Sport Biomechanics
Whether building a stable structure or designing a machine that performs dynamic tasks, numerous factors must be accounted for and managed to ensure durability and efficiency. That being said, if structural and mechanical engineers analyzed the systems of support and locomotion within the human body; they would be impressed at how nature manages physics. Every day the human body must contend with constant force applications and varying conditions to accomplish the voluntary tasks of free living.

During sports and training activities, an athlete may simultaneously manage gravity, contact, and varying external force vectors that act to displace his or her position. In comparison, a building is more simplistic; the conditions by which it functions are vastly predictable. A body at rest is in equilibrium; the sum of forces acting on it equal zero. In sports, equilibrium is referred to as balance and is assessed by relative control in a specific environment. In some cases, the body is in motion, while other times it is in a static position. An individual’s capacity to attain or maintain static or dynamic equilibrium is based on his or her ability to employ the principles of stability.

When the sum of these factors equal zero, a static position is attained; when the body can counter forces to a sum close to zero, dynamic positions can be controlled. Dynamic equilibrium, such as experienced during locomotion, occurs at different levels of stability based on favorable or unfavorable conditions. Thus, changes in the base of support, center of mass in relation to the base, and the height of the center of gravity all affect the body’s ability to maintain equilibrium. This becomes increasingly relevant when applied to an athlete and the various conditions they may experience during sports participation. The fact that the body must contend with constant changes in position during most sporting events emphasizes the need to manage a varying biomechanical environment.

The critical factors of stability function as constants. This suggests that, regardless of the sport, activity, position, or environment, the body will always be under at least one external force as the pull of gravity will always apply. In addition, other sport-specific factors must be taken into account to competently manage both movement and stability. Anthropometrics, friction, segmental alignment, velocity, as well as physiological, visual, and psychological factors may (or may not) play a relevant role in athletic development. Similarly, proper coaching can help the athlete reduce the degree of directional upset using efficient body movements and positions.

Example: staying low while maintaining a broad base of support aligned with the direction of the force helps to reduce external factors that can disrupt position.
The Principles of Stability

When all others things are equal…

1. **The lower the center of gravity – the greater the stability**

   In collision sports, (all forces equal) when two bodies collide, the lower the body's center of mass upon impact, the more significant its potential to upset the position of the opposite force. For example, offensive linemen in football are coached to stay low so they are harder to move when blocking.

2. **The greater the base of support in the direction of the line of pull, the greater the stability**

   Pulling a rope with a base in line with the rope's direction is more stable than when the stance is perpendicular to the line of pull.

3. **The line of gravity should intersect the base of support in the direction of the force and cause motion to allow for the greatest range of motion (ROM) within the area of the base**

   This allows the management of force applied in the opposite direction of movement. Leaning forward when running uphill offsets the increased forces to fall backward. But if the body leans forward excessively, stability is lost and the runner will fall.

4. **The greater the mass of the body – the greater the stability**

   A horse jockey pushing against a sumo wrestler in attempt to move him would most likely be futile; the opposite would not be as true.

5. **The closer the center of mass is to the center of the base – the greater the stability**

   Proper standing posture requires far less effort than leaning forward or backward, as does holding a resistance close to the body versus further away.
Chapter 4

NCSF Advanced Concepts of Strength & Conditioning

The idea of training, or practicing to enhance the efficiency of environment-specific stability, is by no means novel; however, recognition of physiological and psychological factors that affect stability, as well as the modern techniques employed to promote them, have greatly evolved over the last two decades. The first step in developing an integrated program inclusive of stability for athletic enhancement is to understand how the body functions biomechanically. In some cases, limitations to performance are related to impaired function. Others are specific to faulty recruitment patterns associated with prior training and compensations stemming from dysfunctional relationships between joints or movement systems.

6. *The greater the friction between the object base and contact surface, the greater the stability*

Running on a track is much easier than running in sand or on ice. Surface features determine the amount of tolerable force before the connection is disrupted.

7. *A body in motion with visual focus is more stable than one focused on disturbing stimuli*

Lines on the bottom of the pool help keep a swimmer moving in the proper direction.

8. *The healthier one’s physical and emotional state, the more stable one becomes*

The integrity of the tissue and the degree of psychomotor focus determines the outcomes. Athletes who “don’t have their head in the game” are often cited for emotional distracters.

9. *Regaining stability is based on the same factors as maintaining it*

A rugby player that must lunge forward to receive the ball must re-establish the center of mass back over the base in order to continue running or he will fall.

**DEFINITIONS**

Psychomotor – *Physical behavior that is the result of mental processes*
The Integrated Model of Function

Forward thinking and clinical investigations in recent times have led to the integrated model of function. The term function, as medically defined but loosely applied in the fitness industry, suggests the ability of the body to efficiently manage environments and conditions without undue resistance. Poor posture, faulty movement patterns, and incorrect biomechanics due to musculoskeletal deficiencies or imbalances all contribute to known dysfunction, ultimately increasing the risk of injury [1]. While injury prevention is the primary role of a strength coach, reducing resistance to allow full use of natural athleticism is the second. To optimize sport movements, an athlete first requires a functional skeleton. The process of removing musculoskeletal restrictions is similar to unhooking a dragging anchor; it allows for greater acceleration in all aspects of athletic development. This starts at the foundational level and includes aspects of both the musculoskeletal and neuromuscular systems. In terms of training, it underscores the rudimentary aspects of movement efficiency which include adequate range of motion, muscle balance, passive and active elements of stabilization, as well as effective muscle activation and neuromuscular contraction patterns.

The integrated model of function differentiates the role of each bodily system in terms of how they work together in order to accomplish a given physical outcome. This concept will be applied throughout the text and highlights the fact that the human body is really not a group of parts, but rather a whole of functioning parts. The efficiency by which these parts work together ultimately determines the level of performance. The integrated model of function encompasses this interaction between systems (or parts, if sticking to the theme) for the purposes of movement efficiency. It includes three components of a physical nature: form closure, force closure, and neuromuscular activation, as well as one of psychological orientation, which is categorized as emotion. One could compare the concept to a symphony orchestra: the separate sections overlap together to create a particular sound. In the case of physiological integration, functioning systems interact, providing specific characteristics to create an outcome. Whereas the sectional effort in the orchestra is directed by the conductor, the central nervous system (CNS) determines the magnitude of effort within a system or group of systems in the body.
Form Closure

The foundational component for function is form closure. Form closure describes the structural aspects of the body and the specific architecture of articulating segments (joints). In a sense, form closure is the frame of the human machine. It includes the bones, joints, and connective tissues that function to support the body. Whereas bones and connective tissue form all joints, the defining characteristics of individual joints are based on their structure, orientation, and shape [2,3]. These factors ultimately determine the mobility and stability of each movement segment. All joints provide a level of form closure via contact support between articulating surfaces. In some cases, the form closure effect is significant as the segments fit together like a puzzle, providing a high degree of support. In other cases, the joint’s form closure is limited by the connecting surface area, placing greater reliance on additional tissues to provide stability.

