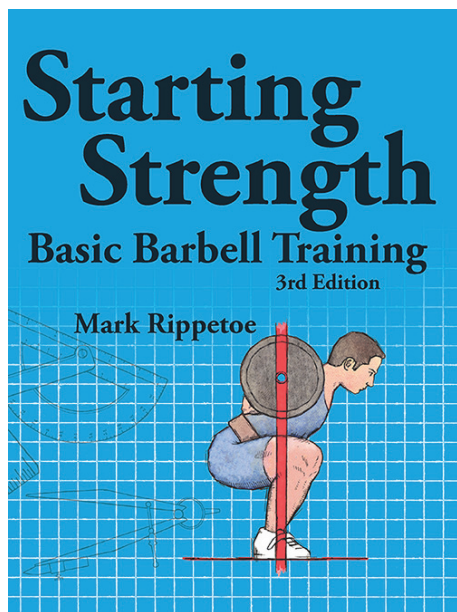


Starting Strength

This is the second part of an excerpt from the Deadlift chapter of Starting Strength: Basic Barbell Training, 3rd Edition, available for sale now directly [through us](#) or [Amazon](#). It deals with the non-vertical arm angle and the biomechanics of the position. This explanation is based on consultations with Dr. Dennis Carter at Stanford University and other mechanical engineers, and is not available anywhere else in the literature.



Read [Part I, Pulling Mechanics](#)

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The correct position from which to pull will be one in which the scapulas, the bar, and the mid-foot are aligned vertically. The back will be held rigid in its normal anatomical position, the elbows will be straight, and the feet will obviously be flat against the floor. This is the position in which the skeleton most effectively and most efficiently transfers force – produced by the muscles that extend the hips

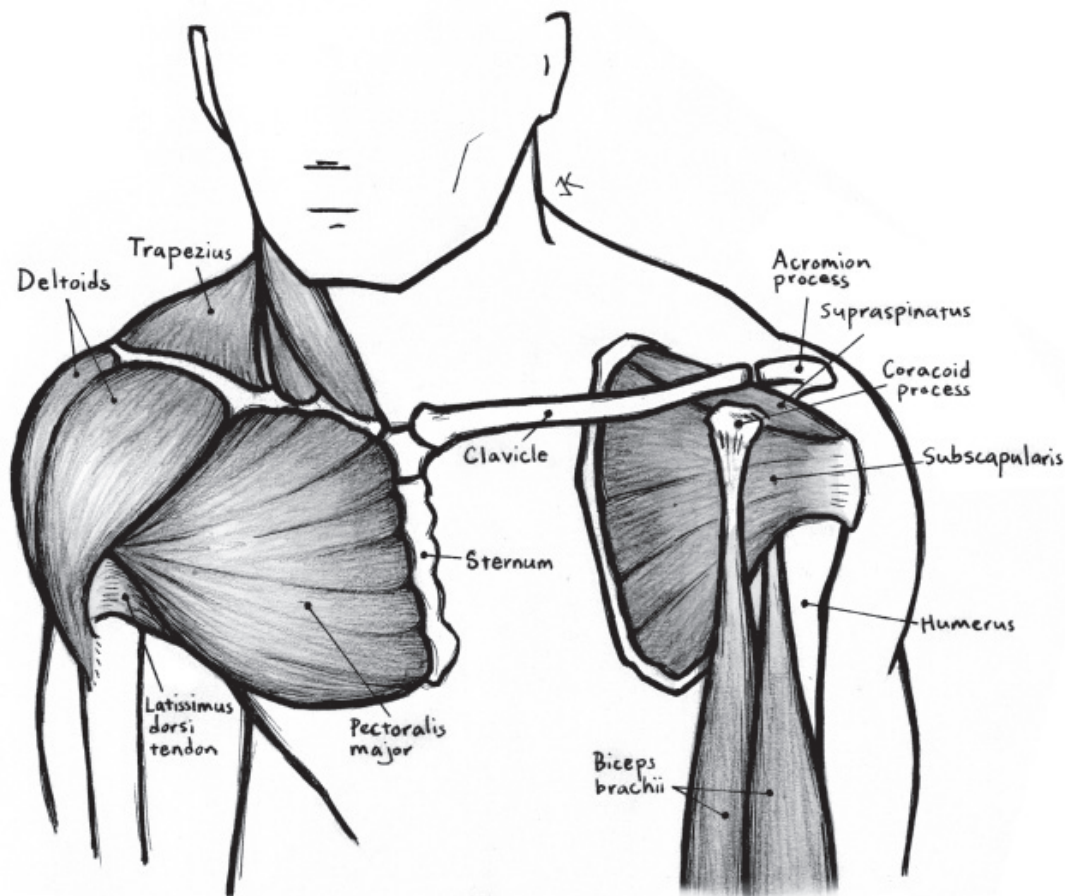


Figure 4-21. Muscles of the upper body involved in the deadlift, anterior view.

