, the "push" is compromised, and the initial part of the downswing must focus on getting the trailing leg in position to "push".



The diagram illustrates the top down view of the *Push and Clear* downswing. The balls at the end of the lines indicate the hip joint positions. The dotted horizontal green line denotes the start position. The black line shows the rotation for a right-handed golfer at the top of the backswing. The solid red line indicates the hip joint position at impact (i.e. slightly beyond the start position of the downswing.

Note that the black ball is on top of, and covering, what would be the green ball, illustrating the point that the trailing hip joint has not moved from the original position during the backswing. In addition, the lead hip has moved toward the ball and away the target. At impact, the red ball denoting the trailing hip has moved directly toward the target, while the lead hip has moved away from the ball and slightly toward the target, all relative to the start position.

The *Push and Clear* downswing involves a "push" off the trailing leg, as well as a "clear" by the leading leg. The "clear" is as important as the push, since it allows the "push" to produce some rotation of the bone structure. The "clear" movement in the leading leg is the same movement that occurs with *Pure Rotation*.

The bone structure and base of the spine move laterally toward the target and away from the ball. The amount of movement is small.

If you want to experiment with the *Push and Clear* movement, here are some ideas. Keep in mind that leaning forward at the hip joints affects the *Push and Clear*, so you get the best sense of the *Push and Clear* movement by standing vertically to the extent possible.

More knee bend at set up and at the top of the backswing translates into greater lengthening of the trailing leg on the downswing, and ultimately more power. Conversely, relatively straight legs defeat the purpose of the *Push and Clear*. If one starts with relatively bent legs, the bend in the trailing leg disappears in the "push" movement, but the bend in the leading leg should be maintained in the "clear" movement until after impact. Straightening a bent lead leg on the downswing has the effect of moving the lead hip joint toward the ball, which neutralizes the rotation.

The direction of the "push" during the downswing matters. Turning the trailing foot outward (and the trailing leg inward) during the downswing plays a key role in determining the direction of the "push". A "push" toward the target commits energy to the direction of the hit.

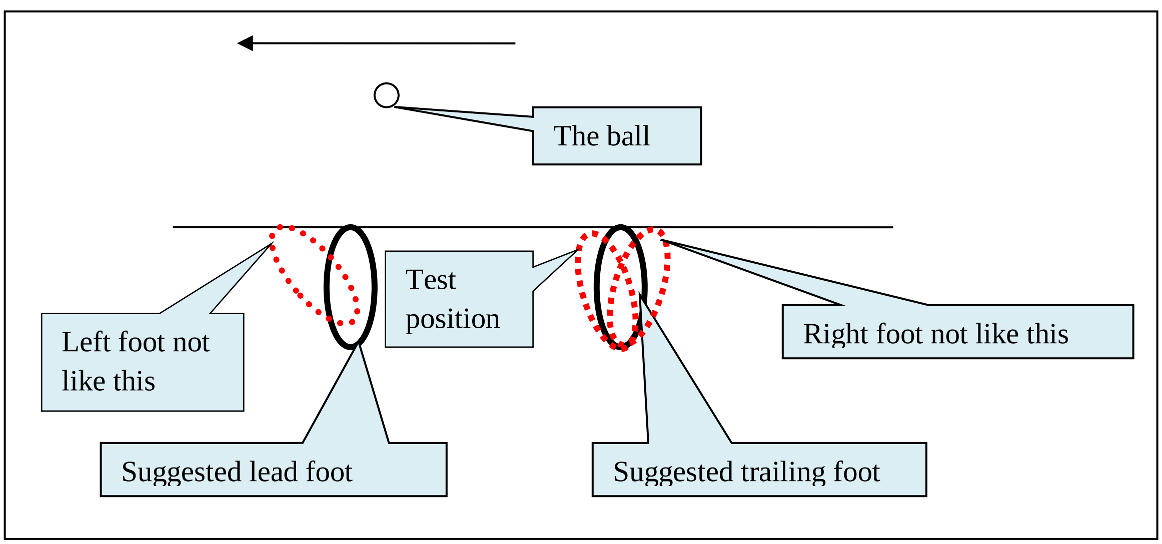
An essential element of the *Push and Clear* is that the trailing hip joint does not move in the backswing. To clarify, the hip joint is inside the perimeter of the bone structure; it should not move. However, the outside points of the bone structure will rotate, since the bone structure itself is rotating. When you look at videos of yourself or others, or watch other players, or look at your swing in a mirror, look at the upper trailing leg, not at the belt position of the side of the trailing hip. A stationary trailing hip joint is indicated by a stationary upper leg.

The belt position on the side of the trailing leg should move, because the bone structure is rotating around the stationary trailing hip joint. As we saw in the section on hip anatomy, the upper leg can rotate to some degree within ball and socket joint in the hip.

The *Push and Clear* feels like a powerful move, because the leg extension uses the quadriceps to straighten the leg at the knee, and the ankle muscles. These are among the strongest muscles in the body.

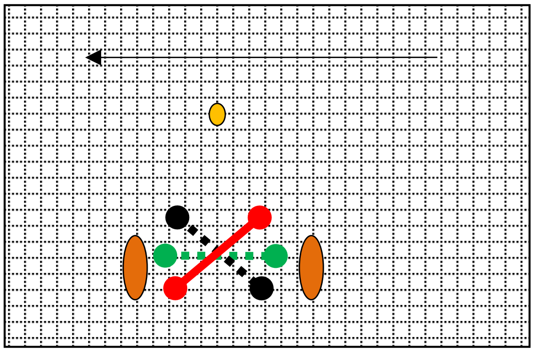
There is a theory in golf that one should “load” up on the trailing leg in the backswing (i.e. shift one’s weight to the back foot), and then push forward in a power move on the downswing. It does not make sense to move one’s weight backward in the backswing, and then forward to the initial position and beyond in the downswing. There is extra, unproductive movement in this swing. It makes more sense to start with one’s weight on the back foot at address and move it forward with “push”. This should work, provided the initial position is such that the trailing leg is in a position to “push” forward. The top players tend not to swing this way. Most start the swing at address with their weight relatively evenly distributed between lead and trailing feet.

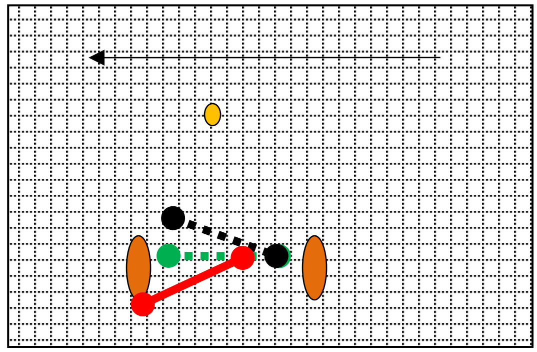
Proper foot position at address can facilitate the *Push and Clear*. The trailing foot should be at least perpendicular to the line of flight at address, to ensure the trailing leg is in a position to “push”. A trailing foot with the toe pointed slightly toward the target can facilitate the “push” on the downswing. It can also help keep the trailing hip joint stationary during the backswing, since it restricts the ability its ability to move. A lead foot perpendicular to the line of flight can facilitate the “clear”, since a plantar flexion of the foot (i.e. move the toe away from the head) can implement the “clear”. The diagram below illustrates the position.



Pure Rotation* Versus *Push and Clear

As a reminder of the technical differences between *Pure Rotation* and *Push and Clear*, the previous diagrams are repeated below. The balls indicate the hip joints. The green structure indicates the start position, the black the position at the top of the backswing, and the red the impact position.





Pure Rotation *Push and Clear*

Which to pursue? The story is not finished. Chapter 9 deals with the spinal tilt, which is intimately related to how one uses the hips and lower body. Chapters 10 to 13 deal with the physics of golf, and they too have something to say on the question. However, the conclusion is that you should try both approaches, and see which works best for you.

Your assessment should take into account the potential distance effect (from the physics of golf), spinal health (related to the spinal tilt), your ability to achieve the potential distance consistently, and your ability to hit the ball online.

The Bottom Line

- Recognize that your "hips" are not a fundamental aspect of your golf swing. Your hips go where your ankles and knees tell them.
- If you are going to think of "hips", then think in terms of moving the hip joints.
- Understand that there are two ways to move the hip joints: *Pure Rotation* and *Push and Clear*.
- To execute *Pure Rotation*:
  - Use both ankles to rotate the bone structure.
  - Stand vertically rather than leaning forward, to the extent possible.
  - Place the feet directly under the balls at the top of the femur, to maximize rotation.
  - Minimize weight shift; keep the centre of gravity around the middle of your stance.
  - Use balance tools such as a BOSU ball or balance board or mirror to help you to keep the centre of gravity around the middle of the stance.
  - Avoid inversion and eversion of the ankles, as they shift the centre of gravity.
  - Keep your knees, whether straight or bent, out of the movement.
  - Recognize that the power comes from the ankles, through a combination of backswing and downswing plantar flexion, dorsi flexion, supination and pronation.

- To execute *Push and Clear*:
  - ”Push” the trailing side in the downswing by straightening a bent knee and pointing the toe in the correct direction. In effect, this elongates the trailing leg and moves the hip joint above it forward and around.
  - Get the correct direction in the downswing by turning the trailing ankle outward, thereby turning the trailing knee inward toward the target.
  - Place the trailing foot at least perpendicular to the target line, or perhaps pointing modestly toward the target.
  - Get positioned for the “push” in the backswing by not moving the trailing leg and hip joint.
  - “Clear” the lead side in the downswing by pointing the lead toe without changing the bend in the knee, effectively moving the hip joint away from the ball.
  - Place the lead foot perpendicular to the target line, to facilitate the “clear” movement.

CHAPTER 9: FORWARD LEAN AND SPINAL TILT

Understanding the Stack and Tilt

SPINAL TILT AND THE FORWARD LEAN

The hip joints rotate under the *Pure Rotation* or *Push and Clear* scenarios. Furthermore, when they rotate, the two joints generally stay at the same level, so they remain parallel to the ground, and the axis of rotation is perpendicular to the ground.

While the two hip joints may be on the same level and generally parallel to the ground, the spinal column is tilted forward. This occurs because the knees are typically bent. The muscles around the hip joints contract to incline forward the bone structure in which the hip joints sit. When the bone structure is inclined forward, the spinal column is also inclined forward.

The angle between the upper leg and the bone structure, when seen from the side view, is 180 degrees when one stands vertically. When one goes from standing vertically, and then starts to bend the knees, the body typically reacts at the ankles by reducing the angle between the ground and the lower leg, and at the hips by tilting the spine forward at the hips and decreasing the angle between the upper leg and the bone structure/spine from 180 degrees. These movements maintain the centre of gravity over the feet and ultimately keep the body from falling forward or backward.

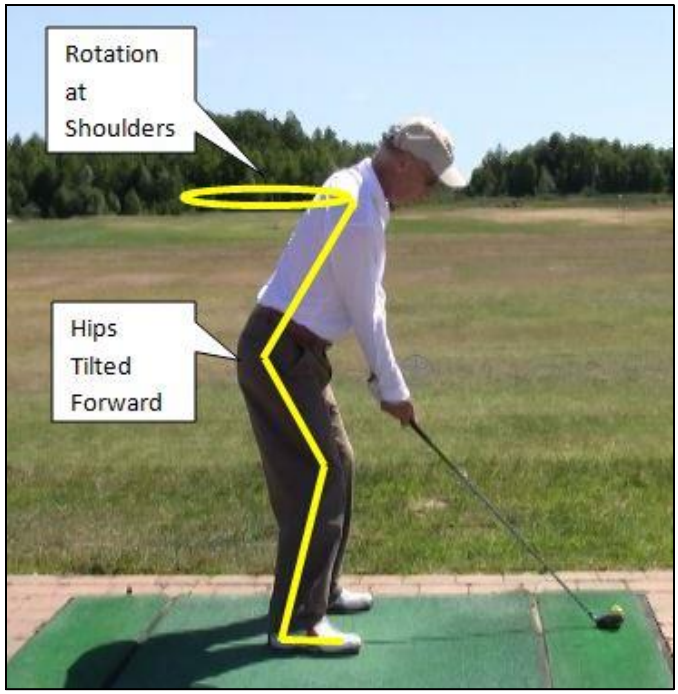
In the golf swing at setup, the bone structure and the spinal column which comes out of the bone structure, are tilted forward a few degrees, as shown in the picture.

Bending forward at the hips (compared to standing vertically) has a number of effects:

- Without any corresponding compensation, it will lead to a rotation of the midpoint of the shoulders during the swing. This rotation will cause the head to move away from the ball and target on the backswing, back to the start position at impact, and toward the target and away from the ball at impact.

- The golfer's centre of gravity will also move throughout the swing. It will go away from the ball and target on the backswing (i.e. weight toward the heel of the trailing foot), back to the start position at impact, and toward the target and away from the ball on the following through (i.e. weight toward the heel of the lead foot).

The picture illustrates the rotation that occurs around the shoulders when the bone structure and hips lean forward. Of particular interest is the amount of movement at the centre of the shoulders and the head. The amount of rotation at the top of the spine will be directly related to the amount of rotation of the hips. If the hips rotate in the downswing through 45 degrees, the downswing rotation at the top of the spine will be 45 degrees. If they rotate through 22 degrees, the downswing rotation will be 22 degrees.



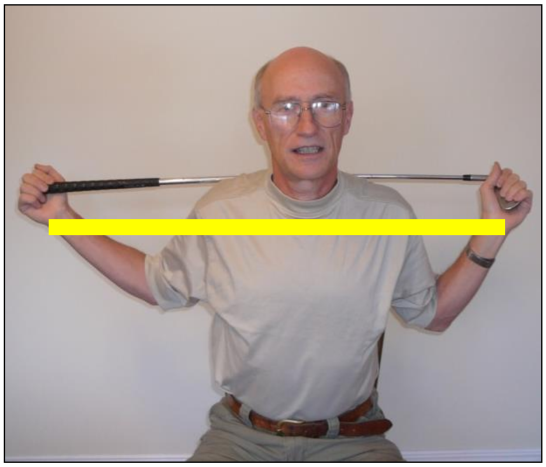
You can get a sense of this movement by sitting in a chair, bending forward so that the spine is about 20 degrees from the vertical, and swiveling on your butt about 45 degrees in each direction from your initial position. Note how much the centre point between the shoulders and your head will move as your swivel. The centre point between your shoulders and your head will be rotating in a circle whose diameter will be determined by the distance from the centre point between the hip joints and the centre point between the shoulders, and the degree of forward tilt.

The golf swing's reaction to all this movement can vary. The simplest physical response is the "do nothing" approach, so the shoulder centre and head rotate around in a circle - away from the ball and target on the backswing, and toward the ball and target on the downswing. A more complex response is to nullify the movement by lateral side bends of the upper spine. As the rotation of the inclined spine moves the shoulder centre away from the target on the backswing, the upper spine tilts toward the target. Let us explain the spinal tilt further.

The Spinal Tilt: Spinal Anatomy and the Golf Swing – Part 2

The "spinal tilt" is the bending of the spine sideways left and right. It is also known as the lateral flexion of the spine. The muscles at the side of the body contract, causing the upper spine to bend left or right, when seen from the front, relative to the lower spine.

If you lay a golf club across your shoulders, a lateral side bend will move the club from the horizontal plane to some degrees off the horizontal plane when seen from the front. The spinal tilt contrasts with the spinal twist, where the club stays on the horizontal plane.



Start Position ***Spinal Tilt: Club is off Horizontal Plane***

In the golf swing, the "spinal tilt" refers to a lateral side bend toward the target on the backswing and away from the target on the downswing. Since the head sits at the top of the spine, side bending causes the head to also move toward the target on the backswing and away from the target on the downswing.

