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Trunk stabilization or "core" stability is a topic discussed by virtually everyone in strength and conditioning, and yet much confusion still exists about the pervasive topic. Spinal stability is important, but the exact mechanics and anatomy of stabilization are more often glossed over and referenced in obscurity than discussed in detail. Given the importance and pervasiveness of spinal stability in sports and training, a sound understanding of the detailed mechanics and anatomy of stability are paramount to effective training. In this article, part one of a four-part series, the focus will be on providing a detailed analysis of the mechanics and anatomy of stabilization. In the subsequent three articles, the focus will shift to clarifying aspects of spinal stability as they pertain to function, training, and weightlifting.

Muscles generate force by pulling. When a muscle contracts, the attachment points move towards each other (sometimes one end moves more than the other and sometimes both ends move evenly). When this occurs, the muscle shortens, creating a "pulling" force onto whatever it is attached. Whether open or closed-chain; eccentric or concentric; isotonic, isometric, or isokinetic, a muscle must have a stable point from which it can generate force to function effectively. In the body, an important stable point is the spine. Most movement in sports and competition is preceded by activation of the spinal stabilizers (3,4,5,9). Without such activation, movement as complex as throwing a javelin to as simple as picking up a weight plate would not be possible.

Stabilization is a complex, continuous, and instantaneous neuro-mechanical process that requires the analysis of a massive amount of sensory-motor information (e.g., tactile, proprioceptive, vestibular, visual) to dictate bodily movements (6). This process is so fast and so complex that the central nervous system must use virtually all of its components (e.g., spinal cord, brain stem, sub-cortex, and cerebral cortex) to maintain stability for movement and function (6). In sports, perhaps more than any other time in our lives, we depend on and challenge our body's limits of stability. So what is stability?

DEFINITION OF STABILITY

Stability is the ability to maintain a desired position (static stability) or movement (dynamic stability) despite motion, force, or control disturbances (12). For the purpose of this article, stability can be thought of as the ability to resist unwanted change in position or motion. In regards to static objects, those that require more force to move (either because of better structural integrity [i.e., lower center of mass and/or wider base of support] or from shear mass [inertia]) are more stable. For example, in Figure 1, Triangle A is more stable than Triangle B because it has both a wider base of support and its center of mass is closer to the ground, making it more difficult for an external force to tip it over. The body, however, is a dynamic object whose stability must also be dynamic. We are not simply talking about maintaining a static position (in most cases). In sports, we are asking our brains and our bodies to stabilize and maintain positions and/or movements simultaneously as we execute complex tasks such as hitting a forehand with a racket while running laterally in a tennis match (Figure 2). In this example, the player must stabilize with his left foot, knee, and hip so that he is able to rotate his trunk to strike the moving ball with precision; all as he manages his own momentum and tracks the path of the opposing player.

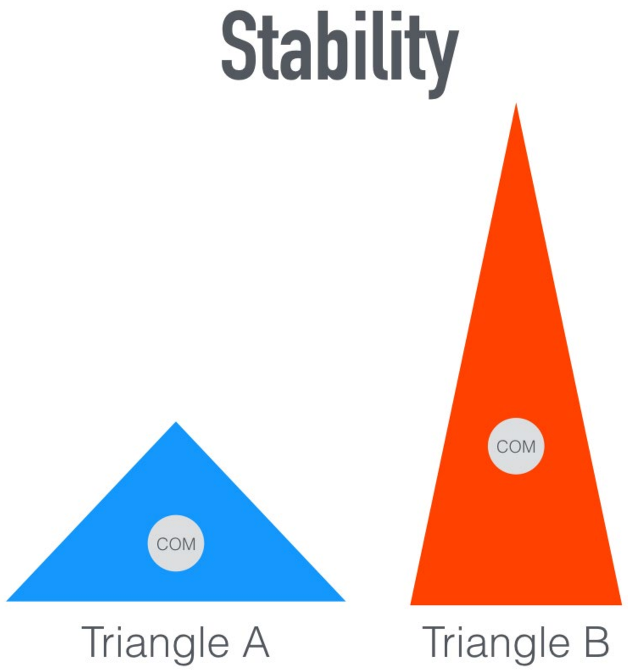

FIGURE 1. STABILITY TRIANGLES

FIGURE 2. TENNIS FOREHAND

Much of the body's stability depends on the stability of each joint within the body, especially those along the kinetic chain supporting the execution of the movement. If each joint is able to maintain the desired joint positioning or path, then the entire movement should also be stable and produce the desired results. When you consider the complexity of the movements seen in weightlifting (i.e., hang squat snatch) or in other sports (i.e., executing a slap shot in hockey while balancing on one skate), maintaining proper positioning or "stability" is a rather daunting task.

