Core Stability Training for Healthy Athletes: A Different Paradigm for Fitness Professionals

Jeffrey M. Willardson, PhD, CSCS
Eastern Illinois University, Charleston, Illinois

Introduction and Purpose

As research expands the body of knowledge within all disciplines, traditional methodologies are modified to yield greater efficiency and effectiveness. Open mindedness is encouraged as new ideas are presented that challenge traditional methodologies. Scientists have the role of comparing new methodologies against old ones to determine differences or potential advantages.

During the last 20 years, the National Strength and Conditioning Association (NSCA) has greatly contributed to the dissemination of scientific facts on the most effective resistance training methods for athletes (1, 5). Sport scientists have attempted to bridge the gap between theory and real-world application. However, fitness professionals may promote new training equipment or methods without objective scientific inquiry. Therefore, sport scientists are often directed by fitness professionals when formulating research questions and testing new training methods (33).

In recent years, core stability exercises have been popularized for training healthy athletes (10, 14, 20, 38, 45). The term core refers to the muscles that control movement and stabilize the lumbar spine and pelvis. From a scientific perspective, core stability represents the complex interaction of passive (i.e., joint articulations and spinal ligaments) and active (i.e., muscle and neural) subsystems that maintain intervertebral neutral zones within physiological limits (35, 36). Resistance exercises performed on unstable equipment (e.g., stability ball, wobble board, balance disc) have been emphasized as most effective for the development of core stability (10, 14, 20, 38, 45).

The benefits of performing resistance exercises on unstable equipment originated from research on muscle activation and methods of preventing or rehabilitating low back, knee, and ankle injuries (12, 19, 32, 34, 44). However, this research was not intended to be applied to healthy athletes with no physical limitations (11, 46–48, 50). For healthy athletes, training in the weight room is most often focused on development of strength and power. Two essential factors that contribute to these training goals are high levels of muscular...
force and high rates of force development (1, 3). Core exercises performed on unstable equipment that are characterized by light loads, long tension times, and low velocities are better suited for increases in muscular endurance rather than strength and power (4, 13, 27, 31, 43).

Clearly a different paradigm is needed among fitness professionals for better development of core strength and power in healthy athletes. Research from the rehabilitation literature has provided valuable information on exercise modalities to restore core function among injured athletes. However, recent studies indicate that healthy athletes may require a different approach for core stability training that addresses performance needs rather than rehabilitative needs (2, 8, 18, 29, 38, 39, 41). Therefore, the purpose of this paper is to discuss research on the effects of core training in different populations and propose a different paradigm for fitness professionals to use when prescribing core exercises for healthy athletes.

**Physiology of the Core**

With the heavy emphasis placed on core training, fitness professionals must understand exactly what the core is and also gain the proper perspective on the necessity of prescribing exercises to target this area in healthy athletes. The core might be considered the link between the lower and upper extremities. The body can be likened to a chain, divided into bony segments, or links, that are connected by joints.

The muscular system provides the force to stabilize or move body segments. During performance of sports skills, a stable core provides a foundation upon which the muscles of the upper and lower extremities can accelerate body segments and transfer force between distal and proximal body segments (23, 24). For example, core stability is important for a baseball pitcher as force is transferred from the ground, up through the lower extremities, across the trunk, and out to the throwing arm.

The muscles that make up the core can be divided into *local* and *global* groups based on location and attachment sites (9). The local group consists of the small, deep muscles that control inter-segmental motion between adjacent vertebrae or act to increase intra-abdominal pressure (e.g., multifidus, rotatores, interspinalis, intertransversalis, transversus abdominis, quadratus lumborum, internal oblique abdominis). Conversely, the global group consists of the large, superficial muscles that transfer force between the thoracic cage and pelvis (e.g., rectus abdominis, external oblique abdominis, erector spinae, latissimus dorsi).

