Starting Strength

Squat Mechanics: A Clarification

by

Mark Rippetoe

Every seminar we hold is attended by people who have read the book, who have been training with the material for various lengths of time, and who are interested enough in what we have to say that they have paid money to hear it from us directly. Yet every Saturday morning's squat session on the platform involves deprogramming the too-vertical back angle of essentially everybody who attends. Almost *everybody*. Why?

I don't know. I thought I had been clear. If the bar is to descend, it is necessary for the hips and the knees to bend. This can be accomplished in several ways, but as you'll see, the movement of the hips should be the primary emphasis. In order for the hips to be the focus of the squat, the back angle has to facilitate a hips-dominant movement. The load is placed on the hips by lengthening the moment arm on the hips and back and shortening the moment arm on the knee. This reflects the anatomical relationships of the knees, hips, and back, their respective muscle masses and leverages, and allows the most muscle mass to be affected by the movement over the greatest effective range of motion. It turns the squat into a hips-dominant back exercise that carries the legs along for the ride. Everybody who comes to a seminar has read the arguments and knows our analysis.

But somehow, this critical detail is getting misinterpreted, misunderstood, or just ignored. We go through about 5 hours of lecture prior to the practical session that deals with the hip's function and the physics of moment forces, yet enough people still try to front-squat their squats that correcting it takes a significant amount of time on the platform.

Our job is to correct things like this, and we do, I assure you. We've had a lot of practice. And once we get it corrected, you always tell us that it works much better this way. So maybe it's time to clarify, ahead of the seminar, so that my obviously obscure point becomes less obscure.

Use Your Hips. Really.

When you squat, use your hips. This means that you will have to use a more horizontal back angle than the one in the picture in your head. You know that picture of the squat you carry around with you, from watching Olympic lifters front squat or doing their "Olympic" squats that are supposed to be more "athletic." Maybe it came from reading *Muscle and Fitness* or any of the other newsstand exercise publications at the cash register, while you were waiting to pay for your skinless chicken breasts and rice. Or maybe it was taught to you by an expert CrossFit Level I coach, who thinks that a squat finally "matures" when you can lead with your chest with 185. You may even have read that elite powerlifters

squat with a vertical back – some of them do, especially the ones who lift with a sumo stance in a monolift, in the triple-ply suit-and-wraps recreational federations that don't judge depth.

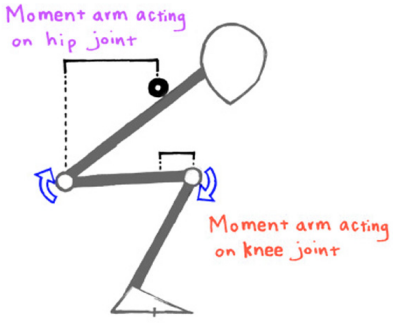
The correct application of the hip-drive model entails assuming the correct back angle and knee position for the bottom of the squat by the time you're about half-way down, and holding it as constant as possible until you get back to that position on the way back up. For most people this will mean that establishing this position requires the knees to travel forward and out to a point *approximately* vertical to the toes (this position in a below-parallel squat will obviously depend on anthropometry), while simultaneously driving the hips back. Our stance places the toes out at 30-35 degrees so that all of the lateral and medial hip musculature that maintains the femurs in external rotation is involved in the movement, so knees must usually be shoved out to keep the thighs parallel to the feet. Knees outside the toes is a common misinterpretation made by exceptionally flexible people. Straight thigh/foot alignment keeps the knees and ankles from any twisting that a misalignment can cause.

At precisely the same time the knees are traveling forward and out, the hips are moving back into their position of loading. They move back because the bar must stay over the mid-foot for balance, and if knees move forward a little, hips must move back more to compensate. "Hip flexion" is the proper term for this movement, and making up new words, like "hinging," is just not necessary.

Your Back Will Be Okay. Really.

I think the problem we see on the platform arises from a misunderstanding about the nature of spinal loading during hip flexion. The Forces of Darkness have done their job well, and they have implanted the notion that you have to stay upright when you squat, with as vertical a back angle as possible. And I'm telling you to wipe this silly bullshit from your mind. Think "rigid," not "vertical" when you squat. A strong isometric contraction of the muscles surrounding your spine keeps your back in Normal Anatomical Position – *flat*, as we say in the business, because a muscular lower back will appear flat across the top of the muscles as they hold a normal lordotic curve in the spine – and a flat back is both an efficient transmitter of force and a safe position to load.