and knees – up the back and down the arms to the loaded barbell. Furthermore, this principle is true for any pull off the floor, with any grip or stance. This alignment produces optimum balance between the lifter/barbell system and the balance point in the middle of the foot.

Any other bar position has the potential to create two problems. The first problem, occurring when a barbell is pulled from a position forward of the mid-foot, is a moment arm between the barbell and the balance point. The lifter must compensate for this moment arm in some way, either by moving the bar back into balance or by applying the extra force needed to act against both the load on the bar *and* the effect of the moment arm. The distance also has a detrimental effect on the hip, knee, and back angles, causing them to assume less-than-optimal relationships with each other and the bar. This is intuitively obvious if you stand with the bar

a couple of feet in front of you – the distance is a huge problem, and when it is exaggerated in this way, the reason is clear. Cut the distance in half by stepping forward, and pulling will be easier but still not correct. Halve the distance again and the trend becomes apparent: the closer you are to the bar, the easier it is to pull; and the reason is the distance's effect on the leverage against the mid-foot.

Even a casual examination of the bar paths of heavy deadlifts, cleans, and snatches demonstrates a tendency for a barbell pulled from a position forward of the mid-foot to move back into balance, producing a curved bar path off the floor. The heavier the pull, as in deadlifts, the smaller the curve in height and amplitude. The lighter the pull, as in snatches, the larger the horizontal displacement that can be tolerated, and the higher the bar can go before settling into balance over the mid-foot. (Some snatches may be so light relative to



Figure 4-22. The correct start position in the standard pulling model. Note the angle at which the arm hangs relative to vertical.

the lifter's absolute strength that they can be pulled through their entire bar path out of balance.) You can see, then, that balance exists directly over the mid-foot, and that it makes sense to design your pulling technique to conform to this physical reality by pulling the bar off the floor in a straight vertical path.

The second problem, occurring with any bar position that is not slightly behind the front of the shoulders, is a lack of equilibrium between the bar and the lifter's arms and spine; to obtain this equilibrium, people tend to move into the correct position during the pull. In this position, your shoulders will be slightly in front of the bar, and your arms will *not* be perpendicular to the floor. It is a common feature of all pulls from the floor that after the back angle stops changing – i.e., the back has settled into a stable angle as the knees and hips extend at the bottom of the pull – the arms do not hang vertically. They hang at an

angle of somewhere between 7–10 degrees behind vertical, placing the shoulders just in front of the bar and, perhaps coincidentally, directly under the scapulas. Most Olympic weightlifting coaches teach this position, shoulders in front of the bar, and a quick online search through the many thousands of available videos of deadlifts, cleans, and snatches, viewed frame by frame, will quickly demonstrate the universal nature of the shoulders-forward position during the pull.

A continuum can be observed from light to heavy pulls: snatches, being very light relative to deadlifting capacity, can be observed to poorly conform to this model for some inefficient lifters. Cleans, being heavier than snatches but still lighter than deadlifts, are more likely to conform, and heavy deadlifts almost always conform as soon as the bar leaves the floor. Furthermore, the tendency of the lifter/barbell system to seek equilibrium in the shoulders-forward position is so inherent in pulling the barbell that if someone tries to pull with vertical or behind-vertical arms, the back angle will change – either before the pull starts or during the first part of the pull – in order to produce this position. The tendency to do this varies with weight in the same way the tendency of the bar to move toward the mid-foot balance point does, with snatches showing a lot of back-angle change over a longer portion of the pull, cleans showing much less, and deadlifts almost always starting the plates right off the floor with the same back angle used until the bar approaches the knees.