The foundation or "keystone" of stabilization of the body is pressure within the abdomen, or as it is commonly called intra-abdominal pressure (IAP). This pressure stabilizes the spine, pelvis, and ribcage, creating a solid fixed point from which muscles can pull in order to create, control, or even prevent movement. The amount of pressure in the abdomen at any given moment is dependent on the stability requirements for the task being executed (2,3,4,8,9). If the force output for the task is small (e.g., sitting on a couch) then the IAP will be minimal. If, however, the task is very demanding and the force output is high (e.g., attempting a one-repetition maximum [1RM] deadlift) then the IAP must be elevated (2,4,8,9). The amount of pressure in the abdomen is regulated constantly to meet the demands of the movement being executed. Researchers have demonstrated in multiple studies the occurrence of subconscious stabilization of the trunk for movement (2,3,8,9). Powerlifting and Olympic-style weightlifting are slightly different from other sports because athletes often consciously focus on bracing or stabilizing prior to initiating movement. Whereas in other sports, like tennis, basketball, or marathon running, stabilization is a complex process running in the background as the athlete focuses on external tasks. In each of these cases, the brain must continuously work to regulate IAP to preserve spinal stability for movement and function, regardless of its complexity or stability requirements. An appropriate question to now pose is, "how is this pressure generated?"

MECHANICS OF STABILIZATION

Pressure and volume are inversely related, so to increase or decrease the pressure within a container, without changing the contents or having a significant change in temperature, involves altering its volume. In sports and in resistance training, or in regards to spinal stability, this concept applies to the abdomen. If we want to increase the pressure within the abdomen, we need to decrease the volume. Therefore, the more IAP required for execution of a task, the smaller the intra-abdominal volume (IAV) must be.

In its simplest form, the abdominal cavity (or container) is comprised of both static and dynamic, non-contractile and contractile components. Static structures are mostly rigid and cannot actively change shape or length without external force. Static structures in the body typically include bones, cartilage, and most ligaments. In the abdomen, static structures include the pelvis, spine, and ribcage. Dynamic structures, on the other hand, typically refer to muscle and can change shape, shorten, and generate force. The dynamic structures in the thorax involved directly with stabilization include the thoracic diaphragm, the abdominal wall (external oblique, internal oblique, and the transverse abdominis), the quadratus lumborum (QL), erector spinae, the thoracolumbar fascia, and the pelvic floor (Figure 3). All of these structures work together to control IAV and therefore IAP to meet the stability demands of a task (3,7).

