Increasing the Spin Rate of a Baseball Aside from Strength & Conditioning

By Dan Galaz at Galaz Baseball Technologies © 2019

Introduction

As I observe what is said online about the spin rate (SR) of a baseball, the question that comes to mind is, "Do pitching experts know how to increase SR aside from improved strength and conditioning?" MLB teams are acquiring more pitchers with high SR, which also raises the question, "Does this mean that these organizations don't know how to teach their pitchers how to improve SR?" Imagine the advantage an organization would have if they could teach their pitchers to increase SR and velocity! Not to mention improving accuracy.

The Spin Rate of a Baseball and how it Works

Increased spin rate improves pitch effectiveness due to how far a baseball deviates from the actual trajectory of the intended target due to what is called the **Magnus force**. It is also called the Magnus effect and was named after a German engineer, **Heinrich Gustav Magnus**, investigating why cannonballs were veering off-target. In the case of a four-seam fastball, the height the ball ends up above where it would have generally finished at a lower spin rate or a curveball's depth below the envisioned target.

According to **Wikipedia**, the Magnus force is an observable phenomenon associated with a spinning object moving through the air or another fluid, and the deflection only occurs when the object is spinning. The deviation is explained by the difference in pressure of the liquid on opposite sides of the spinning object. Therefore, the Magnus Effect depends on the speed of rotation ω or SR.

The Effects of Spin Rate on the Magnus Force

For simplicity, the four-seam fastball will be the focus on demonstrating the SR of a baseball. To be as thorough as possible, yet not getting too deep into mathematics and keeping it conceptual. An effort will be made to explain the SR of a baseball to be easily understood. In the image below, the baseball displays all the physical effects it is experiencing throughout its flight. The four-seam fastball is illustrated by the direction of flight and the blue arrows depicting the air stream moving in the direction opposing the ball. Color coding the terms help in the description of SP related to the Magnus force.

Where:

$\boldsymbol{F_m}$ – Magnus force gives lift on the ball acting perpendicular (90º) to the rotation axis.

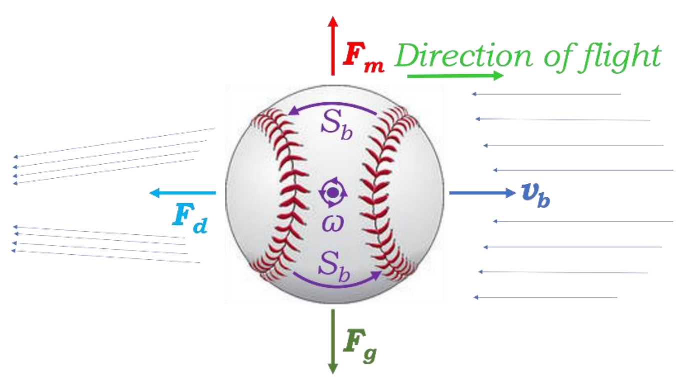
$\boldsymbol{F_g}$ – gravitational force that opposes the Magnus force pulling the ball down.

$\boldsymbol{F_d}$ – drag force that is resisting the ball in the direction of the flight. $F_d = -\frac{1}{2}C_d \rho A \boldsymbol{v}_b^2$

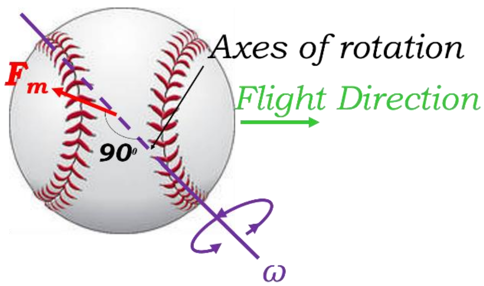
$\boldsymbol{v_b}$ – velocity of the ball toward home plate.

S_b – backspin on the ball at some SR ω.

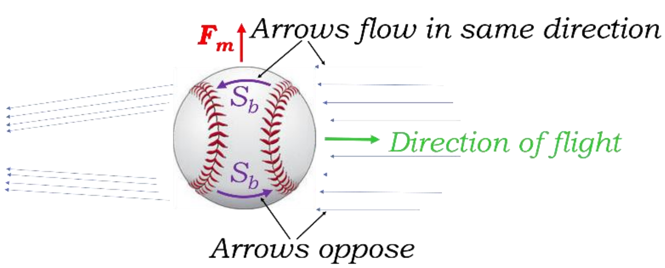
ω – angular velocity of the ball spinning in a counterclockwise called omega.