It should be understood that the specific role of each joint determines how much additional force is needed to ensure its stable function. For instance, when comparing the shoulder joint to the hip joint, there are significant differences in form closure. These differences allow each joint to perform a unique function, but it also determines the amount of stability needed to manage varying force applications. Both the shoulder and hip are considered ball and socket joints; however, there are inherent differences in the efficiency of stability for each. Structurally, the hip is a true ball and socket, as the femoral head sits inside the acetabulum (much like adjacent pieces in a puzzle), creating a high level of form closure. By comparison, the shoulder has a significantly smaller articulating surface; the humeral head sits against the glenoid fossa of the scapula. This lack of articulating contact reduces the form closure capabilities. From a stability perspective, the hip has a significant advantage for loading and stress, but ROM is compromised. The shoulder joint functions to the contrary. The limited form closure reduces stability but provides for a notable gain in mobility. This explains not only the wide ranges tolerated by the shoulder joint but also its susceptibility to injury when compared to the hip.

Force Closure

Where form closure is produced from the integrity of hard contact between articulating surfaces, force closure comes from the support of soft tissues that help maintain the contact position. Consider putting together a cardboard box. The cardboard provides the requisite form integrity for the sides, top, and bottom, but it still requires tape to seal it together. Using one piece of tape may be enough to connect the parts and hold its form, but it will likely not be enough to hold the box together when contents are added. Joints work in the same fashion. When a joint has weak supporting attachments, the integrity becomes compromised. Force closure is produced from myofascial contractions that provide further stabilization and support. Variable stress and loading conditions warrant different levels of stability at different times and at different angles. It is the role of force closure to support the deficiency of form closure by increasing compressive force across the joint surface at the moment of loading. The quantity of force closure needed to adequately ensure support is a product of the individual’s form closure and the overall magnitude of the load (i.e., a cardboard box with heavy contents requires more tape to support the disruptive force). The efficiency of associated ligaments, muscle, and fascia determine the resultant stability. Due to changes in the joint angle, the degree of force closure will vary. The joint is most efficient at resisting shear stress when the joint angle reaches a close-packed position as it has maximized both congruence of the articulating surface and tension of associated ligaments [2,3]. This explains why stability requirements across a movement or joint angle vary when the relative mass and base are consistent. During resistance training the load is harder to move at certain
joint angles due to inefficiency in stability. Weightlifters refer to this position during an exercise as the **sticking point**, as it is the most difficult angle to overcome during the movement.

Form and force closure are also dependent upon the integrity of associated tissues. When connective tissues are healthy, **elastic**, strong, and balanced there is limited disruption to an area, suggesting no undue resistive stress. When **agonist** and **antagonist** muscles lose their functional relationship, or tissues shorten, the internal environment experiences added stress, and these musculoskeletal changes will, over time, offset the skeletal position. When joints are misaligned, the support of form closure is reduced, placing increasing demands on soft tissues for force closure to maintain the same level of stability. In exaggerated conditions, these changes are referred to as skeletal distortions or syndromes (e.g., forward chin, upper or lower cross syndromes). These syndromes, while surprisingly common in athletes, add significant resistance to movement and stability. Due to the compromise in movements, a new battery of exercises designed to correct these issues have become a staple of many competent performance-based programs. These concepts will be addressed further in the following chapter.

**Motor Control**

![Figure 4.3 Foundational components of stability](image)

Motor control is the third component of the integrated model of function. It specifically refers to neuromuscular activation within motor units. Most people think of muscles as movers, but the role of the tissue goes well beyond the need to produce force for acceleration. The idea of motor control suggests forces are produced to cause or resist movement. This is supported by different types and timing of contractions, whether **concentric**, **eccentric** or **isometric**. It is important to understand it is not simply the magnitude of the force that provides stability, but rather the timing of activation and deactivation. Therefore, stability across a joint is unique to the demands placed upon it, suggesting a person may have independently strong muscles but poor relative stability in varying environments. This addition is important for testing and evaluation of muscular tissues as quantifiable force output is a factor of the tissue’s function in a particular environment. This concept is easily exemplified when comparing machine versus free weight lifting. When using machines, the stability is controlled by external factors, as there are no weights to balance or control, whereas with free weight training the body alone provides the stabilizing effort. A person that can generate a large amount of force when using machines will
not be able to produce the same force in free-living conditions. This explains the limited role machines often play in athletic testing and development.

The role of the nervous system is paramount to stability. Performance improvements have been noted within just a few days of training repeated movement patterns. This occurs without discernible changes in muscle strength or size. This has been thoroughly explained by neural improvements such as an increase in the number of motor units recruited, improved motor neuron excitability, improved synaptic efficiency, and increases in antagonist repression (or lower antagonist excitability) [4,5]. As mentioned earlier, activation is referenced as a production of force; depending on the situation a muscle may need to contract for the purpose of accelerating or decelerating a joint, or simply to hold the skeleton in place. The efficiency of motor control is then dependent on the interaction of muscle activation, often referred to as force coupling. When muscles work together, the resultant outcome is greater force produced at the expense of less energy. Unlike fitness-based programs that aim to burn calories, athletic-based programs aim to spare energy to prevent fatigue. The more balanced the activation through cooperative motor units, the better the movement quality, and the lower the energy demands of the activity.

**Emotion**

The forth domain of the integrated system is non-physical in function, but a factor in physical performance nonetheless. Focus is integral to technique and execution, and is psychomotor-dependent. This concept clearly identifies the intimate role of the brain and muscle tissue in physical actions. New research indicates that repetitive practice with increased elements of visual focus and rehearsal improves brain interaction for finite adjustments in movement efficiency. The use of targeting, location stimuli, and other focal interactions with trained movements improve performance. These improvements have been demonstrated at the elite level, suggesting that although rehearsal leads to quality patterns, greater stimulus of the brain can further improve the efficiency of movement [6,7,8,9,10,11].

