Starting Strength

You Must Understand the Gravity of Your Situation.

And the Physics, too.

by

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At the Atlanta Starting Strength Seminar, while watching videos of the clean & jerk and the snatch, we noted that Pyrros Dimas had an unusual pulling style: as the bar passes the knees, Dimas does an exaggerated shrug after having kept his back angle constant to this point. This is unusual because the vast majority of lifters start to make the back angle more vertical before the bar gets to the knees. We didn't have much time to discuss this particular idiosyncrasy, but we did bounce around some tentative ideas as to what this might accomplish. One of the most compelling was the use of the shrug and keeping the shoulders in front of the bar longer, in order to preserve a more horizontal back angle for a longer moment arm to whip through the extension at the top of the pull. And we left it at that.

Forward several weeks, to this discussion which broke out in the Q&A section of the Starting Strength forums, in which we discussed the fact that eventually everyone comes to a deadlift position that is remarkably similar to that taught in *Starting Strength: Basic Barbell Training*, and in the Starting Strength Seminars as well. In that discussion, we were discussing who we considered to have "good form," and why. Steve considered Dimas to have almost perfect form, or about as perfect as one is going to be able to demonstrate when one is trying to get two times bodyweight overhead without mechanical assistance.

In that discussion, we came to the conclusion that Dimas' shrug was in fact an artifice used to keep his back "longer" to a higher point in the pull. One reason that this is important is that the Olympic lifts revolve (literally) around the knees, hips, and shoulders; a longer back will allow for greater acceleration to be applied to the bar as the back whips towards vertical. This is especially important at the point the weight clears the knees and the athlete "jumps." In this position, the bar, which is moving at a relatively low velocity up to this point, must be suddenly accelerated to a velocity high enough that it can be caught on the deltoids. It is imperative, especially at the beginning of the acceleration, that the large, slower, stronger muscles be engaged as much as possible. In the position where the back is closer to horizontal, the posterior chain is ideally suited for this, since they consist of some of the largest, most powerful muscles in the body. So by keeping his back "longer", and whipping the bar upward with a longer lever arm provided by the longer back segment, Dimas can accelerate the bar from a low velocity to a high velocity with greater efficiency. But that's only one reason. There is another, and that reason is the subject of this article.

The Gravity of Your Situation

First, we have to get some terminology out of the way. Velocity is the term that we use to describe the speed *and direction* in which an object is traveling. Acceleration and deceleration are terms we use to describe the rate of change in velocity of an object. For this article we'll use only acceleration, while understanding that deceleration is negative acceleration. In our reference frame, gravity provides the negative acceleration by convention, since up is positive and down is negative. We also have to define some directions: Vertical is obvious – it is the direction in which gravity exerts its force. We will define horizontal as the direction either away from or towards the front of the lifter, perpendicular to the gravity vector. (Lateral motion is used to describe the motion either to the left or right as one faces the lifter. Motion in this direction will not be discussed, since it is intuitively obvious that lateral motion is very bad under all circumstances; therefore, we will not use the term again.)

The first thing to recognize is the conservation of energy – we all remember this as "every action has an equal and opposite reaction." So, when we lift weights off the floor, the most obvious reaction to this is the floor pushing up against us in the vertical axis, against our feet. Actually, we are pushing down against the planet with a force that is equal to the weight of the bar plus a little more, and the planet is so big that it doesn't care. And if the weight we are lifting, when expressed as a downward vector, does not translate through our mid-foot into the floor, we will be out of balance. This vector is the sum total of mass of both the lifter and the weight being lifted, and the middle of the sole of the foot in contact with the floor is the position of greatest stability – the point at which this vector tends to require the least force to react against. When the vector of the center of mass of the lifter/barbell complex moves from over the mid-foot, then the resultant force vector provided back from the ground pushing against our foot moves also. Because there is no motion, the forces must be in balance. This is why we feel like we are "on our toes" or "back on our heels" – that's where the vector from the floor is pressing against our foot, and where our foot is pressing against the floor.

Now, when the weight is light, the vast majority of the mass that affects this vector is the mass of the lifter. This is why you can hold a 5 lb. weight in your hand at arm's length and not fall over on your face. Conversely, and if you were strong enough to do so, if that weight were 500 lbs. instead of 5, you would fall and make embarrassing noises in the gym, as well as bloodstains, which is bad form. The point is that as the weight gets heavier, it becomes a larger percentage of the total mass of the lifter-barbell system. As it does, it becomes more critical for the weight to be over the mid-foot as closely as possible, because otherwise you will have to do one of two things: 1) you will have to counterbalance the weight by extending part of your body away from the mid-foot *in the opposite direction*, or 2) you will have to input a horizontal force on the bar to move the weight back to the balance point, which is hard to do well, and which we will discuss extensively in a minute.

But before we discuss either of those two cases, we have to do some basic physics, or more correctly, kinematics and dynamics.