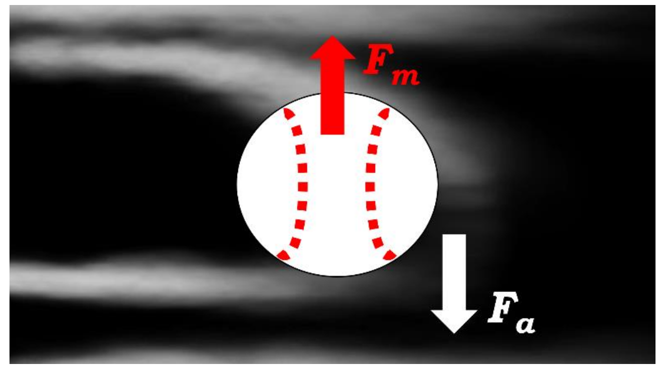
To describe why the four-seam fastball's tendency to rise, interpreting the interaction of the terms labeled on the ball clarifies this fact. The ball moving at a velocity $\boldsymbol{v_b}$ toward the plate encounters two opposing forces; the drag force $\boldsymbol{F_d}$ impedes the motion forward in the opposite direction. The gravitational force $\boldsymbol{F_g}$ pulls the ball downward as it travels toward home plate (HP). From the last image, the backspin of the ball S_b rotating at an angular velocity ω affects the Magnus force magnitude $\boldsymbol{F_m}$, which determines how much lift the ball experiences. The ball actually does not lift, but it has less vertical drop. The higher the value of ω increases the quantity of F_m. Another influence on the Magnus force is if the axis of rotation changes, as shown below. The spin of the ball interacting with the air stream alters the magnitude of the Magnus force in two ways; in size and the direction 90^0 off the new axis of rotation in which the ball moves, illustrated below.



A more straightforward way to explain why the ball has less vertical drop as SR increases is by observing the direction of the backspin and airstream arrows are moving. The top of the ball shows a purple arrow S_b of the backspin, and the airstream flow in the same direction producing a low-pressure system (arrow moving in the same direction creates low pressure). At the bottom of the ball shows a purple arrow S_b of the backspin rotating forward, colliding with the blue arrows of the airstream, causing a high-pressure system there (arrows moving in opposite directions cause high pressure).



The Magnus force on the ball also proves another essential fact concerning Newton's 3rd law. As the ball moves from right to left, the air flows over the top of the ball, the air force F_a is deflected downward around the back of the ball due to friction, pushing the ball down. The air underneath the ball collides with the air coming over the ball, decelerating the air moving under the ball, pushing the ball up with a Magnus force F_m, as shown below.

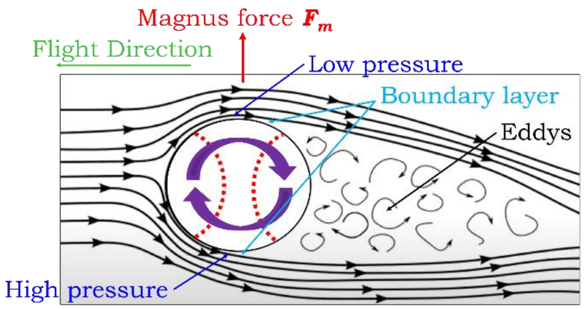


So, the Magnus force is the push upward to abide by Newton's 3rd law, which states; for every action, there is an equal and opposite reaction (**The Magnus effect: a fastball explained**: from fizzics.org).

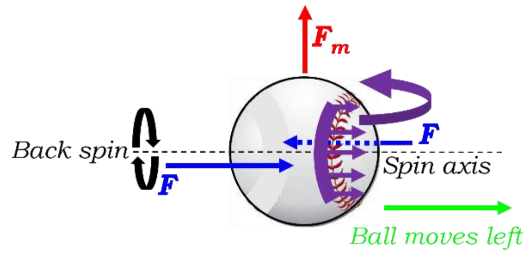
When talking about other pitches in a pitcher's arsenal, the Magnus force usually points in the direction in which the pitch should move. For example, a curveball spins downward; therefore, its movement is downward. Suppose turbulent flow is introduced into the mix; it may make the ball move unpredictably. Although laminar flow is a part of how a ball moves, turbulent flow does some interesting things to make a ball move randomly or move faster.

Laminar Flow vs. Turbulent Flow

The movement of a ball may also be explained by how laminar and turbulent airflow affects its flight. The laminar flow layers are characterized by smooth, even flow moving horizontally with minimal to no mixing of the layers until it collides with the ball, illustrated by the parallel arrows on the front side of the ball in the following image. Turbulent flow is chaotic or random due to the increase in the fluid velocity, in this case, air. The chaotic movement of turbulent flow creates swirly regions called Eddys that break off the laminar flow and become turbulent, represented by the curly swirls in back to the ball, in the following image.