Conversely, lack of focus or specific focal distracters impede motor controls. The fight-or-flight system is based on excitation to promote energy availability. The biochemical response affects both metabolic and neuromuscular pathways. Additionally, the type of emotion and degree of the stress response determines the level of interference with physical actions. Over-excitation can be just as bad as a lack of excitation, which can be further influenced by both real and perceived cognitive stimuli. Stress can cause acute and chronic adrenal responses, leading to varied levels of cortisol and epinephrine in circulation. The concentration of stress hormones released consequently affects the sympathetic nervous system and may elevate the levels of excitation. This is relevant in finite actions, such as putting in golf, as well as highly-controlled actions including throwing a curve ball or kicking a field goal – where psychological or emotional stress can be a significant neural distracter. Kicking a field goal in practice, for instance, does not compare to a game-winning opportunity in the NFL playoffs. Likewise, emotional states are physically expressed and can lead to postural adjustments and mechanical changes. Depression, anger, and perceived defeat can all play an important role in motivation, consequently affecting the resulting physical effort. The effects of emotional state are so significant in high-level performance that a sub-field in psychology is devoted exclusively to sport [12].

---

**DEFINITIONS**

**Cortisol** – A steroid hormone released from the adrenal glands in response to stress; serves a key role in liberating fuel from various tissues.

**Epinephrine** – A hormone and neurotransmitter that affects the sympathetic nervous system and is responsible for the fight-or-flight response, also called adrenaline.
Local and Global Systems

Muscles and joints constantly interact to move and stabilize the body during sports participation. While some segments require high-velocity recruitment for rapid movement, others must simultaneously inhibit undesirable body actions. When harmonized, fluid energy transfer across stable joint segments results, and can be observed by fans as a desired athletic event. This occurs through the coordinated actions of three systems, independently referred to as passive, active, and control systems. Effective load transfer occurs when these three neuromuscular systems cooperate adequately: meaning that the interaction satisfies the desired outcome but is not necessarily optimal. Adequate speed and force transfer, for instance, allow a baseball player to hit a ball 300 feet; however, under optimal conditions, the same player could have hit the ball 400 feet: the difference between a fly-out and a homerun. In most cases, the initial energy potential is lost as heat due to inefficient force transfer across motion segments. Consider this: when a baseball player swings the bat, the energy is derived from ground reaction forces that must transfer through the legs to the hips and trunk; here, force is further accelerated to the arms and ultimately manifested in the hands at the bat. Any loss in energy along the kinetic chain represents a reduction in the quantity of kinetic force that can be applied to the ball.

The interaction between form and force closure dictates the alignment of a joint structure. When misalignments occur, form closure undesirably adapts over time, often resulting in a positional shift between articulating surfaces. For instance, the glenohumeral joint will commonly experience forward migration of the humerus in response to tightness and musculoskeletal imbalances, causing disruptions both in the joint itself as well as scapular function. One must remember that the body is fully connected and integrated, so when one aspect shifts another is thrown off. Subsequent efforts to support movements result in internal modifications as the body adjusts the corresponding force closure of joints to accommodate any changes. Over time, skeletal deviations can become more pronounced as soft tissues lose balance in both strength and activation. This deficiency underscores a fundamental need to restore proper form closure. The structural level should be addressed preferentially in performance-based programs, suggesting joint function should be optimized before attempting acts aimed at acceleration. Consider the following analogy: if a car has a bent axle, it would make more sense to correct the axle issue before adding more horsepower to the motor to make the car drive faster. Pushing the car to attain faster speeds without addressing the compromised axle will simply cause the problem to worsen and eventually will result in structural failure. Positional alignment of the skeleton works in a similar manner. For instance, the aforementioned forward shoulder position is a common disorder in sports that emphasize repetitive, overhead arm movements such as swimming, tennis, and baseball. As might be expected, excess acceleration strength (without adequate deceleration

![Figure 4.4 Major factors influencing the transfer of force](image)
potential) and tightness generally lead to an anterior migration of the humeral head due to a constant forward pull. Again, this situation is similar to the bent car axle. The loss of efficient form closure leads to dysfunction, which presents as resistance to movement and elevated stress on joint tissues, often resulting in injury. In such a scenario, a strength and conditioning coach must ensure adequate strength balance and ROM at each joint segment prior to emphasizing applications of loading or velocity.

At this point, it should be clear that force closure makes up for deficiencies in structural form, adding to stabilization in a joint or joint system such as the spine. While the interplay of connective tissue is relevant to force closure, the muscular system has the greatest potential to promote or resist movement \( [5] \). A muscle’s function at any given time may be to stabilize, neutralize, accelerate, or decelerate a body segment, depending on the action required. To ensure that all roles are appropriately accounted for within and between systems, the body maintains specific muscular arrangements at each joint and between joint segments. These arrangements provide each muscle or muscle group with specific responsibilities, which change from time to time, depending on the action being performed. Generally, they fall under two categories: local systems or global systems \( [13] \). Local systems pertain to those essential to segment stability; the muscles are often smaller and internally located, aiding the ligaments in holding bony segments in place. Examples include the multifidus, supraspinatus, soleus, and pelvic floor. Global system musculature is responsible for regional stability and motion and tends to function in a phasic manner suggesting the activation is not constant but rather cooperative with other muscles. Phasic muscles activate as necessary to promote or reduce movement. Examples include the rectus abdominis, vastus medialis, and gastrocnemius. Global stabilizers may also function as global movers, depending on variables such as the type of action or direction of forces. Inexperienced coaches oversimplify the function of a muscle or its functional group, not acknowledging that these tissues perform a number of varying responsibilities beyond simply accelerating linear movement in a single plane.

Local stabilizers, such as single joint muscles, are designed to reduce segment translation (or articular sliding). They do not control ROM but rather prepare a body segment for oncoming force. Therefore, they must function in an anticipatory manner and must precede movement or a loading condition \( [9] \). This is particularly important for the spine, underscoring the importance of the local stabilizing system of the trunk. Due to the anticipatory response and early activation, there is a significant neurophysiological difference in the timing of contractions between the local muscle system that stabilizes the spine and the global muscle system that acts upon it. This allows one system to anchor to the other. In healthy individuals, the activity of all trunk muscles precedes that of the muscle responsible for limb movement, thus contributing to what is referred to as the feed-forward postural response \( [16] \). Simply put, the trunk must brace for forces placed upon it so it has adequate rigidity at the time the forces are applied. To the contrary, when these muscle experience a delayed firing response, forces go unmanaged, ultimately leading to chronic low back pain \( [14] \). In normal function, local stabilizers perform rapid contractions in anticipation of multi-directional limb and trunk movements. This also occurs under conditions of predictable loading. In the spine, anticipatory actions prepare the vertebrae for unexpected perturbations regardless of the direction of the movement \( [15,16,17,18,19] \). The global system responds more slowly and is, therefore, directionally dependent \( [20,21] \). Individuals with dysfunction demonstrate inefficiency at the local level, ultimately affecting the global level. These individuals demonstrate an increased risk for injury and reduced performance.