Other less-acknowledged global muscles that originate on the pelvis or lumbar vertebrae and insert on the proximal portion of the femur, tibia, or fibula include the hip flexors (e.g., rectus femoris, sartorius, iliacus, psoas major and minor), hip extensors (e.g., gluteus maximus, semimembranosus, semitendinosus, long head of the biceps femoris), hip abductors (e.g., adductor magnus, adductor brevis, adductor longus, gracilis, pectineus), and hip abductors (e.g., tensor fascia latae, gluteus medius, gluteus minimus). Although these muscles primarily act on the hip during open chain exercises when the feet are not planted on the ground, they do act to tilt the pelvis during close chain exercises when the feet are planted. Because the spine is attached to the pelvis at the sacroiliac joints, the tilting of the pelvis results in simultaneous movement of the lumbar spine. Therefore, the actions of these muscles can affect pelvic positioning and core stability.

The core muscles can be likened to guy wires, with tension being controlled by the nervous system. As tension increases within these muscles, compressive forces increase between the lumbar vertebrae; this stiffens the lumbar spine to enhance stability. The nervous system is responsible for continuously monitoring and adjusting muscle forces based on sensory feedback provided by proprioceptors embedded within muscles, tendons, and spinal ligaments (35, 36). The requirements for stability can change instantaneously, based on postural adjustments or external loads supported by the body.

A common misconception is that the local and global muscles can and should be trained separately. For example, Gamble (21) recently stated, “A distinction should be made between lumbo-pelvic exercises requiring fine degrees of coordination and motor control and more dynamic gross motor tasks; this is analogous to the differentiation between the local versus global stabilizing systems or postural versus mobilizer muscles” (p. 61). Such statements are in contrast to research that has clearly demonstrated the synchronized function of both local and global muscles during a wide variety of movement tasks (4, 15).

Cholewicki and Van Vliet (15) used a biomechanical model to compare the relative contribution of various trunk muscles to lumbar spine stability during seated (trunk flexion, trunk extension, lateral trunk flexion, trunk rotation) and standing (trunk vertical loading, trunk flexion 45° while holding a weight) isometric tasks. Muscle activity was measured in the rectus abdominis, external and internal oblique abdominis, latissimus dorsi, iliocostalis, longissimus thoracis, lumbar erector spinae, multifidus, psoas, and quadratus lumborum. The authors demonstrated that the contribution of different muscles to lumbar spine stability was dependent on the direction and magnitude of the load. Further, no single muscle group contributed more than 30% to lumbar spine stability, irrespective of the task. However, removal of the lumbar erector
spinae (global muscle) resulted in the largest reduction in lumbar spine stability during each task.

Arokoski et al. (4) compared rectus abdominis, external oblique abdominis, longissimus thoracis, and multifidus muscle activity during 16 tasks performed in prone, supine, seated, and standing body positions. The key finding was that the multifidus (local muscle) and longissimus thoracis (global muscle) demonstrated similar activity patterns and simultaneous function. These studies contradict the common assumption that the local muscles are more important for core stability and that these muscles can be trained separately from the global muscles.

Clearly, there is not a single most important core stabilizer that can be trained in isolation. McGill (32) stated, “The relative contributions of each core muscle continually changes throughout a movement, such that discussion of the most important stabilizer is restricted to a transient instant in time” (p. 355). Therefore, healthy athletes who perform a variety of ground-based free weight movements are likely targeting both local and global muscles in a manner that specifically meets the performance demands of sports participation. Such exercises might include the deadlift, squat, weightlifting exercises, and unilateral variations of such lifts (1, 3, 22, 30, 37, 50).

**Sports Performance and Core Training**

The popular literature written on core stability training often includes the word *functional* to convey the apparent specificity of such exercises to sports skills and daily activities. Some functional trainers have created a hierarchy in which resistance exercises performed with greater instability or complexity are equated with greater functionality (10, 14, 20, 38, 45). However, the functionality of an exercise depends on several factors that vary in relative importance. Fitness trainers will prescribe exercises that they believe to be the most specific or functional, depending on the phase of training and the performance needs of the client. From this perspective, all exercises have a function and no exercise can be considered truly nonfunctional (11).

Because core stability is required for efficient execution of sports skills, a functionally based program should include resistance exercises that involve a destabilizing component. However, very few sports skills require the degree of instability inherent when resistance exercises are performed on unstable equipment. Therefore, a better approach might be to perform ground-based free weight movements, which involve moderate levels of instability and high levels of force production.