The air that flows around the top and bottom of the ball is a thin layer of nonmoving air called the boundary layer. On an important note, the stitches of the baseball increase the boundary layer. The significance of the boundary layer is that it pushes air over the top of the ball in the same direction as the airflow from left to right, causing a low-pressure gradient. At the bottom of the ball, the boundary layer pushes air against the airflow moving from left to right, causing a high-pressure gradient. High pressure is what creates a force upward called the Magnus force F_m. In the previous section, **'The Effects of Spin Rate on the Magnus Effect,'** the Magnus force pointed in the direction of the break of the pitch, which is not always the case. Laminar and turbulent flow is the reason why it is not always the case. What is essential to understand, depending on the pitch thrown, these two different flow regimes interact with the ball in a way that also affects the ball's movement. When laminar flow encounters the ball's seams, the air becomes turbulent, causing the air to cling closer to the ball than laminar flow. The following image eliminated the left seam to demonstrate how a ball moves due to turbulent flow. As the air moving into the page collides with the ball at the purple circular band, the air becomes turbulent, forcing the air to stick closer to the ball. As the air clings closer to the ball, increasing the air friction moving around the ball is illustrated by the purple arrows spinning the ball from the front to the back on the left side of the ball.



The reaction of the air is that it clings to the right side of the ball creates a force F spinning the ball from front to back, depicted by the circular purple arrow. There is an equal and opposite force, F making the ball move to the right. Something interesting about the illustration concerning the last image. Although the ball's backspin would keep it moving straight or straighter coming out of the page since Magnus force F_m points up because the spin axis is perfectly horizontal, it will still move to the right. Hypothetically speaking, this could be due to the turbulent flow the dominated the Magnus force F_m (**The Magnus effect: a fastball explained**: from fizzics.org)

The **Reynolds number** demonstrates the mathematical explanation for laminar and turbulent flow, and it is dimensionless, named after an Irish mechanical engineer **Osborne Reynolds**. This number predicts if the fluid is laminar or turbulent, written below.

$$Re = \frac{\rho u L}{\mu}$$

Where,

- ρ is the density of the fluid
- u is the velocity of the fluid
- L is the characteristic length dimension (distance of the area cross-section the fluid flows around – baseball diameter)
- μ in the dynamic viscosity of the fluid (moving fluid thickness)

Reynolds number also be written as:

$$Re = \frac{uL}{\nu}$$

ν is the kinematic velocity of the fluid.

$$\nu = \frac{\mu}{\rho}$$

When predicting whether the fluid is laminar or turbulent flow, has to do with whether the inertial forces in the numerator or the viscous forces dominate in the equation below.

$$Re = \frac{Inertial\ Forces}{Viscous\ Forces}$$

If the frictional forces dominate, the fluid is turbulent, and if the viscous forces dominate, the flow is laminar. A visual way to demonstrate this fact is by the size of variables in the equation, as written below.

$$Re = \mathit{uL}/v$$

Since the variable inertial forces are larger than the denominator, the flow is turbulent. As opposed to the variable viscous forces being larger than the variable kinetic forces, the flow is laminar, as shown below.

$$Re = uL/\boldsymbol{v}$$

As it pertains to a pitched fastball, the faster the pitch, the higher the Reynolds number.

This material on Reynolds number was obtained from **The Efficient Engineer 'Understanding Aerodynamic Drag,' YouTube Channel**.

<u>How to increase Spin Rate Aside from Improving Strength and Conditioning</u>

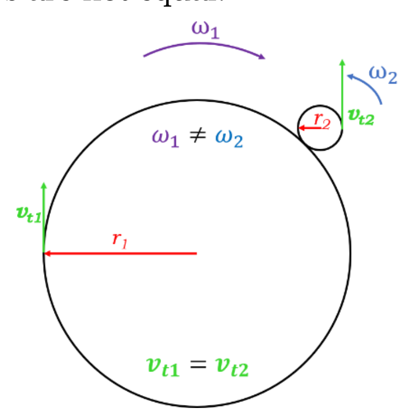
When high spin rate was discovered to be an advantage against hitters, the tactics of how pitchers pitched to hitters changed. Back in the day, all coaches said, "you have to stay down in the zone." Now with 'Rapsodo' and 'Trackman' analysis, coaches now are saying, "work up in the zone if you have a high spin rate and stay down in the zone if you have a low spin rate." Those with a low spin rate are now asking, "how can I increase my spin rate?" What comes to mind on how to increase SP are:

- Increase the contraction speed of the forearm
- Improve the friction between the ball and fingers (make sure your middle & index finger are on the seam(s))
- Work on core strength, stability, & mobility
- Improve pitching mechanics

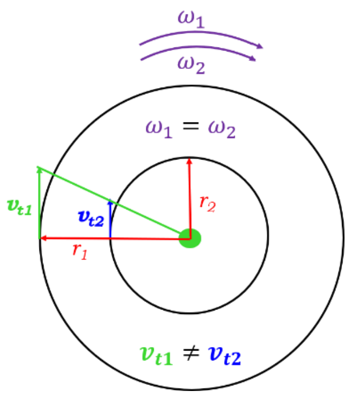
In the previous section, how the Magnus force causes the ball has less tendency to be affected by gravity. In this section, how to increase SR, aside from improving strength and conditioning, is demonstrated.

<u>The Physics of Spin Rate from a Basic Uniform Circular Motion (UCM) & Gear Ratio Theory (GRT)</u>

An understanding of UCM and GRT can give insight into increasing the SP of a baseball. Rotating bodies in contact with one another react so that, as one rotates, the other turns in the opposite direction caused by gears meshed or friction between the two rotating bodies. Also, one of the circles is considered the driver, and the other the driven. In the image below are two circles representing circular rotating bodies in contact with each other. The larger circle is the driver and spins in a clockwise (CW) direction, and the smaller circle is the driven spinning in a counterclockwise (CCW) direction. According to the GRT of connected rigid rotating bodies, when two circular bodies are in contact with one other, the tangential velocities v_{t1} and v_{t2} are said to be equal. However, the angular velocities ω_1 and ω_2 of the two circles are not equal.



If a driveshaft spins both, represented by the green dot imaging going in and out of the page, both ω_1 and ω_2 are equal, and $\boldsymbol{v_{t1}}$ and $\boldsymbol{v_{t2}}$ are not equal, as shown below.



To determine how SR (angular velocity ω) is increased on a baseball, calculating values of ω (omega) while changing the dimension of the larger circle by increasing radius r_1 in the first image above and recalculating brings to light how to increase SR. The result should clarify how the GRT of connected rotating bodies translates to how a pitcher can improve his SP. The only difference is that the force transfer is from the teeth of the larger gear to the smaller, and the motion is only rotational. On the other hand, the force transfers from the pitcher to the ball are rotational and translational to propel the ball to home plate. The relationship between the large and small circles is a theoretical model TM is how SR is produced from the fingertips to the ball. The connection between the pitcher's body from the trunk, arm, fingertips transmit force to the ball, causing velocity, and SR is represented by how the rotation of a larger circle transfers rotation from the larger circle to the smaller circle.

The following calculations demonstrate that leveraging from the hips is more advantageous than leveraging from the shoulder taught by the status quo. The advantages are:

- Increases velocity
- Increases SR of all pitches
- Reduces accelerations & decelerations stresses in the shoulder & elbow
- Allows for higher pitch counts due to the reduction of the shoulder & elbow stresses
- Allow for quicker recovery time from start to start

The lengths similar to an average pitcher's body parts such as the trunk, upper and lower arm, including the hand and fingers, is used in these calculations:

- The average length of the trunk is about 533 mm
- The average length of the upper & lower arm oriented in the throwing position is about 482 mm
- The sum of the trunk and the upper & lower arm hinging at the hips is the radius r_{1h} = 1016 mm
- The average length of the arm alone doing the throwing hinging at the shoulder is the radius r_{1s} = 584 mm

The first calculation is the leveraging from the shoulder, so the radius r_{1s} = 584 mm is the length of the arm hinging at the shoulder. Also, the ω_{2b}, also known as SR of the ball, is given a value of 250 rad/s.

Givens:
ω_{2b} = 250 rad/s is the angular velocity of the ball, r_{1s} = 584 mm is the length of the arm doing the throwing, r_{2b} = 36.4 mm is the radius of the ball, $\boldsymbol{v_{t1s}}$ is the tangential velocity of the arm and is equal to the tangential velocity of the ball $\boldsymbol{v_{t2b}}$ = ? (according to GRT). Find ω_{1s} the angular velocity of the arm.