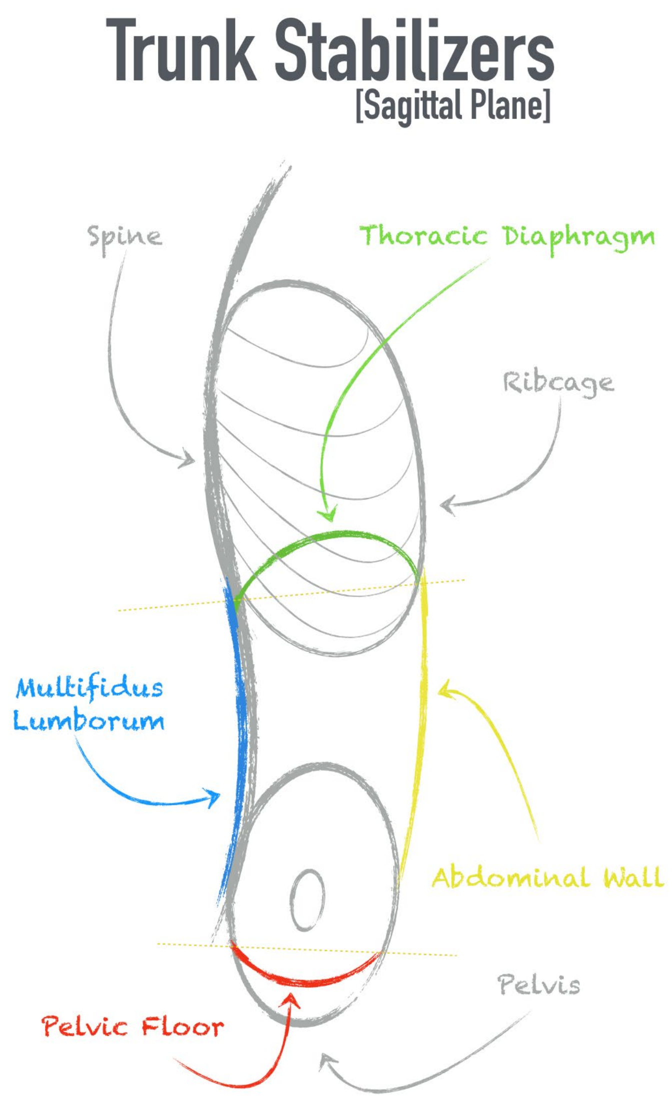

FIGURE 3. TRUNK STABILIZERS

THE DIAPHRAGM'S ROLE IN STABILITY

The initiating event in generating IAP (particularly in resistance training) is concentric contraction of the diaphragm (7). The work of Pavel Kolar, physical therapist of the Prague School of Rehabilitation, has looked at the diaphragm's role in stabilization. Understandably, the focus was on the superficial (more visible) muscles like the erector spinae or the abdominal wall (namely the transvers abdominis). The superficial structures obviously play a vital role in stabilization, but they do not represent the full stabilization system.

The diaphragm is a dome shaped muscle comprised of a flat, horizontally-oriented, non-contractile central tendon surrounded by vertically oriented muscle fibers (Figure 4). Attaching to the lower four ribs and the spine at the thoracolumbar junction, the diaphragm sits in the torso with the central tendon located around the level of the xiphoid process (at the bottom of the sternum), separating the thoracic cavity from the abdominal cavity (1,13).

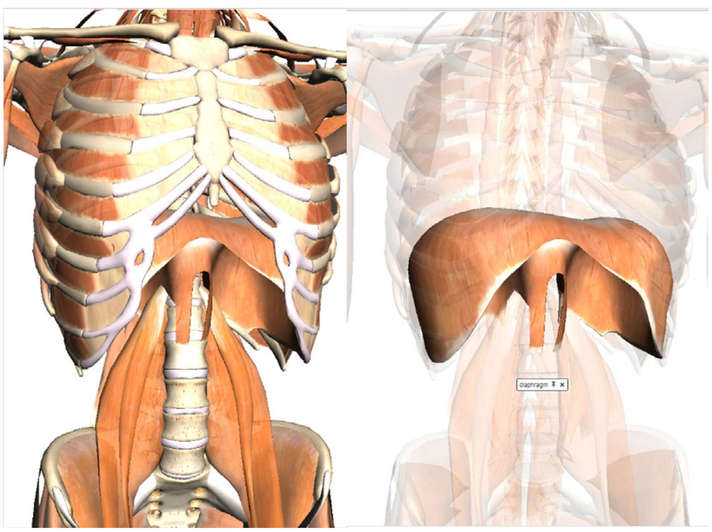

FIGURE 4. DIAPHRAGM

When assuming proper postural alignment (which should be maintained in most weightlifting and resistance training movements) the diaphragm concentrically contracts and the central tendon is pulled towards the pelvis (7,13). This action compresses the fluid, tissue, gas, and other contents in the abdomen, creating an outward-pushing force that pushes into and eccentrically activates the abdominal wall, pelvic floor, and posterior stabilizers (erector spinae, quadratus lumborum, and thoracolumbar fascia) (7). It is important to understand that the abdominal wall, pelvic floor, and back musculature should be eccentrically activated in response to the outward-pushing force created by the diaphragm approximating with the pelvis. These structures will often concentrically activate to stabilize the trunk (i.e., drawing the belly inward via concentric contraction of the transversus abdominis ["hollowing"] or arching the lower back with concentric contraction of the spinal erectors). Concentric activation of these structures blocks full movement of the diaphragm, distorts posture, and prevents optimal generation of IAP (7). This topic will be discussed in detail in Part 2.