Keep in mind that a straight vertical bar path is the most physically efficient expression of barbell movement in a gravitational framework. Starting positions that place the bar forward of mid-foot or that involve vertical arms will either cause the bar to be pulled in a non-vertical path or cause a shift in back angle, both of which are costly in terms of unnecessary energy expended on the lifter's body or the barbell. Not only is a bar that is farther away from the hips harder to pull because of the longer moment arm between bar and hips, but movements that do not contribute to the vertical displacement of the load also represent wasted work capacity. Although some very good lifters may excel at

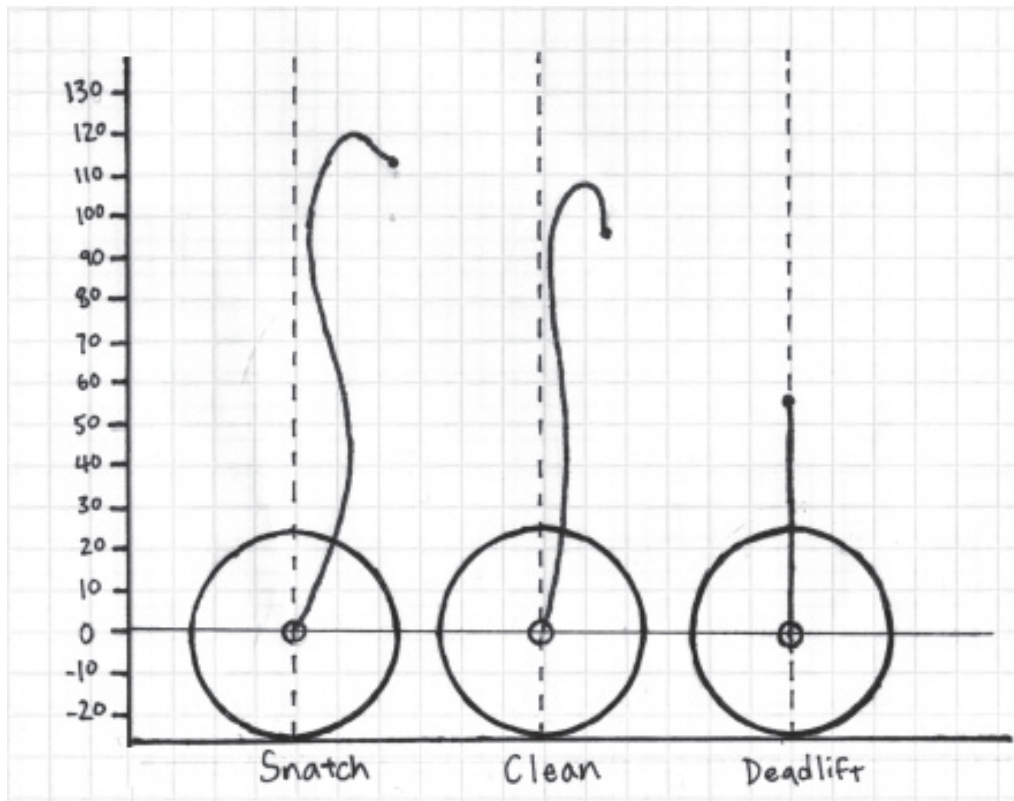


Figure 4-23. Bar path tracings of a typical heavy, snatch, clean and deadlift.

performing the lifts inefficiently, this does not mean that their method is efficient. The most efficient way to pull a barbell off the floor will be the way that produces the most straight vertical bar path, because that's the way that comports with the fact that the actual work to be done against gravity in a deadlift is the energy spent vertically displacing the weight as close to the hips as possible.

Furthermore, the center-of-mass considerations described earlier explain many aspects of this curved bar path. Think of the two ways the bar can move: vertically and horizontally. In a very general sense, vertical movement is accomplished by muscular force generated along the rigid segments of the body interacting with the load, and horizontal movement is accomplished by manipulating the body's mass in relation to the barbell. So pulling force comes from the muscles that extend the knees and hips, and from the muscles that keep the back rigid and keep the bar in the hands and correctly positioned under the spine. Horizontal movement, made necessary by the incorrect positioning of the

body/barbell system over the balance point, results from movement of the body's mass in an attempt to influence the position of the bar.