Equations & calculations:

$$\omega = \frac{v}{r} \;\&\; v = \omega r$$

$$v_{t2b} = \omega_{2b} r_{2b} = 250 \frac{rad}{s} x\ 36.4\ mm = \mathbf{9,100} \frac{\boldsymbol{mm}}{\boldsymbol{s}}$$

$$\boldsymbol{v_{t1s}} = \boldsymbol{v_{t2b}} = \mathbf{9,100} \frac{\boldsymbol{mm}}{\boldsymbol{s}}$$

$$\omega_{1s} = \frac{v_{t1s}}{r_{1s}} = \frac{9,100\frac{mm}{s}}{584\ mm} = 15.58\frac{rad}{s}$$

Now find the angular velocity for the hinging from the hips ω_{1h} for r_{1h} = 1016 mm increased from 584 mm, r_{2b} = 36.4 mm remaining the same, and for simplicity keeping angular velocity of the ball same as in the previous calculation, ω_{2b} = 250 rad/s.

$$v_{t1h} = 250\frac{rad}{s} x\ 36.4\ mm = 9,100\frac{mm}{s}$$

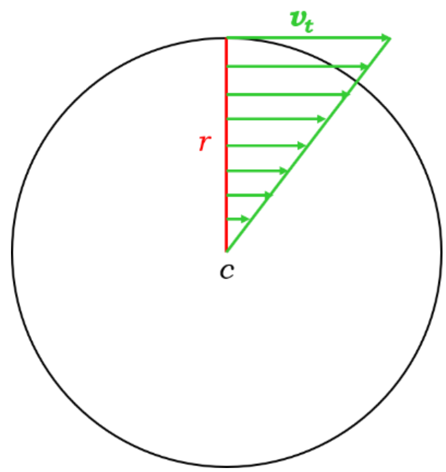
$$v_{t1h} = v_{t2b} = 9,100\frac{mm}{s}$$

$$\omega_{1h} = \frac{v_{t1h}}{r_{1h}} = \frac{9,100\frac{mm}{s}}{1016\ mm} = 8.96\frac{rad}{s}$$

By comparing the angular velocities ω_{1s} and ω_{1h} of the pitcher that hinges at the shoulder and the pitcher that hinges at the hips, one can determine that the pitcher that hinges at the shoulder has to put more effort to generate the same SR of 250 rad/s.

Since pitchers are machine-like, we can determine which pitcher has the higher mechanical advantage (MA). That can easily be ascertained by which pitcher throws the ball with more leverage, which is the one that hinges at the hips since the distance from the hips to the ball is 1016 mm. As opposed to the pitcher that hinges at the shoulder, which is 584 mm.

In the second calculation, as the radius r increases, the angular velocity ω_{1h} or the forward rotating trunk and arm throwing assembly decreases, which means that the effort the pitcher has to exhort is much less to throw a fastball at any speed. Therefore, it should be evident from calculations that a pitcher can increase SR and velocity with less effort and expend less energy. Not to mention less stress on the shoulder and elbow. Also, it should make sense that if the radius increases, so should the SR and velocity of the ball according to UCM, as shown in the following image.

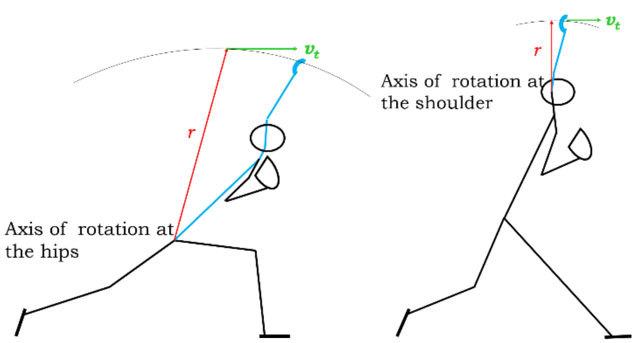


It should go without saying that pitchers should conserve energy throughout their motion, not what they are taught. Pitchers are told that if they want to throw with maximum speed, they must speed up their release by shortening their movements and shortening their stride, which contradicts the laws of physics. Physical law stipulates that if a pitcher wants to throw with maximum speed, they must take longer before delivering the ball. Without going into much detail since this material is about SR, the **impulse-momentum principle** equation written below is algebraically manipulated, solving for velocity $\boldsymbol{v}$ to prove this theory.