Performance of ground-based free weight movements allows for the simultaneous development of core stability and upper and lower extremity strength, which might be more transferable to sports skills (46–48). No studies have demonstrated significant performance improvements in healthy athletes consequent to core training programs that emphasized resistance exercises performed on unstable equipment (17, 39, 40, 42). Studies that have demonstrated performance improvements utilized untrained (16) or recreationally active (25, 41, 49) individuals who probably would have responded to any novel training stimulus in a positive way (Table 1).

Despite the conflicting evidence, the stability ball, wobble board, and balance disc are still popular tools utilized when training healthy athletes (10, 14, 20, 38, 45). This has prompted sports scientists to compare different exercises performed on unstable equipment versus a stable surface. Generally, the findings have indicated that as the degree of instability increased, the degree of core muscle activity increased proportionally (3, 4, 7, 27, 28, 43). However, the findings for the activity of the limb muscles have been less consistent.

Anderson and Behm (3) compared core (i.e., abdominal stabilizers, upper lumbar erector spinae, lumbo-sacral erector spinae) and lower extremity (i.e., soleus, vastus lateralis, biceps femoris) muscle activity during 3 squat movements with varying levels of instability: relatively unstable, relatively stable, and very stable. The relatively unstable squat was performed with a balance disc under each foot, the relatively stable squat was performed with a free weight bar while standing on a stable floor, and the very stable squat was performed in a Smith machine while standing on a stable floor.

Anderson and Behm (3) demonstrated that core muscle activity progressively increased from the very stable to the relatively unstable squat. However, for the limb muscles, the relatively stable and very stable squats resulted in the higher levels of vastus lateralis and biceps femoris activity, while the relatively unstable squat resulted in higher levels of soleus activity. The higher levels of soleus activity during the relatively unstable squat confirmed the importance of this muscle in controlling the ankle joint and maintaining erect posture. Therefore, the squat can be performed on balance discs for ankle rehabilitation or reducing the risk of falls caused by uneven surfaces.

Other studies that compared unstable versus a stable push-up or dumbbell bench press demonstrated similar results. Lehman et al. (26) compared muscle activity in the rectus abdominis, external oblique abdominis, triceps brachii, and pectoralis major while performing 4 variations of push-ups: with feet on a bench, with feet on a stability ball, with hands on a bench, and with hands on a stability ball. Variations of a push-up plus (i.e., scapular protraction at the top) were also compared with hands positioned on either a bench or a stability ball.

Lehman et al. (26) found that the activity of the pectoralis major did not change
## Table 1
### Unstable Equipment and Performance Measures

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Sample</th>
<th>Mode</th>
<th>Results</th>
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| Behm et al. (8)      | Trained secondary school hockey players     | Wobble board                                                         | Correlations between wobble board balance ratio (contact with floor versus no contact) and maximal skating speed age dependent:  
<19 y \( (r = -0.65) \)  
≥19 y \( (r = -0.28) \)  |
| Cosio-Lima et al. (16)| Untrained sedentary individuals            | Stability ball group versus control group †                         | Stability ball group demonstrated significantly greater timed unilateral stance balance                                      |
| Cressey et al. (17)  | Trained collegiate soccer players           | Unstable group versus stable group †                                | Stable group demonstrated significantly greater power for the bounce drop jump and countermovement jump tests             |
|                      |                                             | Unstable group performed exercises, such as the squat, deadlift, lunge, single-leg squat, and single leg balance on dyna-discs | Significant improvements were demonstrated by both groups for the 40- and 10-yd sprint tests                             |
|                      |                                             | Stable group performed the same exercises on the ground             | Stable group demonstrated significantly greater improvement 40-yd sprint time and a trend toward greater improvement in 10-yd sprint time |
|                      |                                             |                                                                    | Significant improvements were demonstrated by both groups in T-test agility with no significant differences between groups |
| Kean et al. (25)     | Untrained recreation-ally active individuals| Wobble board group versus control group *                           | Wobble board group significantly greater countermovement jump height and rectus femoris activity on jump landing tests   |
| Scibek et al. (39)  | Trained collegiate swimmers                 | Stability ball group versus control group *                         | Stability ball group demonstrated significantly greater scores on the forward medicine ball throw and postural control tests |
|                      |                                             |                                                                    | No significant differences between groups on vertical jump, backwards medicine ball throw, and hamstring flexibility tests |
|                      |                                             |                                                                    | No significant differences between groups for improvement on 100-yd swim time                                              |
| Stanton et al. (40) | Trained secondary school basketball and football players | Stability ball group versus control group *                       | No significant differences between groups on \( V_{\text{o2, max}}, \) velocity at \( V_{\text{o2, max}}, \) running economy, and running posture |
| Thompson et al. (41)| Untrained recreationally active golfers     | Functional group (performed core exercises on stable floor and stability ball) versus control group * | Functional group demonstrated significantly greater club head speed                                                      |
| Tse et al. (42)      | Trained collegiate rowers                   | Core group versus control group *                                   | No significant differences between groups on rowing ergometer test (2,000 m), vertical jump, broad jump, 10-m shuttle, 40-m sprint, 2-kg medicine ball throw |
| Yaggie et al. (49)   | Untrained recreationally active individuals | BOSU group versus control group *                                   | No significant differences between groups shuttle run, vertical jump, or unilateral stance balance on BOSU               |