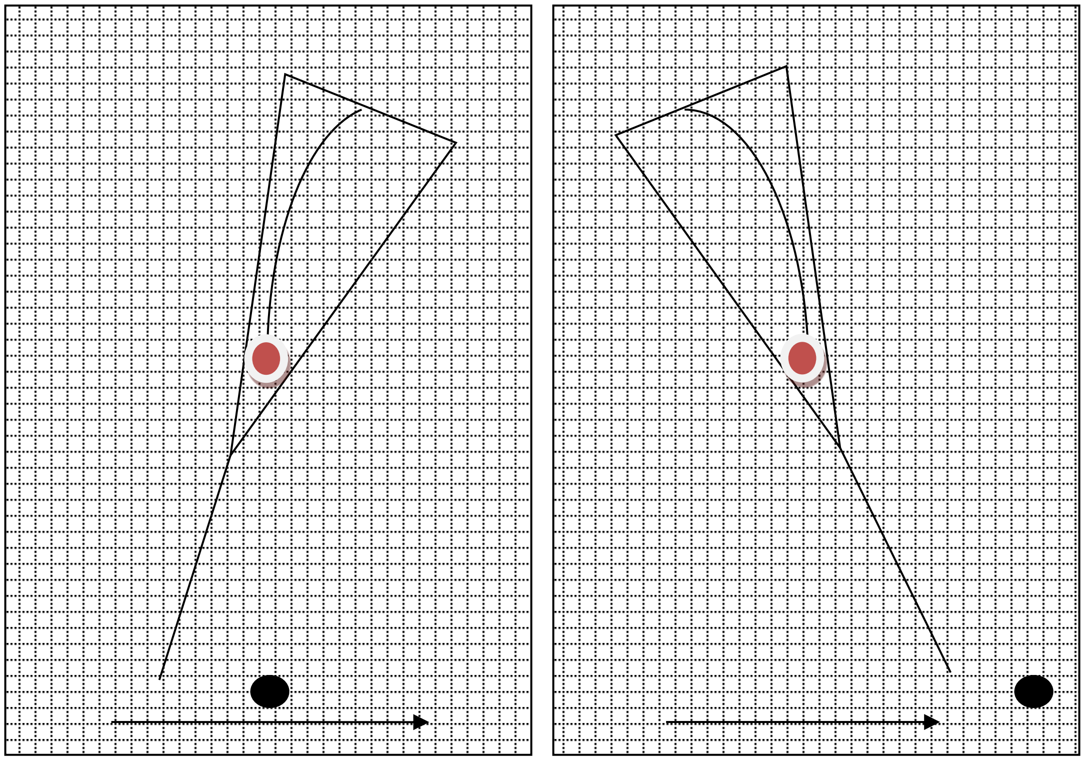
The spinal tilt is a power source, albeit a mild one, in the golf swing.

One can get a sense of lateral side bending as a power source by taking a five iron, putting a ball on a tee (to ensure a clean hit), contracting the muscles on one's lead side during the backswing and then contracting the muscles on trailing side on the downswing, all while immobilizing all other muscles. The lateral side bending will create a rocking motion that will propel the club away from the target on the backswing and then forward toward the target on the downswing, causing the ball to go forward.

You may find a bit of a challenge in hitting balls only using the spinal tilt. If you do, step away from the ball, do a number of spinal tilts to get the feel of using only the spinal tilt muscles, then retry hitting the ball. You may be able to get 10 to 20 yards distance, which would amount to one club less on iron shots.

The stick diagrams below illustrate how side bending can move the shoulders around a circle centred at the base of the spine. Because the arms and the club extend substantially beyond the base of the spine, the shoulder movement translates into a power source capable of moving the ball forward. The curved line represents the spine, bending right in the front view in the backswing (right-hander) in the left diagram, and then bending left in the downswing in the right diagram. The equal length sides of the triangle depict the arms and the top depicts the shoulders.

The line at the end of the triangle depicts the club. The black circle is the ball. The arrow shows the direction of the hit. The red ball indicates the centre around which the shoulders are rotating, namely the base of the spine.



In Chapter 11, we shall see that this power source is real but small.

The spinal tilt is a golf movement highlighted by Plummer and Bennett when they introduced the “stack and tilt” golf swing. However, a number of players employ some degree of spinal tilt/lateral side bending in their swings. Most do so unconsciously. When you watch good players swing, the head and the centre of the shoulders typically stay relatively motionless, even though their bodies lean forward at setup and they rotate their hips. This occurs because lateral side bending is taking place to counteract the effect of hip rotation in combination with the forward lean.

Keeping the head relatively still during the swing makes maximum use of vision as a controlling element in the golf swing. If you think vision is not relevant, try hitting balls with your eyes closed. Because of the importance of vision, most good players keep their heads (and eyes) relatively still during the swing.

Look at swing videos of the top players. Draw a line from the head to the centre of the stance, and then watch what happens to the belt buckle. These days, the belt buckle stays on the line or moves only slightly away from the target in the backswing, but moves forward while the head remains fixed over the ball in the downswing. To a large extent, the only way to achieve this positioning is to tilt the spine through lateral side bends.

You may also be able to feel lateral side bends in your golf swing. To do this, swing slowly, and see if you can feel the muscles around your ribs on your lead side contracting during the backswing, and the muscles around the ribs on your trailing side contracting during the downswing. As a further experiment, try to keep your head in the same place over the ball in your backswing, and see if you can feel contractions on the muscles on your upper lead side. On the downswing, try to keep your head motionless and see if you can feel yourself automatically contracting the muscles on your trailing side.

Is the spinal tilt healthy? Maybe not. In most cases, tilting the spine will occur simultaneously with twisting the spine. As discussed under Spinal Anatomy, one would think intuitively that this could put undue pressure on disks, particularly when the movement is performed quickly. Some spinal tilting is likely to be okay for most people, but an exaggerated spinal tilt could be problematic, particularly when carried out without adequate warm-up, in cold weather, or with countless repetitions.

The spinal twist involves primarily the lower discs in one's back. If the spinal tilt engages primarily the upper discs in one's back, the health risks are reduced. The health risks go up when spinal tilting engages the lower discs as the same time that spinal twisting engages these same discs.

Hip Joint Movement, the Forward Lean, and the Spinal Tilt

Spinal tilting and hip joint movement must be considered together, since they function interdependently. They combine to produce four options for the golf swing:

- *Pure Rotation* without Spinal Tilt
- *Pure Rotation* with Spinal Tilt
- *Push and Clear* without Spinal Tilt.
- *Push and Clear* with Spinal Tilt.

These options will be explored more fully when we look at the physics of the movements in the golf swing. At this point, the spinal tilt is presented as an option for your consideration.

The Bottom Line

- The rotation of the "hip" bone structure, in combination with leaning forward at the hips at setup, will cause the shoulders and head to rotate in a circle, in the absence of spinal tilting.
- This rotation affects the head position, the ability of the eyes to control the swing, and the centre of gravity throughout the swing.
- The spinal tilt neutralizes this movement, keeping the head and shoulders relatively centred in the same place throughout the swing.
- In muscle terms, the spinal tilt is often referred to as "lateral side bends".
- The spinal tilt is a power source, albeit a relatively small one.

- The spinal tilt can be harmful to one’s spine.

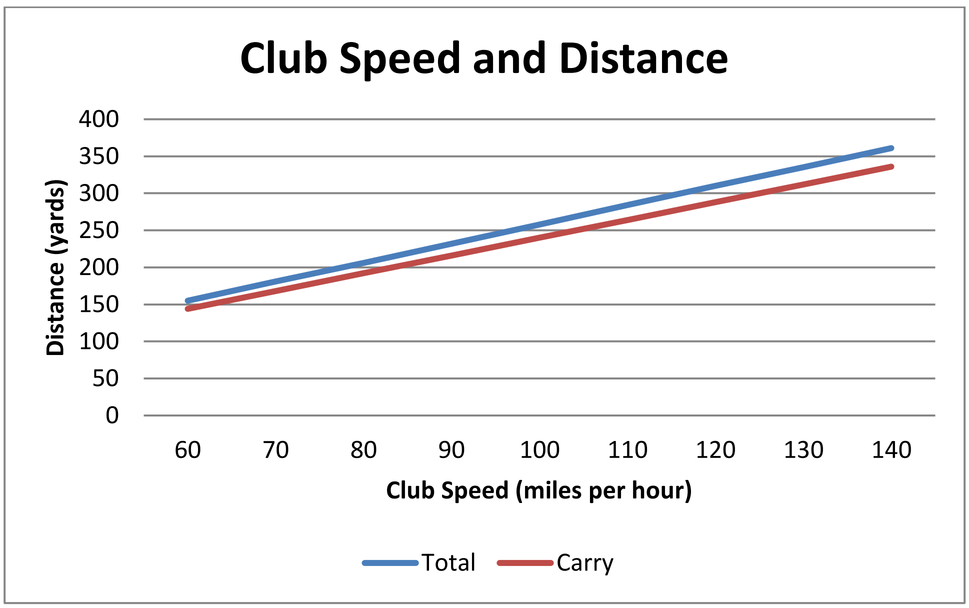
Chapter 10: Some Elementary Physics

It's elementary (my dear Watson)

Club Head Speed and Shot Distance

This should not come as a surprise. Club speed is related directly to the distance of a golf shot. The faster the club moves, the farther the ball will go.

The graph below relates distance to club head speed. The table shows a direct relationship between club speed and distance. For every 1 mile per hour increase in club speed, total distance increases by about 2.57 yards. Keep this in mind as a point of reference.



Source: Jaacob Bowden, Carry Distance versus Swing Speed Chart, (www.GolfWRX.com)

Distance Travelled by the Club Head

There are two elements to club head speed: distance travelled and time. Speed is the distance travelled divided by the time taken to travel the distance.

We are all familiar with straight line distance. We measure straight line distance with familiar measuring devices such as our feet, our paces, rulers, yard sticks, tape measures, and range finders.

Distance around a circle can also be measured using measuring devices, but it is usually easier to calculate this distance. To do so, we need to know the circumference of the circle, and the portion of the circle traversed.

- The circumference of the circle in turn can be calculated from the radius, using the formula where the circumference is 2 times the radius of the circle (straight line distance from the centre of circle to the circumference) times the constant pi (approximately 3.1416).
- The portion of the circle traversed can be calculated from the degrees of rotation in the downswing, divided by number of degrees in the circle (360).

Almost all movements in the golf swing, taken individually, cause the club head to move around the circumference of a circle.

Determining the radius of the circle traversed by the club head through particular movements (taken in isolation) is more complicated, and involves two notions: circle radius, and distance from the circle centre to the ball. In some cases, the circle radius is the distance from the circle centre to the ball. In other cases, it is different.

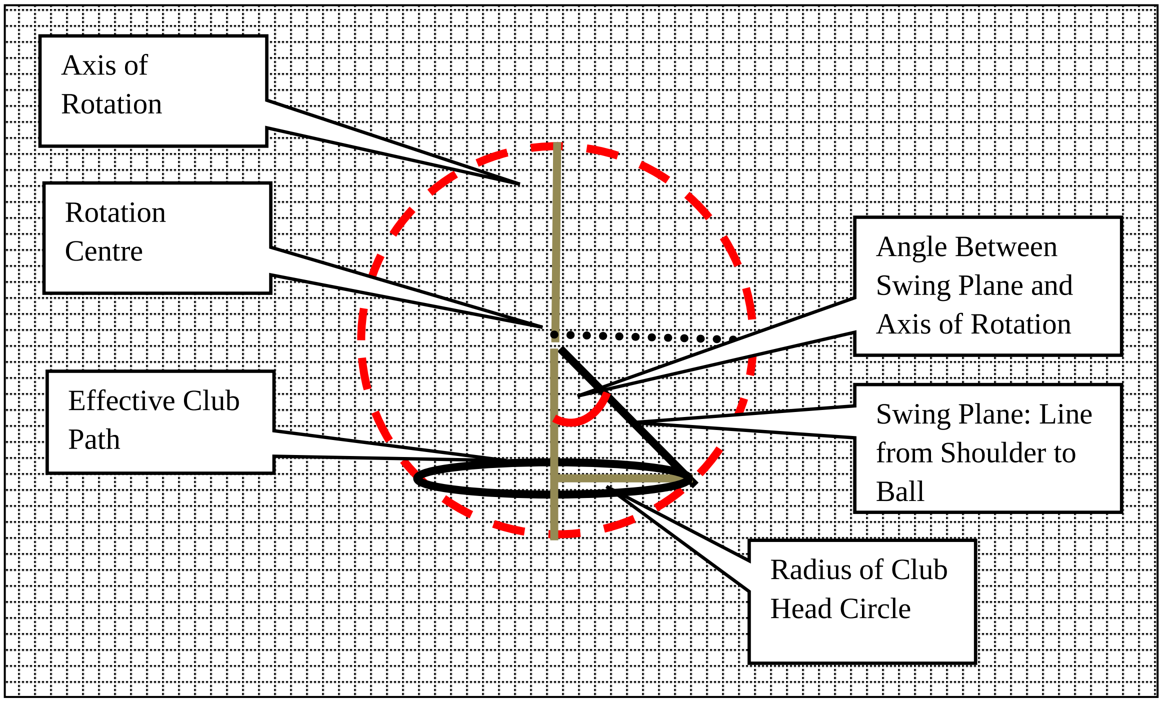
To illustrate the difference, picture a stick hanging down from a shaft that can rotate vertically to the ground. If the shaft rotates very slowly, the stick appears to not move but continues to hang vertically to the ground. The distance from the circle centre to the tip of the stick hanging from the shaft is the length of the stick, but the radius of the circle traced out by the hanging end is zero.

If the shaft rotates sufficiently quickly, the stick will move in a circle perpendicular to the shaft and horizontal to the ground. The radius of the circle traced out by the loose end of the stick will be the length of the stick, which is also the distance from the circle centre to the circumference.

One can imagine the situation where the shaft rotates at a rate that causes the loose end of the stick to trace a circle with a radius greater than zero but not the full length of the stock. The distance from the circle centre to the circumference of the circle traced by the loose end of the stick is the length of the stick, but the radius of the circle being traced is less than the length of the stick.

The picture below depicts what is happening. As the angle between the axis of the shaft and the stick increases from 90 degrees to 180 degrees, the circle being traced out by the loose end gets smaller. Note the difference in size between the circle with the dotted line compared with the one with the solid line. In both cases, the distance from the circle centre to the circumference is the same.

Call outs in the picture emphasize key concepts to be applied to the movements in the golf swing: the rotation centre; the axis of rotation; the distance from the rotation centre to the circle circumference traced out by the golf club and including the golf ball; and the angle between the axis of rotation and the line from the rotation centre to the golf ball at the circumference of the circle.



The picture shows that the distance to the circumference from the centre of rotation is not always the radius of the club head path/circle. The critical issue is the angle between the axis of rotation and the line from the centre of the circle to the circumference.

The sine of this angle is used to calculate the radius of the club head path/circle when the angle is from 90 to 180. The table provides the sine of various angles between 90 and 180 degrees. Note how the sine of the angle starts to drop quickly after 130 degrees.

Angle	Sine of the Angle
90	1.000
100	0.985
110	0.940
120	0.866
130	0.766
140	0.643
150	0.500
160	0.342
170	0.174
180	0.000

When the angle is 90 degrees, the radius of the circle traced out by the club is the distance to the circumference from the centre of rotation. When the angle is 130 degrees, the radius of the circle traced by the club head is the distance from the circumference of the circle from the rotation centre times .766.

CALCULATING DISTANCE TRAVELLED

A key aspect of physics is measurement, and here are some basics we will apply for the golf swing in total and individual movements:

- Lengths of arms, legs, spine and distance between body parts such as shoulders and hip joints. A tape measure works fine.
- Angles such as between the club and lower arms, the upper and lower legs, the spine relative to the vertical, etc. Pictures of the golfer and a protractor are excellent tools.
- Amounts of rotation through the various movements such as cocking and uncocking the wrists. A protractor and mirror are useful tools.
- Trigonometry can assist in calculating distances which are difficult to measure directly. For example, if one knows three of six elements (lengths or angles) of a triangle, trigonometry can calculate the remaining lengths or angles. There are triangle calculators on the internet.

Measuring Time

Measuring the time required for the golf swing and its components is essential for calculating club head speed. Accurate measurements require sophisticated equipment, but a simple technique can help.

High speed video cameras typically take pictures at rates defined in terms of frames per second. Counts of the number of pictures in the downswing will let you determine the seconds required for the downswing.

An analysis of all the frames during the downswing can generate a great deal of time related information, including duration of the downswing, the duration of particular movements within the downswing, the number of degrees of rotation of the club during the frame and the relationship between degrees of club rotation and time in the downswing.

The table below illustrates the results of a detailed analysis of the golf swing pictures from a typical high definition camera. The results have been incorporated into the golf swing model.

