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CORE STABILIZATION IN THE ATHLETE

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OVERVIEW

The core is where the human body's center of gravity is located and where all movement begins. Core stabilization is particularly important for an athlete to achieve optimal performance. Whether the individual is competing at the school-age or an elite level, the athlete may experience pain symptoms only with functional overloading, while the pain may be absent or not disabling in normal daily activity. Additionally, injuries in other regions of the body can occur primarily because of poor core stability. However, treatment of injury is also different for the athlete, for complete functional recovery needs to take place in as short a period of time as possible (1).

All athletes are subject to the repetitive axial compressive and torsional forces required in athletic competition (1,2). Other factors involved include injuries due to collisions, the quality of the playing surface, the athlete's age and experience, and excessive physical demands of the sport (3). Many individuals have developed functional strength, power, neuromuscular control, and muscular endurance; however, few people develop the muscles required for spinal stabilization. Even with their peak conditioning, superior motor skills, and higher motivation, elite athletes have not only about the same incidence of back pain as the nonathlete population, but also have the same problems with activation of stabilizing muscles of the trunk (4). Athletes who train in one particular sport frequently, or who compete year-round without rest, may experience overtraining syndrome due to lack of definition of an optimal training zone and the limited ability of bone and connective tissue to quickly respond to match the demands of the sport. This has led routinely to arm, shoulder, and lumbar instability, chronic nonsteroidal anti-inflammatory (NSAID) use, and time loss injuries during the season (3).

THE CORE

The athlete's core is composed of the trunk, and the pelvic and shoulder girdles. The core operates as an integrated functional unit enabling the entire kinetic chain to work synergistically to reduce force load, dynamically stabilize, and generate force against abnormal forces. An efficient core allows for the maintenance of optimal length-tension relationships of functional agonists and antagonists, which makes it possible for the body to maintain optimum force-couple relationships.

All functional activities are multiplanar and require deceleration, dynamic stabilization, and acceleration. Movement may appear to be single plane dominant, but the other planes need to be dynamically stabilized to allow for optimum neuromuscular efficiency (1). Optimal articular range of motion, muscle strength and extensibility, stability, and the best automatic movement patterns possible must be present in these areas (5).

The trunk muscles must be able to hold the vertebral column in a stable position in order for independent upper and lower extremity movement to occur and to enable load to be transferred from the upper extremity to the ground. If extremity muscles are strong and the core is weak, there will not be enough force created to produce efficient movements. A weak core is a fundamental problem inherent to inefficient movement that leads to predictable patterns of injury. The core musculature is an integral part of the protective mechanism that relieves the spine of the excessive forces during competition.

Athletes who participate in high-impact sports that require great physical strength need strong core musculature in order to generate sufficient force to play their position safely and absorb the impact of collisions. Football players and hockey players must be able to generate force quickly, while being able to perform highly coordinated movements. This is not possible without a strong base musculature, trained in a sport-specific manner. Throwing or racquet athletes require strength and neuromuscular coordination throughout their trunk, pelvic and shoulder girdles, and lower extremities to generate the needed force from their proximal to distal upper extremity. Golfers generate most of their power though the trunk and pelvic girdle, even though the successful golf swing is mediated through the upper extremities (2).

The core maintains postural alignment and dynamic postural equilibrium during functional activities, and relies on an efficient neuromuscular system. If the neuromuscular system is not efficient, it will be unable to respond to the demands placed on it during athletic endeavors. A strong and stable core can improve optimum neuromuscular efficiency by improving dynamic postural control. As the efficiency of the neuromuscular system decreases, the ability of the kinetic chain to maintain appropriate forces and dynamic stabilization decreases significantly. Decreased neuromuscular efficiency leads to compensation and substitution patterns, as well as poor posture during functional activities. These altered patterns lead to increased mechanical stress on the contractile and noncontractile tissue, and lead to repetitive microtrauma, abnormal biomechanics, and injury. Research has demonstrated that people with low back pain have an abnormal neuromotor response of the trunk stabilizers accompanying limb movement, as well as greater postural sway and decreased limits of stability (1).

Decreased dynamic postural stability in the proximal stabilizers has been demonstrated in individuals who have sustained lower extremity ligamentous injuries. It has also been demonstrated that joint and ligamentous injury can lead to decreased muscle activity. Articular or ligamentous injury can lead to joint effusion, which causes pain, which in turn leads to muscle inhibition and altered proprioception and kinesthesia. The result is altered neuromuscular control in other segments of the kinetic chain, destabilizing them and breaking down the kinetic chain (3).