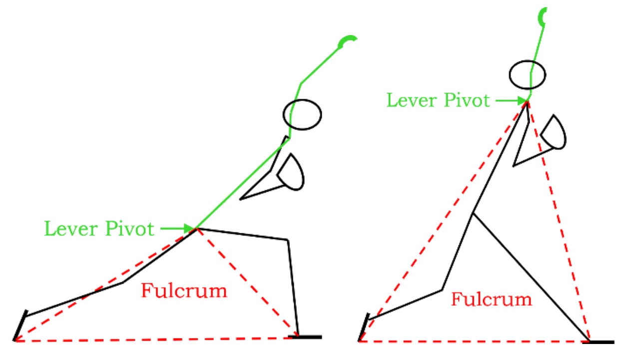
$$\boldsymbol{F}t = m\boldsymbol{v} \Rightarrow \boldsymbol{v} = \frac{\boldsymbol{F}t}{m}$$

Simply plug in values on the right side of the equation, and it speaks for itself. One thing that must be understood is that both force $\boldsymbol{F}$ and velocity $\boldsymbol{v}$ are time t dependent. You notice that when t goes up, the magnitude of $\boldsymbol{F}$ goes down, and $\boldsymbol{v}$ goes up. In other words, a smaller $\boldsymbol{F}$ applied longer produces more $\boldsymbol{v}$ than a bigger $\boldsymbol{F}$ applied in less t. **Therefore, less effort produces more velocity**.

Connecting the results of the calculations above to increasing the SR and velocity of a baseball, the two pitchers below show two types of releases, although both create a catapult effect. The second pitcher's release below is the method most taught in all of baseball.



Intuitively speaking, the first pitcher above would have a higher SR due to the larger radius *r*. So, according to UCM, the longer the radius, the more tangential velocity $\boldsymbol{v_t}$ is generated, as shown in the first image above. Although, the majority of pitching experts are convinced that the first pitcher is unstable at ball release. The reason for this is that if the front knee collapses forward, it will not allow the complete transfer of momentum up the rest of the kinetic chain, which is accurate to an extent. But if the front knee's position remains rigid, the entire transfer of momentum occurs. The second pitcher posted his front leg, limiting forward trunk rotation and reducing the throwing arc radius. Locking out the front leg decelerates the trunk too early, decelerating the arm too soon and reducing the radius. The physics thought process is correct, but the application is wrong. This technique puts a tremendous amount of stress on the shoulder and elbow in both the acceleration and deceleration phases of the pitching motion. Suppose we apply trebuchet theory to the second pitcher, shown in the following series of images. In that case, the fulcrum hinges at the shoulder, which illustrates that most energy is transferred back to the ground from the shoulder, trunk, and extended front leg. The fulcrum in the first pitcher hinges at the hips, where the glove side hip is receiving the bulk of the energy and redirecting it back to the ground by the landing leg side quads, glutes, and the throwing lat side.



As mentioned earlier, finishing with a bent front knee like the first pitcher above cannot transfer energy efficiently if it collapses forward beyond the shoelaces. Still, if the front knee finishes strong and rigid, it takes advantage of the increase in the radius, increasing velocity, and SR.

If we were to apply rigid body mechanics (structural analysis), the shoulder and elbow forces would be extremely high. The pitcher's body has members resembling columns and beams as in a structural building. Structural engineers build design techniques that make sure forces or energy are redirected to the ground efficiently to avoid failure. In a nutshell, a Structural engineer's training in building design is to transfer energy created by wind loads or seismic (earthquake) loads back to the ground efficiently, whether by implementing a damping system or increasing the stiffness or mass of the structure, or both. Loads are transferred back to the ground through the columns, ultimately. The legs are analogous to how the columns receive and redirect energy back to the ground when the back leg pushes off until the front leg lands. Both legs are involved in transferring energy from the ground up the kinetic chain, but the landing leg is left with the most demanding job of redirecting the energy back to the ground. As the back leg drives off the rubber, it produces a force of about 35% of the pitcher's body weight. The landing leg absorbs a shear force of about 72% of the pitcher's body weight (MacWilliams BA, Choi T, Perezous MK, Chao EY, McFarland EG. **Characteristic ground-reaction forces in baseball pitching**. Am J

Sports Med. 1998 Jan-Feb;26(1):66-71). If the landing leg is not stable enough to adequately resist the shear load, it cannot effectively dampen the shoulder and elbow forces, increasing the risk of injury. The first pitcher above, the trunk and throwing arm, move as one lever reducing the shoulder and elbow stresses in the acceleration and deceleration phases. In other words, the arm is along for the ride.

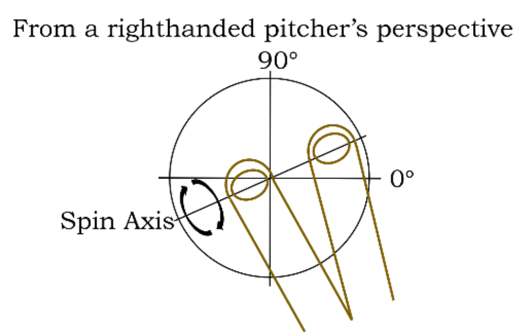
In the two pitching sequences shown below, both pitchers demonstrate stable bent front knees. Their knees do not collapse forward at landing but stay rigid from the landing to the follow-through, not allowing the kneecap to go beyond the landing foot's shoelaces. Also, notice how both pitchers, starting from the 1st to the 3rd image, match in position up to how they hinge at the hips – finishing chest to thigh and armpit over the opposite knee.