As the central tendon of the diaphragm drops towards the pelvis and the contents of the abdomen are pushed into the abdominal wall, the brain has a choice: allow the abdominal wall (including the posterior structures such as the erector spinae) and the pelvic floor to expand or increase contractile activity of these structures to resist this outward-pushing force. This choice depends on the stability demands of the movement being executed. If the demand is low (e.g., laying on the floor after a difficult workout), then the abdominal wall will allow the abdomen to expand to preserve IAV at the necessary level to maintain proper IAP. If, however, the demand is high (e.g., an athlete in the bottom position of a 1,000-lb back squat), then the abdominal wall will increase contractility to minimize lengthening and work with the descending diaphragm to shrink the IAV as small as necessary to generate the proper amount of IAP (Figure 5).

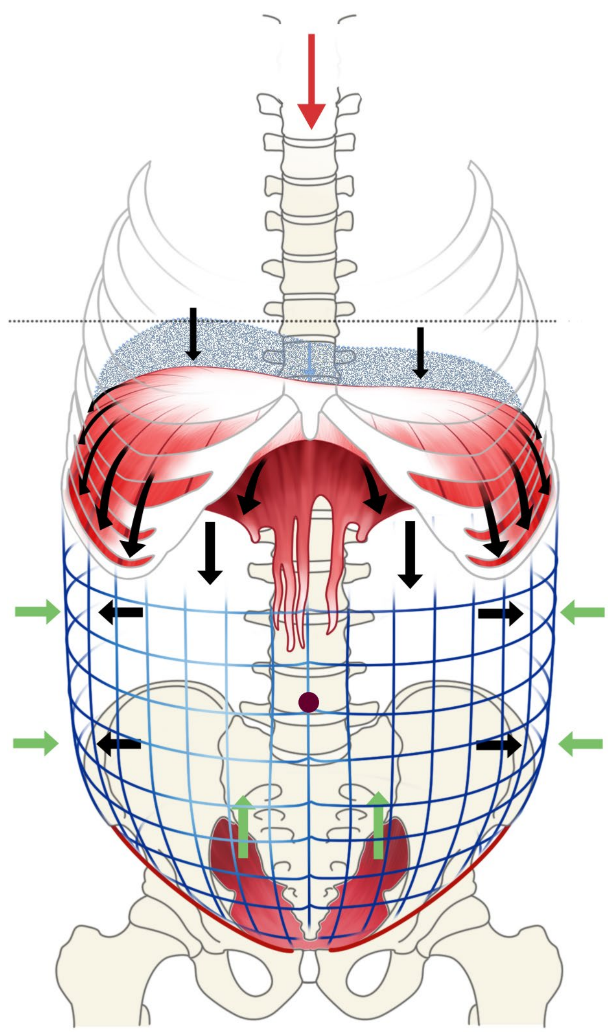

FIGURE 5. PRESSURE IN THE ABDOMEN

Another major contributor to spinal stabilization is the thoracolumbar fascia, which is a large diamond shaped piece of fascia on top of the lower back (Figure 6). The thoracolumbar fascia relates to stabilization in that it blends with virtually every contractile and non-contractile structure in the area including erector spinae, latissimus dorsi, external oblique, internal oblique, transverse abdominis, and the serratus posterior inferior, in addition to the pelvis, lumbar spine, and even the lower ribs (13). As the central tendon of the diaphragm descends and the abdominal wall reacts to regulate IAP, two things happen: 1) the outward-pushing IAP increases, pushing not only forwards but posteriorly into the lumbar spine, and 2) the increasing IAP results from and causes increased tension in the abdominal wall. Because the thoracolumbar fascia blends with the abdominal wall, increasing tension in the abdominal wall causes an increase in tension of the thoracolumbar fascia. Essential to this process is the fact that the thoracolumbar fascia attaches to the posterior aspect of the spine, creating a facial sling (Figure 6) (13). This sling traps the spine between the posterior-pushing IAP and the anterior-pulling force of the thoracolumbar fascia (Figure 7). The thoracolumbar fascia essentially blocks and locks the lumbar spine in a neutral position against the IAP in a way that does not increase axial compression (squishing) of the spine and requires minimal activity of the spinal erectors.