We can make the bar move two ways – vertically and horizontally. When we impart a vertical or horizontal force into the bar, the force must be "reacted out" – *something* in the lifter/barbell system must react equally and opposite to *any* force we put into the bar, both vertical and horizontal force. In the case of a vertical force, that reaction is against the surface we are standing on through the mid-foot. However, horizontal forces imparted to the bar can only be reacted out using two different mechanisms: 1) the foot/floor interface via friction between the foot and the floor, and 2) the mass of the lifter. Each has inherent issues when it comes to Olympic-style lifting (this would not apply to the deadlift, which is not really a dynamic lift). In the first case, the feet are in solid contact with the floor during the pull until they break ground contact at the jump to start the racking phase, so the planted feet serve as a base from which to apply horizontal force when needed. That horizontal force will be applied along the legs from the ankles up to where the bar happens to be at the time. The higher up the legs, the longer the vertical distance between the ankle and the bar. More critically, the farther the weight gets away from the foot, the more moment at the ankle joint is required to react out a horizontal force. In the second case, any motion imparted into the bar is going to be reacted out by motion of the body in the opposite direction, and that motion will be rotational around the body's center of mass.

Because the feet are in contact with the ground until the full completion of the jump, a wholesale shift in the position of the body will be prevented. Any motion will look like lean back or forward towards the bar – a translation of the body's center of mass forward or back. If the horizontal motion is too great, or the displacement too far from the mid-foot, then the lifter will have to either step forward or back to regain balance. But the farther the bar is from the foot vertically, the harder it is to react out a horizontal bar force at the ankle. This is because the moment arm increases the farther vertically we get from the ankle while the bar weight remains constant, so the moment about the ankle increases. This happens vertically in our discussion because we are talking about a *horizontal force*, applied at a right angle to the gravity force vector. Therefore that moment arm must be measured vertically, as the vertical distance defines the length of the moment arm for a horizontal force.

There are, therefore, two moment arms to consider: the one operating between the barbell and the balance point that is due to the vertical force of gravity, and the one operating along the vertical distance between the floor and the bar due to the horizontal force created by the body's mass reacting against the load on the bar. Eventually the vertical moment will get too large, and the foot will rotate off the floor – towards the heels if the weight is moving back, and onto the toes if the weight is moving forward. This will result in the lifter having to step forward or back if he introduces too much horizontal motion into the bar path. The higher in the lift this occurs, the more the lifter must use the second method discussed above: control of the lifted weight using the body's mass.

Using the body's mass as a counterbalance for moving the lifted weight horizontally becomes more critical as the bar travels further vertically from the lifter's mid-foot. We already discussed why the feet/ankles cannot be used high in the lift – the forces along the vertical moment arm become too great to be expressed against the floor, and the foot rotates off the floor. But to understand the next concept, we have to understand the body's center of mass, and exactly what this means. Every shape, geometric or not, has a center point about which it will rotate in any of the three dimensions. In dynamics, we call this a *centroid*. But since everyone is familiar with "center of mass," we'll continue to use that since it's just another set of words for the same concept. So where is the body's center of mass? We could identify it quite easily if we could get rid of gravity and then spin people around. All we'd need is some time on the space station (finally, a study worthy of our tax dollars!), a video camera, and some airsickness bags. Spin the people and observe, right? Here's the thing: even though we live in the Earth's gravity well, we will still rotate around our center of mass in certain circumstances. It's just hard to see because we fall and hit the ground quickly. So we'll turn to another sport to view this phenomenon. Click this link to watch Mark Clayton make a nice catch. Then watch the hit and the resulting motion of his body. At the time, this was called the "helicopter hit," because Clayton makes a flat spin – rotating in a plane perpendicular to the gravity vector. This is important for two reasons: 1) it eliminates gravity's having a visual effect on the rotation, and 2) it clearly illustrates the concept of center of mass and what it means: Clayton spins around his center of mass. In fact, if you watch the video in it's entirety, you will see several demonstrations of this concept. This is because they do not have time to brace against the hit by using the feet on the ground to react out the rotation.

Back to weightlifting: the concepts of center of mass of the lifter and rotation about that point become more critical as the lifted weight out-masses the lifter. As an example, Pyrros Dimas set the World Record in the 85kg category with a 180.5kg snatch – well more than twice his body's weight. Any horizontal movement in the bar would necessarily result in more than twice as much movement of or about his body's center of mass, which would have to be dealt with. Since that force will produce motion that is expressed as a rotation about his center of mass, this will result in large movements of the upper body the further the mass is above the lifter's center of mass. This means that technical perfection – expressed as a bar path that allows an absolute minimum of horizontal motion – becomes more critical as the mass of the lifter goes down in relation to the mass of the weight being lifted. This is especially critical in the lighter weight classes, because they are lifting proportionally more than the heavier lifters.

