Core Stability: The Centerpiece of Any Training Program

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Core strengthening and stability exercises have become key components of training programs for athletes of all levels. The core muscles act as a bridge between upper and lower limbs, and force is transferred from the core, often called the powerhouse, to the limbs. Stability initially requires maintenance of a neutral spine but must progress beyond the neutral zone in a controlled manner. Some studies have demonstrated a relationship between core stability and increased incidence of injury. A training program should start with exercises that isolate specific core muscles but must progress to include complex movements and incorporate other training principles.

Introduction

Earlier sports training programs have focused on strengthening the extremities. Gyms traditionally were filled with athletes trying to maximize the weight of their bench presses and leg extensions. Recently, training programs that incorporate core strengthening and stability exercises have become popular because the core is the anatomic and functional centerpiece and the powerhouse of the body. All motions are generated from the core and are translated to the extremities [1•]. The importance of an efficient and stable core is promoted by most physical therapists, athletic trainers, and coaches despite the paucity of studies supporting its efficacy. Core stability is presently a theoretic concept that is becoming more popular as experience authenticates its benefits. It is a sensible theory that coaches and trainers have seized and are now incorporating into athletic training programs. A simple analogy gives credence to the concept: a car, for example, with the finest of tires, smooth transmission, and streamlined body still functions only as well as its engine, the powerhouse. Similarly, an athlete without a strong and stable core generates submaximal power and falls short of his or her athletic capabilities. He or she may also be at increased risk of injury [2]. In essence, the athlete is only as strong as his or her weakest link. Because the core is the athlete's powerhouse and links the trunk to the extremities, core stability should be the centerpiece of any athletic training program.

Defining the Core

Anatomically, the core is the musculature that surrounds the lumbopelvic region and includes the abdominals anteriorly, the paraspinals and gluteals posteriorly, the pelvic floor musculature inferiorly, the hip abductors and rotators laterally, and diaphragm superiorly. All these muscles have direct or indirect attachments to the extensive thoracolumbar fascia and spinal column, which connect the upper and lower limbs. Consequently, the core musculature and the thoracolumbar fascia are thought to play a role in trunk rotation and load transfer, and therefore, stability of the lumbopelvic region [1•]. Core muscles can be isolated as in doing a crunch which activates the rectus abdominus and obliques. However, a program in which core training focuses solely on crunches misses the mark because, functionally, all the core muscles act in concert with one another through varied and complex movements, especially when the person is participating in a sport. These muscles must act synergistically to stabilize the lumbopelvic region.

Defining Stability

Stability seems to be a straightforward concept; however, it is worth defining for this article. Similar concepts include core strengthening, muscular fusion, lumbopelvic stabilization, and dynamic stabilization. All these concepts are incorporated into our definition of core stability. However, it is our opinion that there is an important distinction between strength and dynamic stabilization. Core strength refers to muscle strength and endurance. Dynamic activities are those that cause the perturbations in the center of gravity in response to muscular activity [3]. Dynamic stabilization refers to the ability to utilize strength and endurance in a functional manner through all planes of motion and action despite changes in the center of gravity. Lumbopelvic control, and therefore strength, is thought to be inefficient without proper dynamic stabilization of the lumbopelvic region during daily activities, and in this case, during sport participation [4•].

Figure 1. Advanced lateral bridge.

Stabilization requires a neutral spine position as well as the ability to move through that position in a controlled manner. Neutral spine is commonly, but incorrectly, thought to be synonymous with a flat backed posture. Neutral spine is not one fixed position. Rather, it is a midrange of joint movement and is usually a position of comfort [5]. It is dictated by individual's inherent musculoligamentous flexibility and structural anatomy. Hence, adequate strength, muscle endurance, and flexibility of the hamstring, quadriceps, iliopsoas, gastrocsoleus, hip rotators, and tensor fascia lata muscles are necessary for postural control of the lumbopelvic region [6]. A position of balance is a position of power.

Force Transfer From Core to Limb

The process of using force generated at the core or trunk and transferring it to the limbs has been called the serape effect [7•]. Moreover, the serape effect incorporates the concept of transferring stored energy into potential energy [7•]. An example is a tennis player with a powerful and precise swing. What is not immediately evident is that the abdominal muscles, the transverse abdominus in particular, will activate first before limb movement is initiated [4•]. Consequently, as a tennis player tosses the ball up to serve, contraction of the transverse abdominus will first brace the body as the core generates power which will eventually be translated to the shoulder, elbow and wrist, and finally to the ball as the player makes contact.

The inability to transfer forces generated at the core to the extremities can result in decreased efficiency or injury. Previous studies have demonstrated the negative effect of weak core musculature on distal limb injuries. Beckman and Buchanan [8] compared subjects with chronic ankle instability with normal controls and noted a significant delay in firing of the gluteus medius muscle. Nadler *et al.* [9•] noted a nonsignificant reduction of low back pain in male athletes who participated in a core strengthening program.