Since a pitcher is a structure, energy transfer techniques used by structural engineers should be adopted by those involved in pitching motion analysis. These methods would not only help decode mechanisms of injury but assist in improving accuracy and velocity. It is without question injury detection must be looked at from a different point of view.

Again, this kind of finish takes advantage of the increase in the radius, which produces an increase in velocity and SR, indicating a linear relationship between the three parameters (increasing *r*, increases ***v*** & SR). Not to mention, and more vital, finishing in a fashion shown in the pitch sequences above decreases the risk of injury by allowing the arm more time to slow down, reducing the deceleration stresses in the shoulder and elbow, and improving accuracy due to more forward trunk rotation. Also, which should make sense, with this kind of finish, the fingers stay in contact with the ball longer, assisting in increasing SP.

Improving Spin Efficiency (SE)

Increasing SR is not necessarily the only skill in addition to velocity that must be improved for a pitcher to be successful. To understand pitch design theory, one must understand how SE is enhanced by altering the ball's spin axis. The spin axis, also known as axis tilt or spin direction, is illustrated with index and middle finger orientated as if throwing a four-seam fastball in the image below.



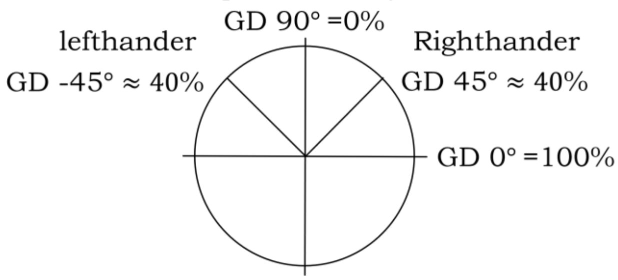
There are different types of spin on the ball that must be considered to improve SE. SE is a metric used to enhance the ball's movement in every pitch in a pitcher's arsenal. There are four types of spins:

- **Total SR** (raw spin)
- **Productive SR (PSR)** (spin responsible for the movement of the ball)
- **Sidespin SS** (spin causing the ball to move laterally)

- **Gyro spin GS** (spin that does not affect the movement of the ball)

The only spins that are used to improve SE are productive SR and GS. To enhance SE, GS must be reduced to affect PSR positively. SE is productive SR/total SR x 100% or cos(**Gyrodegree**) from 0° to 90° and right & left upper quadrants represented on a trigonometric circle, as shown below.

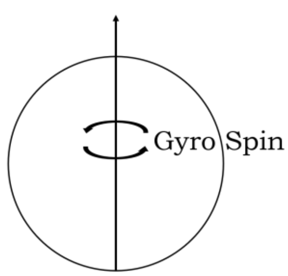
Spin Efficiency



From a righthanded pitcher's perspective

The diagonal lines on either side of the 90° verticle on the trigonometric circle characterize the SE associated with the spin axis angle depicted in the upper left and right quadrants.

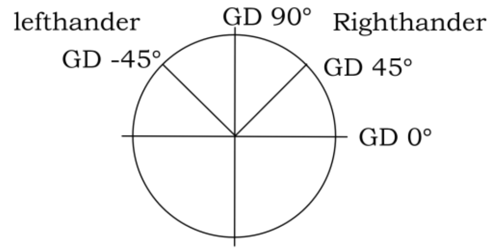
Gyro spin is also known as bullet or rifle spin and is considered unproductive spin, which does not contribute to the ball's movement, as shown below. Gyro spin is that of football spiral.



Top View of a righthanded pitcher of ball traveling to HP

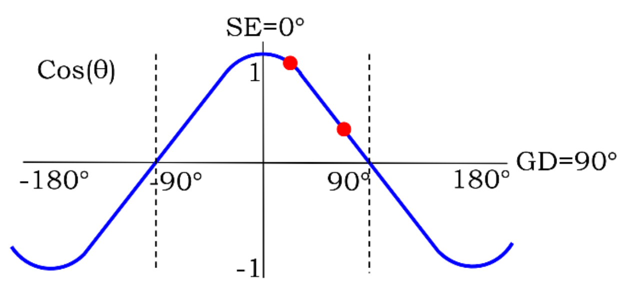
As mentioned earlier, GS must be reduced to enhance PSR, which is accomplished by bringing the spin axis closer to the GD 0° line, as shown below.