**DEFINITIONS**

**Local systems** –
Musculature essential for localized joint stability and neutral joint position; the muscles are often smaller and internally located and do not produce movement.

**Global systems** –
Musculature responsible for regional stability and motion that tends to function in a phasic manner (works cooperatively with other muscles).

**Translation** –
A motion in which all body parts are involved in the same movement vector, often refers to joint sliding.

---

**Sport Biomechanics**
While each joint possesses a local and global system that requires some level of attention for proper function, the greatest risk for inefficiency occurs at the trunk. This risk results not only due to the number of joints and muscles involved, but also because of the relationship the trunk plays in the function of the hip and shoulder. Over the last two decades, significant attention has been paid to the efficiency of the lumbopelvic region’s local system in both the prevention of back injuries and efforts to improve athletic performance. While the local system must perform functionally to protect the articulating segments of the spine, it also serves as the foundation of energy transfer from the hip. While efficient form closure of the hip allows for excessive loading, the ability to transfer energy across the joint requires optimal efficiency in trunk stability through force closure. Lack of efficiency in the trunk reduces performance in any condition where the energy manifests itself in the hands (i.e., baseball, volleyball, basketball) or feet (i.e., soccer, swimming, track), particularly when the hips are the foundations of force development.
Components of Local and Global Stability

The local stabilizers of the trunk are referred to as the **inner unit**, whereas the global segments are often called the **outer unit**. Collectively these muscles represent the “core,” a term commonly used in error to describe the abdominal musculature. While many experts agree that the inner unit is comprised of the diaphragm, pelvic floor, transverse abdominis, and multifidus, others argue a second layer is continuous to localized stability including the deep fibers of the psoas, medial fibers of the quadratus lumborum, lumbar parts of the lumbar iliocostalis and longissimus, and the posterior fibers of the internal oblique. It is likely that these muscles play a dual role, acting tonically or phasically under varied conditions. Regardless of the specific role each muscle plays, the collective contribution is the relevant factor, as this system of muscles must stabilize the spine and pelvic girdle (anticipate and respond) to manage both additional (running) and external (lifting) forces. The purpose for the discussion of these concepts is not to encourage memorization or argument as to the muscles involved, but rather to create training conditions that promote the desired performance outcome by understanding what effectively challenges these systems. Again, looking at training from a systems approach ensures that proper integration of muscle activity is accomplished. Conversely, individually addressing these muscles promotes independent activation, rather than cooperation.

**The Inner Unit**

*Transverse abdominis (TVA)*

The TVA is an anticipatory muscle vital to spinal stabilization. A delayed firing response in the TVA is linked to dysfunction in segment stability and lower back pain. Along with the
diaphragm, the TVA plays a key role in producing and maintaining intra-abdominal pressure to manage flexion and extension of the lumbar spine\textsuperscript{[14]}. Efficient recruitment of the TVA and diaphragm provides resistance to undesirable anterior or posterior movements of the spine. In addition, the TVA aids in rigidity of the thoracolumbar fascia: an anticipatory response requisite to preparation for external loads\textsuperscript{[33]}.

**Diaphragm**

If the inner unit is compared to a box, the diaphragm represents the top panel. While often considered solely a respiratory muscle, it also serves as a local trunk stabilizer with incredible multi-faceted control. Regardless of the phase of respiration, contraction of the diaphragm occurs simultaneously with the TVA. Additionally, under sustained loads, the diaphragm responds tonically throughout the respiratory cycle to support the trunk. The muscle can also function phasically to modulate upper body actions while respiratory and postural activation occurs\textsuperscript{[32]}. The diaphragm functions in three ways: increased tonic activity, phasic modulation with respiration, and phasic modulation with movement. When combined, these functions allow for a variety of repeated loading conditions\textsuperscript{[33]}.

**Pelvic Floor**

Continuing with the box metaphor, the pelvic floor serves as the bottom of the box and critically stabilizes the spine: it captures the internal energy by anchoring the pelvic girdle\textsuperscript{[14]}. The pelvic floor, or pelvic diaphragm, is composed of muscle fibers of the levator ani, the coccygeus, and associated connective tissue of the parietal pelvic fascia that span the area underneath the pelvis. The pelvic floor separates the pelvic cavity from the perineal region. Movement of the pelvic girdle during loaded conditions disrupts the anchoring effect, decreasing stability and increasing risk for injury. It seems to function based on abdominal activity and vice versa, contracting in response to abdominal hollowing and bracing, whereas the abdominals react to pelvic floor contraction commands. When the pelvic floor is weak, or maintains limited endurance, the abdominals take over and rotate the pelvis posteriorly due to the anterior insertion. This is evident in the posterior tilt that occurs during the lower phases of a back squat. Researchers suggest that a reflexive interplay exists in the pelvic floor\textsuperscript{[24]} as well as an intimate relationship between abdominal activation and spinal stabilization\textsuperscript{[34]}. Emphasis on pelvic floor contraction throughout loaded movements significantly improves inner unit activation\textsuperscript{[23]}. Empirical data suggests that focusing on proper activation of the pelvic floor is likely the best technique to ensure spinal/pelvic stability throughout a given movement. Contracting the muscles used to prevent urination is an easy cue for stimulating pelvic floor activation among athletes.

**Multifidus**

The multifidus is a deep muscle that connects the moving segments of the vertebrae. A distinction can be made between the functions of deep and superficial multifidus fibers. Superficial muscle fibers act on the spinal position, while the deep muscle fibers contribute spinal stability through reactive stiffening\textsuperscript{[35]}. The deep fibers of the multifidus are also known to anticipate the lumbar spine's need for stabilization. They are recruited prior to movements of the upper extremities when the timing of the load is predictable\textsuperscript{[35]}. The multifidus broadens upon con-
traction, providing rigidity in the thoracolumbar fascia via a “pump-up” action (hydraulic amplification). This contraction, in conjunction with the TVA, increases stiffness in the sacroiliac joint via intra-compartmental pressure which creates the hydraulic effect. This cascade functions with the pelvic floor to prevent undesirable changes in pelvic position during heavy squats and deadlift exercises.