Some coaches teach that the hips should be dropped, the shoulders should be positioned behind the bar, and the back should be as vertical as possible. This start position will always create a lot of movement in both lifter and barbell before the weight actually leaves the floor, because this position places the bar forward of the mid-foot as the hips drop and the knees drop forward, pushing the shins and the bar forward, away from both the mid-foot and the hips. It also places the lifter's COM behind the bar. At heavy weights, the bar out-masses the lifter by perhaps more than 300% in strong lifters. The lifter can move the bar horizontally by manipulating the mass of his body relative to the bar, as evidenced by the layback at the top of a clean or snatch, where the bar is forward of the balance point. Since the barbell is much heavier than the part of the lifter's body behind it, the reaction between the bar and body positions will be proportionate to

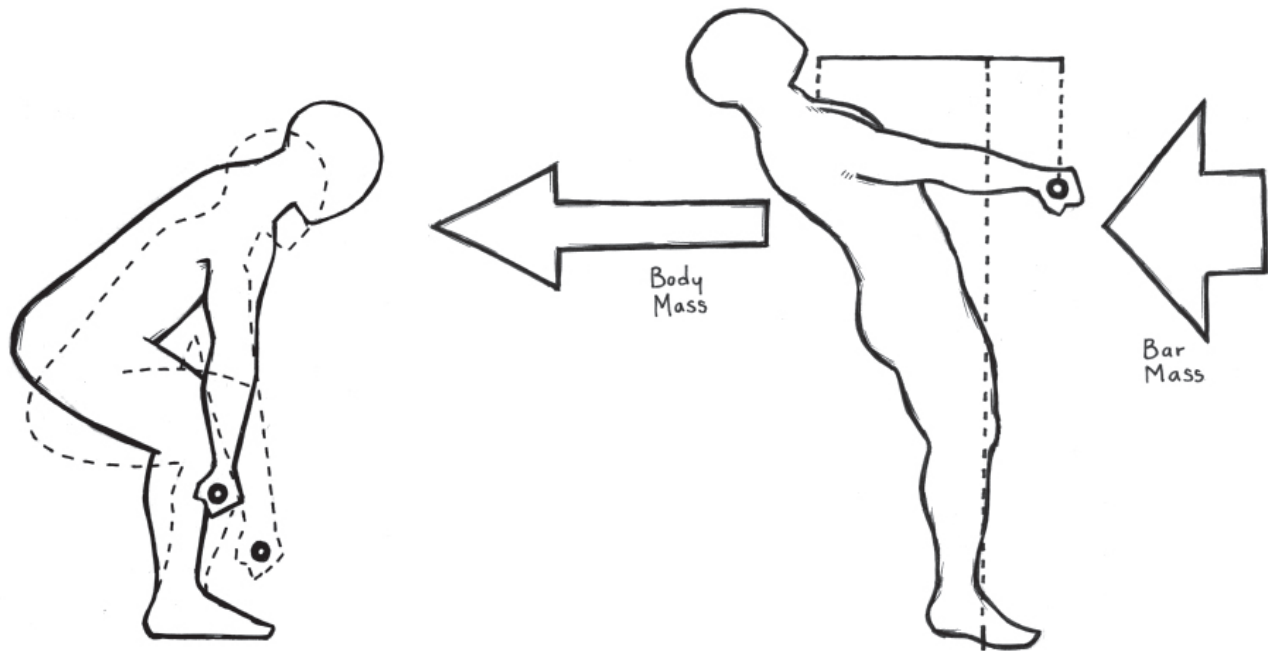


Figure 4-24. Use of the body’s mass is necessary to produce a horizontal bar path component. The body’s pulling machinery can efficiently move the bar upward, but the vertical orientation of the lifter/barbell system cannot effectively move the bar horizontally. For that, we make the mass of the body move horizontally to react against the mass of the barbell. Since the heavy barbell out-masses the lifter, his body must move further horizontally to effectively react against the barbell.

the differences in the mass. If the bar is forward of the balance point by 3 inches as it passes the hips in a clean, the layback will have to be *much greater than that* since the body is lighter than the bar. And if the layback does not sufficiently dampen the forward displacement, the lifter will have to jump forward to make the catch.

The same thing happens when the bar is on the floor: if you shove a heavy bar forward, your body mass behind it reacts against the bar’s forward displacement by acting as a cantilever for the horizontal motion necessary to bring the bar back into balance over the mid-foot and closer to the hips. The feet are pinned to the ground by the load, so as the pull starts, the mass of body behind the bar reacts against the mass of the bar which is forward of the balance point. The bar rolls back and leaves the ground in a curve as the body swings forward around the hands and positions itself in equilibrium, with the shoulders forward of the bar. As this position settles in, the bar path becomes vertical. This movement is, of course, completely

unnecessary if the bar starts out in balance with the body’s preferred position of pulling equilibrium so that a vertical bar path can be produced.