Assessing the Core

Assessment of an athlete should include strength testing of the limbs and the entire kinetic chain. The core should not be neglected as it is the center of the kinetic chain and the origin of power. There are a few simple tests that will provide the examiner with essential information regarding the athlete's core strength and endurance.

Four tests that yield significant information are the prone and lateral bridges, and the torso flexor and extensor endurance tests. Whereas a simple crunch or reverse crunch provides information about abdominal strength, it does not tell us how those muscles function with more complex movements. The bridge tests are considered more functional because they assess strength, muscle endurance, and how well the athlete is able to control the trunk by the synchronous activation of many muscles. This more accurately approximates how the muscles function together. In our experience, it is astonishing how often athletic people who display exceptional limb strength lack both core muscular strength and endurance in order to perform these tests.

The prone bridge is done by supporting the body's weight between the forearms and toes and assesses primarily the anterior and posterior core muscles (Fig. 1). It is essential that the athlete keep the pelvis in a neutral position and the body straight. Failure occurs when the athlete loses neutral pelvis and falls into a lordotic position with anterior rotation of the pelvis. If the athlete lacks the endurance to hold this position, then he or she should start by supporting the body's weight on the knees instead of toes, which reduces the lever arm. Advanced athletes should progress to holding this position with the forearms positioned more cranially or with a weight on the back.

The lateral bridge assesses primarily the lateral core muscles. Juker *et al.* [10] laud this exercise as the most effective way to assess and train the abdominal obliques with little psoas (a hip flexor) activity as determined by myoelectric testing. Failure occurs when the athlete loses the straight posture and the hip falls toward the table. Like the prone bridge, the athlete may start out by supporting the body's weight between the knees and forearms. Advanced athletes should progress to abducting the upper arm and adding slight rotational movements while holding the position (Fig. 1).

Testing of the torso flexors can be done by timing how long the athlete can hold a position of seated torso flexion. The torso should be flexed at 60° and the knees and hips flexed at 90°. The toes should be secured under toe straps or held by the examiner (Fig. 2). Failure occurs when the athlete's torso falls below 60°.

Testing of the torso extensors can be done with the athlete in a prone position and the pelvis, hips, and knees secured on a table (Fig. 3). The upper body is held out straight over the end of the table. Failure occurs when the upper body falls from horizontal into a flexed position.

McGill [11••] has provided normative values for measuring endurance in each of these positions. They are as

Figure 2. Trunk flexors endurance test.

Figure 3. Trunk extensors endurance test.

follows (in seconds): left lateral bridge 86, right lateral bridge 83, flexion 34, and extension 173. Women's mean values are slightly less than men's with the exception of extension endurance. Unfortunately, normative values for the prone bridge have not been calculated, but in our experience, the athlete should be able to maintain this position for at least 60 seconds. Remember, strength will enable the athlete to get into the position; endurance will enable him or her to hold the position.

Another quick functional assessment is the star excursion test. The athlete stands on one leg and reaches as far as possible in all planes with the non–weight-bearing leg without touching the ground. The hips are evaluated for stability. A Trendelenburg sign may be apparent, indicating weak hip abductors. Lumbopelvic control and balance are also assessed and any functional differences between the planes should be noted and incorporated into the training program. Although Kinzey and Armstrong [3] have questioned the reliability of the star-excursion test, they suggest that it may be a useful way to improve proprioception and balance during training.

A quick trial of performing these tests with and without lumbopelvic bracing (by co-contracting the abdominals, multifidi, and gluteals) will convince any athlete of the importance of activating the core in order to better control the limbs.

How to Train the Core: The Inside-Out Concept

Foremost, proper technique is imperative, as loading the muscles with improper technique or poor biomechanics places the athlete at risk of injury. According to Hodges and Richardson [4•] and Sharp *et al.* [5], dynamic lumbopelvic stabilization is achieved through training of both local and global systems. The local system consists of muscles that have direct attachment to the spine and controls segmental motion. These are the transverse abdominus and multifidi. Local stability depends on the ability to activate these muscles.

The global system consists of muscles that do not have direct attachment to the spine and produce larger torque that cause trunk and spine movements. These muscles are the rectus abdominus, the internal and external obliques, and the thoracic iliocostalis [4•,5].

Because of the proximity to the spinal column, the local muscles have shorter lever arms. Therefore, they effect small movements and should be activated before the global muscles. Research has shown that, prior to hip motion, the transverse abdominus is the first muscle contracted, and this muscle together with the multifidi activate in anticipation of forces produced by lower extremity movements [4•,12]. Therefore, proper training requires that the athlete learn to activate the local system to stabilize the lumbopelvic region prior to recruiting larger torque-producing muscles.