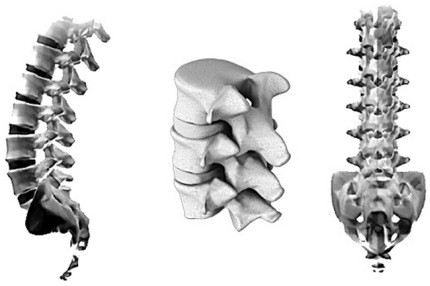
You have been told that a more horizontal back angle exposes the spine to something called "shear," an apparently fatal situation that arises when the back bears weight while positioned at an angle. From previous discussions, you know that *moment* – or leverage, the force transmitted along a wrench that causes a bolt to rotate and the force that the barbell applies to your back during a squat – is a "shear" force, since it is comprised of forces acting in two co-planar directions within the stressed object. In the squat, the moment force on the back is comprised of the force of the weight of the bar pushing vertically (gravity, right?) down on the back, which



is held at an angle, and the force that is applied through the back in the opposite direction to resist the weight and move it through the range of motion.

So it is correct to say that the back is "under shear stress," because moment is a shear force. It's incorrect to say that the back "will shear" – the use of "shear" as a verb that means one segment sliding past another along their shared plane – during a squat, since that cannot and will not happen. It's just as incorrect to say that if you walk outside when it's cold, you will get sick because you were warm, then cold, then warm again: the Temperature Change Theory of Disease.

Amazingly enough, mechanisms exist to prevent your spine from falling apart, due to the fact that it would have been inconvenient during human evolutionary development towards a bipedal posture if the spine had fallen apart every time it was loaded at an angle. You can see how that might have happened occasionally over several million years. Absent the spinal condition known as "Spondylolisthesis," a vertebral deformity where the vertebral body is separated from its posterior structures, the vertebral bodies cannot slide past each other because these posterior structures of each vertebral segment overlap the one underneath.



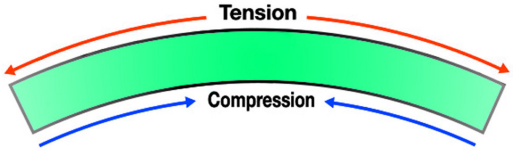
Try as I might, I cannot find a single reference anywhere to a thoracic or lumbar spinal cord/cauda equina injury sustained during ***properly supervised and performed squats and deadlifts*** (note the emphasis). We did find one case of a bad cervical injury that was associated with "weight training" – perhaps looking *up* isn't the greatest idea. But during the entire time I've been teaching people how to lift barbells, since 1978 and not always correctly, I've never heard of such a thing, certainly not from anyone I've coached or taught to coach. People are remarkably diligent when it comes to telling you about spinal cord injuries they sustain as a result of your advice, and I've had no reports.

I'm not saying that spinal cord injury during strength training using the ***correctly-performed squat*** (note again the emphasis) hasn't happened. I'm just saying that *had* it happened, we'd probably already have heard about it. So I'm not quite sure why all these Physical Therapists, personal trainers, and Certified Strength and Conditioning Specialists are so concerned about something that probably hasn't ever occurred, and why they don't seem to understand that your back adapts to the stress of training just like everything else does. Truly puzzling.

Round Is the Real Problem. Really.

In the real world, when the back fails to do its job of efficiently transmitting force in a squat or pull, it fails in *flexion* – it rounds over, out of extension, due to the failure of the posterior erector muscles to maintain sufficient isometric force production during the movement. At the level of the flexing spinal column itself, like a loaded beam, the posterior (top side of the back when you're bent over in a squat) components are placed in tension as they tend to elongate around the convex side of the curve, while the anterior (lower) components are loaded in compression as they mash together on the concave side of the curve.

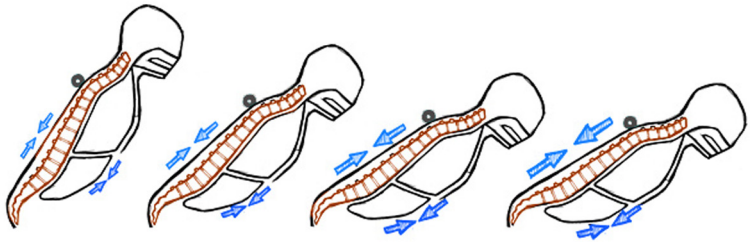
A flexing spine *could* smash the anterior side closed and stretch the posterior side open, producing the possibility of a disc injury. But actually, spinal flexion under load is not so much dangerous as it is inefficient.