The non-vertical arm angle is perhaps the most poorly explained phenomenon in weightlifting. Why does the back angle become stable for the first part of the pull when the shoulders are in front of the bar and the arms assume their characteristic angle of 7–10 degrees from vertical? Why is there an apparent equilibrium between how far the shoulders are in front of the bar and how far the hips are behind the bar? Our working theory is that the critical relationship is the interaction between the lats, and the teres major, the triceps, and the humerus. There is a back angle at which the lats can best stabilize the arms and shorten the distance between bar and hips in order to facilitate a vertical bar path, and a heavy deadlift settles into this angle because it cannot do otherwise.

The humerus is suspended from the scapula by lots of muscle and ligament, and it would seem

as though the arms should just hang vertically, as a weight on the end of a rope hanging from the ceiling hangs vertically, or “plumb” as it is called. But the arms don’t hang vertically, not with a weight that is actually heavy enough to force you to tighten your back and arms. Check the videos yourself. If you want that rope to hang from the ceiling at any angle other than vertical, you will have to apply another force to the system from a different direction – you’ll have to tie *another rope* to the one hanging plumb. And that second rope will work best against the first one if you pull at a right angle to the loaded rope, because a right angle is the configuration that allows the force to be applied most efficiently. Like pulling on a wrench at any angle other than 90 degrees, pulling on the rope from anything other than a right angle fails to generate the maximum turning force. It’s easier to see this when the first “rope” is your humerus, and the second rope is your lat.

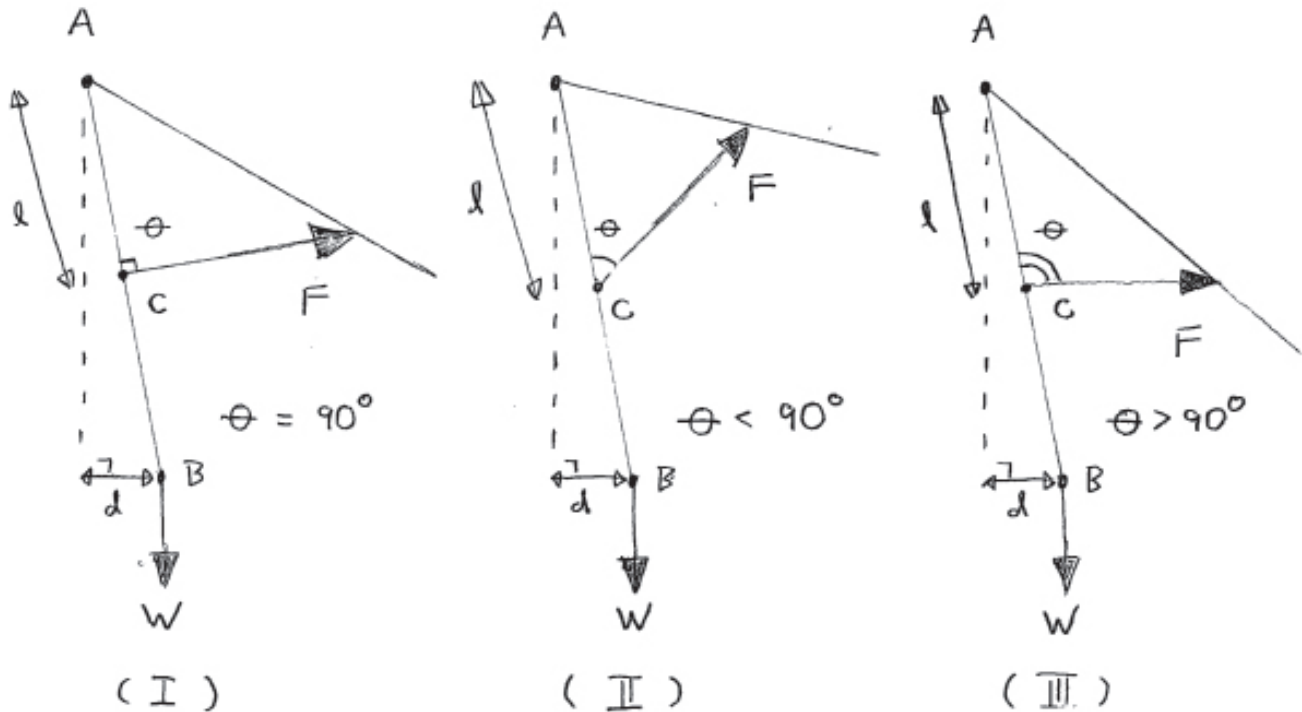
So, there is another rope after all; there are actually several of them. The teres major and the triceps control the angle between the scapula and the humerus. The teres major connects the inferior part of the scapula to the proximal end of the humerus on the anterior side, only millimeters away from the lat attachment under the armpit on the arm side. The triceps attaches the superior scapula, up high on the shoulder side of the armpit, to the elbow, although its leverage position is weak. More important, the lats connect their large origin along the low back directly to the shaft of the humerus, up under the armpit on the anterior side, so it pulls across the full thickness of the shaft. These muscles add to the large number of attachments from the shoulder joint area, which, working together, transfer force from the trunk to the arms.