Frame Number	Club Angle (Horizontal = 180 Degrees) at End of Frame	Degrees of Rotation	Observations
0	180		Start of downswing – club is parallel to ground
1	178	2	Hips have started to rotate
2	175	3	
3	169	6	
4	162	7	
5	154	8	Spine has started to untwist – the angle between the shoulders and the hips has begun to decrease
6	142	12	Upper arms have started to move in shoulder sockets – trailing elbow has moved closer to the body Shoulder sockets have started to move – lead shoulder socket has moved away from chin
7	115	27	
8	85	30	Forearms have begun to roll and wrists begin to uncock
9	50	35	
10	-10	60	
11	-90	80	Impact – Club has reached perpendicular to ground

Observations from the table include:

- The downswing has taken 11 frames and the camera takes 27 frames per second, so the elapsed time is (11/27 =) 0.407 seconds.
- The club begins the downswing horizontal to the ground, and ends vertical. From a 2-dimension perspective, it has rotated 270 degrees.
- The number of degrees of rotation increases throughout the downswing.

- Not all movements start at once. The hips start rotating first, followed by the spine, the arms and shoulder sockets, and then the forearms and wrists.
- The rapid increase in degrees of rotation occurs because different movements are kicking into action during the downswing, but may also occur because each movement imparts some acceleration to the club head during the course of the movement.

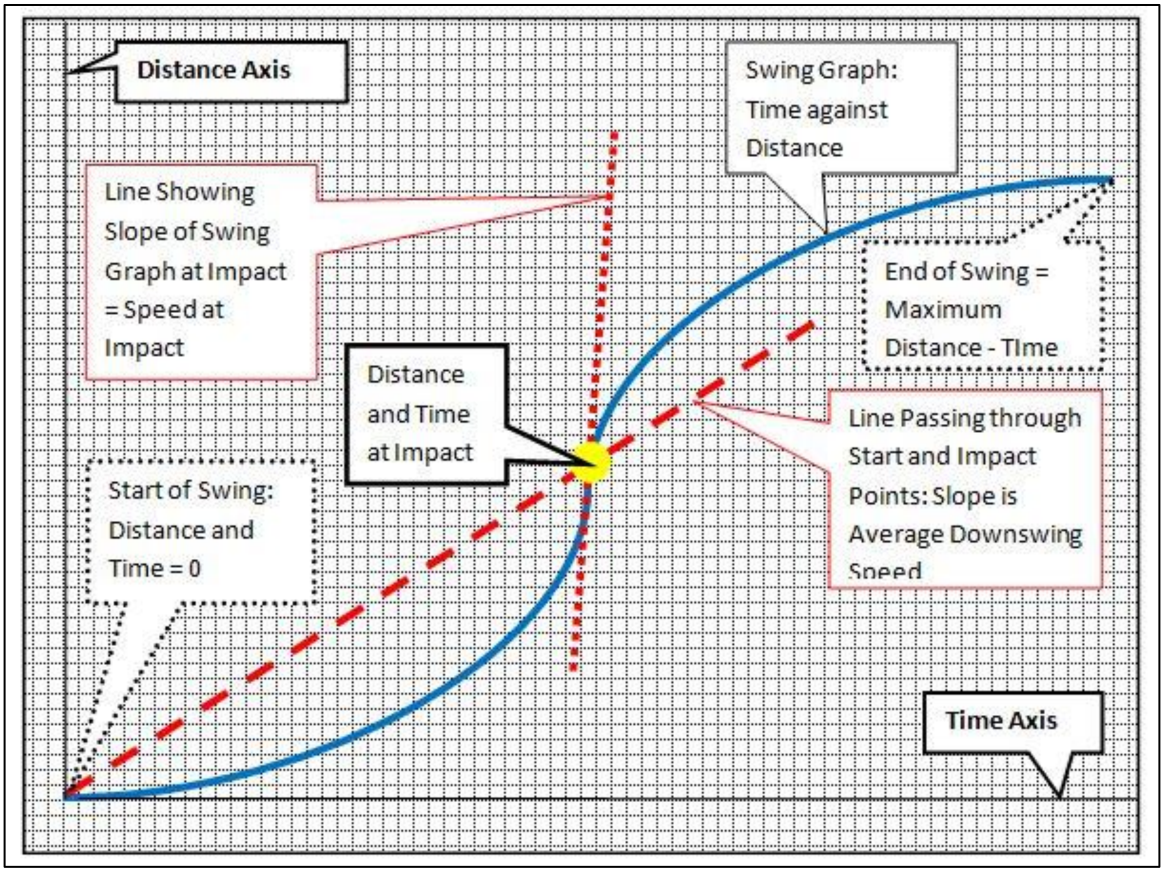
Average Speed and Impact Speed

In all movements, we will be calculating the distance travelled through the movement divided by the time required for it. The result is the average speed during the movement.

More relevant than the average speed for the movement is the speed at the moment of impact.

We are not in a position to provide a definitive relationship between average speed and impact speed. However, here are some ideas:

- From the previous section, it is clear that the club head speeds up during the golf downswing. However, the previous section provides one explanation, namely that the acceleration during the downswing occurs because the various movements kick in at different times.
- One would expect that each movement in an efficient golf swing, taken in isolation, would see an increase in speed (acceleration) during the downswing, with the maximum speed occurring at impact. Specifically, for each movement in the downswing taken in isolation, the club head will begin with a speed of zero at the start of the movement, then accelerate throughout the downswing (i.e. increase its speed), leading to a peak speed at impact. After impact, the club will decelerate (i.e. decrease its speed) and end up at speed zero at the end of the movement. The graph below shows this process, and illustrates that with such a pattern, the speed at impact will be greater than the average speed. The blue curve illustrates the relationship between distance travelled by the club head and time during the downswing. At the start of the downswing, there is relatively little distance travelled per unit time. However, as time passes, the club head travels larger distances and the slope of the curve gets steeper. At impact, the distance travelled per unit time is at its maximum, and the slope of the curve is its steepest. After impact, the club head slows down, with less distance travelled per unit time. At the end of the swing, there is no further movement. The red dotted line illustrates the slope of the curve at its steepest point, namely the point of impact. The red dashed line passes through the start position (time and distance travelled = 0) and the impact point. Its slope illustrates the average club speed during the downswing. The dotted line is steeper than the dashed line. Impact speed is greater than average speed.



- One reason for acceleration in the downswing is inertia. An object (the club) will stay at rest unless a force is applied. Initially, the force works to overcome inertia. However, in the golf swing, the club is relatively light, some muscles are much stronger (legs and ankles) than others (wrists), and some movements occur in shorter time periods (uncocking wrists) than others (hip rotation).
- Attention must be paid to how muscles work. They work through signals to contract from the brain to fibers within muscles. The messages probably arrive relatively simultaneously. In other words, muscle contraction is more akin to an instantaneous process leading to rapid transition to full speed, rather than sequenced, gradually accelerating process.
- That said, the brain probably takes into consideration the risk of injury when rapid acceleration occurs at the end of a range of movement. This could lead to slow rates of contraction at the extreme end of the range of movement, followed by fast rates when the injury risks are lower.
- In addition, muscles do not generally contract at the end of their range of movement in day to day living. As a consequence, they may not be as strong or conditioned to contract rapidly

Each movement will likely see acceleration during the downswing because of the need to overcome inertia, muscle weakness at the end of range of movement, lack of muscle conditioning at the end of the range of movement, and the sequencing of contraction instructions from the brain at the end of the range of movement. However, the acceleration may not be rapid because the club head is light relative to the strength in most muscle groups and the fact that for the most part brain messages are instantaneous.

This Guide refers to the "scalability factor", which is impact speed divided by average speed. In essence, this Guide calculates average speed in the downswing, and recognizes that these average speeds will need to be scaled up to determine impact speed. Because of the uncertainty around scalability factor, this Guide assumes a factor of 1 for all movements and recognizes that impact speeds will likely be greater than speeds estimated herein. With a scalability factor of 1, all speed estimates are minimums.

As an observation, average speeds calculated using the golf model in this Guide are about 15 percent less than overall impact speeds calculated through golf club speed measuring devices.

THE BASIC ROTATION EQUATION

Minimum club speed from a movement (taken by itself) = Hypothetical Distance Travelled by the Club Head from the movements (= **circumference of the rotation circle** [= *2* **times** *the constant pi* {= 3.1416 } **times** *the radius of the circle* {= distance from the rotation centre to the ball **times** the sine of the angle between line from the rotation centre to the ball and the axis of rotation }] **times the portion of the rotation circle traversed by the club head** [= **amount of downswing rotation in degrees divided by 360 degrees in a circle**]) divided by **duration of the movement** times **a factor converting inches per second to miles per hour** (= **seconds per hour** [*=3600*] **inches per mile** [*= 5280 times 12*]) **times a scalability factor converting average club speed to speed at impact.**

In applying the above to the movements in the golf swing, for each movement we need to know:

- the rotation centre;
- the distance from the rotation centre to the ball;
- the angle between the line from the rotation centre to the ball and the axis of rotation;
- the amount of rotation in the downswing relative to a full circle ;
- the duration of the movement within the downswing; and
- a factor converting the average downswing speed of the club head from the movement to speed at impact.

In the following chapter, we shall explain how to estimate the club head speed from the individual movements in the swing.

The Bottom Line

- We can calculate the contribution of each movement in the swing when we know the foregoing elements.

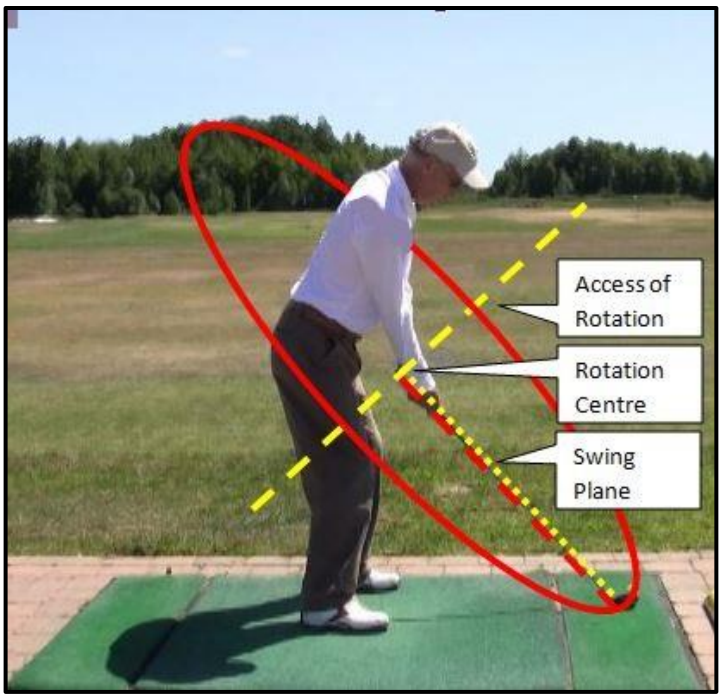
CHAPTER 11: THE PHYSICS OF THE SWING'S MOVEMENTS

It's elementary (my dear Watson)

THE PHYSICS OF COCKING AND UNCOCKING THE WRISTS.

Cocking and uncocking the wrists was discussed in Chapter 2. The picture below summarizes the key physical aspects of the movement.

- The rotation centre is the wrist in the lead hand, which grips the club at its end.
- The distance from the rotation centre to the ball is the length of the club.
- The angle between the line from the ball to the centre of rotation and the axis of rotation is 90 degrees, when the movement is properly executed.

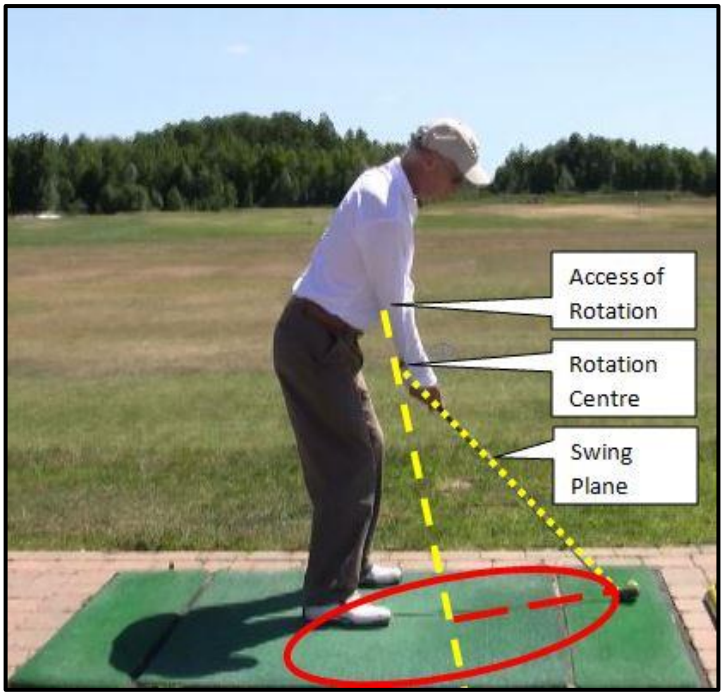


THE PHYSICS OF THE FOREARM ROLL

The forearm roll is discussed in Chapter 3. The picture below summarizes the key aspects of the forearm roll:

- The rotation centre is the wrist in the lead hand, which grips the club at its end.
- The distance from the rotation centre to the ball is the length of the club.
- The axis of rotation is the line along the forearm.

- The angle between line from the rotation centre to the ball and the axis of rotation can be measured with a protractor from pictures such as the one below. As we saw in Chapter 3, this angle depends on a variety of factors, including how the club is gripped (palms versus fingers) and the lead wrist is held (radial abduction versus ulnar adduction).
- Club speed will be at least the distance travelled divided by the time required for the movement.



The Physics of Rotating the Upper Arm in the Shoulder Socket

The rotation of the upper arm in the shoulder socket was addressed in Chapter 5. The physics of upper arm rotation in the shoulder socket are the same as the forearm roll, with the same rotation centre, axis of rotation, and distance to the ball.

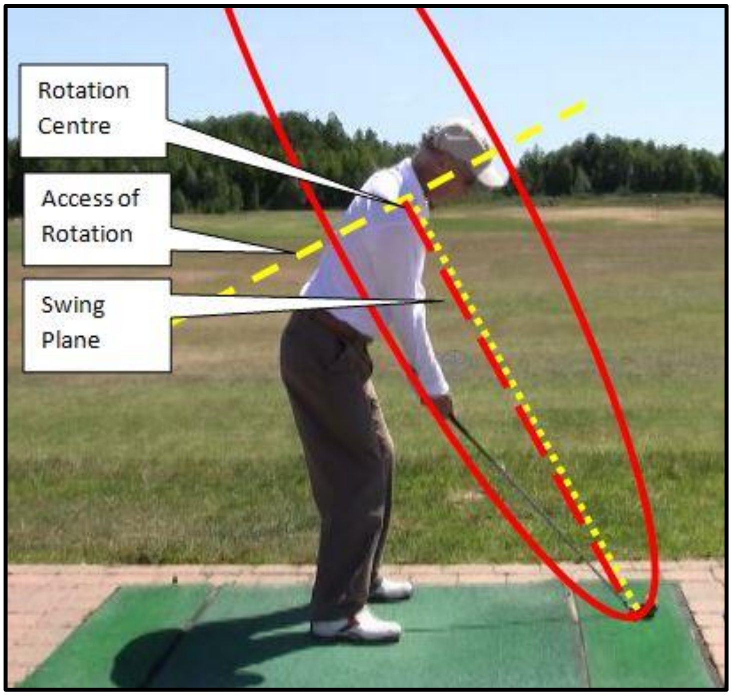
The Physics of Moving the Upper Arms in the Shoulder Socket

Chapter 4 discussed the proper movement of the upper arm in the shoulder socket. The picture below illustrates key physical components of the movement:

- The rotation centre is the lead shoulder socket.
- The rotation axis in a properly executed movement is perpendicular to the plane traced out by the line from the ball to the lead shoulder socket during the downswing. The upper arm can rotate along this axis because the shoulder socket is a ball and socket joint that can move in a variety of directions and there are no anatomical restrictions on the axis of rotation from the joint.
- The distance from the rotation centre to the ball can be calculated from the length of the golf club, the length of the arm from the shoulder socket to the wrist, and the angle

between the shaft of the club and the straight lead arm using the law of cosines expressed through the equation **$x^2 = y^2 + z^2 - 2yz\cos X$**, where **x** is length of the side to be determined, **y** and **z** are the lengths of the two known sides, and **X** is the angle opposite the length to be calculated and between the two known sides.