After all, you've been picking things up off the floor with a round back for a long time, and you probably haven't been killed. Of course, those things were very light relative to a heavy deadlift. We save permission for rounding the back under the bar for the 3rd attempt at the meet; sometimes a limit attempt will be done with less-than-perfect technique, and competition is the place to assume the risk of doing it "wrong." (Don't tolerate it in training, or your back will never get strong.)

But more importantly, if the back stays rigid, all the force gets from the extending hips and knees to the bar, efficiently. A flexing spine leaks some of the force into the changing geometry, meaning that the knee/hip extension doesn't all get to the bar.

When we lift weights, we fight moment forces with the tools at our disposal. Our tools are the tension-producing contractile mechanism of the muscles and the structural form, rigidity, and hardness of the bones that act as levers in the system. In fact, within the correctly extended spine during a squat or pull, each vertebral segment is held in neutral *compression* along the spinal axis by the isometric contraction of the muscle mass that keeps the spine rigid. The erectors, abs, and all the surrounding musculature squish the column down into a compression load, which increases as the changing angle of the segment increases the moment force. The resulting rigidity of the trunk segment enables the entire structure to function as a solid bar to transmit moment force between the hips and the load. If you keep your back in rigid extension, the back is loaded as a solid segment, not as individual vertebral components.



A tight, flat, rigid back therefore holds all the vertebral components in their normal position relative to each other, and this prevents both injury and loss of force transmission. If the intervertebral discs receive the same force across their inferior and superior articular faces in an anterior/posterior direction, they don't get hurt.

Back and Hips Together

So, when you squat, you're going to use your back. Get used to the idea that the back must be locked – and I mean *locked* tight and flat – into a rigid bar when you squat. If it is, the back angle is not your concern, since the back is okay at an angle if it is rigid. But *the angle of hip flexion must equal the back angle if the spinal relationships are to remain neutral.*

Read that again: here's the conceptual problem you've got to fix. If you're going to flex your hips to use them in the squat, you must also bend over enough to keep your back in its normal anatomical relationship with the pelvis if you're going to use the back as a safe and efficient transmitter of moment force between your hips and the bar.

In other words, your *isometric contraction* around the spine that locks the back rigid and aligns it with the pelvis protects the spine, *not a more vertical back angle*. A vertical back is not a "functional" position for either the hips or the back; you cannot lift anything – a loaded barbell or a bale of hay – in this position and keep it in balance over the mid-foot. Eliminate this flawed thinking, and make up your mind that when you squat you're going to use your back. You're going to keep it flat, make it strong enough to stay flat, and make it do its job as an efficient transmitter of force between hips and barbell.

This means that you're probably going to have to bend over more than you want to. We've found that the cue to "Point your nipples at the floor" works remarkably well. Everybody has them, everybody knows where they are, and everybody knows which direction they're pointing at any given time.

And it's also very interesting that our recommended eye-gaze direction reinforces this position. Looking at the floor directly in front of your feet makes this back angle much easier to obtain and hold throughout the movement. It keeps your cervical spine neutral, and orients the rest of your spine correctly. Looking up at the wall or the ceiling does nothing but fight against the correct back angle. So don't do it. Look *down*, you hard-headed assholes.

There Will Be No Good Mornings

Many people seem to be afraid of goodmorning-ing their squats. Perhaps they have read criticisms of our low-bar method of squatting from young geniuses on the internet who think that only since *SS:BBT* was published have people been using a more horizontal back angle to squat. The most common mischaracterization of the technique is to equate it with the goodmorning, a barbell exercise in which a changing back angle through the range of motion is the loading mechanism.

I shall reiterate: The correct application of the hip-drive model entails assuming the correct back angle and knee position for the bottom of the squat by the time you're *about half-way down*, and holding it *as constant as possible* until you get back to that position on the way back up.