This posterior pull is responsible for the non-vertical angle of the arms as they hang from the shoulders under a loaded spine, and must equal the tendency of the weight to rotate the arms forward to a vertical position. If the arms rotate forward, this will place the bar forward of the mid-foot and thus off-balance, unable to be pulled if it is heavy enough. Since the triceps and the teres major are actually minor contributors to the situation due to their poor positions of leverage, the total contribution

of the lats, teres major, and triceps averages out to approximately the same as just the lats. When the shoulder is in front of the bar and the back angle is stable in a pull, the angle of attachment between the lat and the humerus is about 90 degrees, since *this is the angle at which the least muscular force is required to produce a rotation force that is equal and opposite to the weight*. It is the angle at which these muscles can exert their tension on the humerus most efficiently and thus provide the maximum force transfer and stability during a pull from the floor in which the bar needs to stay over the mid-foot and as close to the hips as this stable “hang” will allow (see Figure 4-25). And the back angle adjusts to produce the 90-degree lat angle in equilibrium between the shoulders and hips.

The fact that several muscles are contributing to this posterior pull makes the angle hard to calculate precisely, and some variation with anthropometry would be expected, but the lats appear to be the major factor in the system, and the angle of attachment in a stable configuration is probably very close to 90 degrees. What is absolutely clear is that through the bottom of the pull, there exists a back angle in which the shoulders are in front of the bar, the arms do not hang straight down, the hips are closer to the bar than they would be if the arms did hang straight down, and pulling the bar off the floor in this position results in a vertical bar path. With this path, the lifter can most efficiently maintain the balance point over the mid-foot and use the lats and related muscles to maintain a vertical bar path.

Stated more succinctly, **the arms are not plumb in a deadlift because the lats do not attach to the arms at 90 degrees when the arms are plumb**. The arms must slant back to achieve a position of stability as they hang from the shoulders. So the body must assume a position that allows the arms to be at 90 degrees to the lats and for the bar to be pulled in a straight vertical line off the floor. If the hips are too low, the lat attachment angle will be less than 90 degrees, and the hips will rise as the back angle adjusts to the stable position. If the hips are too high, the angle is greater than 90 degrees, and the lifter cannot as efficiently prevent the bar from continuing forward.



In each of the drawings above the arm hangs at an angle that places the shoulder (point A) a horizontal distance d in front of the weight. The weight pulls downward on the arm at point B with a force W producing a clock-wise moment about point A. The magnitude of this moment is $W \cdot d$.

The lats attach to the arm at point C and pull on it with a force F . This produces a counter-clockwise moment about point A. The magnitude of this moment is $l \cdot F \cdot \sin \theta$. The back angle controls the angle θ .

In order to prevent the arm from rotating about point A the magnitude of the two moments must be equal.

$$l \cdot F \cdot \sin \theta = W \cdot d \quad \Rightarrow \quad F = W \cdot d / (l \cdot \sin \theta)$$

F will be smallest when $\sin \theta$ reaches its maximum, which occurs at $\theta = 90^\circ$ (I). Any other angle will require a relatively larger force F (II and III).

Matt Lorig

Figure 4-25. A proof of the theory that the lat stabilizes the humerus most efficiently at 90 degrees, from our friend Matt Lorig, Ph.D. This is the kind of analysis you get when you ask a physicist to think about barbell training.