- Club speed will be at least the distance travelled divided by the time required for the movement.



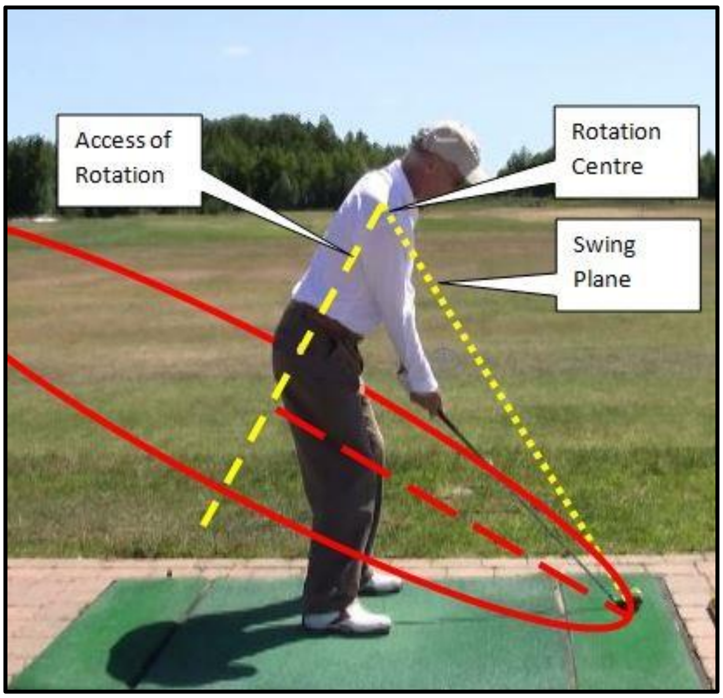
THE PHYSICS OF MOVING THE SHOULDER SOCKETS

Shoulder socket rotation was addressed in Chapter 6, which noted that the forward movement of one shoulder socket and the backward movement of the other socket, in combination, lead to a rotation of the shoulder sockets around the spinal column.

The picture below illustrates the key aspects of this movement:

- One can calculate the number of degrees of rotation caused by moving the shoulder sockets, if one knows the amount of movement of the shoulder socket when it goes from a neutral start position to the forward position and backward positions. With this information, one can calculate the amount of rotation of the shoulder sockets through the equation **$Y = \arccos((x^2 + z^2 - y^2)/2xz)$** where **x** and **z** are the distances from the mid-point to the shoulder socket, **y** is the linear movement of the shoulder socket, and **Y** is the angle opposite the amount of linear movement.
- The rotation centre is the mid-point between the shoulder sockets.

- The axis of rotation is the spine, around which the shoulder sockets rotate. Typically, the golfer leans forward at the hips, so that the spine twists around an axis that is tilted forward.
- The angle between the axis of rotation (the spinal column) and the line from the rotation centre to the ball can be determined through a behind-view picture of the golf swing and a protractor.
- Typically, the shoulder sockets will rotate slightly beyond the start position at impact, so additional degrees of rotation should be added to the base rotation calculated in the previous point.
- The distance from the rotation centre to the ball is approximately the same distance as from the two shoulder sockets to the ball. The distance from the rotation centre to the ball can be calculated from the length of the golf club, the length of the arm from the shoulder socket to the wrist, and the angle between the shaft of the club and the straight lead arm using the law of cosines expressed through the equation $\mathbf{x^2 = y^2 + z^2 - 2yz\cos X}$, where **x** is distance from the rotation centre to the ball, **y** and **z** are the lengths of the arm and club respectively, and **X** is the angle between the arm and the club.
- Club speed will be at least the distance travelled divided by the time required for the movement.



The Physics of the Spinal Twist

The spinal twist was discussed in Chapter 7. The physics of the spinal twist are almost identical to that of moving the shoulder sockets.

- The rotation centre is the mid-point between the shoulder sockets.

- The axis of rotation is the spine, around which the shoulder sockets rotate. Typically, the golfer leans forward at the hips, so that the spine twists around an axis that is forward leaning.
- The angle between the axis of rotation (the spinal column) and the line from the rotation centre to the ball can be determined through a behind-view picture of the golf swing and a protractor.
- Typically, the spine will rotate slightly beyond the start position at impact, so additional degrees of rotation should be added to the base rotation calculated through the foregoing points.
- The distance from the rotation centre to the ball is approximately the same distance as from the two shoulder sockets to the ball. The distance to the rotation centre to the ball can be calculated from the length of the golf club, the length of the arm from the shoulder socket to the wrist, and the angle between the shaft of the club and the straight lead arm using the law of cosines expressed through the equation $\mathbf{x^2 = y^2 + z^2 - 2yz\cos X}$, where **x** is distance from the rotation centre to the ball, **y** and **z** are the lengths of the arm and club respectively, and **X** is the angle between the arm and the club.
- Club speed will be at least the distance travelled divided by the time required for the movement.

The Physics of Hips Rotation

As noted above, there are four ways in which hip rotation can be executed:

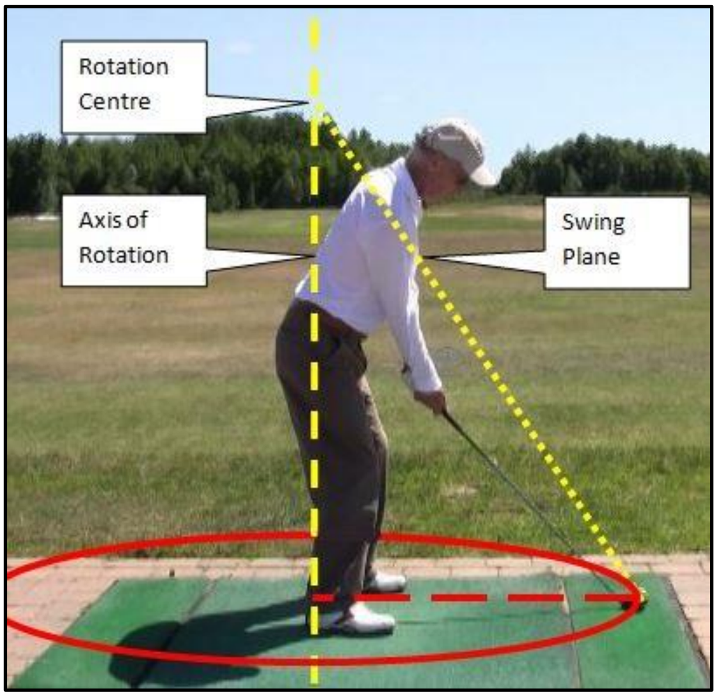
- *Pure Rotation* without spinal tilt.
- *Pure Rotation* with spinal tilt.
- *Push and Clear* without spinal tilt.
- *Push and Clear* with spinal tilt.

Pure Rotation without Spinal Tilt

The picture below illustrates key aspects of the physics of *Pure Rotation*, without tilting the spine.

- The axis of rotation is a vertical line from the ground through the mid-point between the two hip joints. The line is vertical because the hip joints rotate in a circle parallel to the ground. The leg movements do not change the elevation of the hip joints.
- As we saw in Chapter 9, the forward lean causes the shoulder sockets to rotate in a circle around the axis of rotation. The effect of this is to move the rotation centre to a point on the axis of rotation where the projection of the line from the ball through the shoulder sockets meets the axis of rotation.
- To calculate the radius of the rotation circle that the club would follow from this movement, we need to know the angle between the axis of rotation and the swing plane at the rotation centre and the distance from the ground to the rotation centre.
- The angle between the axis of rotation and the swing plane can be measured from a picture with a protractor.

- The distance from the ball to the rotation centre consists of two components: the distance from the ball to the shoulder socket, and the distance from the shoulder socket to the rotation centre.
- As we have seen, the distance from the ball to the shoulder socket can be calculated from the length of the arm, the length of the club, and the angle between the arm and the club.
- To determine the distance from the shoulder socket to the rotation centre, notionally draw a line from the mid-point between the hips and the shoulder sockets to create a triangle defined by the rotation centre, the shoulder socket, and the mid-point between the hips. In this triangle, all the angles can be estimated from a picture using a protractor. In addition, we can use a measuring tape to determine the distance from the mid-point between the hip joints and the mid-point between the shoulder sockets. The distance from the shoulder socket to the rotation centre can be calculated from this information using the sine rule (**x/sin(X) = y/sin(Y) = z/sin(Y)** where the small letters refer to lengths of sides and the capital letters refer to angles opposite the side with the small letter.
- Club speed will be at least the distance travelled divided by the time required for the movement.

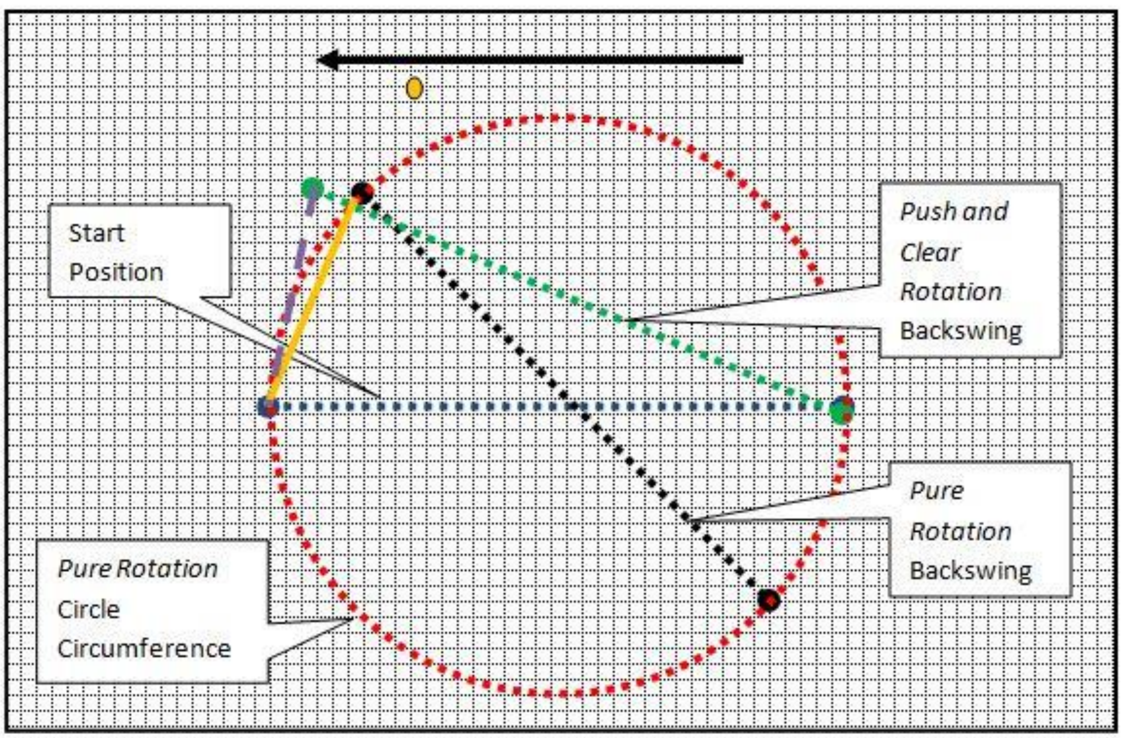


Push and Clear without Spinal Tilt

There are three aspects of *Push and Clear* without spinal tilt.

- Compared with *Pure Rotation*, the amount of rotation is less, because only the lead hip is moving. The trailing hip remains in the same place. We need to determine how much less.

- The picture below illustrates how a *Pure Rotation* hip movement would translate into a *Push and Clear* hip movement. The blue dotted line represents the initial start position for both *Push and Clear* and *Pure Rotation*. The blue end dots represent the hip joints. The black line and end dots reflect the *Pure Rotation* hip movement, with the trailing and leading hips moving around a circle circumference (red dotted circle). The green line and end dots illustrate the *Push and Clear* hip movement. The trailing hip remains at the initial start position. In *Pure Rotation*, the lead hip moves toward the ball and away from the target. In the picture below, the solid yellow line depicts the amount of linear movement of the lead hip in *Pure Rotation.* We assume the lead hip in *Push and Clear* has the same linear movement. In other words, the solid yellow and purple dotted lines have the same length. The length of these lines in *Pure Rotation* can be calculated if one knows the distance between the hip joints and the amount of rotation. The calculation is the sine of half the angle of rotation times the half the distance between the hip joints times 2. Assuming the length of this line in *Pure Rotation* is equal to the length of purple line, the amount of rotation in *Push and Clear* can be determined. The lengths of the black, blue and green lines are equal, as these lines represent the distance between the hip joints. The amount of rotation is 2 times the angle whose sine is half the length of the yellow line divided by the distance between the hip joints.



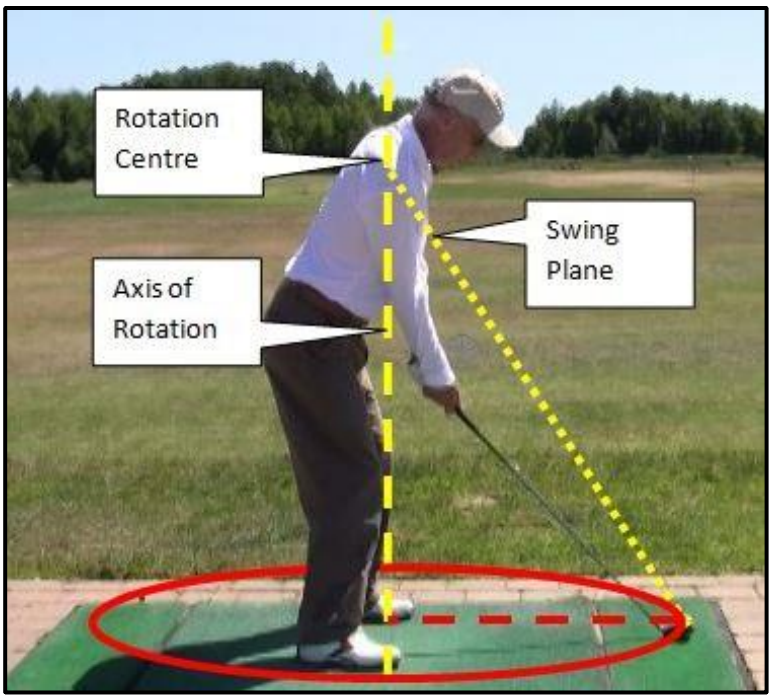
- The physics principles underlying the basic rotation in *Push and Clear* will be exactly as described for *Pure Rotation*, except that the amount of rotation will be less.

- There is intrinsic lateral movement in *Push and Clear* in the absence of spinal tilt. It arises because the centre point between the two hip joints must move forward toward the target as a result of the *Push* and the *Clear*. This intrinsic lateral movement will move the shoulder centre, arms and ultimately the club head toward the ball, generating a distance effect that will be the amount of lateral movement divided by the time required for the movement. The amount of lateral movement can be measured from photographs.
- The total effect on club head speed from *Push and Clear* without spinal tilt will be the sum of the basic rotation effect and the intrinsic lateral movement.

Pure Rotation with Spinal Tilt

The spinal tilt involves lateral side bending. The amount of lateral side bending is generally that amount required to keep the head/eyes/shoulder centre stable in the face of movement away from this stable centre that would come from hip rotation and the forward lean. The physics of *Pure Rotation* with spinal tilt involves (1) calculating the effect on club speed from hip rotation when the "forward lean" effect is neutralized by spinal tilting, (2) calculating the amount of lateral movement being neutralized by the spinal tilt, and (3) determining the effect on club speed from the spinal tilt, given the amount of lateral movement neutralized by the spinal tilt.