At this point, it should be clear that an athlete will become more efficient when the neuromuscular system adequately senses anticipatory responses and can willfully manage activation based on appropriate signaling. The value of this information is not confined to the laboratory. Training conditions can educate the nervous system to better anticipate and respond to changing conditions on the field, court, or floor. This highlights the demand for specialized conditioning of the spinal and pelvic musculature; the better the ability of the CNS to predict force application, the better prepared the body will be to manage it. Additionally, diverse conditions stimulate different responses from the neuromuscular system, identifying the role of different loading variations and changes in velocity during speed-specific exercises and drills.

The idea of rigidity causes misconceptions for those training the trunk for velocity-based force or heavy loading. Notably, and perhaps counterintuitively, it has been shown that stability comes from offsetting forces, not from rigid environments\(^\text{[36]}\). Angular displacement of the vertebrae precedes limb motion in the opposite direction; likewise, rapid movements of the limb do not stiffen the trunk but are accommodated by trunk motion. Observing the principles of stability, in order to prepare for a movement the trunk moves in the opposite direction of the force and then contracts to resist the direction of the loading force. This suggests that the body utilizes “reactive stiffness” and movement to dampen or dissipate the forces acting to upset stability\(^\text{[36,37]}\). Therefore, rather than an absolute rigid response, the body utilizes mobility and motor-controlled reactive stiffening for local actions and global stabilization. It is like playing the piano; if the keys are pushed in the proper order, the collective interaction creates a song. However, if the keys are not hit at the right time, incorrect keys are hit together, or one key sticks, the song becomes noise. Firing the appropriate muscles at the precise moment emphasizes the importance of motor control for integrated stability, and by extension, supports the use of dynamic applications (rather than isolated or static) for improved stabilization. Supine abdominal exercises on the floor and back extension on an incline bench hardly replicate the varying conditions to which the trunk is exposed in sport participation. It has also been well documented that static training (i.e., planks and wall squats), while useful for teaching initial activation, provide little transfer for improved sports performance. Appropriate trunk training activities will be illustrated later in the text.

The Global or Sling Systems (The Outer Unit)

The idea of mobility for stability identifies that the body functions using anticipation and cooperation. It inherently knows how to counteract force and will do so through whatever means necessary. Movement efficiency is not innate, but rather based on experience as well as physical and emotional health. This can be observed while watching different athletes (or non-athletes) perform drills and specific actions during competition. The means to the outcome may be “ugly” or fluid, but, in either case, the task is completed. Outer units or global movers also interact to produce optimal force and conserve energy by reducing resistance to force production. Early training models used to promote mass and strength, while still widely employed, are antiquated and often contradictory to many aspects of athletic performance. Training dominated by a single plane of motion or isolated muscle actions (as opposed to coordinated actions) causes the body to excel in the “weightlifting environment.” When that environment changes, so does the tissue’s

**Definitions**

**Hydraulic amplification** – The thoracolumbar fascia surrounding the muscles of the back creates a stable cylinder; back muscles contract within this cylinder creating a hydraulic effect via increased intra-compartmental pressure.
ability to generate the same force due to the specificity of stability. Bench press and leg press, while viable exercises for improving strength and mass, have limited transference into sport applications unless balanced with multidirectional athletic activities. In order to benefit from these types of exercises, ground-based activities must be utilized to incorporate these limited attributes into the kinetic chains employed in sports.

Clearly, the human body functions as a continuum rather than a series of independent muscle group actions. The entire body is connected by fascia, the nature of which permits muscle contractile forces to extend well beyond their respective insertion sites (whether for stability or movement). This fact suggests that integrating these systems during training would best serve overall athletic performance. Global muscle systems, or **sling systems**, are cooperative units designed to manage closed-chain actions \(^{2,3}\). Whereas energy is rooted in the ground and normally must manifest in limb actions during sports, the vital controls occur in the hip and trunk \(^{37,38}\). The limbs simply serve as the appliance. When it comes to locomotion and acts of sport, local stabilizers function with global systems (both stabilizers and movers) to optimize movement efficiency. There are four systems that function to stabilize the pelvis and allow for acceleration via the global movers: the anterior oblique, posterior oblique, deep longitudinal and lateral systems. As the term system implies, select arrangements of structures express the intimate interactions of specific local and global stabilizers with global movers \(^{2,3}\). For efficient athletic movements to occur, the skeletal system must be stabilized to allow for force transfer, external forces must be neutralized to prevent unwanted actions, and the global movers must fire in a coordinated manner to maximize acceleration. The body will utilize specific recruitment patterns from functional groups to support actions of locomotion, sprinting, climbing, throwing, and swinging.

**Anterior Oblique Sling System**

**Muscles involved** – external oblique, anterior abdominal fascia, contralateral internal oblique, and hip adductors

The anterior sling consists of the external oblique, the anterior abdominal fascia, and the contralateral internal oblique and adductors. The muscles coordinate to create cross-stabilization, much like a cross beam of a bridge, to stabilize the pelvis for sagittal plane locomotion. As the lower limb swings forward, the contralateral arm counter balances, and the trunk is stabilized from a diagonal (off-setting) firing pattern and reactive myofascial stiffening. The obliques, along with the abdominal fascia, support the trunk and rotate the pelvis in concert with the opposite adductor. This allows for an aligned heel strike under the hips during locomotion. Trunk stability contributes crucially to speed and the ability to run on varied terrains. Athletes who are required to accelerate quickly must develop an efficient anterior system.

**Posterior Oblique Sling System**

**Muscles involved** – latissimus dorsi, thoracodorsal fascia and gluteus maximus

The posterior sling system serves as the counter “cross-beam” to the anterior system. It contains a functional connection between the gluteals and contralateral latissimus dorsi through the thoracolumbar fascia which, under stretch, promotes sling force. During locomotion, the glutes fire for hip extension, serving the propulsion phase while the latissimus dorsi is activated for shoulder extension, providing counter rotation. The posterior fascia assists in stabilizing the pelvis and spine and maintains sling force, which assists in the transfer of load, while preserving

---

**DEFINITIONS**

**Sling systems** – Cooperative units designed to manage closed-chain actions
energy during basic locomotion. The fascia is integrated with internal stability, further aiding in energy sparing when the systems are efficient.