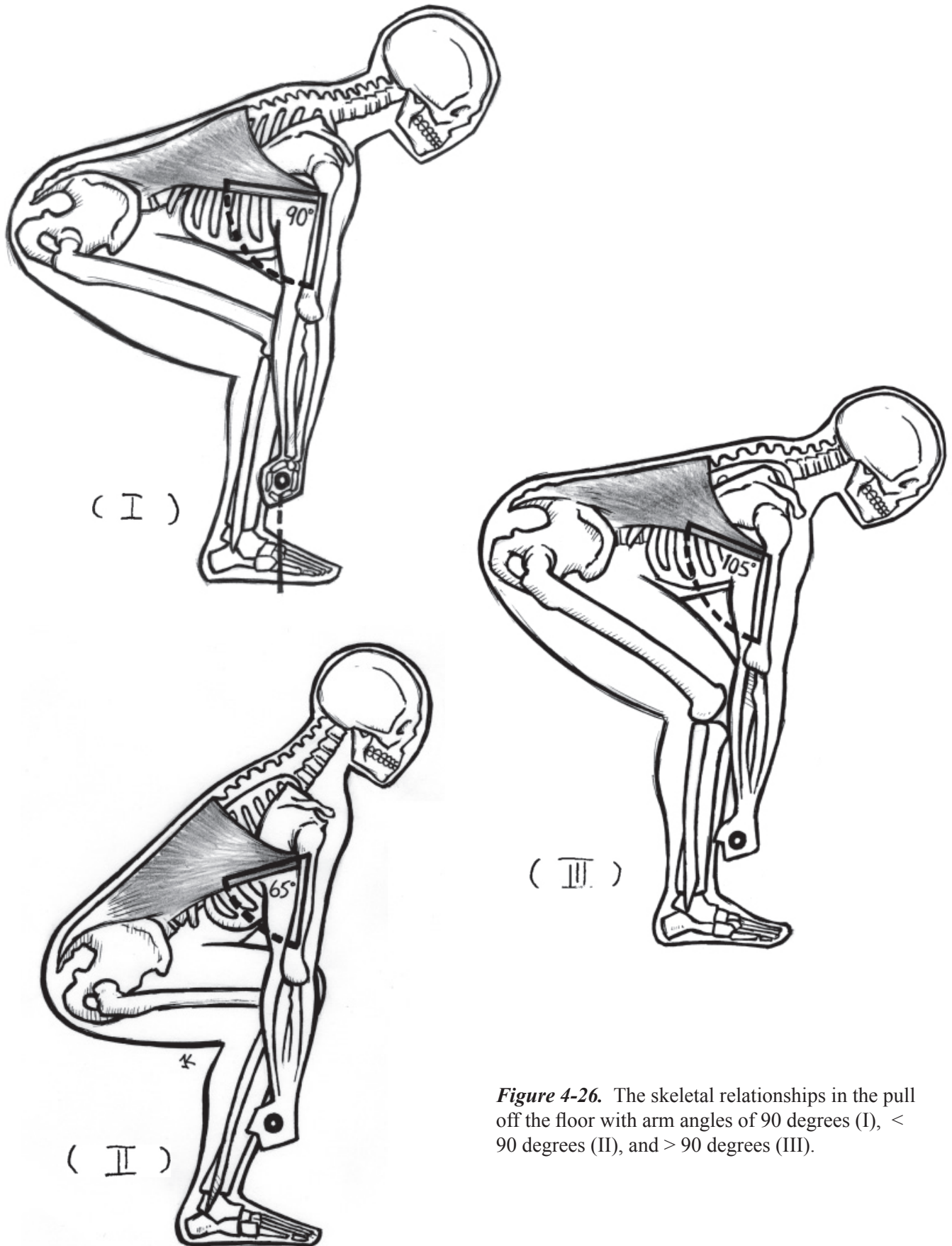


Figure 4-26. The skeletal relationships in the pull off the floor with arm angles of 90 degrees (I), < 90 degrees (II), and > 90 degrees (III).

Mark Rippetoe is the author of Starting Strength: Basic Barbell Training, Practical Programming for Strength Training 2nd edition, Strong Enough?, Mean Ol' Mr. Gravity, and numerous journal, magazine and internet articles. He has worked in the fitness industry since 1978, and has been the owner of the Wichita Falls Athletic Club since 1984. He graduated from Midwestern State University in 1983 with a Bachelor of Science in geology and a minor in anthropology. He was in the first group certified by the National Strength and Conditioning Association as a CSCS in 1985, and the first to formally relinquish that credential in 2009. Rip was a competitive powerlifter for ten years, and has coached many lifters and athletes, and many thousands of people interested in improving their strength and performance. He conducts seminars on this method of barbell training around the country.

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