Nearly constant: the initiation of the movement out of the bottom with the hips will look like a very small change in back angle as the hips lead out of the hole. This is actually produced with a very slight knee extension. Hip-bone's connected to the Knee-bone, as it were, and if the hip comes up a little, the knee will have moved back, a little. This slight knee extension is essentially a quadriceps contraction, an obviously important part of the squat, but you think about it *proximally* even as it is a distal action.

Thinking about leading straight up with hips instead of thinking about extending the knees is the important thing going on in the lifter's mind that keeps the motion from turning into a goodmorning, which happens sometimes when the lifter moves hips *back* instead of *up,* and the knees have extended excessively. If the back angle changes to the extent that the bar drifts forward of the mid-foot balance point, or if too much back angle is lost horizontally, it changes the mechanics of the lift. And if it is excessive, it will change what is essentially an isometric hamstring function – that of maintaining the back angle – into an eccentric lengthening, which is what a goodmorning actually is. If your hamstrings get sore when you squat, this is probably what you're doing.

Dem Bones

But thinking about lifting the chest first pulls the knees forward – Chest-bone's connected to the Back-bone, Back-bone's connected to the Hip-bone, Hip-bone's connected to the Knee-bone – and this closes the knee angle. Knee flexion – "loose knees" or "knee slide" – slacks the hamstrings in two different ways. First, knees-forward coming into the bottom with a vertical back angle, like a front squat, slacks the hamstrings quite a bit from both proximal and distal ends. A closed knee and an open hip place the hamstring in the shortest position it can occupy while you're standing on the ground. If the bar is to stay over the mid-foot with the back held more vertical, the knees *must* slide forward more than they have to in a squat done with a more horizontal back angle. In either squat, this knee

placement should take place by the time you're about halfway down, just like the establishment of your back angle. Many lifters make the mistake of allowing the knees to slide forward at the *bottom* of a back squat, and the mental picture of a chest-up position is usually responsible.

Knees forward is required for an Olympic lifter, who is trying to rack a clean on his shoulders with a vertical back as fast as he can get under the bar. It's a submaximal squat anyway, and you don't have to front squat a submaximal weight with much hip, even though all heavy front squats are started with the hips too. Speed is far more important here than anything else, and loose stuff can be moved around faster than tight stuff. The moment arm the hamstrings support in a front squat is very short, because the back is vertical and the bar is therefore close to the hips. But trying to back squat a heavy weight with slacked hamstrings is terribly inefficient. It can be done, but it's not optimal.

Second, lifting the chest in the middle of the movement, on the way back up, slacks the hamstrings *a little*, primarily from the distal end, killing the hamstring tension necessary for operating the longer moment arm on the back and hips. Keeping the knees "tight" and "staying in the hips" keeps the back and hip musculature engaged in the squat. The large muscle mass actively used in this way is why we can squat more weight than we can front squat. The contractile mass of the quads is less than the contractile mass of the posterior chain musculature, and using both quads and posterior chain to their maximum capacity is more efficient than leaving out some of the posterior chain.

Compare these videos (click each image above to follow link).

Moving Knees Leak Power

Both mistakes involve too much knee movement. Moving knees leak hip power. The correct movement is "all" hips. Specifically thinking about holding the knees still at the bottom while "bouncing" off the hips behind you can be a good cue to fix this. Placing the knees where you want them as you set the back angle half-way down, holding them tight, and driving up with the hips can correct both problems. The knees will move a little, but the idea is for them to move just enough, at the right time, by focusing on force production at the hip, facilitated by "frozen knees," or "tight shins," or whatever cue works best for you.

In practice, the coach looks for a very slight hip lead, the lifter thinks about driving the hips straight up, and the system stays nicely in balance as the lifter "stays in the hips" all the way up while maintaining a constant back angle until it's time to stand up straight, when you get back to about half-way up. There is no goodmorning-aspect to this squat if it's done correctly, as fun as it might be to say there is.

The correct squat places the back angle in line with the hip angle for the best use of hip drive during the squat, and places the bar directly over the mid-foot for the most efficient mechanical execution of the movement. A more horizontal back angle uses both quads and posterior chain to their maximum capacity, while a more vertical back angle restricts the potential of the posterior chain muscle mass to contribute to the movement of the weight. Get used to the idea that your chest is

pointed down when your back is horizontal enough, and that your downward eye-gaze direction anchors the movement. It will speed the process on Saturday morning.

T-nation's version of this article appeared 1/15/2015.

Starting Strength : Resources : Articles : Forums : Discuss This Article