Note: The control groups maintained current activity levels and performed no specific core exercises (*) or performed the same core exercises on a stable floor (†).
with any variation of the push-up. However, the activity of the triceps brachii was significantly greater when the push-up was performed with hands positioned on a stability ball. Furthermore, the activity of the rectus abdominis and external obliques was significantly greater when the push-up plus was performed with hands positioned on a stability ball.

Similarly, Marshall and Murphy (28) compared muscle activity in the rectus abdominis, transversus/internal oblique abdominis, pectoralis major, triceps brachii, anterior deltoid, and biceps brachii when the dumbbell bench press was performed on a bench or stability ball. The key finding was that the activity of the rectus abdominis, transversus/internal oblique abdominis, and anterior deltoid was significantly greater when the dumbbell bench press was performed on a stability ball. The results of the these (2, 26, 28) and similar studies (28, 43) may lead a fitness professional to believe that athletes will obtain greater performance benefits by performing resistance exercises while lying or standing on unstable equipment. However, what must be considered is that the level of core muscle activity elicited was typically less than 50% of maximal voluntary contraction. This level of intensity is far less than that achieved during ground-based free weight movements and does not meet the level needed by healthy athletes for gains in core strength and power (1, 3).

Although power can be developed effectively at low intensities (i.e., less than 50% maximal voluntary contraction) and high velocities of contraction (1, 5), performing resistance exercises on unstable equipment has been shown to result in low velocities of contraction, which negates the stimulus for power development (18). Other factors that are important for power development include force production and rate of force development. Four studies have demonstrated reduced external force production and rate of force development. Four studies have demonstrated reduced external force production and rate of force development when resistance exercises were performed on unstable equipment.

Behm et al. (6) demonstrated that maximal force output of the leg extensor and plantar flexor muscle groups decreased 70.5% (leg extensor) and 20.2% (plantar flexor) when actions were performed on a stability ball versus a stable bench. Anderson and Behm (2) demonstrated that maximal force output of the pectoralis major decreased 60% when chest presses were performed on a stability ball versus a stable bench. McBride, Cormie, and Dean (29) demonstrated that maximal force output and rate of force development were 45.6% and 40.5%, respectively, when squats were performed on balance discs versus the ground.

Recently, Drinkwater, Pritchett, and Behm (18) demonstrated clinically meaningful differences when comparing the ground-based free weight squat versus the BOSU free weight squat with a 10 repetition load. Clinically meaningful differences were determined using effect size (ES) statistics, with values of 0.2, 0.6, and 1.2 being considered small, moderate, and large, respectively. Moderate to large differences between squat surfaces were demonstrated for concentric power (ES = 1.3), concentric force (ES = 0.82), concentric velocity (ES = 0.80), squat depth (ES = 1.73), and eccentric power (ES = 1.42).