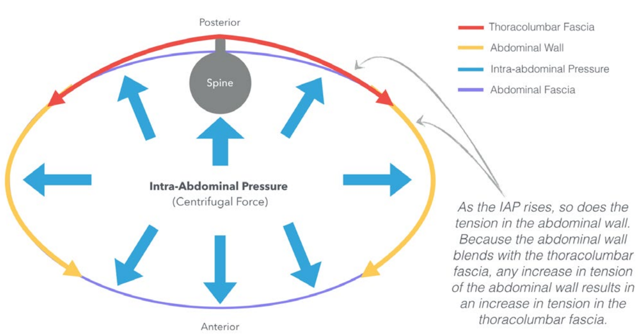

FIGURE 6. THORACOLUMBAR FASCIA AND IAP

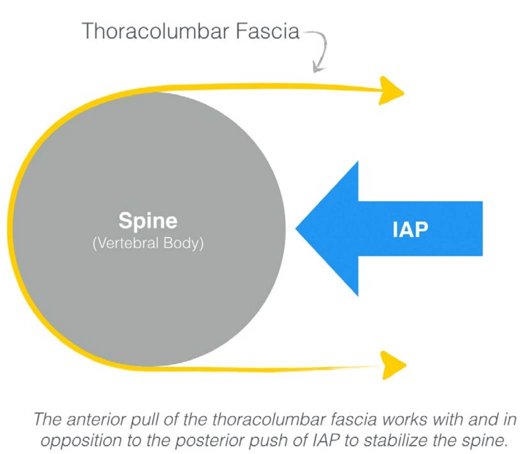

FIGURE 7. THORACO PULL

In order for the stabilization process to occur properly (Figure 8), the thoracic diaphragm and pelvic floor must be positioned parallel to each other (7). In this position, the thoracic spine will have a mild kyphosis, the ribcage will be down with the sternum vertically oriented, the lumbar spine will have a gentle lordosis, and the pelvis will be in a neutral position. When the central tendon of the diaphragm is horizontally oriented, the body is able to efficiently and effectively generate IAP. Since the diaphragm is a dome shaped muscle with the muscle fibers vertically oriented around the central tendon, concentric action of the diaphragm will pull the central tendon directly towards the pelvis, maximizing change in IAV. If the diaphragm is oblique to the pelvic floor (e.g., the ribcage is elevated) then concentric contraction of the diaphragm will move the central tendon more anteriorly (forwards) than downward, towards the pelvis. Malpositioning of the diaphragm prohibits significant change in IAV, which may result in an inadequate amount of IAP for the task being executed (i.e., pulling a 1RM deadlift off the floor), and forcing the athlete to use less efficient, compensatory stabilizing strategies. This will be elaborated upon in Part 2.

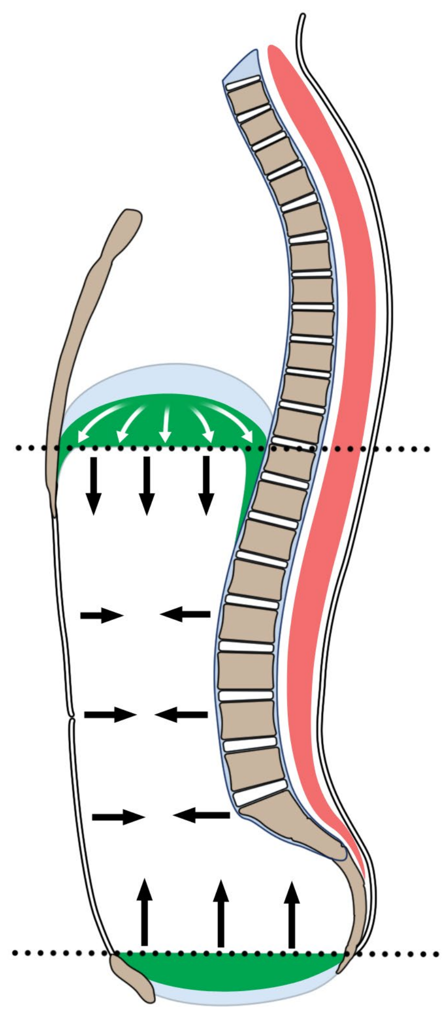

FIGURE 8. PROPER STABILIZING POSITION (SIDE VIEW)

Maintaining the diaphragm in horizontal orientation is no easy task; it requires activation of the abdominal obliques (external oblique [EO] and internal oblique [IO]). In addition to working with the diaphragm and pelvic floor to regulate IAV, the abdominal obliques are responsible for pulling the ribcage into a downward position to maintain proper orientation of the diaphragm. Without activation of the abdominal obliques, activation of the diaphragm and pectoralis muscles will pull the ribcage upward, creating obliquity between the diaphragm and pelvic floor. Such positioning is not ideal may prohibit optimal performance in training and in sport.