CORE MUSCULATURE

The neuromuscular system must be able to stabilize the spine against shear in all directions (i.e., torque, traction, and compression) if the trunk is to remain stable during repetitive or forceful activities and be able to absorb the impact of collisions. Stability is dependent on three systems (4,5):

1. A control system (neurologic).
2. A passive or inert system (skeleral, including the spine, and pelvic and shoulder girdles).
3. An active system (spinal and trunk muscles).

Bergmark classified the lumbar muscles as either local or global, while Lee refers to these muscles as the inner unit and the outer unit (5,7,8).

The Local Stabilizers

Local stabilizing muscles tend to produce little movement due to their positioning, and their overall length changes very little during contraction. They tend to be monarticular and contract during both agonistic and antagonistic movements, especially during high-speed movement. They are deep muscles that attach to the inert structures of the joint (capsule and ligaments), and tend to be tonic rather than phasic muscles.

The main local spinal stabilizers are considered to be the following (5):

- Lumbar spine: transversus abdominis and multifidus

- Thoracic spine: sternocostalis and rotators
- Cervical spine: multifidus, rotators, longus capitis, longus colli, and semispinalis cervicis
- Pelvic floor: levator ani, puborectalis, iliococcygeus, ischiococcygeus

The inner unit is thought to be composed of the pelvic floor musculature, the lower multifidi, the transversus abdominis, and the diaphragm (5). The pelvic floor muscles have been shown to contract with the abdominals. If all of the abdominals are contracted, all of the pelvic floor muscles also contract. If specific abdominal muscles contract, the specific pelvic floor muscles they are paired with also contract. Pelvic floor musculature is capable of moving the sacrum into either flexion or extension, and can prevent sacral movement when co-contracting.

The Global Stabilizers

Global stabilizers are larger muscles that function primarily in an agonistic manner, providing for movement of larger joints and functional units. Excessive contraction of the global muscles may occur in patients with poor ability to activate their local stabilizers. The result can be low back pain, or symptoms elsewhere in the body, depending on the activity of the athlete. The global musculature includes (5):

Longissimus thoracis
Iliocostalis lumborum thoracis
Quadratus lumborum (lateral fibers)
Rectus abdominis
Internal obliques (some authors include the internal obliques as part of the innet unit)
External obliques
Erector spinae

Key hip musculature involved with core stabilization includes (6):

Gluteus maximus
Gluteus medius
Psoas
Adductor complex
Hamstrings
Quadriceps

Four global muscular subsystems are associated with movement of the trunk and limbs, and equalize external loads placed on the body. These muscles function as integrated functional units, and are important because they transfer and absorb forces from the upper and lower extremities to the pelvis. These subsystems are as follows (6):

1. *Deep longitudinal:* Erector spinae, biceps femoris muscles; also the thoracolumbar fascia and sacrotuberous ligament. This system allows for reciprocal force transmission longitudinally from the trunk to the ground.
2. *Posterior oblique:* Latissimus dorsi, gluteus maximus muscles; also the thoracolumbar fascia. This system works synergistically with the deep longitudinal subsystem.
3. *Anterior oblique:* Internal and external obliques, contralateral adductors, and hip external rotators. This system provides transverse plane stabilization and force transmission.
4. *Lateral:* Gluteus medius, gluteus maximus, tensor fascia latae, the adductor muscle complex, and quadratus lumborum.

The fundamental precept of core stabilization is that muscles function as an integrated unit. The central nervous system is designed to optimize the selection of muscle synergies, not isolated muscles. Muscles not only produce force (concentric contractions), in one plane of motion, but also reduce force (eccentric contractions) and provide dynamic stabilization in all planes of movement during functional activities (1,6).

Core Stabilization Mechanisms

Three mechanisms assist in providing core stabilization in the athlete (1):

Thoracolumbar stabilization mechanism
Intra-abdominal pressure mechanism
Hydraulic amplifier mechanism

The thoracolumbar stabilization mechanism relies on the thoracolumbar fascia, which is a network of noncontractile tissue that plays an essential role in the functional stability of the lumbar spine. Although these tissues are noncontractile, the fascia can be engaged dynamically because of the contractile tissue that attaches to it. These muscles include the deep erector spinae, multifidi, transversus abdominis, internal oblique, gluteus maximus, latissimus dorsi, and quadratus lumborum. Contraction of the transversus abdominis and internal oblique creates a traction and tension force on the thoracolumbar fascia, which enhances the regional intersegmental stability in the lumbo-pelvic-hip complex. This contraction decreases translational and rotational stresses at the lumbosacral junction.