**Deep Longitudinal Sling System**

**Muscles involved** – erector spinæ, thoracodorsal fascia (deep lamina), sacrotuberous ligament, biceps femoris and peronei

When an athlete sprints, increasing stride length and frequency places greater demands on force production for both propulsion and stabilization. Forward acceleration is rooted in the ground and the energy must travel over multiple joint segments to allow for efficient turnover. This requires the center of mass to be elevated to make the runner “light on his feet,” while allowing for the greatest loss (and regain) of stability, observed by longer strides. The longitudinal sling connects the deep lamina of the thoracolumbar fascia and erector spinæ to the bicep femoris via the sacrotuberous ligament, extending distally through the peronei. Due to the length of the system, there are several segments which must be stabilized. Above the pelvis, the erector spinæ and thoracolumbar fascia manage the energy. Below the pelvis, the biceps femoris coordinates the system by relaying communication from the superior musculature through the sacrotuberous ligament of the pelvis. Essentially, it uses a top down approach for hip and knee stability. Distally, the peronei muscles control ankle and foot stability. Interestingly, to generate high speeds, the trunk is a key element of stability. Upon a foot strike during locomotion, the thoracolumbar fascia and erector spinæ capture ground reaction forces, allowing for efficient forward displacement. Accelerating force without stiffness would reduce the effectiveness of the system in mass displacement both vertically and horizontally, resulting in reduced speed.

**Lateral Sling System**

**Muscles involved** – gluteus minimus, gluteus medius, tensor fascia latae, long and short ipsilateral adductors and contralateral quadratus lumborum

The lateral system functions to stabilize a loaded hip on an anchored base for actions such as climbing and stepping. The system is comprised of the hip abductors (tensor fascia latae, gluteus medius and minimis), ipsilateral hip adductor, and contralateral quadratus lumborum. During an action such as a step-up, the pelvis is stabilized by the abductors and adductors of the plant leg while the quadratus lumborum elevates the pelvis in conjunction with the rising femur. This system is also integral to climbing, as the downward leg anchors the pelvis while the ascending hip and knee flex to establish a new anchor height.

**Overall Role of the Sling Systems**

Primal humans would have pursued energy sources (food) and safety (fleeing predators) by walking, running, and climbing. The intensity of these activities in sports subjects the body to high forces and ever-changing environments. As previously detailed, the sling systems are important for proper function of the skeleton during mobility via regional stabilization. Therefore, training programs should be mindful of the connections and interactions within and between these systems. To further underscore their relevance, the interactions of these muscle groups produce “slings” of force that transfer the load across bodily segments. Although the description of the sling system has been oversimplified for learning purposes, the actual interactions between the body’s inner and outer units during sport actions entail a highly coordinated relationship. They allow an athlete in motion to take advantage of the forces already created. It is much easier
to manage force once it has been created, than to constantly have to produce more. Consider running downhill compared to running uphill. Running at a slight decline allows the body to take advantage of the forces produced by gravity, whereas running uphill presents the opposite case. When training and conditioning for sport movement, the idea is to create more stable segments that consequently increase both the load the body can sustain and the rate at which the given load can be transferred. Likewise, in sprinting and agility movements, the pelvis must be stabilized to accelerate and control mass. Overemphasizing machine-based training or simply loading athletes without these foundations will significantly limit player development for athletic performance.

The concept of integration also complements the fact that a muscle may variously serve as a global mover and/or stabilizer during a sequence of rapid actions. The muscle may participate in more than one system, and slings may overlap during a sport action in order to capture and control force. Because fascia is connected, it logically follows that the slings are continuous to one another, comprising a single functional system in which selective activation occurs based on changing conditions [37]. In athletics, the body must manage the constant transference of force across the middle of the body as it represents the primary intersection between various limb actions. Previous examples, such as the bench or leg press, potentially disconnect this system concept in exchange for externally stable environments. Ultimately, one must understand that the environment to which the body is exposed and in which it gains experience is the one in which it will thrive. When the body is trained athletically, it becomes more comfortable in athletic environments, which are free-living and do not have the mechanical advantage of external support.

Common Postural Distortions

The body maintains an established process for stability and force management, but the efficiency of the interactions actually determines performance potential. Athletes predisposed to postural imbalances, or those that develop muscle imbalances, often experience impaired joint function, which compromises the coordination between systems and increases the risk for injury. Causes may include repetitive action common to a given sport or type of training, poorly-devised weight training programs, incorrect instruction or technique, and/or injury-related movement compensations. Although these conditions are often referred to as postural deviations, several interrelated factors exist that can also affect the joint’s efficiency. While some of these factors may be explained by localized dysfunction, others result from interaction between segments within a specified kinetic chain. For instance, a forward shoulder will likely cause impingement syndrome, an example of localized dysfunction. On the other hand, plantar fasciitis developed from gait changes associated with sciatica provides an example of a kinetic chain disturbance. Common postural deviations include a forward head position, rounded shoulders, abducted scapulae, kyphotic thoracic spine, hyperlordotic lumbar spine, and lateral pelvic tilt. Additionally, knee and ankle joints may also deviate due to local and global muscle imbalances.

When an athlete attains correct posture and movement mechanics, the subsequent efficiency equates to favorable use of force. Otherwise, muscular imbalances increase stress and resistance to stability and movement. Consequently, athletes with dysfunction require additional force and energy to perform the same task.
Assessment of posture is a mainstay to building an athlete from the skeleton out. This can be easily accomplished by using a plumbline to observe variations in anatomical positions. A plumbline aligned to the side of an athlete should run vertically through the hole of the ear, acromioclavicular joint of the shoulder, central vertebral bodies, the greater trochanter of the hips, slightly anterior to the midline of the knee, and end at the heel through the lateral malleolus of the ankle through the calcaneocuboid joint. This plumbline method was originally proposed in 1889 by Braune and Fischer [40]. Variations to this posture suggest a possible consequence in static posture and movement.

Genetic predisposition may increase one’s propensity toward postural deviations, but in general, afflictions developed over time may explain most occurrences. Repetitive forward and rotational (internal) acceleration at the shoulder common to baseball, tennis, swimming, and volleyball may lead to anterior migration of the shoulder. Tightness in the hip flexors from running or cycling can rotate the pelvis anteriorly, while weakness in the gluteals and imbalances in the knee extensors may lead to a propensity for an inward knee. Often, more than a single joint affects the functional system due to kinetic chain relationships. When one joint becomes misaligned, the resultant asymmetries can lead to several additional problems down the chain. For instance, recruitment of agonist muscles can become inhibited by overactive antagonists. This is commonly seen when the hip flexors take on a greater role in pelvic stability, resulting in inhibition of the abdominals and hip extensors. Additionally, changes in the joint angle can lead to range of motion deficiencies. This is commonly observed in the glenohumeral joint due to tightness in the latissimus dorsi and pectoralis musculature, which results in limitations to shoulder movement. When these issues occur, the body experiences greater resistance to joint movement as well as a reduction in stability and energy transfer.

