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How a Knuckleball Knuckles

To understand how to pitch to win, you have to understand physics, aerodynamics, and ball rotation. Knowing how to use them to your advantage helps you counter the forces of nature. Like every human who ever lived, you have to respect, plan for, and deal with the pull of gravity, the laws of momentum, and the atmosphere we live in. No matter how great a pitcher you are, you can't overcome the laws of physical nature—but you can toy with them, to the frustration of anyone holding a baseball bat.

Most of what you can do with a baseball involves those marvelous little stitches—their shape, size, orientation, and rotation. If those stitches did not exist, the game would be very different. Most pitchers use the skilled spin of those stitches to do their job; a knuckleballer uses little or no spin to do his. This book explains the magic world that baseball becomes when those stitches don't spin normally.

Have you ever been in a small boat and noticed the little knots of water that swirl in the boat's wake? Air going

around a baseball produces this very same effect, seen best in a wind tunnel. You can find much more information about coefficients of drag, fluid dynamics, and Reynolds numbers. To understand the action of the knuckleball in technical terms, check out the work of some of these noted experts: Dr. Joel Hollenberg, Robert K. Adair, Robert G. Watts and Eric Sawyer, Kai Tang, Adam Kleinbaum, and Dane Shellhouse. As an object moves through the air, air is compressed along all sides of it, especially in front. This produces drag on the object where the air is compressed.

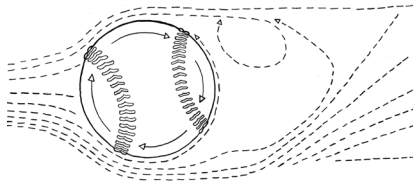
Air doesn't slide along solid surfaces very well, but air easily slides over pockets of air moving in other directions. This is the key to producing the knuckleball effect on a baseball. The seams on a baseball act like the air dam underneath the front of a car. The air dam pushes the air aside and forms swirls (a vortex) of air that move in all kinds of directions around all the car parts behind the air dam. These swirls act like ball bearings, allowing the nearby air stream to flow smoothly past. Without the air dam, the air would drag across all those parts.

The stitches on a baseball push the air flow away from the ball's leather surface just enough to form tiny swirls of air behind them.

Air moving faster across a surface produces lower pressure than air moving more slowly elsewhere on the same surface. An airplane wing works that way: air pushed aside by the curve on top has to move fast to meet up with the air moving along the straight bottom, so pressure is lower on top and the wing has lift. Low pressure draws the

object toward it, so wherever the lowest pressure is on that object from moment to moment, that's where the object will drift to. This is known as the Magnus effect. It does not have much effect on a baseball, but air currents sliding behind the ball—faster and easier in some places than others—can have a strong effect on the wake behind it.

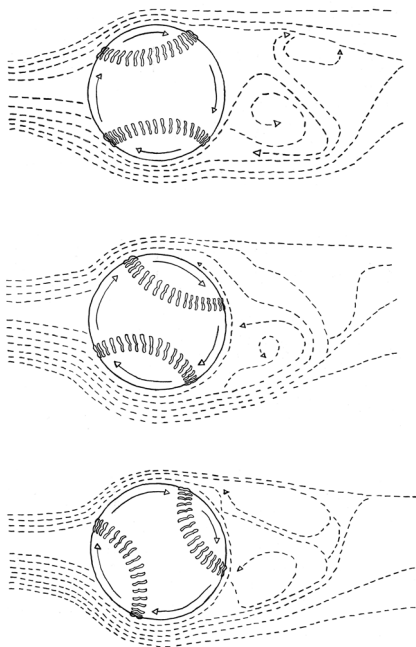
What greatly affects the movement of a baseball is the size, shape, and location of that wake behind it, which causes enough drag to change the path of the ball. When a pitcher throws a fastball, the pitch spins rapidly, allowing this wake to fill and keeping it relatively small. You might think of this effect as using the seams to pump a flow of air toward a particular area behind the ball. There the airflow may develop some lift—as on a four-seam fastball, or slightly less on a two-seamer (which doesn't present as many seams to keep the wake as small), or some drag to one side as with a curve ball. This effect is easily apparent on a rapidly rotating ball, as shown here:



This ball is moving through the air from right to left, and is rotating rapidly forward across the top, in the direction of the plate. It appears that this is pumping air across the top, helping to fill in the wake in a predictable and steady manner. The actual airflow around a spinning ball may not

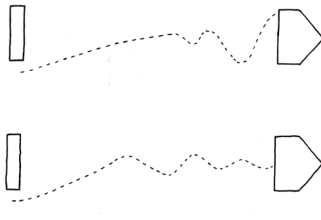
look exactly like this, but it will always keep the same look throughout its path from pitcher to target, and similar rotation with each pitch will produce the same effect.

In the action of the knuckleball, however, some stitches are moving toward the flow of air in front, and others are moving away, *at a slow speed*. The stitches move around the ball in quite a complex curve on a knuckleball, and the ball may rotate at different rates in different ways. This causes the swirls of air to change size and direction, form and disappear, and move location on the ball, thus producing changing locations of low pressure that really can't be predicted. The wake behind a single knuckleball at various points in flight may look like this:



Fast rotation can partially counteract gravity. A hard-thrown fastball rotating front to back counterclockwise over the top produces lift just behind and slightly above the center of the ball, tending to hold it up so that gravity doesn't drop it so quickly. A ball with little if any rotation doesn't generate that lift, and it produces a larger wake, maybe a foot or longer, so it naturally falls away. This explains the drop of a knuckleball (and, similarly, the forkball or split-finger fastball). Also, the sudden growth of the wake acts like a brake, suddenly slowing the ball. If it happens to be moving to one side at the time, the ball may suddenly dive off to that side. It's the rapid change of the shape and size of the wake behind the knuckleball that produces the odd movement.

Picture this: imagine a chihuahua with its tail; that's a fastball. Now, imagine a chihuahua with a German Shepherd's tail; that's a knuckleball. A slowly rotating ball can develop a very large tail, which can wag the dog! That's a knuckleball . . . it gets wagged by its tail. Here are overhead views of the possible flight paths of two knuckleballs.



Phil Niekro is a Hall of Fame pitcher and one of the best knucklers ever. Measurements of Niekro's pitch concluded

that a knuckleball moves the most at around 72 miles per hour. Knuckleballs at about that speed have been measured to move as much as 18 inches off line! Home plate is only 17 inches wide.

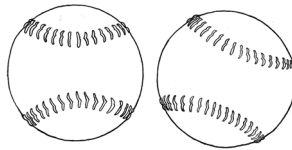
Slower knuckleballs start moving at around 50 miles per hour and usually exhibit just some drop. Very fast knuckleballs almost vibrate before they drop at the last moment, because they don't move much side to side. Faster knuckleballs, since they arrive at the plate quicker, also have less time to move very much, and the fast air stream tends to keep them in line; slower ones, thrown in a tall curving arc, have more time to vibrate, shake, drop and dance side to side, and have less air pressure around them to keep them in a straight line.

Now, there's one influence no one talks about that explains why a nonrotating knuckleball may still swoop all over the place. I call this the Ferris wheel effect.

Ride a Ferris wheel and notice that although you always face forward, the air comes from above as you rise, then it shifts to the front as you reach the top, then from below as you ride down the front.

A knuckleball, thrown slowly in a big arc, "sees" the wind from slightly above the front-center, then directly in front, then slightly below front-center. This movement of the "relative wind" along the front of the ball will naturally produce shifts in where and how those stitch-produced swirls happen, and therefore the size and shape of the ball's wake. It's known that only a small rotation of a knuckleball, as little as 15 degrees, can produce a huge change in this wake. That's why practiced knuckleball

pitchers who can reduce the ball's spin experiment with different orientations of the ball in their hand to produce the ideal action for them personally—maybe with less than predictable results. Some position their fingers to produce a “horseshoe” facing front; others grip the ball where the seams come closest together; and most monkey around with multiple variations. This is easy to show: look at these two baseballs. The difference is a turn of only 15 degrees.