Gyro Degree



From a righthanded pitcher's perspective

The GD function is considered to be more significant from a productive movement standpoint than SE. Also, GD and SE seem linearly related since SE at 0° is 100% and SE at 90° is 0%, one would think that at 45° would be 50% SE. On the contrary, the SE at 45° is approximately 40%, as shown in the image for SE on page 7. Taking the slope of the cos(θ) function from 0° and 90° at the red dots, we could ascertain that the change in slope closer to the GD axis nearer to 90° is more significant than if we took the slope closer to the SE axis at 0°, as shown on the cos(θ) graph below. Therefore, altering GD shows significant productive movement on the pitch.

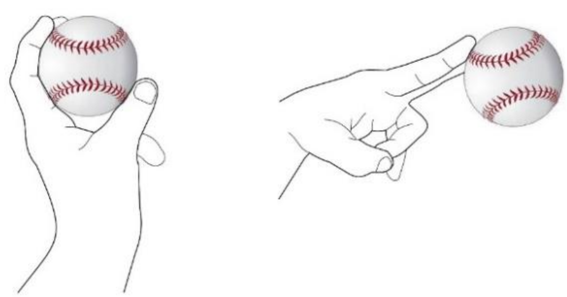


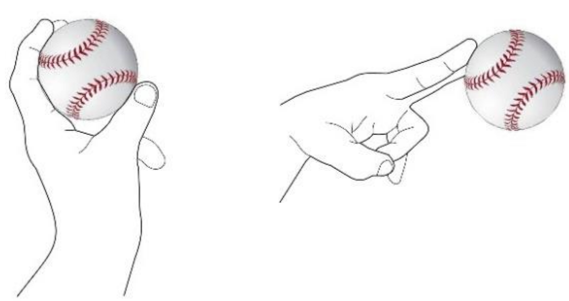
'Improving Spin Efficiency' was obtained from **Simple Sabermetrics from Jake Stone's YouTube Channel**. This very informative YuoTube channel helps simplify sabermetrics, as the title implies.

<u>The Wrist Action</u>

Proper arm action is crucial in pitching and understanding the importance of wrist action to improve SR. The wrist is the last joint in the kinetic chain to activate for ball release, not considered with the trunk and arm in **'The Physics of Spin Rate from a Basic Uniform Circular Motion (UCM) & Gear Ratio Theory**

(GRT)' section for a specific reason. The physics of the two connected bodies did not include an added energy transfer system from the large circle to the smaller, which means if there were, it would have made the SR ω_2 of the smaller circle larger. The reason being, the SR of the smaller circle, is the analog of the SR of the ball. Other aspects for improving SR concerning the wrist would be the grip on the ball, as shown below, thrown by a left-handed pitcher. The first set of two images shows the pitcher gripped the ball so that fingertips are last touching the seams of the ball at release, enhancing the friction between the fingers and the ball. Contrarily, the second set of images, where the fingertips are placed beyond the seams, reduces friction at release.





Another way to increase friction and use by pitchers for a long time is sweat, spit, and rosin. Not many are aware of releasing the ball later in the motion, which means the fingertips would stay in contact with the ball longer, sustaining friction longer.

Can SR be increased aside from improving the strength & conditioning of a pitcher?
The answer is yes. As mentioned earlier, the interpretation of the status quo's physics involved is correct concerning the posting of the front leg, but their application is wrong. Posting the front leg reduces the throwing arc radius, which conflicts with the mechanics of UCM. As illustrated in the image on page 6, the radius r and velocity v_t on the circle show that velocity gets larger as the radius increases from the origin at point c depicted by the red arrows. If we revisit the first stick figure pitchers on page 7, the first pitcher's axis of rotation starts at the hips, and the second begins at the shoulder. It is intuitive to say that the larger the radius, the greater the velocity and SR.

Conclusion
The information on increasing SR, aside from improving strength & conditioning, enclosed in this material also gave insight that helps increase velocity and, most importantly, the assistance for detecting mechanisms of injury.

Another concept covered is how pitchers can increase velocity while exerting less effort, primarily in the shoulder and arm region. In addition, while the pitcher is throwing with less effort, less effort would mean reduced acceleration and deceleration stressed in those regions.

This material also gave awareness that pitchers can throw an entire game without worrying if they have the stamina to complete a game more often than not. Also, the physics in this paper gives the secret to reducing the recovery time of a pitcher to half.