In addition to helping regulate IAV and pulling the ribcage into a downward position, the abdominal wall is also responsible for stabilizing the costal (rib) insertions of the diaphragm. As mentioned above, the diaphragm attaches to the spine at the thoracolumbar junction and to the lower four ribs (Figure 4) (13). Structurally, the spine is a naturally stable insertion point; the ribs, however, are not. They require considerable muscular activity to stabilize. When the abdominal wall is functioning correctly and the diaphragm is in proper position, the full circumference of the diaphragm's muscle fibers will work together to pull the central tendon directly toward the pelvic floor. If the abdominal wall is not working properly, then the insertion of the costal fibers of the diaphragm will be unstable, resulting in either inefficient activation of the costal fibers of the diaphragm and/or the contraction of the costal fibers of the diaphragm, which will elevate the ribcage. If the ribs are not properly stabilized by the abdominal wall, then the diaphragm will drop toward its spinal insertion, which causes elevation of the ribcage (7). As identified, a muscle will always approximate towards the most stable insertion.

SUMMARY OF KEY POINTS

In summary, proper stabilization of the spine and pelvis centers on generating pressure within the abdomen. It is the diaphragm, pelvic floor, abdominal wall, and dorsal erectors (namely the quadratus lumborum, the erector spinae, and the thoracolumbar fascia) that work together to regulate IAV to achieve the necessary IAP to meet the demands of whatever movement the body is executing. To optimize our ability to generate IAP, we need the diaphragm and pelvic floor to be parallel to each other. This requires considerable activation of the abdominal wall to maintain proper positioning of the ribcage and to stabilize the costal fibers of the diaphragm necessary for maximal and efficient force output of the diaphragm.

IMPLICATIONS IN STRENGTH TRAINING—BRACING

So how does this understanding of stabilization affect training? First, it changes the way in which we consciously stabilize the spine and pelvis for a lift or movement. We know now that when preparing for a maximal (or even sub-maximal) lift, "bracing" or "tightening up the core" should focus on generating IAP instead of concentric contraction of the abdominal wall ("abdominal hollowing") or the erector spinae, pulling the pelvis into an anterior pelvic tilt. This enables us to better cue and coach our athletes to stabilize for training. It is important to note that generating maximal amounts of IAP (via the Valsalva maneuver) should only be done for short periods of time—one should breathe between each repetition. Generating maximal levels of IAP elevates blood pressure significantly (2,10).

BRACING FOR A LIFT—USING THE SQUAT AS AN EXAMPLE

1. Breathe into (pressurize) the abdomen. Concentric contraction of the diaphragm creates an outward-pushing force, which eccentrically activates the abdominal wall and pelvic floor. This is actually rather difficult. Many people are "chest-breathers" and struggle with activation of the diaphragm, which is necessary for both abdominal breathing and generating IAP. These individuals will elevate the ribcage as they breathe in, which does not increase IAP optimally. Specific exercises are often necessary to teach athletes how to breathe into their abdomens.
2. Without expiring, activate the abdominal wall and pull the ribs downward into a caudal position. This ensures that the diaphragm is positioned properly and the abdominal wall is adequately activated. It is important to note that expiration should not occur at this time because expiration elevates the central tendon of the diaphragm, causing an increase in IAV and, therefore, a reduction in IAP (remember, pressure and volume are inversely related). For this, we need full activation of both the abdominal wall and the diaphragm, not just the abdominal wall. I must also emphasize that bringing the ribs into a caudal position should happen without any spinal flexion. Often, because athletes struggle with separating rib motion from spinal motion, in an attempt to pull the ribs downward, they will flex the spine instead of downwardly rotating the costovertebral joints (the joints where the ribs meet the spine). Flexion of the spine gets the ribs into a downward orientation (approximates them with the pelvis), but it does so at the cost of proper and safe spinal positioning. As mentioned above, for both performance and safety, the entire spine from the skull to the pelvis should be in a neutral position throughout the bracing process and the movement.
3. Once the abdomen has been pressurized and the ribs pulled downward, the athlete is properly stabilized and can begin the movement. In most pressing exercises (particularly in the squat) the transition position between the eccentric and concentric phases is the weakest position in the entire movement. This weakness is the result of an increase in torque output necessary to maintain or move through the position secondary to increasingly longer moment arms acting on the body. In Figure 9, you can see how much longer the moment arm acting on the hip is at the bottom of the squat (right) compared to the top of the squat (left).