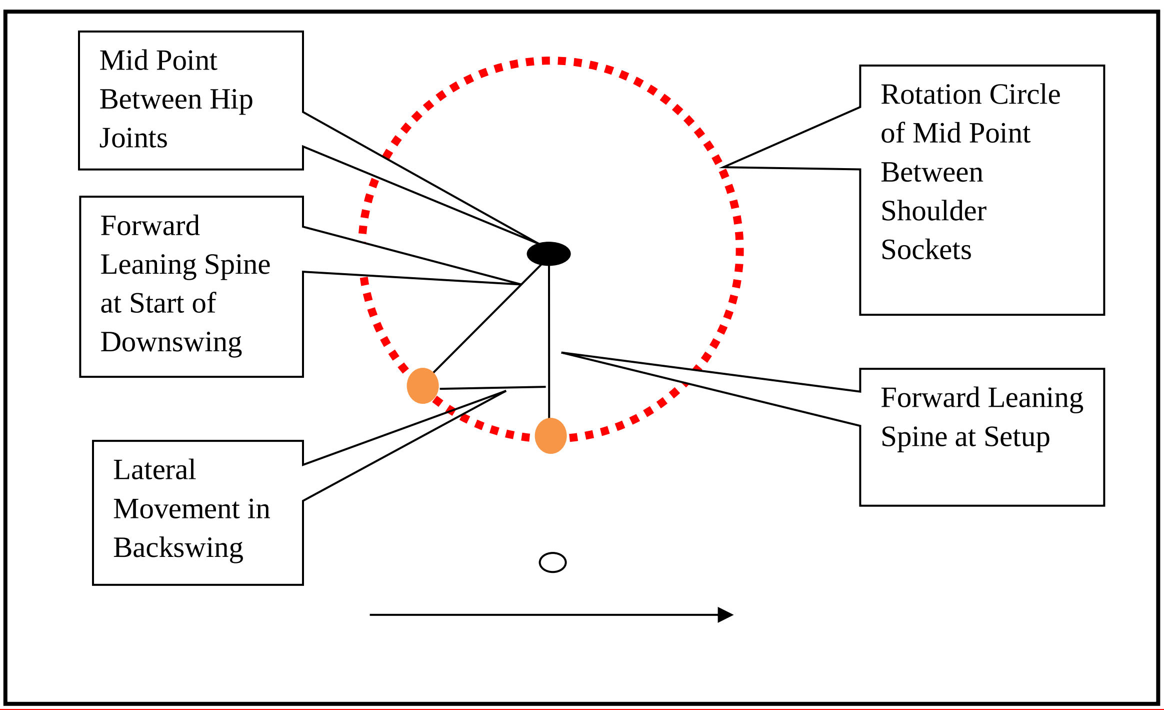
In the discussion of *Pure Rotation* without spinal tilt, the forward lean widens the circle that the club head would follow as a result of the hip rotation. The picture below illustrates the physics of *Pure Rotation* with spinal tilt.



To calculate the club head speed from hip rotation:

- The axis of rotation is a vertical line from the ground through the mid-point between the shoulders. The line is vertical because the hip joints rotate in a circle parallel to the ground. The leg movements do not change the elevation of the hip joints. The line goes through the mid-point between the shoulder sockets, as the rotation of the hips is transferred directly to the shoulder sockets. No allowance is made for the forward lean, because the spinal tilt neutralizes it.
- To calculate the radius of the rotation circle that the club would follow from this movement, we need to know the angle between the axis of rotation and the swing plane at the rotation centre and the distance from the ball to the rotation centre (shoulder socket).
- The angle between the axis of rotation and the swing plane can be measured from a picture with a protractor.
- As we have seen, the distance from the ball to the shoulder socket can be calculated from the length of the arm, the length of the club, and the angle between the arm and the club.
- The distance travelled by the club head will be sine of the angle between the axis of rotation and the swing plane times the distance from the rotation centre to the ball times the amount of rotation in the downswing to impact.
- Club speed will be at least the distance travelled divided by the time required for the movement.

As discussed above, the rotation combined with forward tilt in the absence of spinal tilt causes lateral movement of the shoulder sockets. The diagram looks at the golf swing from the top and illustrates this lateral movement. The red dotted circle is the path that the mid-point in the shoulder socket would trace as a result of hip rotation with forward lean. The diagram shows that there will be lateral movement away from the target in the backswing.



Calculating the amount of lateral movement comes through a two-step process.

The first step involves calculating the radius of the rotation circle for the mid-point between the shoulder sockets. We can calculate the distance from the hip joints to the mid-point between the shoulder sockets through measurement. We can determine the angle between the vertical and the forward leaning spine through a picture and protractor. The radius of the rotation circle is the sine of the spine angle times the distance between the mid-point between the hip joints and the mid-point between the shoulder sockets.

The second step involves the calculation of the lateral movement. From the first step, we can calculate the radius of the rotation circle. We can know the amount of hip rotation by observing individual golf swings. The amount of lateral movement is the sine of the angle representing the hip rotation times the radius of the rotation circle.

The picture below illustrates the physics of the spinal tilt. In essence, the spinal tilt involves two rotation circles with a common centre. One circle is the tilting shoulders circle, while the other is the club head circle.

The amount of rotation in the tilting shoulders circle is also the amount of rotation in the club head circle.

Regarding the tilting shoulders circle:

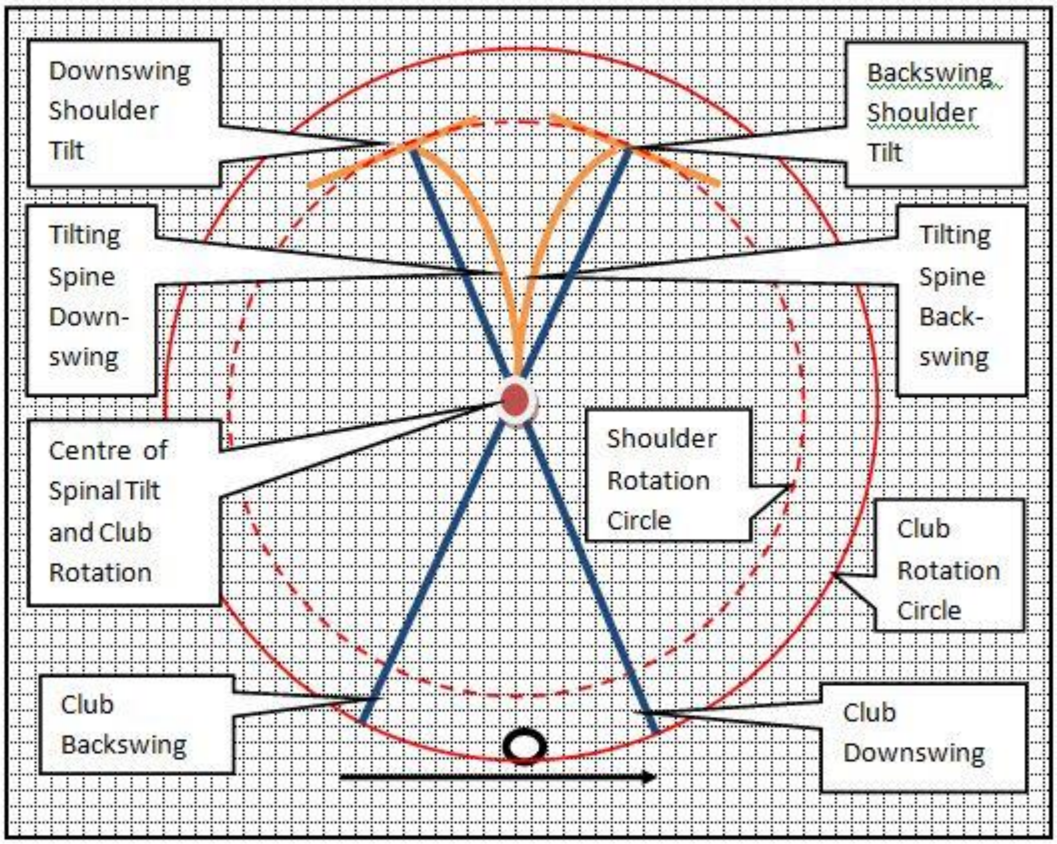
- The centre of the tilting shoulders circle is approximately the base of the spine. The radius of this circle is the distance from the base of the spine to the mid-point between the shoulder sockets. The word "approximately" reflects the fact that spinal column bends toward the top and is not a straight line.
- The mid-point between the shoulder sockets moves a particular distance away from start position in the backswing to counter the lateral movement arising from the forward lean and lateral movement intrinsic to *Push and Clear*. We have developed the calculation for this lateral movement above.
- The amount of rotation in the backswing is the angle whose sine is the lateral distance of shoulder movement from the start position divided by the radius of the tilting shoulders circle.

Regarding the club head circle:

- The amount of rotation in the backswing of the club head circle is the same as the rotation in the tilting shoulders circle.
- As we have seen above, the distance from the ball to the mid-point between the shoulders can be estimated from the length of the arm, the length of the club, and the angle between the club and arm. The radius of the club head circle is the distance from the club head to

the shoulder mid-point less the radius of the "tilting shoulder" circle (e.g. mid-point between shoulder sockets and the base of the spine).

- The downswing movement of the club head from the spinal tilt can be estimated from the radius of the club head circle and the amount of rotation.
- Club speed will be at least the distance travelled divided by the time required for the movement.



Push and Clear **with Spinal tilt**

The physics of the *Push and Clear* with spinal tilt has four elements:

- The club head speed resulting from the effect of the hip rotation taken by itself.
- The lateral movement in the basic rotation as a result of the forward lean.
- The lateral movement intrinsic to *Push and Clear*.
- The club head speed resulting from spinal tilt effect, which is ultimately based on the lateral movement in the basic rotation as a result of the forward lean plus the lateral movement intrinsic to *Push and Clear*.
- Summing the club head speed from the basic hip rotation and from the spinal tilt.

The basic rotation effect is based on the same physics as described under *Pure Rotation* with spinal tilt, except that the amount of rotation will be less because *Pure Rotation* has two hips moving while the *Push and Clear* keeps the trailing hip in a fixed place and includes movement only in the lead hip.

The physics of calculating the amount of rotation resulting from hip rotation in conjunction the forward lean is outlined in the section on *Pure Rotation* with spinal tilt, except the amount of rotation will be less because there is less rotation in *Push and Clear*.

There is a certain amount of lateral movement intrinsic to the *Push and Clear*, and this amount is independent of the forward lean.

Assuming the spinal tilt functions to a large extent to keep the head still in the backswing and downswing while lateral movement is occurring, the amount of spinal tilt in the *Push and Clear* with spinal tilt will be the sum of the lateral movement from the basic rotation and the lateral movement intrinsic to the *Push and Clear* movement.

The physics of calculating the impact of the spinal tilt on club head speed resulting from a given amount of lateral movement will be the same as that described in the section on *Pure Rotation* with spinal tilt.

The Bottom Line

- For each movement in the golf swing, we can calculate a minimum club head speed.

Chapter 12: Modelling the Golf Swing

I feel pain that someone is going to have to read this stuff - Wife

In Chapter 10, we presented the basic rotation equation. We noted that the equation depends on:

- the rotation centre;
- the distance from the rotation centre to the ball;
- the angle between the line from the rotation centre to the ball and the axis of rotation;
- the amount of rotation in the downswing;
- the duration of the movement within the downswing; and
- a factor converting the average downswing speed of the club head from the movement, to speed at impact.

Chapter 10 also looked at the duration of movements in the downswing, and the factor converting the average downswing speed of the club from the movements to speed at impact.

In Chapter 11, we looked at each movement in the golf swing in terms of rotation centre, distance of the rotation centre to the ball, the angle between the line from the rotation centre to the ball and the axis of rotation.

In this chapter, we build on the foregoing to develop a “big picture” model of the golf swing. The model is necessary because the individual movements are to some extent interdependent. Changes in the way some of the movements are performed affect the performance of other movements.

Our model has three components:

1. Parameters. These are the inputs to the model, and are based on the characteristics of the individual golfer, including physical dimensions, flexibility, equipment, swing posture, and duration of movements in the swing. For purposes of our discussion, default values based on the author are provided. Changes in some default values will be explored to determine their impact. The model is designed so that you can insert your own values into a spreadsheet to get a perspective of your swing.
2. Calculated values. These are values determined from parameters and used as inputs into the Club Speed Calculator Table.
3. Club Speed Calculator Table. The table consists of the application of the basic rotation equation, lateral movement and spinal tilt, for each movement in the golf swing.

The parameters used in the model are listed below, with the default values on which the conclusions of the model are based.

1. How many frames per second in your video camera? Default=27
2. How many frames to uncock the wrists in the downswing? Default=4

3. How many frames to roll your forearms and rotate your upper arm in the shoulder socket? Default=4
4. How many frames to move the upper arm in the shoulder socket? Default=6
5. How many frames to move the shoulder sockets around the spine? Default=6
6. How many frames to untwist the spine? Default=11
7. How many frames to rotate the hips? Default=11
8. Acceleration Scaling Up Factor. Default=1
9. What is the length of your club (inches)? Default=45.5
10. What is the length of your arms in inches? Default=24.0
11. How many inches do you move your shoulder sockets around the spine in the downswing? Default=3.0
12. What is the distance in inches between your two shoulder sockets? Default=13.0
13. How many inches do your hips move laterally in the *Push and Clear*? Default=3.0
14. What is the distance in inches between your hip joints? Default=7.0
15. How many degrees do you tilt your spine/upper body forward at the hips relative to the vertical? Default=30
16. How many inches from your shoulders to the base of the spine? Default=17.5
17. How many inches from the base of your spine to the centre between the two hip joints? Default=7.5
18. What is the angle in degrees between the club shaft and the arm? Default=130
19. What is the distance from the ground to the hip joint (inches) when standing erect? Default=32.0
20. How much distance should be subtracted to allow for knee bend, use of tee, etc.? Default=2.5
21. Downswing Rotation of Wrists (degrees) Default=45
22. Downswing Rotation of Forearms (degrees) Default=45
23. Downswing Rotation of Upper Arms in Shoulder Socket (degrees) Default=45
24. Downswing Rotation of Upper Arms Around Shoulder Socket - Basic (degrees) Default=45
25. Downswing Rotation of Spine - Basic - Top to Start (degrees) Default=60
26. Downswing Rotation of Hips – *Pure Rotation* - Basic - Top to Start (degrees) Default=45
27. Downswing Rotation of Spine - Additional - Start to Impact (degrees) Default=5
28. Downswing Rotation of Hips - *Pure Rotation* - Additional - Start to Impact (degrees) Default=10

Key observations about the parameters include:

- Parameters 1 to 7 enable calculations required for the movements in the downswing. They are based on video of the downswing, and the examination the individual frames to determine when particular movements start.
- Parameter 8 is the "Acceleration Scaling Up Factor", which is the amount by which average club speed during the downswing needs to be increased to determine impact speed. The default value of 1 denotes no increase. As such, club speed estimates must be viewed as minimum speeds.
- Parameter 9 deals with club length. The default value approximates the 2015 average men's driver. Note that club lengths have been increasing in recent years.

- Parameters 15 and 18 involve angles determined from measures using pictures of the golf swing.
- Parameters 19 and 20 are taken together. Parameter 19 allows for a physical measurement. Parameter 20 allows for adjustments to that measurement for knee bend, use of tees, etc.
- Parameters 11 and 21 to 28 are based on observations of the joints in the gymnasium. As such, they are maximums. These degrees of rotation may be greater than those that actually occur in the swing.
- Parameters 25 to 28 address the fact that in the downswing, the hips and spine rotate beyond the start position by a few degrees. This is evident from photos that show the hips and shoulders are slightly open to the target line at impact.

From these parameters, a number of additional values needed to calculate club speed can be calculated as follows:

1. How many inches does the centre of the spine move away from the target as a result of the forward lean in *Pure Rotation*? Answer: 8.8 inches
2. What is the angle in degrees between the line from the shoulder socket to the ball and the ground? Answer: 53.5 degrees
3. How many inches does the lead hip move forward in the backswing in *Pure Rotation*? Answer: 2.7 inches
4. How many inches does the centre of the spine move away from the target as a result of the forward lean in *Push and Clear*? Answer: 4.7 inches
5. What is the distance (inches) from the ball to the shoulder centre? Answer: 63.64 inches
6. Downswing Rotation of Shoulder Socket Around Spine – Basic. Answer: 26.7 degrees
7. Downswing Rotation by Hips –*Push and Clear* - Basic (degrees). Answer: 22.1 degrees

The table on the following page summarizes the combined effect of rotation, lateral movement and spinal tilt for each movement in the golf swing.