Richardson *et al.* [12] advocate the co-contraction of the transverse abdominus and multifidi. They also stress the importance of simultaneous activation of pelvic floor and transverse abdominus. The subject is educated in the co-contraction through palpation of the lower abdominal wall during a "drawing in" exercise when the lower abdomen is actively pulled posteriorly. At the same time the subject contracts the pelvic floor and slightly anteriorly rotates the pelvis to activate the multifidi [12]. Assessment of optimal recruitment of these muscles, particularly the transversus and multifidi, is done through palpation, but may also be done with pressure readings obtained by a biofeedback unit or with electromyography [5].

It should be noted that McGill [11••] does not agree with the concept of the two separate systems. Rather, he theorizes that all stabilizers are important and dynamically change depending on their need to contract to perform the required task. McGill advocates "bracing" the spine, which activates all the abdominal musculature and extensors at once. This is usually accomplished with the athlete in a standing position by first palpating active low back extensors while the torso is slightly flexed. The athlete then moves into extension until the extensors shut off, at which

Figure 4. The bird-dog test and exercise.

time the abdominals are contracted and the extensors reactivate [11••].

Diaphragmatic breathing is also an essential component of training the core musculature as the diaphragm is the roof of the core. The athlete is taught to breathe with the diaphragm rather than the accessory muscles of the upper rib cage. Stability of the spine is increased as the diaphragm contracts and increases intra-abdominal pressure [13••].

Progression of the Training Program

Once the athlete has learned to stabilize the lumbopelvic region utilizing the above isometric-type exercises to create a functional muscle corset, progression of core conditioning and stabilization can begin. McGill [11••] recommends early incorporation of the "big three" exercises into a training program. They are as follows:

1. Curl-ups for rectus abdominus. The rectus is most active during the initial elevation of the head, neck, and shoulders. The lumbar spine should stay in neutral.
2. Side bridge exercises for the obliques, transverse abdominus, latissimus, and quadratus. This exercise is very challenging to the lateral obliques and transverse abdominus without generating high compressive loads at the lumbar spine.
3. Leg and arm extensions in a hands-knees position, eventually leading to the "bird-dog" exercise for the back extensors (Fig. 4).

These basic strengthening exercises are initiated on the ground; however, the exercises must progress to positions of function, from a stable ground environment to a progressively less stable environment, and movements must increase in complexity. In other words, the athlete must progress from muscle activation and strengthening to a program of dynamic stabilization. Practice is critical to ensure that proper stabilization will be transferred from the training setting into the sports arena [14].

There are several important principles when it comes to progression. They are dynamic exercises, multiplanar exercises, balance, proprioception, power exercises (plyometrics), sport-specificity, and engram motor programming. First, when the athlete has mastered proper activation and control of the lumbopelvic region, he or she should progress from a stable surface to a labile surface. Eventually, external input can be added to challenge the athlete even more. An example of dynamic progression is progressing from lunges done on the floor to lunges done on a soft mattress. In addition, exercises performed on a stability ball greatly challenge the athlete dynamically.

Second, exercises must be performed in all planes. The sagittal plane is the most commonly trained plane. Sit-ups and forward lunges are examples of common sagittal plane core strengthening exercises. Frontal plane exercises are also popular and include side walking and lateral bridges. The transverse/rotational plane is frequently neglected but crucial to incorporate into the training program. An example of an exercise that incorporates the transverse plane is when the athlete, in a standing position, grasps a medicine ball with both hands and moves it diagonally through all planes. This exercise serves to strengthen the often-neglected external obliques and mimics the more complex movements of sports. The exercise can be further upgraded by standing on a labile surface, which will challenge strength, endurance, balance, and proprioception.

Third, proprioceptive training should be incorporated. It has been noted that proprioception is significantly impaired by muscular fatigue [15], which highlights the importance of incorporating all training principles into a comprehensive program. Sharpening proprioception is actually quite simple and remarkably useful to the athlete. A sprained ankle will not be fully rehabilitated if proprioception training is not incorporated. Balance board or Dyna-Disc (Lake Eerie Medical, Hinckley, OH) training not only sharpens the body's reaction to postural perturbations at the ankle, but at other joints up the kinetic chain as well. Mechanoreceptors are present in all tendons and muscles including the core musculature. Learning is quick as unconscious neural patterns are established that provide the athlete with increased joint stability, freeing the athlete to concentrate on other aspects of the game.

Finally, power exercises (plyometrics) and sport-specific training should be incorporated. Jumping exercises hone the skills of eccentric and concentric loading of muscles, which has been shown to be important in the prevention of tendinous injuries [16]. Keep in mind that the core is the powerhouse and the athlete must have a strong and stable core in order to translate that power to the lower limbs for the most effective jumping. Additionally, these exercises should be multiplanar and upgraded to include labile surfaces.