4. As the athlete completes the transition and moves through the concentric portion of the lift, he or she can slowly expire through pursed lips (or through the common yell) to reduce the magnitude of the brace (via elevation of the diaphragm). The athlete is able to lighten up the brace as he or she continues through the concentric phase of the lift because the leverage over the resistance improves (the length of the moment arms decreases) (Figure 9).
5. Athletes attempting a maximal double, triple, or even sets of five, should breathe out at the top of the movement and breathe in again, setting for the subsequent repetition. Athletes often do this without intent when they break up their heavy sets into singles. This allows the athlete to breathe in between sets and brace properly for each repetition.
6. For loads that do not require intense bracing (i.e., sets with a relative intensity less than 85% or longer sets, greater than six repetitions), the athlete should maintain respiration throughout most of the movement other than perhaps the transition. To stay with the squat as an example, athletes should maintain respiration on the descent until they reach a depth which they will need to brace temporarily (increase IAP) through the transition until they begin the concentric portion and can resume breathing again. Because of the increased torque demands, athletes will often feel an involuntary increase in the intensity of their brace (more IAP, more abdominal activation), even without focusing on it as they descend. This is the sub-cortex regulating the IAP to meet the demands of the task (3,4,5,9).

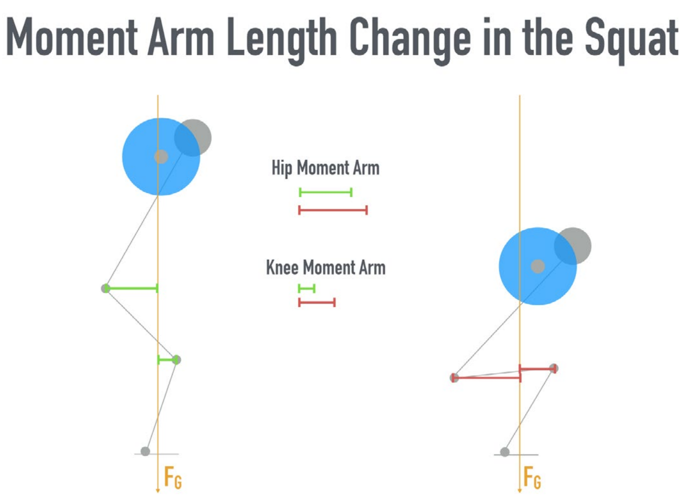

FIGURE 9. MOMENT ARM LENGTH CHANGE IN THE SQUAT

Using this bracing or setup for sub-maximal or maximal lifts will help athletes reduce the incidence of injury and might even improve performance for the simple reason that their spine and pelvis will be more stable and therefore, able to more efficiently transfer energy.

CONCLUSION

In both training and sport, we must remember that movement is preceded by stabilization of the spine (2,3,4,5,8,9). In this article we have covered the anatomy and mechanics of spinal stabilization and how to properly brace for both maximal and sub-maximal lifts. Because of the forces that are generated by and transmitted through the body during resistance training, having a sound understanding of stabilization is paramount for safe and effective training. Part 2 of this four-part series will cover a common compensatory stabilizing strategy that I call the Extension/Compression Stabilizing Strategy. This stabilization strategy is endemic in the weightlifting population. We will also discuss how this new understanding of stabilization and posture affects weightlifting technique and training.

Richard Ulm will be presenting on this topic at this year's 2017 NSCA National Conference in Las Vegas, NV on Thursday, July 13 at 8:30 a.m. and then will do a follow-up workshop later in the day with Drew Dillon at 2:00 p.m. to cover auxiliary exercises to improve spinal stability and technique.

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Currently the owner and treating physician at the Columbus Chiropractic and Rehabilitation Center in Dublin, OH, Richard Ulm works with a wide variety of patients ranging from professional athletes to those trying to avoid serious surgery. Prior to becoming a chiropractic physician, Ulm competed on a national level in track and field for many years (2004 and 2008 Olympic Team Trials qualifier), and was a Division I strength coach in the National Collegiate Athletic Association (NCAA). Ulm is an international instructor of Dynamic Neuromuscular Stabilization (DNS) for the Prague School of Rehabilitation and is a certified DNS Exercise Trainer (DNSET). He is also the creator of Athlete Enhancement, an organization through which he teaches seminars and clinics on weightlifting, rehabilitation, and manual therapy to strength coaches, physicians, physical therapists, and chiropractors all over the country.