Club Speed Calculator									
	Basic Rotation						**Lateral Move-ment**	**Spinal Tilt**	**Club Speed at Impact**
	Duration (seconds)	Total Rotation (degrees)	Distance from Rotation Centre to Ball (inches)	Angle Between the Rotation Axis & Line from Rotation Centre to Ball (degrees)	Radius of Circle Followed by the Club (inches)	Basic Rotation Effect (miles per hour)	Lateral Move-ment Effect (miles per hour)	Spinal Tilt Effect (miles per hour)	(miles per hour)
Cocking/Uncocking Wrists	0.15	45.0	45.50	90	45.50	***13.71***	***0***	***0.00***	***13.71***
Forearm Roll	0.15	45.0	45.50	50	34.86	***10.50***	***0***	***0.00***	***10.50***
Rotation Upper Arm in Shoulder Socket	0.15	45.0	45.50	50	34.86	***10.50***	***0***	***0.00***	***10.50***
Moving Upper Arm Around Shoulder Socket	0.22	45.0	63.64	90	63.64	***12.78***	***0***	***0.00***	***12.78***
Moving Shoulder Socket	0.22	31.7	63.64	67	58.37	***8.25***	***0***	***0.00***	***8.25***
Spinal Twist	0.26	65.0	63.64	67	58.37	***14.51***	***0***	***0.00***	***14.51***
Hips									
Pure Rotation Without Spinal Tilt	0.41	55.0	100.03	37	59.52	***7.97***	***0.00***	***0.00***	***7.97***
Push and Clear Without Spinal Tilt	0.41	32.1	100.03	37	59.52	***4.64***	***0.42***	***0.00***	***5.06***
Pure Rotation With Spinal Tilt	0.41	55.0	63.64	37	37.86	***5.07***	***0.00***	***3.29***	***8.35***
Push and Clear With Spinal Tilt	0.41	32.1	63.64	37	37.86	***2.96***	***0.00***	***4.44***	***7.40***
Total									
Pure Rotation Without Spinal Tilt									***78.21***
Push and Clear Without Spinal Tilt									***75.31***
Pure Rotation With Spinal Tilt									***78.60***
Push and Clear With Spinal Tilt									***77.64***

Can the results for the individual movements be added to create a total? To address this, note the rotation circles resulting from the movements in the golf swing. While the circles show some variability, note that what really matters is the instant of impact. All of the rotation circles pass through the ball, and the point when they pass through the ball is the instant of impact. Proper execution of the various movements should ensure maximum consistency among the movements in terms of propelling the ball straight down the fairway (rather than left or right) at the instant of impact. As such, while adding up the club head speeds from the individual movements may overstate the actual club head speed, the overstatement is likely to be minimal. On this basis, we shall continue to use the practice of adding up the speeds of the individual movements to get the overall club head speed.

The Bottom Line

- Through the application of the principles of physics and some basic measurements, we have calculated the minimum club head speed arising from each movement in the golf swing.
- We have added the impact of the individual movements to estimate a minimum club speed from the golf swing, based on given parameters.

Chapter 13: Applying the Golf Swing Model

The poor people just want to play the damn game and get a good score. They don't care about all this stuff. - Wife

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The golf swing model is a tool to help answer some questions.

Hip Joint Movement, the Forward Lean, and the Spinal Tilt

In Chapter 9, we looked at the four options for the hip joint and spinal tilt movements. These options were:

- *Pure Rotation* without spinal tilt;
- *Push and Clear* without spinal tilt;
- *Pure Rotation* with spinal tilt;
- *Push and Clear* with spinal tilt.

The model tells us that given the default values, *Pure Rotation* with spinal tilt is the best, followed by *Pure Rotation* without spinal tilt and *Push and Clear* with spinal tilt. However, the difference between these options is small, in the order of 1 mile per hour from best to third best.

	Basic Rotation					**Lateral Move-ment**	**Spinal Tilt**	**Club Head Speed at Impact)**
	Duration (seconds)	Total Rotation (degrees)	Distance from Rotation Centre to Ball (inches)	Radius of Circle Followed by the Club (inches)	Basic Rotation Effect (miles per hour)	Lateral Move-ment Effect (miles per hour)	Spinal Tilt Effect (miles per hour)	(miles per hour)
Pure Rotation Without Spinal Tilt	0.41	55.0	100.03	59.52	***7.97***	***0.00***	***0.00***	***7.97***
Push and Clear Without Spinal Tilt	0.41	32.1	100.03	59.52	***4.64***	***0.42***	***0.00***	***5.06***
Pure Rotation With Spinal Tilt	0.41	55.0	63.64	37.86	***5.07***	***0.00***	***3.29***	***8.35***
Push and Clear With Spinal Tilt	0.41	32.1	63.64	37.86	***2.96***	***0.00***	***4.44***	***7.40***

Key points to note from the table include:

- There is more rotation with *Pure Rotation* than with *Push and Clear*. In *Push and Clear*, the trailing hip joint does not move, and this limits the rotation of the bone structure.
- There is lateral movement inherent in the *Push and Clear* movement of the hips without spinal tilt. There is no lateral movement in *Pure Rotation* with or without spinal tilt. There is no lateral movement whatsoever with spinal tilt, because the tilting spine neutralizes the lateral movement from the hips by keeping the shoulder sockets in the same place even though the hip joints move forward.
- The forward lean by itself widens the swing arc, as illustrated by the greater distance from the rotation centre to the ball and the greater radius of the rotation circle. The hip rotation with spinal tilt reduces the swing arc and correspondingly the basic rotation effect, but enhances the spinal tilt effect. On balance, the spinal tilt effect outweighs the basic rotation effect.

In comparing the options, here are some further points:

- Feasibility: *Pure Rotation* without spinal tilt may not be feasible for most players. The problem is that the backswing rotation from the forward lean shifts the centre of gravity away from the centre of the stance toward the back foot. With weight on the back foot, it may be difficult, if not impossible, for the ankles to generate the rotation needed for the swing.
- Consistency: Swing consistency comes with practice, and any swing can become consistent with sufficient practice. Greater consistency means more hits in the centre of the club and fewer fat or thin shots. Consistency will normally translate in greater average distance. The golfer's eyes are a tool that can be used to increase consistency, because they can be used to inform the swinger whether the body is in its proper place. The eyes can contribute to consistency more easily when the golfer's head is still. This stillness comes through spinal tilting. Without spinal tilting, the forward lean will cause the head to move with hip rotation. The amount of movement will depend on the amount of hip rotation. We have noted that the amount of hip rotation is greater with *Pure Rotation* than *Push and Clear*.
- Weight Management/Fat Shots: *Pure Rotation* without forward lean keeps the centre of gravity in the same place, essentially over the mid-point in the stance, throughout the swing. When we add the forward lean of the upper body without spinal tilting, the centre of gravity changes during the swing. At the start of the swing, the centre of gravity is toward the toes in the centre of the stance. In the backswing, it moves away from the ball and the target. The greater the rotation, the more the movement. In the downswing, the muscle contractions in the ankles and feet need to not only rotate the hip joints/bone structure, but also bring the centre of gravity to the impact position. Even if *Pure Rotation* without forward lean is feasible, a lot of golfers, particularly beginners, will have trouble with this movement. The result is back foot shots, which are often fat and lack power. *Pure Rotation* with spinal tilting keeps the weight centred, and eliminates the weight management issue. *Push and Clear* with or without spinal tilt addresses the

weight management question by reducing the amount of backswing rotation, and by generating sufficient power in the push movement to get the weight off the back foot.

- Spinal Health: Spinal tilting can lead to back injuries. One solution is to avoid spinal tilting. If one applies spinal tilting, the amount of tilting can be reduced by using *Push and Clear* over *Pure Rotation*.
- Downswing Time: The table above assumes the same downswing time for each of the movements. However, one may be able to execute the *Push and Clear* movement in less time than *Pure Rotation*, not only because there is less rotation, but also because the movement involves more powerful muscles. In the golf swing model, a reduction of downswing time in *Push and Clear* with spinal tilt of 0.046 seconds produces club head speed approximately equal to that of *Pure Rotation* with spinal tilt.
- The Feeling of Power: Some golfers, particularly men, like the athletic feel of powering into the ball with a powerful movement like the *Push and Clear*.
- Rhythm: Many golfers tend to jump at the ball with the powerful *Push and Clear* muscles. For golfers inclined to jump, *Pure Rotation* may produce a more rhythmic, consistent swing.
- Standard Practice: Most current professional use *Push and Clear* with spinal tilt.

Try these options and see what works for you.

For most players, the option most likely to be successful is *Push and Clear* with spinal tilt. This is the option presented in the rest of this document.

Priorities

The table below looks at the individual movements in terms of the club speed as a percent of total club head speed. The numbers are based on the default values. It gives some guidance on how you should be allocating your practice range and exercise time.

	Club Head Speed at Impact	
	Miles Per Hour	Percent Total
Cocking/Uncocking Wrists	13.71	17.66
Forearm Roll	10.50	13.52
Rotation Upper Arm in Shoulder Socket	10.50	13.52
Moving Upper Arm in Shoulder Socket	12.78	16.46
Moving Shoulder Socket	8.25	10.62
Spinal Twist	14.51	18.69
Hips - *Push and Clear* with Spinal Tilt	7.40	9.53
Total	77.65	100.00

Perhaps surprising is the relatively small impact the “hips” have on the total swing. The “hips” are moved by the most powerful muscles in the body, but they have relatively little impact on performance.

To Roll or Not To Roll

Some professionals advise against rolling the forearm and (by implication) rotating the upper lead arm in the shoulder socket. Certainly, not rotating these elements simplifies the golf swing and removes a potential source of error. The ball should go straighter.

However, the forearm roll and rotating the upper arm in the shoulder socket are significant power sources representing, according to the model and its default values, about 27.04 percent of the total swing speed. Most cannot afford to give up these power sources, so the proper execution of these two movements is recommended.

Grip in Fingers or in Palm

In Chapter 3, we noted that if one grips the club in the fingers rather than the palm of the lead hand, the angle between the club and the lower arm is less. We also noted that radial abduction of the wrist also reduces the angle. The smaller angle produces more club speed from the forearm roll and the rotation of the upper arm in the shoulder socket. However, it also reduces the distance from the shoulder sockets to the ball, making other movements less effective. Whether one should strive for a lower angle is a complicated physical question involving a number of aspects of the golf swing.

The table below is based on the club speed calculator and the default values for various angles between the lower arm and the club. It suggests that the smaller the angle between the forearm and the shaft of the club, the greater the club speed. The benefits from the forearm roll and upper arm rotation in the shoulder socket outweigh speed losses in terms of the distance between the shoulder socket of the lead hand and the ball.

Club Speed at Various Angles Between Lower Arm and Club			
	Angle Between Lower Arm and Club		
	120 Degrees (mph)	130 Degrees (mph)	140 Degrees (mph)
Cocking/Uncocking Wrists	13.71	13.71	13.71
Forearm Roll	11.87	10.50	8.81
Rotation Upper Arm in Shoulder Socket	11.87	10.50	8.81
Moving Upper Arm in Shoulder Socket	12.28	12.78	13.20
Moving Shoulder Socket	7.72	8.25	8.67
Spinal Twist	13.57	14.51	15.24
Hips – *Push and Clear* with Spinal Tilt	6.81	7.40	7.86
Total	77.83	77.65	76.30

TIMING

In the golf swing model, the downswing movements did not all start at once. The hips started first, followed by the spinal twist, then the shoulder sockets and upper arms in the shoulder sockets, and finally the rotation of the upper arm in the shoulder socket, the forearm roll, and the wrists.

The model dealt with timing by examining the individual frames in a video of the downswing. There were eleven frames. With the default values, the hips rotated through eleven frames. The spinal twist occurred in the last seven frames. The shoulder sockets and upper arms rotations covered the last 6 frames. The wrists rotated in the last four frames.

Suppose each movement could be delayed by one frame. The table below summarizes the results when the default times for each movement except the hips are reduced by 1 frame. The result is that delaying the various movements by one frame can increase minimum club head speed by 10.79 miles per hour.

The intuitive thought is to hit the ball further by swinging faster and getting all movements to start sooner, whereas club speed and distance can come by delaying the execution of some movements and then performing them faster.

Sergio Garcia's swing illustrates the effect of delaying the execution of movements. He holds his wrists in a cocked position almost until impact, and then uncocks his wrists at the very last fraction of a second, with powerful results.

	Default Times		Default Times Reduced by One Frame	
	Time Required (seconds)	Club Speed (mph)	Time Required (seconds)	Club Speed (mph)
Cocking/Uncocking Wrists	0.15	13.71	0.11	18.27
Forearm Roll	0.15	10.50	0.11	14.00
Rotation Upper Arm in Shoulder Socket	0.15	10.50	0.11	14.00
Moving Upper Arm in Shoulder Socket	0.22	12.78	0.19	15.34
Moving Shoulder Sockets	0.22	8.25	0.19	9.90
Spinal Twist	0.26	14.51	0.22	16.93
Total		70.25		88.44

SWING SETUP

Swing setup includes ideas such as bending more or less at the knees and leaning forward more or less at set up.

Swing setup affects the efficiency of three movements, specifically the rotation of the shoulder sockets around the spine, the spinal twist, and *Push and Clear* with spinal tilt.

Moving the shoulder sockets and twisting the spine would be most efficient when the line from the ball to the shoulder socket at setup is 90 degrees. As discussed earlier, human anatomy prevents getting to 90 degrees. Measures which can increase the angle toward the optimum of 90 degrees include:

- Leaning forward more. In the golf model, the default value for the forward lean was 30 degrees from the vertical. Note that notable tall players such as Tiger Woods and Adam Scott have a forward lean of around 35 degrees. The shorter Rory Mcillroy has a forward lean of 30 degrees
- Reducing the angle between the line from the shoulder socket to the ball and the ground by:
    - Teeing the ball higher. A typical modern tee is 2.75 inches long. If 0.75 inches goes into the ground, the ball is 2 inches higher, and the angle falls.
    - Bending the knees more. This will bring the shoulders closer to the ground and lower the ankles.
    - Using longer clubs.

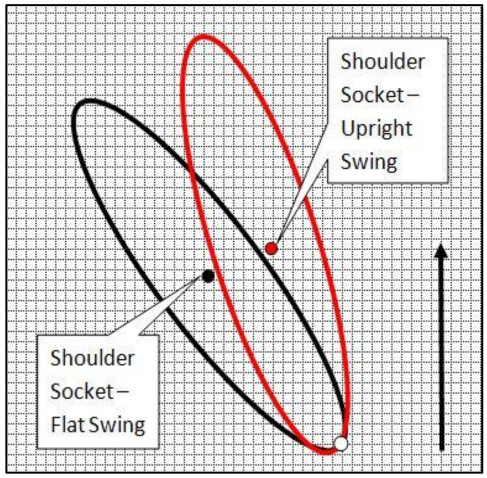
Consider bending the knees. The Club Head Speed Calculator includes a parameter reflecting amount of knee bend plus amount of elevation from using a golf tee. The default value for this parameter is 2.5 inches. Here is what happens when the default value is increased.

- 2.5 inches produces a club head speed of 77.64 miles per hour.
- 3.5 inches increases the club head speed to 77.99 miles per hour;
- 4.5 inches increases the club head speed to 78.32 miles per hour; and
- 5.5 inches increases the club head speed to 78.62 miles per hour.

Consider leaning forward more. The Club Head Speed Calculator assumes a forward lean of 30 degrees from the vertical. Here are the club head speed calculations for greater lean:

- 30 degrees – 77.64 miles per hour;
- 35 degrees – 79.28 miles per hour;
- 40 degrees – 80.58 miles per hour; and
- 45 degrees – 81.51 miles per hour.

Note that when one leans forward more, one is also likely to bend the knees more, to keep the balance. Note too that we previously observed that greater knee bend can improve the execution of the *Push and Clear* movement. The conclusion is that posture issues such as increased forward lean and knee bend can have a noticeable impact on club head speed.



However, increased forward lean and knee bend can affect accuracy. Both will lower shoulder position. Since the distance from the shoulder to the ball is determined by the length of the arm, the length of the club and the angle between the club and the arm, a lower shoulder does not affect its distance from the ball, but it will affect the distance of one's feet from the ball. It will also flatten the swing plane. Regardless of swing plane, there is only one point on the circumference of the circle that will propel the ball forward on the precise target line. With a flatter swing, impact before or after that optimum point will put the ball off line more than with a more upright swing. The diagram illustrates the point.