This is what the wind in front of the ball “sees,” so you can understand that one position creates its own movement, and a different position as slight as this produces something entirely different.

There is no ideal rotation distance or speed. The numbers indicate that it takes only a few degrees of rotation difference from ball to ball to produce entirely different action. Knuckleball pitchers have generally arrived at less than a half-turn of the ball on its way to the plate as necessary to get it to do strange things. Add that to differences in pitch speeds, wind direction and speed, humidity, and altitude, and you have a totally unpredictable pitch as well as the near impossibility of producing the same action from pitch to pitch.

A good way to judge what may be good enough low rotation is this: when you throw a knuckleball, can you see the

stitches? If you can, you've probably cut the rotation down enough to produce a good knuckler. It has been demonstrated, though, that if the ball rotates slightly clockwise or counterclockwise, and the stitches are aligned properly from the start, this may produce a spiral shape to the wake behind the ball, producing a ball that actually corkscrews! Hoyt Wilhelm called it his "spinner," it's believed. Also, throwing into a strong wind produces more air speed. The ball may move a *lot* more, compressing its action into a much shorter distance. A real catcher's nightmare! This is why many a knuckleball pitcher likes a little breeze in his face. Seeing the stitches and maybe even the writing on a ball can produce a hypnotic effect on a batter, but to see the ball make several unexpected darts and bumps with a dive at the end, well, sometimes that Louisville Slugger won't be of much use.

Often a knuckleball moves or jumps only a few inches, but that's enough to mess up a batter. Spectators, many feet away and often off to one side, have an impossible time judging any side-to-side movement from that distance and angle. But what counts most is that the batter will have a hard time getting the sweet spot of the bat on this ball. The pitch isn't ending up where he thinks it will, so he has to make unusual adjustments in his swing just to make contact. Even a tiny variation in a smooth swing is enough to cause the hitter to miss the pitch or not make solid contact. This will result in a weak grounder or pop-up.

Atmospheric conditions do have an effect on the knuckleball, but not as most people think. Denser air,

such as you'd get on hot and humid days, will allow the ball to move more. Altitude generally does not affect it as much as air density. Pros like Tim Wakefield like to throw in domes because the air is controlled; to keep them from turning into saunas from the lights and body heat of all those fans, the HVAC systems keep the air circulating in a predictable manner. If the air is predictable, a good knuckleball pitcher can usually adjust to it quickly. Throwing into a hard breeze, besides essentially compressing the movement of the ball, forces the pitcher to pay more attention to guiding the pitch home, as opposed to throwing it. I once threw one into the teeth of a howling wind, right past my nephew, who just stood there and stared in wide-eyed amazement as it *corkscrewed* past him. I accidentally snapped my wrist off to the outside at exactly the right moment at release, which put a light outside rotation on the ball. Other pitchers have thrown these corkscrews, and as soon as we figure out how to throw them consistently, we'll have one killer *easily locatable* knuckleball, predictable to the pitcher but not to the batter. Some pitchers, like Red Sox prospect Charlie Zink, report they can get the ball to sink off to one side or another with a bit of predictability by orienting the stitches particular ways. But until we get so skilled we can throw any kind we want, we'll all have to pitch like Phil Niekro did: just throw it at the catcher's mask and cheer for it on the way in.

As there's a psychological advantage to throwing a hypnotic and mind-numbing pitch, so too is there an advantage to using a grip and seam orientation that you're

comfortable with. Confidence in what you're throwing takes you a long way. Poise on the mound can be obvious, and that can have an additional intimidating effect on opposing batters. And it can make throwing a so-called tough pitch much easier.