Drinkwater et al. (18) hypothesized that these variables were reduced for the BOSU condition due to a stiffening strategy that involved cocontraction of agonist and antagonist muscle groups. Although increased antagonist activity may contribute positively to balance development and joint protective responses, it could also contribute negatively to strength and power development by opposing the intended direction of motion. Therefore, unstable equipment does not provide the optimal stimulus for core strength and power development in healthy athletes.

A Different Paradigm for Fitness Professionals

In the past, core development for healthy athletes has been addressed as if trying to fix something that isn’t broken. Seminars and workshops conducted nationally have encouraged fitness professionals to prescribe exercises that are more common in physical therapy clinics. However, rehabilitative-type core exercises that typically involve light loads, long tension times, and low velocities are better suited for increases in core muscular endurance than core strength and power (4, 13, 27, 31, 43).

For injured athletes attempting to regain normal levels of core functioning, muscular endurance training is ideal and should be performed prior to heavy ground-based movements (e.g., deadlift, squat, weightlifting exercises, unilateral variations of such lifts). Research has demonstrated that rehabilitative-type exercises were effective in preventing or rehabilitating injuries in the low back, knee, and ankle (12, 19, 31, 34, 44). These exercises can also be helpful during off-season training cycles to maintain general muscular fitness and provide a break from the rigors of heavy training. However, rehabilitative type exercises do not address the performance needs of healthy athletes during preseason and in-season mesocycles, during which strength and power become the primary focus (1, 3).

A different paradigm is needed among fitness professionals to change the prescription of core exercises to meet performance needs rather than rehabilitative needs. Few sports skills are performed under conditions of high instability that characterize stability ball, wobble board, or balance disc exercises. More often, sports skills are performed under conditions of moderate instability, while standing on stable ground. This is why ground-based free-weight movements might be the best choice for core stability training in healthy athletes (46–48). Although few studies of this theory have been conducted, the force, velocity, and
core stabilizing requirements of ground-based free weight movements are similar to the demands of sports skills (1, 5).

Many times an athlete must execute a skill while supported on a single leg, and research has demonstrated higher core muscle activity when resistance exercises were performed unilaterally rather than bilaterally (7). Therefore, ground-based free weight movements should be modified occasionally to focus on unilateral strength and power development (30). The squat and deadlift can be performed while supported on a single leg, and the weightlifting exercises can be performed with a single arm.

The squat, deadlift, and weightlifting exercises address trunk flexion and extension in the sagittal plane, but the frontal and transverse planes of movement must also be addressed for optimal core development. The trunk is capable of lateral flexion in the frontal plane and rotation in the transverse plane. Trunk lateral flexion can be trained by holding a heavy dumbbell in one hand and activating the external obliques, internal obliques, rectus abdominis, quadratus lumborum, and erector spinae to bring the trunk to an upright position. Trunk rotation can be trained through coordinated joint actions with the upper and lower extremities. For example, trunk rotation can be coordinated with unilateral cable rows or chest presses while in a lunge position. Trunk rotation can also be trained by performing medicine ball throws that involve shoulder joint diagonal adduction and abduction.

A sports-specific core training program should include isometric, concentric, and eccentric core muscle actions. Bilateral and unilateral cable shoulder joint extension and flexion movements can be used to train the core muscles isometrically. However, the ability to accelerate or decelerate the trunk through concentric or eccentric muscle actions should also be addressed. Weightlifting exercises and medicine ball movements that involve high levels of acceleration and concentric muscle activity are beneficial for core power development. Conversely, supramaximal loaded squats and barbell curls, performed through the eccentric phase only, can be used to strengthen the core muscles to resist spinal flexion forces.

When prescribing core stability exercises, the concept of specificity should have foremost importance (37). Not all stability ball and wobble board exercises are specific or functional, as several fitness professionals have suggested. However, these types of exercises have their place, particularly during postseason and off-season mesocycles or for the purpose of injury prevention and rehabilitation. Based on the current literature, performance of ground-based free weight movements might be the best choice, due to the force, velocity, and core stabilizing requirements of such lifts that are similar to the demands of sports skills.

References


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**Jeffrey M. Willardson** is an assistant professor in the Physical Education Department at Eastern Illinois University.