Driver Length

Should you get a longer driver? The Club Head Speed Calculator's default value is 45.5 inches, which is approximately the average length in mid-2015. Club manufacturers have been moving to longer clubs in recent years.

Increasing the driver length from 45.5 inches to 46.5 inches increases the club speed from 77.64 miles per hour to 79.35 miles per hour. From the golf model, there is a case for a longer driver based on club head speed, provided that you continue to swing the club at the same speed. You also need to take into account hitting accuracy; longer but less accurate drives do not necessarily help your game (but may aid your ego). You also need to take into consideration hitting consistency; what matters is your average driving distance, and averages go up when you hit the ball consistently in the centre of the club.

The Bottom Line

- Take the golf model, fill in your own parameters, and check out the results.
- Experiment with *Pure Rotation* with spinal tilt, *Push and Clear* with and without spinal tilt, to see which works for you.
- Allocate your practice time to work on particular movements according to your faults and the importance of the movement in the golf swing
- Incorporate the forearm roll and rotation of the upper arm in the shoulder socket in your swing.
- Consider adjusting your grip and wrist position to decrease the angle between your arm and club.

- Work on improving your timing by delaying the start of movements as long as possible during your downswing.
- Experiment with your setup, particularly with more forward lean and more knee bend.
- Experiment with a longer driver.

Chapter 14: Applying the Movements in Your Swing

"If to do were as easy as to know what were good to do, chapels had been churches, poor man's cottages prince's palaces."

Edward de Vere a.k.a William Shakespeare

Now you know what to do. Your challenge is to put this together to make is work. Here are some ideas.

Diagnosing Your Swing

If you are an experienced golfer, you may want to take inventory of your swing in terms of each movement. You have a variety of inventory tools, including swing shot results; the feelings and sensations in your muscles and what you see when you are swinging the club; what you can see in a mirror or reflective window; snapshots and videos; and comments from professionals and knowledgeable golfers.

Swing Shot Results

Start with checking your results. Do you hit with power relative to your size and strength? However you hit the ball, are you consistent? If you are inconsistent, is there consistency to your poor shots; for example, does a percentage go in one direction and the rest go in some other direction? Does your ball start out along the intended line of flight? To the left? To the right? At the end of its flight, does it hook? Slice? Do you hit behind the ball? Do you hit the ball thin (i.e. half way up the ball)? Do you hit your shots high? Low? With power or without?

The results can provide information on the club path (straight, inside the target line to outside the target line and vice versa), the club face angle relative to the swing path (square leads to straight along the club path, closed leads to draws or hooks, open leads to fades and slices), weight shift (weight too much on back foot leads to fat shots), weight shift (inadequate weight shift often leads to fat shots), and so on.

Swing Feelings

Then, analyze your position at the top of your swing. Go to the top of your backswing and then hold the position. You want to ask yourself a number of questions about that position.

- Have you cocked your wrists properly (dorsi flexion and palmar flexion, rather than ulnar adduction and radial abduction)?
- Have you rolled your forearms?

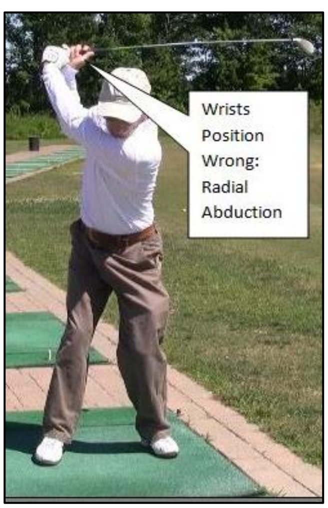
- Is your trailing upper arm pointing down, rather than out?
- Has your lead arm moved across your body and up, but not so far up to be an over-swing? Has your lead upper moved up to your chin (indicating an over-swing)?
- If you have opted for *Push and Clear*:
    - Has your trailing hip joint moved during the backswing?
    - Are your trailing leg and foot in a position to start the downswing with a push?
- Are you twisting your spine? Can you feel the stretch in your abdominal muscles and your back? Are the stretching sensations the same that you felt when sitting on a chair and turning your shoulders?
- Is your head in the start position over the ball? Has it moved backward with your backswing? Is your head moving because you are rotating your spine as a result of the forward lean? If your head is staying over the ball in the start position, are you feeling a stretch of the muscles in your sides – a feeling you would get from the spinal tilt?

Now, analyze your downswing, with or without the ball. Take a number of downswings and in each downswing, think about each individual movement in turn. Is there anything you notice, regarding the various movements and your application of them? Can you feel your lead shoulder socket moving backward during impact, for example?

Then, check your finish position. In particular, do you have your weight totally on your front foot, and are you facing the target?

Videos

Take a video of your swing. Analyze it from various angles. Look for specific movements; are you performing them correctly? You never know what you will find.



The movement inventory should give you some ideas about what you need to work on.

Making Corrections

Practice without the Ball

The best way to build the golf swing is to practice the swing (including each of the specific movements) without a ball to distract you.

First, you want to focus on getting in the right position at the top of the swing by initiating all the movements in some sequence and by holding the position at the end of the backswing. After each movement is executed, pause, and then proceed to the next movement. Once all movements are complete, stop and examine the position you are in. You are striving for a sense of how the swing should feel at the top of the backswing.

Use the stop at the top of the backswing to think about how you are going to implement the downswing. Then, start the downswing by completing all the downswing movements at a sufficiently slow pace that you are conscious of each movement. You may even want to implement each movement individually. Practice this routine over and over again, gradually building up the speed in the downswing.

At the Driving Range

If you want to make major swing changes, the professionals say that 10,000 swings are necessary to ingrain the changes into your swing memory. That's 100 trips to driving range at 100 balls per session. If you take a practice swing before every ball swing, you can cut reduce the trips to 50.

Beyond this, be realistic and patient. Use your practice session to learn more about the game, about your swing, about how to hit the ball. Look at your time as an investment for the future, and a quick preparation for the next game.

On every shot:

- Pay attention to foot alignment. It is a foundation for your swing. Use alignment aids.
    - Put clubs down along your line of flight. Put markers to indicate your takeaway pattern.
    - Take time to line up each shot properly. Place your club behind ball. Line up the club face by looking from the target back to your club face. Try to get the club face perpendicular to the target line. Establish your lead foot position. Put your trailing foot beside it. Look at the target, and while looking at the target, move the trailing foot backwards so that that you feel you have aligned your shoulders parallel to the target line.
    - Check your line up process by placing a club along the line of your toes after you have completed the lineup process. It should aim at the target.

- Pay attention to ball position relative to your feet. Your ball should be placed relative to the low point in your swing. Iron shots should be slightly behind the low point, so you hit the ball before the ground. Tee shots should be slightly ahead to catch the ball on the upswing. Fairway woods should be at the low point. The low point in your swing will be the net result of the low points of the various rotations created by the swing's individual movements. However, the dominant low point will be below your lead shoulder joint, which is the rotation centre for the rotation of your lead arm in its shoulder socket. Once you have found the low point, always position the ball accordingly, to ensure consistency.
- Get your setup right. Setup includes grip, wrist angle, knee bend, and forward lean.

Use your swing inventory. If the inventory of your swing has led you to conclude that you need to work on only one or two movements, focus on those movements. If the inventory has led you to conclude that you need to work on many movements, develop a program over several weeks to work on individual movements in priority sequence. Use the golf model to help you prioritize movements. Keep in mind that some movements are closely related (e.g. forearm roll and rotation of upper arms in shoulder sockets, moving shoulder sockets and spinal twist) and can efficiently be practiced together.

A technique for working on one movement is to practice the movement several times by itself in isolation before stepping up to hit a ball, then within a few seconds (while the muscle memory remains), incorporate the practiced movement into a swing.

Putting all the movements together is challenging physical and mental exercise.

Divide each swing into two components: backswing and downswing.

In the backswing, force yourself to swing sufficiently slowly so that you can see and/or feel what is going on.

Work on isolating the various movements in the backswing by applying them individually, rather than trying to apply all movements simultaneously. By isolating each movement, you can make sure you are getting it right. If you get each movement right, your position at the top should be good.

Sometimes, we are so intent on hitting the ball at the top of the swing that we do not give ourselves time to complete some movements. This is particularly true for cocking and uncocking the wrists, and the forearm roll. To address this, put these items at the start of your backswing. There is no "correct" sequence for the movements in the backswing, so develop your own.

Stop your swing at the top. Feel your muscles. Check things out. When you have the backswing right, you can think about the downswing.

In practicing the downswing, select a movement to think about in each swing. You only have time for one or two swing thoughts in the downswing, so do not burden yourself with too many thoughts. Take the swing at half speed. Since the objective is to develop a downswing in which all movements are functioning together simultaneously, cycle your swing thoughts through all the movements in the downswing within your practice session. For example, on the first swing, think leg action based on the ankles. On the second, think upper back (rotating your spine with the abdominal muscles). On the third, focus on moving the lead shoulder socket backward using the muscles attached to the upper arm and shoulder socket.

As your practice session proceeds, if you feel you are doing the movements correctly, gradually speed up your downswing.

Do not become fixed on the results of each shot. Focus on how well you perform the movements, and what you are learning as you go.

Once you have the swing movements in order, work on getting your revised swing to perform well. In performance terms, you cannot expect to hit every shot perfectly, but you can expect to understand why you have a hit bad shot so you do not hit another one. Developing a notebook table with the headings “bad shot result”, “possible causes”, and “solutions”. When you get into a rut where you are hitting a particular type of bad shot, and you figure out the cause and solution, put all this in your notebook table. Over time, your table will catalog your learning experiences, and have a guide so you can identify bad tendencies when they begin to emerge, and correct them quickly.

On the Course

Golf is a game of continually adjusting your swing in response to your experience. No golfer swings precisely the same way, day in and day out or throughout a round or during a practice session, although some players are better at it than others.

Keep a golf diary, and after each round, note:

- The number of greens (and perhaps fringes, where the greens are small) hit in regulation. This is the number of holes in which the golfer gets on par three holes in one shot, or par four holes in two shots, or par five holes in three shots.

- The number of strokes over “par” tee to green. Tracking greens hit in regulation does not take into account poorly played holes, where, for example it may take three or more shots to get on the green on a par three. One way to take into account these poorly played holes is to count the number of shots required to get on greens, and subtract from this number one for each par three, two for each par four, or three for each par five. If you also track putts per round, you would be able to figure out where you lost strokes on each round. For example, if you shoot 9 over par, you might note that you were three under “par” on the greens (i.e. three under two putting every green, or 33 putts) and twelve over “par” tee to green.

- Count the total number of full swing shots in a round, and the number of full swing shots that you would take over if given the chance, and express the ratio of in terms of “take-over" percentage. These "take-overs" reflect the player's ability. Good golfers would claim "take-overs" that poorer players would find acceptable. Well hit shots that do not get great results, perhaps because the shot was exceptionally difficult in the first place, would probably not be "take-overs". Bad shots that miraculously get good results would probably be "take-overs". The "take-over" percentage is an excellent performance measure for the swing.

- Count the takeovers by type of miss-hit e.g. pulls, pushes, slices, hooks, fat, thin, topped, straight but without distance. Note any patterns. Use the patterns to guide your practice sessions.

Your diary will help you to identify areas in need of improvement and common faults. Review and analyzed it over time; it should become a useful tool for tracking improvement.

For Beginners

One problem with beginners is that they have hit so few golf shots in their lives. As a result, they do not have the "feel" of a golf swing, and consequently do not swing consistently. These beginners often end up in front of golf professionals with the hope that one professional lesson can provide the magic advice that will make every ball go straight and far. If you do not swing more or less consistently, simple advice is unlikely to solve the problem. You have to find the balance between hitting enough golf balls so that you begin to hit the ball consistently on the one hand and learning proper techniques on the other. In many cases, without a background of practice to develop consistency, that simple lesson to improve techniques can confuse and make problems worse.

Beginners need a golf program that begins with an understanding of the swing's movements and how they work individually and together. They need to work on the movements at home without hitting a ball, to hit lots of balls on the driving range, and to get regular feedback from an external source, which could include a series of professional lessons focusing systematically on the movements, or self-videos that are studied in terms of the movements, or regular advice from a knowledgeable player.

The Bottom Line

"How poor are they that have not patience! What wound did ever heal but by degrees?"

Edward de Vere a.k.a. William Shakespeare

Chapter 15: Exercising for the Golf Swing

Exercise programs can speed the recovery from injury, prevent injury in the first place, increase stamina, help to reduce weight, create a more muscular or attractive appearance, improve mental alertness, reduce blood pressure, reduce cholesterol, improve posture and reduce posture-related pain, reduce stress (or at least increase the ability to manage it), create a feeling of well-being (the exercise "high"), and increase the ability to perform specific functions (e.g. swing a golf club). This Guide focuses on the last point.

When you consider the requirements of the golf swing, your downswing swing lasts less than a quarter second. Depending on your ability, you may make anywhere from 35 to 60 full swings, over a period of 3 to 5 hours in a typical game.

As for exercising for the golf swing, several objectives are key:

- Hit the ball further. It makes sense that the stronger and more flexible the player, the greater the potential distance in the golf swing. Several studies have confirmed that general exercise programs can increase strength, flexibility and distance. A golf-specific golf exercise program should do even better.
- Prevent injury and speed recovery from injury. Golf is not a dangerous game, but injuries happen. Repetitive strain injuries can result from a lot of practice and play. Impact injuries can occur when hitting trees or the ground in the downswing. Golf is notorious for back injuries, because the golf swing, particularly the spinal tilt, can stress the back. Golf can cause elbow injuries. Golfer's elbow can be particularly painful and destroy one or more seasons.
- Improve the swing technique. Normally, the golfer's brain focuses on the total swing, and does not isolate on particular muscles within the swing. Exercise can create muscle awareness. Through greater awareness of the muscles that stretch and contract in the swing, the golfer can improve technique. For example, if the wrong muscles are being stretched on the backswing, the golfer can detect and fix the problem. By focusing on a particular muscle, the golfer can make sure it is performing correctly, and increase the speed at which it performs.

In the golf swing, let's look at objectives that are not important.

- Muscle appearance, particularly size.
- Endurance. It might be useful to train the leg and posture muscles for endurance to facilitate walking a golf course, but endurance is not important in any individual golf swing. The swing does not last long enough to fatigue the muscles, and there is usually a significant interval between swings.
- Balance. In action sports like football, hockey, track and field, basketball and soccer, the athlete is constantly moving in relation to the ground. For these sports, training core muscles in the abdomen and the stabilizer muscles in the legs helps the athlete improve balance. Golf is played on a solid platform, with both legs and feet rooted (more or less)

to the ground. Assuming balance is obtained through proper swing techniques, there is limited need to work on balance and stabilizer muscles for golf.

With all this in mind, this chapter looks first at flexibility, and then muscle development, particularly as they apply to the golf swing.

FLEXIBILITY

Flexibility is important in the golf swing for three reasons:

- A good range of movement in key joints (wrists, forearms, shoulders, and torso) is clearly desirable. A muscle contraction in a specific time period applied over a large range of movement is going to produce more club head speed than the same contraction in the same time period over a small range of movement.
- Reduced resistance increases effective strength. Groups of muscles work in opposition to each other. For example, the contraction of the biceps in the front of the upper forearm causes the elbow to flex. The more flexible the triceps in the back of the upper forearm, the less resistance to the contraction of the biceps, and the greater the strength of the contraction.
- Injury risks are reduced.