During the neurodevelopmental stage of postural control, the athlete may consciously brace the core muscles, but eventually, it becomes second nature. Patterns are established and the athlete progresses from basic postural awareness and control to engram motor programming that is automatically patterned in the motor cortex, available without conscious effort [4,6]. To use the previous example, the tennis player will automatically brace the core in anticipation of limb movement for a swing or serve. Once engram motor programming is established, the athlete no longer has to think about what to do. It happens automatically, without additional thought or effort.

Conclusions

All athletes strive to achieve their highest level of skill through sport-specific training regimes. In order to attain this level, the athlete should have a focused core stability training program incorporated into the overall regimen. Core stability should be initiated at the start of the training program and must be continuously upgraded as strength, endurance, coordination, and skill improve. We have addressed what constitutes core musculature, how those muscles relate to lumbopelvic stability, and the vital importance of addressing core stability in any training program.

References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:

- • Of importance
- •• Of major importance

1.• Vleeming A, Pool-Goudzwaard AL, Stoeckart R, *et al.*: **The posterior layer of the thoracolumbar fascia: its function in load transfer from spine to legs.** *Spine* 1995, **20**:753–758.
Detailed and comprehensive study that describes the anatomic basis of effective load transfer between the core and limbs.

2. Solomonow M, Zhou B, Harris M, *et al.*: **The ligamento-muscular stabilizing system of the spine.** *Spine* 1998, **23**:2552–2562.

3. Kinzey SJ, Armstrong CW: **The reliability of the star-excursion test in assessing dynamic balance.** *J Orthop Sports Phys Ther* 1998, **27**:356–360.

4.• Hodges PW, Richardson CA: **Inefficient muscular stabilization of the lumbar spine in association with low back pain: a motor control evaluation of tranversus abdominis.** *Spine* 1996, **21**:2640–2650.
Experimental study that describes the contribution of the transverses abdominus to lumbopelvic stabilization. The authors conclude that that delayed onset of contraction of the transverses abdominus results in a deficit of motor control, which is hypothesized to result in efficient lumbopelvic stabilization.

5. Sharp RW, Olson KA, Maxeiner A: **The effectiveness of the pressure biofeedback unit in the treatment of a patient with clinical lumbar spinal instability: a case report.** *Orthop Phys Ther Pract* 2004, **16**:17–21.

6. Saal JA: **Dynamic muscular stabilization in the nonoperative treatment of lumbar pain syndromes.** *Orthop Rev* 1990, **19**:691–700.

7.• Konin JG, Beil N, Werner G: **Facilitating the serape effect to enhance extremity force production.** *Athlet Ther Today* 2003, **8**:54–56.
Descriptive article that explains why deficits in core strength and flexibility and the inability to transfer forces generated at the trunk to the extremities can lead to injury in the athlete.

8. Beckman SM, Buchanan TS: **Ankle inversion injury and hypermobility: effect on hip and ankle muscle electromyography onset latency.** *Arch Phys Med Rehabil* 1995, **76**:1138–1143.

9.• Nadler DF, Malanga GA, Bartoli LA, *et al.*: **Hip muscle imbalance and low back pain in athletes: influence of core strengthening.** *Med Sci Sports Exerc* 2002, **34**:9–16.
A pilot study that assesses the influence of a core-strengthening program on low back pain in NCAA division I athletes. The authors found a trend in reduction of low back pain in male athletes, and also suggests that core strengthening programs should be sex specific.

10. Juker D, McGill S, Kropf P, *et al.*: **Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks.** *Med Sci Sports Exerc* 1998, **30**:301–310.

11.•• McGill S: *Ultimate Back Fitness and Performance.* Ontario: Wabuno Publishers; 2004.
Recent detailed publication about core fitness and how it relates to performance by widely published and authoritative author Stuart McGill.

12. Richardson CA, Jull GA, Hodges PW, *et al.*: *Therapeutic Exercise for Spinal Segmental Stabilisation in Low Back Pain: Scientific Basis and Clinical Approach.* New York: Harcourt; 1999.

13.•• Akuthota V, Nadler SF: **Core strengthening.** *Arch Phys Med Rehabil* 2004, **85**:S86–S92.
Most recent comprehensive review of current concepts in core strengthening and stabilization.

14. Stevans J, Hall KG: **Motor skill acquisition strategies for rehabilitation of low back pain.** *J Orthop Sports Phys Ther* 1998, **28**:165–167.

15. Taimela S, Kankaanpaa M, Luoto S: **The effect of lumbar fatigue on the ability to sense a change in lumbar position: a controlled study.** *Spine* 1999, **24**:1322.

16. Middleton P, Montero C: **Eccentric muscular contraction: implications in treatment of athletes.** *Ann Readapt Med Phys* 2004, **47**:282–289.