So, to react out horizontal forces (or prevent horizontal motion of the bar), the other thing we can do is counterbalance them. In general, at all times the summed vector of the mass of the lifter and the mass of the lifted weight must be expressed vertically through a point that is in the general area of the mid-foot, or horizontal motion of the bar, the lifter, or both will result, and will then have to be dealt with. This is not ideal in the physical world, because any force that we expend to make the weight move horizontally is force that is not making the weight go *up*. "Good technique" means maximizing the efficiency with which force is applied to the bar. And now we can define that as the ability to produce a vertical bar path, because it is the way to lift the bar that requires the least total force expended.

By using less than optimal technique, we may place the body in compromised positions during execution of a lift. Utilizing our body's mass as a counterbalance has limited application, and only at specific points in a lift, making it difficult for accurate use at any time except for the very slow points of a lift, since the positions in which it may be useful will be passed through more quickly as the explosive lifts move further away from the floor. Errors at the start of the lift will become magnified and harder to deal with as the pull progresses. This is because the speed of the bar is changing as the bar gets further from the floor, until reaching maximal velocity at the time the bar passes the hips (when the lifter jumps). From this point on the bar slows down until it lands on the shoulders, having started to fall again. Three phases to the lift have to be considered:

1) Off the floor to the knees, where the ability to impart horizontal motion is high, but the anthropometric configuration of the body does not allow very much (shins are in the way in one direction, you end up on your toes in the other). So the possible range of motion of the bar is rather low in this phase.

2) Knees to hips (jumping phase), where force can be applied to the bar horizontally by using the mass of the body, but because of the acceleration of the bar there is little time to do so, and its potential decreases rapidly. This means that while large forces can be applied horizontally through this phase of the pull, the ability to accurately do so is very limited. This makes any horizontal motion imparted to the bar in the first phase more troublesome to deal with here.

3) Hips to deltoids (the racking phase), where the only real way to move the bar around is momentum transfer between the lifter and the bar. One point to remember here: once the lifter has jumped, and until he is once again weighted on his feet (i.e., he has stopped "falling under the bar" or finished "pulling himself under the bar"), there is no contact and therefore no friction between the foot and the floor, which is why horizontal motion must be taken out of the bar via motion of the body itself.

So why is all this important, and of what use is it?

For example, the current dogma would have the lifter keep the knees forward, the hips low, and the back vertical, with the shoulders even with or behind the bar. The theory is to move the bar around the body. We suggest that it's far easier to teach people to move the body around a barbell as it moves in an efficient, vertical, path. We've already discussed the importance of a vertical bar path, and why a vertical bar path becomes increasingly important the farther the lift gets from the floor. We've discussed the mechanisms that can be used to both induce and react out horizontal motion in the bar. So what important lessons can we take away from all of this?

First, no lifter is perfect, certainly not novices (who we are either actually coaching, or are reading this to learn from it). There is almost always going to be some horizontal motion to the bar – imperfect pulls off the floor, early jumps, excessive bouncing off the thighs, and being pulled back when it is racked. That means that in every lift we have to think about management of the bar horizontally. This does not mean that perfection is not important. Especially in the beginning lifter, it is critical that perfection be a goal, since the lifter does not have the experience or the technical skill to control lifts that have excessive horizontal motion. He's having difficulty enough coordinating the timing of the floor pull followed by a jump. Asking him to rescue a horizontally pulled bar moving at a relatively high velocity compared to a deadlift or a squat is rather much, don't you think? So novice lifters need to worry about as perfectly vertical a bar path as possible, while their coaches can use that same vertical bar path model to analyze where the lifter is inefficient.

Secondly, there is the "Elite" athlete factor. The most critical time for horizontal motion of the bar is at the top of the lift – when it is hardest to deal with. Any motion in the bar at this point will require either strength, experience, and/or technical skill to deal with – the latter two only coming with much practice. The novice lifter may not possess the perceptive sense and the reaction skill necessary to deal with excessive horizontal motion in the bar. While we see world-class lifters deal with horizontal motion in the bar all the time, realize that these people are the result of a very, very Darwinian process that produces athletes who are incredibly strong, very fast, and extremely good at handling the bar. It is quite literally in their genes to be great athletes. They will succeed, even with what we would call major technique flaws, because they are the best in the world. They can lift inefficiently *because* they are the best – not necessarily because the way they do it is the *best way*. Realize that our lifters – the kids we are coaching – most likely will not possess these abilities to the extent exhibited by world champions. And yet they will be attempting lifts that, by definition, are every bit as difficult for them as a PR for Dimas would be for him.

Especially for novices, it is important to remember this critical point: we may not be able to improve their reaction time, or their explosive ability, since these things are the gifts of talent. But we can *and must* increase their strength, and we can do so relatively easily if we understand how. And we have to teach them to use that strength in a way that reduces the chance for errors that require skill or experience beyond their means. Good technique is important, most especially for those lifters for whom strength is not a luxury. And strength should not *be* a luxury.

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