There are several different types of stretch exercises:

- Ballistic stretching. Ballistic stretching uses the momentum of a moving body or a limb in an attempt to force the joint and related muscles beyond the normal range of movement. Ballistic stretching risks injury, has limited effect on flexibility, and is not recommended.
- Dynamic stretching. This type moves parts of the body to gradually increase reach, speed of movement, or both. Dynamic stretching consists of controlled leg, arm or torso swings that take you (gently) to the limits of your range of movement, without trying to force a part of the body **beyond** its range of movement.
- Static-active stretching. A static-active stretch is one where you assume a position and then hold it there for a period of time with no assistance other than using the strength of the muscles that got you into the stretch. It can be difficult to hold a static-active stretch. Static-active stretching develops the muscles that are used to create the stretch. However, the muscles used to create the stretch may not be sufficiently powerful to fully stretch the target muscles.
- Static-passive stretching. This uses apparatus such as a floor, partner, wall or chair (rather than other muscles) to create and hold the stretch. An example would be a stretch of the hamstring by putting one’s leg on a chair. Stretches are gentle and held for a period of time. The focus is on relaxing the muscles to overcome their resistance (and the related pain) to the stretch so that the target muscle can be fully stretched. This gets a full stretch of the target muscle without risk of injury.
- Isometric stretching. This involves putting a muscle in a relaxed, stretched position, and then contracting the muscle. The contraction puts additional pressure to lengthen the muscle, helps strengthen the muscle being stretched, and may reduce the pain related to stretching.
- Proprioceptive Neuroskeletal Facilitation (PNF) stretching. This is a fancy expression which amounts to a combination of static-passive and isometric stretching. Begin with a static-passive stretch held for 20 to 30 seconds, followed by an isometric contraction of

> the flexed muscle for about 10 seconds, followed in turn by a passive-static stretch. The type of stretching combines the best features of isometric and static-passive stretching. In addition, it appears to numb the pain reaction in a stretched muscle. This pain reaction protects the muscle from injury, but also limits the stretching of the muscle to its fullest (prior to injury).

The foregoing suggests that proprioceptive neuroskeletal facilitation stretching may be the most effective stretch technique for golf.

Since golfer's elbow is a common golf injury, here are two static-passive stretches that all golfers should do. These stretches provide an opportunity to try proprioceptive neuroskeletal facilitation stretch.

Muscle Development

A muscle development program for the golf swing should include two elements: exercises and the way they are performed.

The Way Exercises are Performed

The golf swing requires the rapid contraction of muscles moving a light load. The load is the golf club, and it does not weigh much.

Elements in a muscle cell include:

- myofibrils, which are the cell's contractile elements;
- the mitochondria, which provides the fuel for contraction; and
- the sarcoplasmic reticulum, which is a network of tubules running from the exterior of the cell to the myofibrils and which assist in distributing the nerve impulses that trigger muscle contraction.

The myofibrils include a range of fiber types from white, "fast-twitch" fibers which have a thicker nerve supply, and red, "slow-twitch" fibers which have a greater number of mitochondria and are important for sustained contraction. "Fast-twitch" muscles fire all at the same time, whereas "slow-twitch" muscle motor units are recruited asynchronously, with some resting and others firing. For golf, it is important to develop the white, "fast-twitch" fibers in a few key muscles. The development of "slow-twitch" fibers is relatively unimportant. The development of the nerve system which can trigger the nerve impulses that trigger contractions is critical.

Since the golf swing occurs quickly and does not require a great amount of strength, the key aspect of the training is not the weight to be lifted, but the speed of the contraction. The speed of contraction is to a large extent a mental activity. The brain says "contract". The message is carried to particular muscles, and the muscles cells, particularly the fast twitch fibers, contract simultaneously.

Conventional weight training programs are built around the following elements: amount of weight to be lifted; number of repetitions of the lifts per sets; speed of repetitions within a set; interval between sets; etc. Weight training programs should be designed to reflect the objectives being pursued. Here are some objectives:

- Endurance: Endurance training develops the ability to perform repeated contractions, or to hold a contraction for a period of time. Running a one-hundred meter dash is an example of an activity that requires muscle contractions in the legs for 10 or more seconds. Running a marathon requires contractions over 2 or more hours. Endurance training typically uses lots of repetitions of a particular movement at relatively light loads. The purpose is to stress muscles to build up the mitochondria, which provide the energy in the cell to fuel the contractions in the movement
- Muscle Size: Body building training seeks to develop large muscles. One builds muscles by trying to develop all the components in the cell, with priority given in proportion of the size of the component within the cell. The myofibrils are the largest component of the cell, so an emphasis is placed on contracting the muscles under heavy loads to develop the myofibrils. Exercise movements are performed at slow speeds. Loads are selected as those which cause muscle failure after 6 to 12 repetitions. Typically, loads start at 60% of the maximum one can lift with one contraction and increase to over 80% over a period of a few months. Because the muscles are engaged over a period of 20 to 40 seconds per set of repetitions, there is development of the mitochondria as the contraction in each repetition requires fuel.
- Maximizing Strength: Maximal strength training focuses on the ability to handle a heavy load in a short period of time. The classic example is an Olympic weight lifter, who has to hoist a massive weight just once and the event is over in a few seconds. The focus is on developing the myofibrils, whose contractions provide the power, and the nerve connections which support the rapid synchronized contractions. Training programs for those seeking maximal strength typically involve a few repetitions of the movement. Loads are selected to cause muscle failure after 1 to 5 repetitions. Typically, loads start at 60 percent of the maximum one can lift in one contraction and increase gradually over a period of a few months to 80 percent or more of one's maximum for one contraction. Movements within the set are performed quickly. The interval between sets is relatively long at 4 to 5 minutes to allow the nervous system to recover. Within the movement, force typically starts slowly, builds to a maximum, and declines as the movement ends. The maximum rate of force development over the movement can be tracked to monitor progress. The target is to increase the maximum rate of force development.
- Explosive Strength. Explosive strength training focuses on the ability to handle a light load in a short period of time. Examples include the strength required for high jumping, or sprinting, or pitching a baseball, or shooting a basketball jump shot. The focus is on developing the myofibrils and the nerve connections, with the emphasis more on the latter than the former. Training programs focus on moving light loads with maximum acceleration. Loads are selected to cause a decline in "speed of the movement" within 1 to 5 repetitions. Note that for maximum strength training and body building, load

selection is based on the inability to lift the load, not the decline in speed of the movement. The interval between sets is relatively long, at 4 to 5 minutes, to allow recovery of the nervous system. Within the movement, the focus is on a high initial rate of force development (i.e. a high rate of force development at a fixed point after the start of the movement).

It is conceptually logical to extend the conventional training options by adding a new category – explosiveness only. This option would apply to situations where one wants to perform a movement quickly and there is no or minimal load.

The table below outlines conventional weight training programs and by extension, how they might be applied in an "explosiveness only" option.

	Performance Options				
	Endurance	**Body building**	**Maximal Strength**	**Explosive Strength**	**Explosiveness Only**
Repetitions per Set	Target 15 to 20, based on muscle failure	Target 6 to 12, based on muscle failure	Target 1 to 5, based on muscle failure	Target 1 to 5, based on ability to maintain rate of force development	As many as possible, based on ability to maintain rate of force development and good form. No counting.
Load (as % of the one repetition maximum)	Less Than 60%	Greater than 60%	Greater than 60%	Less than 60%	Minimal
Speed of Repetition	Slow	Slow	Fast	Fast	Fast
Interval Between Sets		1 to 2 minutes	4 to 5 minutes	4 to 5 minutes	4 to 5 minutes

Some important points on explosiveness training include:

- Maximal strength, explosive strength and explosiveness only options all include performing movements fast. Fast movements carry risks of injury. Those who choose to perform exercises in this way should take care. Warm up, start performing the movement slowly, build up speed gradually with repetitions, and increase loads only when they can be managed.
- Explosiveness only training is different from other standard types of training in terms of the weights to be lifted, repetitions per set, speed of each repetition, and interval between sets.

- Explosiveness only is the most compatible with many movements in the golf swing. In golf "explosiveness" is much more important than "strength". The goal of at least some movements within the downswing is to move a light load quickly.
- Explosiveness training involves light loads, starting with no weights, increasing the weights gradually over time. It also involves fast movements.
- The set is over when the speed of repetitions starts to slow, or the form deteriorates, or muscle fatigue sets in, or synchronization is lost when two related movements are performed simultaneously.
- Since counting repetitions detracts from concentration on speed of movement, one should not count repetitions. Instead, think of moving fast.
- Mental concentration is part of explosiveness training, as neuron development is part of the objective.
- The incorporation of mental thinking about the performance of fast movement without actually carrying out the movement may be effective in developing neurons.
- For all muscles not used in the golf swing, one's weight training program should be designed according to the objectives of muscle development for those muscles.

Exercises

In the foregoing chapters, the golf swing has been reduced to basic movements. Any exercise program for the golf swing should mimic these movements.

The exercises below typically entail a movement in one direction, and then a reverse movement in the opposite direction. It is important to pause at every direction change for several reasons:

- It is easy to get into a "back and forth" rhythm without concentration on the movement in one direction, then the other. Each exercise consists of two components involving different muscles. These components get lost in a rhythmic "back and forth" execution.
- The pause forces a controlled deceleration leading to a stop. This prevents ballistic stretching, which can occur when the momentum of the body carries the movement beyond its range. The faster the exercise is performed and the more weight being moved, the greater the risk of overstretching and injury.

These exercises mimic the movements in the golf swing. Most movements start at one limit of the range of movement, and then go in the opposite direction to the limit of the range of movement. In the golf swing, the impact point is approximately at the mid-point between the two limits. To the extent that one decides to perform the movement fast, the speed typically must be achieved by the mid-point in the movement. After the mid-point, the speed should decelerate and stop in a controlled way, to prevent injury.

Cocking and Uncocking the Wrists


To perform the exercise, place both elbows on their respective legs. This isolates the movement to the forearms and wrists. Put both palms perpendicular to the ground i.e. facing inward toward each other. Move the wrists to the right, then pause, and then move them to the left in synchronization. At the outset, you may want to try to do the movements in the left and right wrists separately.

Rotating the Forearms at the Elbow


To perform the exercise, place both elbows on their respective legs. This isolates the movement to the forearms and wrists. Rotate both forearms counter-clockwise and clockwise repeatedly. At every change in the direction of rotation, pause. At the outset, you may want to try to do the movements in the left and right forearms separately.

Moving the Upper Arm in the Shoulder Socket


To perform the exercise, hold one arm out in front at an angle relative to your spine that is approximately equal to the angle it would have in your golf swing. Move the upper arm toward the centre of the body to the end of its range of movement, taking care not to move the shoulder socket forward at the same time. This is the "start" position. Once in the start position, move the upper arm away from the centre of the body to the point approximately straight out in front. In the golf swing, this mid-point would be the impact point. The movement from the start position to the impact point is the one that needs to be performed with speed in the swing. Decelerate and stop approximately the same distance from the mid-point as when going from the start position to the mid-point. Then, reverse the movement to get the arm back to the start position. Repeat the movements a number of times. Then, do the same movements with the other arm.

Rotating the Upper Arm in the Shoulder Socket

To perform the exercise, hold both arms out in front at an angle relative to your spine that is approximately equal to the angle in your golf swing. Rotate both upper arms clockwise to the end of their range of movement on a synchronized basis. The right elbow should be pointing down, the left elbow pointing out. Stop, and then rotate both upper arms counter-clockwise to the end of their range of movement. Elbow positions should have reversed. The right elbow should be pointing out, and the left pointing down. Repeat the movements a number of times.

Moving the Shoulder Sockets

To perform the exercise, sit on a chair. Put your right hand on your right shoulder. This ensures that the upper arm and related shoulder muscles are not active in the movement. Move your right shoulder socket forward toward the centre of the body (counter-clockwise) as far as it will go. This is the start position. Then, move the right shoulder socket clockwise to the end of its range of movement and stop. Then, reverse the movement by moving the right shoulder socket counter-clockwise to the start position. Repeat the movement a number of times. Repeat the exercise with the left shoulder socket. After you have mastered the movements in the separate shoulder sockets, do the exercise with both shoulder sockets on a synchronized basis. Note in the pictures that the chest and head do not move. The shoulder sockets are moving independently, and in combination, create rotation around the spine.

Twisting and Untwisting the Spine

To perform the exercise, sit erect on a chair or bench. This will immobilize your butt and legs and isolate focus on the spine. Hold a pole, golf club or similar object with both hands, and place it across your back (not on top of your shoulders). The lower the pole position, the less likely you are to move the shoulder sockets as part of the exercise, and the more able to focus on your spine only. Rotate clockwise to the end of your range of movement, keeping the pole, golf club, etc. horizontal to the ground. Stop. Rotate counter-clockwise to the end of your range of movement. Stop. Repeat the movement in both directions a number of times.

Spinal Tilt (Stretch)

To perform the exercise, sit on a chair. This immobilizes your lower body. Hold a pole, rod, golf club in your hands, and place it across your shoulder blades. Contract the muscles in your right side to tilt the pole so that the lower end is on your right. Go to the end of your range of movement. Note that much of the energy to tilt the spine comes from gravity, as well as the stretch of the muscles along your left side. Stop and hold the stretch for 30 seconds. Contract the stretched muscles in your right side for 10 seconds while continuing to hold the position. Contract the muscles on your left side to tilt the pole so that the lower end is on your left. Go to the end of your range of movement. Hold the stretch for 30 seconds, then while continuing the stretch, contract the stretched muscle for 10 seconds.

Push and Clear

To perform the exercise, stand with your right foot at the edge of an elevated surface such as a step, with the front part of your foot on the surface and the back part of your foot hanging below the surface, so that tendons in your lower leg are stretched. This is the start position. Raise yourself straight up, so you end up standing on your toe. Do not change your knee bend during the exercise, so that the change in elevation results solely from pointing your toe. Repeat the movement a number of times. Repeat the movement using your other foot.

Pure Rotation

To perform the exercise, stand on your right leg with your left leg off the ground. Hang on to a support to help with balance. Using only your right ankle, put your weight on the instep through eversion (turning the sole of your foot outward) and keep your weight on the instep throughout.

Then, rotate your hips clockwise to the end of the range of movement, and then stop and then rotate your hips counter-clockwise to the end of the range of movement. Note what is happening. In essence, the rotation occurs because of a combination of pronation and supination, and plantar flexion and dorsi flexion in the ankle. Repeat this clockwise and counter-clockwise movement a number of times. Then, repeat the movements with your other ankle.

Note that this exercise moves your entire weight above the ankle. Rapid movements at your ankles can create a lot of momentum in your body. This momentum can cause you to over-rotate at your ankles, leading to injury. The injury risk is exacerbated because the foot has a lot of small bones, which injure easily. Because we generally and golfers particularly rely on our feet, it is best to perform exercises at safe speeds to reduce the risk foot problems.

Warming Up

Warming up before a round is a great idea. It prevents injury. It improves your score by eliminating the bad swings and bad shots early in the round. A golf swing with muscles that are not warmed up is usually painful. To reduce the pain in the overstretched muscles, most golfers swing faster than normal by cutting short the backswing. A fast swing can do a number of things to the golf shot, most of which are bad. Studies of the warm-up patterns of golfers indicate that most people do not warm up properly. Avoid being a member of this group.

Warming up before a trip to the driving range is also a great. It prevents injury. It improves your practice by giving you more benefit from the initial balls. In particular, warming up will give you a better tempo for your practice.

All the exercise books suggest that before stretching or contracting muscles, you should warm up the total body with five minutes of brisk activity – a good walk or jog, stair climbing, aerobic workout equipment (e.g. tread mill, elliptical machine, or stationary bike). If you can find a way to warm up your total body at your golf course prior to playing, do it.

Then, carry out the exercises outlined above. Most exercises can be carried out without any extra equipment other than a chair or bench. If time is limited, do one set of each exercise, to ensure all the relevant muscles are warmed up.

Now you are ready for your first swings. There are a number of devices available to help the golfer warm up, including special warm up clubs and weights that can be attached to your clubs. If you have these aids, use them.

Take practice swings, starting with gentle swings and working up to normal swings. Continue until you are totally comfortable.

If you are at the range, start with easy swings using a high iron. Work toward harder swings with lower irons and woods only when your muscles are telling you it is all right to do so.

At this point, you should be ready to either step up to the first tee.

The Bottom Line

- Recognize the importance of stretching, and the paradoxical result that stretching can make your muscle contractions stronger by reducing resistance to them.
- When stretching, apply proprioceptive neuroskeletal facilitation (passive-static stretching combined with isometric stretches)
- Stretch the forearms in particular to prevent golfer's elbow.
- To develop the muscles whose contractions make up the individual movements in the golf swing, perform exercises which mimic the individual movements.
- Recognize that the golf swing requires the movement of a light load quickly a limited number of times per round, typically separated by long intervals.
- When exercising for the golf swing, try to develop explosiveness, rather than maximal strength, explosive strength, endurance, muscle size, etc.
- Consider the possibility that developing speed may be a mental exercise in addition to a physical one.
- Warm up properly.

"Good night, good night! Parting is such sweet sorrow, that I shall say good night till it be morrow."

Edward de Vere a.k.a William Shakespeare