The intra-abdominal pressure mechanism decreases compressive forces in the lumbo-pelvic-hip complex. As the abdominal muscles contract, they push superiorly into the diaphragm and inferiorly into the pelvic floor. This results in elevation of the diaphragm and contraction of the pelvic floor musculature, and assists in providing intrinsic stabilization.

The hydraulic amplifier mechanism occurs at approximately 45 degrees of lumbar flexion when the electromyographic activity of the erector spinae decreases and "load-shifting" occurs to the noncontractile tissue and the eccentrically contracting gluteals and hamstrings. Potential energy is stored in these structures, which is then transferred into kinetic energy in the erector spinae during hip and trunk extension, reestablishing an upright posture. This is superimposed on an efficient thoracolumbar fascia mechanism. These stabilization mechanisms interdependently provide stabilization to the athlete's core.

Goals of Core Stabilization

Core stabilization is a concept that considers the integrated relationship between the legs, pelvis, trunk, and upper extremities. The aims of core stabilization are as follows (7):

1. Achieve localized segmental neuromuscular control.
2. Ability of the athlete to achieve and hold, isometrically, the position of power (neutral pelvis) or optimal stability.
3. Improve neuromuscular coordination between the trunk, pelvic, and shoulder girdles during changing movement patterns.
4. Improve the athlere's musculoskeletal and cardiovascular fitness and endurance.
5. Educate the athlete about what he or she can and cannot do, with regard to the particular injury or condition, if present.

Benefits of core stabilization training include improving dynamic postural control, ensuring appropriate muscular balance and joint arthrokinematics, allowing for the expression of functional strength, and improving neuromuscular efficiency throughout the entire kinetic chain. Manual therapy techniques are used to restore segmental and joint range of motion and decrease pain, reducing facilitation and inhibition of muscles and allowing better control of movement via appropriate concentric and eccentric work. If joint dysfunctions are present, they must first be addressed because they can inhibit the function of the surrounding muscles. Muscles can be inhibited due to pain, reflex inhibition, or disuse. Atrophy of multifidi muscles has been observed as a result of any of these causes. Pain and nonpain reflex inhibition must be reduced or eliminated before adequate activation and recruitment can occur. Core stabilization exercises provide for the education of intrinsic stabilizer muscles, thereby reducing stress on the anatomic restraints and providing a better base for the larger muscles to work from. Balance therapy reduces the amount of work the body must do to maintain stability over a constantly changing base of support. It is the clinician's job to ensure that the athlete has the following (or as optimal as possible) (5):

Pain-free status
Full segmental/articular range of motion
Segmental/articular stability
Normal muscle tone
Full muscle strength (isometric, eccentric, and concentric)
Full muscle extensibility
Normal balance
Normal movement patterns

Scientific Rationale

Most individuals, athletes included, do not adequately train their core stabilizers in comparison with other muscle groups. It is detrimental to perform exercises incorrectly or to perform exercises that are too advanced for the athlete. Research has demonstrated the following (1):

- Decreased firing of the transversus abdominis, internal oblique, multifidi, and deep erector spinae has been noted in individuals with chronic low back pain.
- Abdominal training without proper pelvic stabilization increases intradiscal pressure and compressive forces in the lumbar spine.
- Hyperextension training without proper pelvic stabilization can increase intradiscal pressure to dangerous levels, cause buckling of the ligamentum flavum, and lead to narrowing of the intervertebral foramen.
- Individuals with chronic low back pain demonstrate decreased stabilization endurance.
- Individuals with low back pain demonstrate decreased cross-sectional area of the multifidus. The multifidus did not spontaneously recover following resolution of symptoms. Traditional curl-ups increase intradiscal pressure and increase compressive forces at L2-3.

The core stabilizers are primarily type I slow-twitch fibers that respond best to time under tension muscle contraction. The contraction lasts for 6 to 20 seconds and emphasizes hyper-contractions at the end ranges of motion. This method improves intramuscular coordination, which improves static and dynamic stabilization. Core strength endurance must be trained appropriately to allow an athlete to maintain dynamic postural control for prolonged periods of time (1). It is important for the cervical spine to maintain a neutral position during core training as this will improve posture, muscle balance, and stabilization. Research has also demonstrated increased electromyographic activity and increased pelvic stabilization when an abdominal drawing-in maneuver is performed prior to initiating core training (1). This maneuver is described later in the chapter.

CORE STABILIZATION TRAINING GUIDELINES

Following a kinetic chain assessment, the clinician must address any muscle imbalances and arthrokinematic deficits that are discovered prior to beginning an aggressive core training program with any athlete. The following training guidelines are based on the optimum performance training method developed by the National Academy of Sports Medicine.