Program models based solely on load may fail based on two common traits. The first situation occurs when loads are applied to a body that has skeletal function limitations. Without proper form and force closure, compensatory stabilization occurs as global movers are recruited to manage the effort. This leads to the rehearsal of faulty recruitment patterns, resulting in unde-
sirable adaptations. The second occurs in response to a poor progressive training model. Too often prime movers are trained in stable environments and then progressed to heavy, closed-chain, compound movements without establishing an efficient kinetic chain. High levels of strength in the local musculature without supportive stability from interactive joints leads to mechanical compensation and poor technique, which often leads to acute or overuse injuries. For instance, a hamstring pull may result during sports participation, but in many cases the impetus stems from improper training and programming. The problem with load-emphasized training methodologies is the risk they impose on postural faults rather than serving the primary role of preventing injury.

Each athlete should be evaluated for musculoskeletal efficiency to detect flaws in static and dynamic postures. In doing so, a program can be constructed to correct postural distortions. The first step in this process involves understanding the underlying characteristics that perpetuate the limitations. Commonly, the postural and phasic muscles are either becoming too tight or over-active, or they may become lax or underactive, depending on the chronic conditions applied. While the groupings are not synonymous, opposing groups generally reflect one side that is strong and inflexible while the other is weak and lax. Interestingly, postural muscles tend to exhibit tightness and increased strength from over-activity whereas phasic muscles progressively weaken [41].

Common postural muscles referenced in distortion include the upper trapezius, sternocleidomastoids, levator scapulae, spinal extensors, and hip flexors. The phasic muscles cited for risk include the lower/mid trapezius, abdominals, gluteal muscles, and vastus medialis. Without efficiency in joint function, postural muscles will incur increasing demands. In response, phasic muscles experience reduced stress and become weakened over time, inhibited by compensatory actions [41]. In order to influence phasic muscle activity while inhibiting postural muscle activation, traditional programs must be redesigned to emphasize specific activation patterns.

The deterioration of a functional system becomes most obvious when it is required to repeat high-velocity movements or stabilize heavy loads. Issues are worsened when system efficiency relies on the joint alignment of collective segments. For instance, in upper body actions, the shoulder depends on the position of the shoulder complex and thoracic spine, while in the lower body hip action depends on the relationship of the pelvis and lumbar spine (lumbo-pelvic hip complex). Independent joint systems, such as the knee or ankle, are also affected by the position and function of other joints. As such, a deficiency in hip musculature can affect efficiency within the knee, while changes in knee position can affect the ankle, and vice versa. This further demonstrates the relevance of addressing the kinetic chain in its entirety.

The aforementioned deviations have been categorized into clinically diagnosed musculoskeletal problems, including upper-extremity postural distortion, lumbo-pelvic-hip postural distortion, and lower-extremity postural distortion. Upper extremity distortions are often classified at one of three progressive levels in athletes. As mentioned earlier, these include a forward chin, kyphotic exaggeration, and upper-cross syndrome. In the elderly, an additional condition may occur as exaggerated structural changes coincide with osteoporotic microfractures, presenting as a Dowager’s Hump. While Dowager’s Hump is a structural deformity, the other three upper body distortions can be corrected with exercise. Interestingly, upper body problems tend to occur in the sagittal plane, whereas lower body distortions manifest in both the sagittal and frontal plane. Lower extremity distortions affect both the hip and limb joints. They include lower-cross syndrome (lumbar lordosis) and lateral pelvic tilt at the lumbo-pelvic hip complex, and foot pronation or outward rotation at the ankle.
Sometimes referred to as a level one upper body distortion, initial changes in posture begin at the cervical spine. In upper body distortions, the functional segment migrates forward. In the case of a forward chin, the postural muscles acting on the top of the axial skeleton become overactive; these postural muscles include the scalenes, sternocleidomastoids, upper trapezius, and levator scapulae with a coinciding underactive group of deep cervical flexors. This issue progresses into a kyphotic exaggeration as the mid/lower trapezius becomes less active, while scapular function is further compromised due to the chronically distorted posture. The progressive forward migration begins to affect the retractor and horizontal abductors as the rhomboids and the external rotators lengthen, adding to the current mid/lower trapezius dysfunction. This progressive cascade of events ultimately leads to rounded shoulders, a occurrence common to both inactive individuals and athletes alike. Amongst sedentary individuals, rounded shoulders are generally the result of poor daily posture and physical decline; on the other hand athletes have a tendency to participate in activities that overemphasize the musculature that mobilizes the arms in the anterior-sagittal and transverse plane. When this occurs, the glenohumeral head is pulled anteriorly, as the latissimus dorsi, teres major, subscapularis and pectoralis muscles become overactive, while the infraspinatus, teres minor, rhomboids, and mid/lower trapezius become lengthened and weak. Additionally, the posterior joint capsule of the shoulder tends to tighten and further fuel an anterior glenohumeral position. Upper-cross syndrome presents in the anterior view with raised, internally-rotated or horizontally-adducted shoulders, in addition to a kyphotic thoracic spine and rounded shoulders, in the lateral view of both erect and seated posture.

These upper body distortions not only create significant dysfunction during movement, but perpetuate injury during training, practice, and competitive play. Common issues include shoulder complex dysfunction, impingement syndrome, and kinetic chain disturbances. Prior to pain, a strength coach should recognize the tell-tale signs of limited spinal function, reduced shoulder complex efficiency and poor ROM. Loading these conditions will worsen the problem as compensatory adjustments will further fuel dysfunction. An athlete will not be able to successfully
perform Olympic lifts and other key compound movements like squats with proper technique if such deficiencies go uncorrected.

Problems associated with anterior migration within the upper body may also occur in a similar manner in the lower body. Lumbo-pelvic-hip postural distortions are characterized by increased lumbar extension and decreased hip extension, as the lumbar spine and pelvic spine are pulled forward. Lower-cross syndrome describes a combination of postural muscle tightness with phasic muscle weakness, recognized as a hyper-lordotic posture. Tightness is commonly seen in the hip flexors and back extensors including the iliopsoas group, rectus femoris, and thoracolumbar extensors. The phasic muscles that responsively weaken are the muscles of the inner unit, rectus abdominis, hamstrings, and gluteals. Athletes that suffer from lower-cross syndrome may experience acute or chronic hamstring strains, groin strains, low back pain, and related hip pathology [42,43,44]. Other associated problems include trochanteric bursitis, IT band syndrome, and plausibly spondylolitic conditions of the back [45,46,47]. Additionally, the hamstrings may not only be weak but also tight, further placing them at risk for injury. The combination of anterior tilt and weak abdominals will also increase the risk for weightlifting injuries during axially loaded conditions. Importantly, this issue results in a major compromise: the inability of the hip to be effectively employed as part of a functional kinetic chain. The anterior tilt inhibits the function
of the inner unit and the hip extensors. Of particular interest beyond the concern for injury is the fact that the hip extensors drive sports movement and acceleration, which may be significantly compromised with this level of dysfunction.