Program Design

The core stabilization program should be progressive, systematic, activity specific, integrated, proprioceptively challenging, and based on current science (1). During stabilization exercises, the athlete is taught to specifically recruit the trunk muscles isometrically and then to maintain this brace as he or she moves the upper and lower extremities independently. Initially, the base of support is very stable. The program is progressed by increasing the level of difficulty, by reducing the base of support, by making the base more unstable, and by increasing and changing the load that must be controlled. It is important to make the exercise program multiplanar and multidimensional, to use the entire muscle contraction spectrum, to use the entire contraction velocity spectrum, and to manipulate all acute training variables (sets, repetitions, intensity, rest intervals, frequency, and duration).

The core training program must address movements in the frontal, sagittal, and transverse planes, plus a combination of all three planes. Varying body positions can include supine, prone, side lying, sitting, kneeling or half-kneeling, and standing. The base of support can be varied, for example, a chair or exercise bench, a stability ball, or other balance modality. The lower extremity stance should be varied and progressed: two legs, two legs staggered stance, single leg, two legs unstable, staggered stance unstable, and single leg unstable. The upper extremity progression should also be varied: two arms, alternate arms, single arm, and single arm with rotation. Forms of external resistance can include barbells, dumbbells, cables, tubing, medicine balls, power balls, Bodyblade, and so on. Balance modalities that can be used to challenge the individual include progression from a stable surface (floor or chair) to a sport beam, Airex Pad, Dyna Disc, BOSU, Proprio shoes, and sand, to name a few.

The athlete should begin working in the most challenging environment he or she can control. The athlete is progressed through the program as mastery of the exercises is achieved, maintaining stability and optimum neuromuscular control. The exercises the athlete performs should be safe, challenging, progressive, proprioceptively enriched, and sport specific. The core training program can be manipulated regularly by changing the plane of motion, range of motion, loading parameters (stability ball, ball, weight vest, dumbbell, tubing, etc.), body position, amount of control, speed of execution, amount of feedback, duration (sets, repetitions, tempo, time under tension), and frequency.

The athlete is progressed by advancing the exercise components from slow to fast, from known to unknown, from a stable environment to a controlled environment to a dynamic functional environment, from low force to high force, and by emphasizing correct exercise execution with increasing intensity. Again, the goal of the program is to develop optimal levels of functional strength and dynamic stabilization. Neural adaptations are the focus of a core stabilization program rather than achievement of absolute strength. Quality of movement is stressed over quantity. The clinician who allows the athlete to train with poor technique and poor neuromuscular control may cause the development of poor motor patterns and poor stabilization. The focus of the program must always be on function.

From Small to Large

It is important to ensure that the athlete is able to recruit the inner unit or local stabilizers in a neutral pelvic position prior to beginning a core stabilization program. If this is not done, reinforcement of faulty postures and facilitation of abnormal movement patterns may predispose the athlete to injury in the future. Activation of the multifidi and transversus abdominis muscles is the initial building block of any core strengthening program.

Transversus Abdominis

In the hook-lying position, the athlete is asked to perform a drawing-in maneuver to bring the navel toward the spine. The pelvis is optimally in a neutral position, but if pain is a consideration, an anterior or posterior tilt may be incorporated, especially in the early stages of exercise. The athlete must not demonstrate the following compensations (5):

- Lumbar kyphosis or lordosis, or pelvic or thoracic movement; this indicates the inability to activate the transversus abdominis independently of the other abdominals. If this global recruitment occurs later, then fatigue may be the issue.
- Failure to perform the maneuver, delayed global recruitment, or shuddering; this indicates abnormal fatigability.
- Loss of normal breathing pattern or loss of abdominal draw; this indicates the inability to use the transversus abdominis independently of the diaphragm.

The athlete may find it easier initially to perform contraction of the transversus abdominis in four-point kneeling. In this position, the weight of the abdominal contents provides a stretch to the abdominal wall and may facilitate the contraction by increasing the athlete's awareness of the muscle and its contraction. If the athlete is able to activate the transversus abdominis independently, he or she is asked to maintain a contraction for 5 to 10 seconds while continuing to breathe normally.

If the athlete has a difficult time understanding how to contract the transversus abdominis, a pressure feedback cuff may be used in either supine or prone position to assist in providing him or her with feedback. In the prone position, the cuff is placed under the abdominals, and in the supine position, the cuff is placed under the lumbar spine. In prone, the cuff is inflated to 70 mm Hg while the athlete is asked to lift the abdomen off the cuff while continuing to breathe normally. If the pressure is reduced 6 to 10 mm Hg successfully, contraction has occurred. In supine, the cuff is inflated to 40 mm Hg. Again, the athlete is asked to perform the muscle contraction. He or she is asked to perform specific and progressive loading tasks while maintaining a steady pressure under the spine. Increases in cuff pressure (posterior pelvic tilt) or decreases in cuff pressure (anterior pelvic tilt) indicate a loss of stabilization.

Joseph Pilates developed a series of exercises that focus on increasing core strength, with emphasis on the individual's ability to perform the abdominal drawing-in maneuver to facilitate isolated contraction of the transversus abdominis. The cue "navel to spine" is frequently used while teaching exercises based on his method. Pilates classes are very popular today, and are used in both the rehabilitation and fitness arenas. Certified instructors teach exercises on the mat or the Reformer, and also use other aids such as the chair, the barrel, their Fitness Circle, and tubing.

Multifidi

The lumbar multifidi are important local stabilizers of the spine. The muscles are innervated segmentally. If the multifidi need to be reeducated in the athlete, palpation of the specific muscle in the paraspinal gutter will assist in determining if any atrophy has occurred, or if the area is tender. In prone, the athlete is asked to "swell" the muscle against the clinician's palpating finger. Facilitation by rapid stretching of the muscle by sudden, deep palpation may be necessary. The multifidi work synergistically with the transversus abdominis, so if the athlete is unable to activate these muscles volitionally, they may be activated in concert with the transversus abdominis. Electrical stimulation to the local muscle may also be of assistance (5).

Exercise Progression

Once the athlete is able to demonstrate isolated and sustained contraction of the local stabilizers with normal breathing and without overactivity of the global muscle system, and in any posture, he or she is ready to begin restoration of optimal movement patterns, or functional rehabilitation related to the specific sport. Volitional contraction of the local stabilizers must be transformed into an automatic load that is being put through the spine. Lighter loads and less complex movements are trained first.

Initially, the muscles are trained under light loads and static conditions. Isometric contractions in a variety of positions are designed to improve intrinsic stabilization and provide optimum neuromuscular control for the core. Gradually, the isometric stabilization exercises are replaced with dynamic concentric and eccentric activities throughout the full range of motion. The athlete is asked to move the arms and legs in functional directions while maintaining the abdominal draw in the pelvic neutral position. He or she must maintain control during active, and then resisted, concentric and eccentric muscle contractions. The specificity, speed, and neural demand of the exercises are progressed. Total kinetic chain neuromuscular efficiency is enhanced by providing maximum proprioceptive stimulation to the central nervous system during integrated functional movements while maintaining optimum stabilization of the entire core. Resistance from a variety of directions is initiated in supine hook lying, prone, and four-point kneeling positions. Once the athlete masters these positions, he or she assumes the sitting position and remasters the exercises. As previously mentioned, positions that may be used in training include

- Supine lying
- Side lying
- Four-point kneeling
- Two-point kneeling
- Sitting
- Standing
- Walking
- Running

Exercises that may be incorporated include

- Supine trunk and pelvic rotation
- Supine arm and leg
- Supine double leg bridge
- Four-point kneeling arm and/or leg extensions
- Sitting leaning
- Balance ball

Arm and leg extensions
Trunk rotations
Wobble board
Standing
Arm and leg extensions

Normal breathing and neutral spine posture must be maintained. The athlete can be challenged while walking or running, progressing to sport-specific activities. Swiss balls, wobble boards, inclined planes, discs, pads, and the like can all be incorporated into the program, thereby decreasing stability and increasing muscle recruitment to challenge the athlete as he or she masters successive activities.

Once the athlete demonstrates optimal neuromuscular control with a variety of movements, the training focus changes to the performance of sport-specific movement patterns. This incorporates more normal movement such as proprioceptive neuromuscular facilitation patterns. Sudden changes in direction, velocity, and contraction type (concentric, isometric, eccentric) are demanded from the trunk, arms, legs, and head. The athlete performs specific exercises at a similar intensity and similar rate of force production that is expected in his or her sporting environment.

CONCLUSION

All athletes should train their core through a functional exercise program to assist them in obtaining optimal physical performance as well as injury prevention. Specific functional exercise progressions are most beneficial, with the athlete mastering contraction of the inner unit muscles in a pelvic neutral position before progressing to more demanding exercises that incorporate the outer unit muscles and the entire body. Sport-specific core training exercises will provide the athlete an opportunity to use all body structures in a controlled environment before being subjected to the competitive environment. Faulty postures and poor mechanics should always be avoided. An athlete's core can nevet be too strong.

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