Forward and backward rotation of the hip is expected, but in some cases, frontal plane disturbances occur as muscles lateral to the spine and hip become imbalanced, resulting in a lateral tilt. Lateral pelvic displacement is one of the five major kinetic determinants of gait, but when stuck in a fixed position, it creates dysfunction in posture, locomotion, and movements involving knee and hip flexion \[1\]. When functional, the pelvis tilts laterally to synchronize the rhythmic movements of walking. This response is produced by the horizontal shift of the pelvis or relative hip abduction. Dysfunction often presents as a hip elevating or “hiking up” on one side of the pelvic spine, while the opposing side is depressed. A genetic scoliotic condition may be the cause. However, in athletes, a lateral postural distortion, sometimes referred to as lumbar scoliosis, or compensatory thoracic scoliosis, is more often the problem. Changes in the pelvic position lead to increased hip adduction on the raised side and subsequent increased hip abduction on the lowered side. The elevated hip causes adaptive shortening of the quadratus lumborum, erector spinae, multifidi, obliques, rectus abdominis, iliopsoas and hip abductors on the high side. The often overlooked and under-treated muscles include the entire adductor group on the depressed side of the lumbo-pelvic tilt. A lateral tilt is commonly attributed to repeated actions such as running or single-side dominant postures. Progressively, muscles become imbalanced in the associated stabilizers and are often cited as the primary problems: in particular, the quadratus lumborum, psoas, and iliacus on the elevated side, and hip abductors, including the gluteus medius on the lowered side are often overactive and tight. Lateral pelvic tilts can often be visibly diagnosed from the posterior view during squatting movements and, in more exaggerated conditions, presents as dysfunctional gait. Athletes commonly present with sacroiliac joint, hip, and midback pains. Complaints may also arise from translatory problems radiating away from the hip resulting from compensatory kinetic chain disruptions, (i.e., lateral thigh pain). Strength coaches should also be mindful of iliotibial band (ITB) tightness, which can occur due to consequent myofascial deformation. This often occurs from excessive training volumes applied without adequate preparation or an over-aggressive return to play.

Below the hip, additional lower body problems may exist. Tibial-femoral dysfunction is a collective term used to refer to the various distortions seen at the knee and ankle joints. These issues can include flat pronated feet with or without internal rotation of the knees (knees in), or feet pointed outward (heels in). Certainly, tightness specific to the joint can be the problem, but in many cases the disturbances originate along the kinetic chain. For example, dysfunction at the lumbo-pelvic-hip complex often leads to positional compensation in the knee and ankle. This occurs in response to changes in force that act on the femur. Essentially, biomechanical adjustments in the hip create a sub-optimal pelvic-femoral position. Consequently, changes in the length-tension relationship due to muscular imbalances affect the static and dynamic positions of the knee. To further emphasize the relevance of the kinetic chain in the lower limbs, when the hip flexors become too tight, the ability of the gluteals and hamstring to rotate the pelvis becomes limited. Since these muscles are integral to pelvic position and subsequent knee stability, weakness leads to femoral-tibial adjustments and postural dysfunction.

In the anterior view, when the feet are pronated and the knees move in, the probable over-active muscles are the vastus lateralis, short head of the biceps femoris, TFL, and adductor complex. The distortion occurs in response to weak gluteal muscles and inefficiency within the vastus medialis \[42\]. Similarly, when the feet “turn out” and heels rotate inward the issues likely lie

Positional compensation in the knee and ankle often occur due to disturbances further up the kinetic chain.
in the soleus, lateral gastrocnemius, and short head of the biceps femoris that have become overactive, while the medial gastrocnemius and hamstring, and long adductors have become underactive. Other muscles worth evaluating when faulty movements occur in the lower limb segments are the peroneals, adductors, ITB, ilioptosas, rectus femoris, sartorius and popliteus. Common injuries associated with adjustments in the knee position during flexion and extension includes plantar fasciitis, shin splints, IT band syndrome, and patellar tendonitis (jumper’s knee)\(^0\).

<table>
<thead>
<tr>
<th>Segmental Problem</th>
<th>Issues</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| **Forward chin**  | *Overactive:* Upper trapezius, scalenes, sternocleidomastoids, levator scapulae  
*Underactive:* Serratus anterior, mid-low trapezius, deep cervical muscles | Contributes to upper cross/upper thoracic hump, limits spinal function, reduces shoulder complex efficiency and ROM  
**Training issues** – vertical transfer from pulls, overhead pressing limitations, difficulty in receive positions of cleans and snatches and compromised core stability during front squats |
| **Kyphotic exaggeration**  | *Overactive:* Pectoralis muscles, subscapularis, latissimus dorsi, teres major  
*Underactive:* Rhomboids, mid-lower trapezius, teres minor, infraspinatus, posterior deltoid | Shoulder complex dysfunction, impingement and kinetic chain disturbances leading to injury  
**Training issues** – inability to perform overhead lifts, receives, and proper bilateral row position; compromise to spinal position during pulls and squats |
| **Lumbo-pelvic-hip postural distortion** (Lower cross) | *Overactive:* Calves, hip adductors, erector spinae, rectus femoris, iliopsoas  
*Underactive:* Glutes, hamstrings, abdominals, spinal stabilizers | Hamstring strains, groin strains, and low back pain  
**Training issues** – compromise to bilateral hip and knee flexion activities such as squats, inability to access core musculature, inhibition to glute-driven hip extension, and knee position during heavy loading |
| **Lumbo-pelvic-hip postural distortion** (Fixed lateral pelvic displacement) | *Overactive:*  
**High side:** Quadratus lumborum, iliopsoas, adductors  
**Low side:** Gluteus medius, TFL  
*Underactive:*  
**High side:** Gluteus medius, TFL  
**Low side:** Quadratus lumborum, erector spinae, adductors | Unilateral low and/or mid-back pain, hamstrings strains, adductor strains, IT band friction syndrome, lateral hip pain  
**Training issues** – compromise to all squatting actions, compensatory dominance in leg exercises and ballistic hip extension, difficulty in spinal stabilization |
| **Lower-extremity postural distortion** | *Overactive:* Calves, peroneals, adductors, iliobibial band, iliopsoas and rectus femoris | Planter Fasciitis, shin splints and patellar tendonitis (jumper’s knee)  
**Training issues** – improper activation during squats and compromised pull position, difficulty in single leg balance exercises |
REFERENCES:


