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Core Stabilization Exercise Prescription, Part I: Current Concepts in Assessment and Intervention

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Context: Injury to the low back can cause significant pain and dysfunction, which can affect an athlete's performance and result in time lost from sport. A common conservative treatment is therapeutic core stabilization exercises, which can address pain and musculoskeletal dysfunction in patients with low back pathology.

Evidence Acquisition: MEDLINE and CINAHL were searched (from 1966 to March 2013) to identify relevant research. Keywords and keyword combinations searched included *motor control exercise*, *segmental stabilization*, *core stabilization*, *transversus abdominis*, *multifidi*, and *low back pain*.

Results: There are 2 popular rehabilitation strategies to assess core function and promote core stabilization. Each has been developed based on biomechanical models of lumbar segmental stability and observed motor control dysfunction in patients with low back pain.

Conclusion: Controversy exists among clinical and research groups as to the optimal strategy for an athlete with low back pain.

Keywords: core stabilization; motor control exercise; multifidi; low back pain; transversus abdominis

Injury to the low back can cause significant pain and dysfunction, which can affect an athlete's performance and result in time lost from sport. An athlete with low back pain is frequently evaluated and treated by multiple members of the sports medicine team. Numerous conservative and invasive treatments have been advocated, each with various levels of efficacy.^{5,12,13,16,22,23}

A common conservative treatment is therapeutic exercise. Core stabilization exercises^{5,12,13,16,22,23} decrease pain, reduce disability, restore/increase muscular function, promote stability, and reduce risk of subsequent injury. Despite the general acceptance of exercises for the "core" for patients with low back pain, there is disagreement among professionals as to the optimal assessment and intervention strategy.^{16,22,23}

This article describes the core region and core stabilization, presents the biomechanical rationale for a core stabilization exercise program, and reviews 2 assessment and therapeutic exercise prescription rehabilitation strategies for patients who present with low back pain.

CORE REGION AND CORE STABILIZATION

Athletic performance depends on the creation and transfer of forces between segments of the body. For example, during the windup motion, a ground reaction force is generated between the mound and the pitcher's dominant lower extremity, with the force subsequently transferred through the body to the upper extremity.¹² Failure to transfer forces through the body may result in suboptimal performance and may increase risk of injury to the athlete. During sport or other activities, the core region plays an integral role in reducing the risk of back injury.¹² The core includes the muscles and joints of the abdomen, spine, pelvis, and hips.¹² These muscles are responsible for dual roles of stabilizing the spine from potentially injurious forces and creating and transferring forces through the body.^{12,16}

When treating an athlete with nonspecific low back pain, clinicians address the dysfunction (eg, poor neuromuscular control, poor muscular endurance capacity) identified during the musculoskeletal examination with various treatments,

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including therapeutic exercises such as core stabilization.^{15,22,23} Stabilization is the process of decreasing abnormal or excessive symptomatic translations about articulating joint surfaces.

Through mechanical modeling, biomechanists have described energy wells (potential energy state and the relationship between spinal segments), whole body stability (factors that respond to loads or perturbations), elastic energy and stiffness (joint stiffness as a result of muscular activation), and sufficient stability (adequate activation for functional movement) to define requirements for a stable spine.^{2,16,18} These aforementioned biomechanical concepts, in addition to changes in motor control of the core muscles after an injury (see forthcoming discussion), explain segmental instability and the effect of imposed loads to the spine and provide a clinical rationale for increasing segmental stiffness (eg, the ability to stabilize) via targeted exercises.^{2,16,18,22}

A definitive description of lumbar instability is not agreed on.^{1,15} Some have suggested a clinical entity of “functional lumbar segmental instability” (FLSI).^{15,19} FLSI is the “loss of the spine’s ability to maintain its pattern of displacement under normal physiological loads.”²⁷ It results from the failure of a segment’s osseoligamentous structures to provide stability in the presence of poor neuromuscular control.^{15,27} A patient with FLSI may not present with a structural segmental instability (excessive translation of one segment compared with an adjacent segment) per se on a radiograph but may experience a segmental instability resulting from failure of ligamentous restraints and inadequate segmental stiffness via poor muscular activation.^{15,22} Assessment of FLSI is challenged by the diagnostic accuracy of clinical tests; however, symptoms associated with FLSI may be amenable to stabilization exercises.^{1,5,14,15,19,20}

CURRENT REHABILITATION STRATEGIES: LOCAL VERSUS GLOBAL APPROACH

Current rehabilitation and training strategies for the core have been influenced by biomechanical models of stability.^{2,16,18} Of particular interest is the promotion of muscular endurance and strength. When activated, the muscles of the core increase stiffness, enhancing stability. Bergmark categorized muscles that stabilize the spine as either local or global.² The transversus abdominis (TA) and multifidi are local muscles, whereas the erector spinae, quadratus lumborum, obliques, and rectus abdominis are global muscles.²²

There are 2 popular core stabilization rehabilitation strategies: the motor control exercise approach, emphasizing specific training exercises for local muscles, or the general exercise approach, which includes exercises for global muscles.^{16,22} These strategies differ in part because of the interpretation of the biomechanical role of the local and global muscles.^{16,22,23}

ASSESSMENT AND REHABILITATION STRATEGY FOR LOCAL MUSCLES

An assessment and rehabilitation strategy for the core is based on dysfunction in the local muscles (the TA and multifidi) and

their biomechanical role.^{2,22} A series of experiments evaluated the function of the TA in people with a history of chronic low back pain and identified a delay in the anticipatory contraction of the TA before perturbation.^{6-9,22} In healthy participants, this anticipatory contraction occurs before extremity movement and reflects its contribution to core stabilization. In addition, there were additional changes in the motor control strategy of the TA: The change in anticipatory function mirrored the response of other abdominal muscles to direction-specific forces, a change from tonic to burst contractions, and an ability to contract only in response to fast movements.⁶⁻⁹ Dysfunction in the multifidi also occurs in persons with low back pain.^{21,22} The multifidi are less fatigue resistant and demonstrate lower concentric activation, atrophy, and pathologic structural changes, supporting the need for targeted rehabilitation for the local muscles.^{3,21,22,24,25,28}

Based on these dysfunctions in the TA and multifidi, a clinical assessment (Table 1) and intervention strategy was developed using education, assessment, and subsequent training.²² The patient is first educated about the anatomy and function of the core muscles and is taught the drawing-in maneuver, which is a muscular contraction that activates local muscles without activation of global muscles.²² The abdominal drawing-in test should be performed initially in the quadruped position with the patient’s spine in neutral. Activation of the TA should be also assessed in prone and supine positions (Table 1, Figure 1).

A patient’s performance establishes a baseline from which the motor skill can be developed by performing low-load isometric exercises prone and supine. The patient continues use of a biofeedback device and should be monitored for compensatory movements. As the ability to demonstrate proper activation of the TA and multifidi during the initial exercises is mastered, patients can advance to other forms of stabilization exercises, such as bridging or bird dog.^{22,23} The prone and supine abdominal drawing-in tests are recommended to ensure proper activation of the TA.²² The final phase of the initial rehabilitation program based on local muscle dysfunction should include functional tasks with heavier loads. These exercises are performed with co-contraction of local and global muscles.

When rehabilitating a patient with low back dysfunction, low-load isometric motor control exercises for the TA and multifidi should be emphasized.²² The drawing-in maneuver should be performed with each exercise to elicit TA and multifidi contraction without activating global muscles. Rehabilitation of the local muscles with specific motor control exercises is necessary to enhance stability while protecting the spine from excessive loads during the rehabilitation program.²² The local muscles promote segmental stabilization. Inclusion of global muscles too early may be deleterious during the rehabilitation program.²² Local muscles are superior to global muscles in controlling shear loads; unnecessary activation of global muscles may impose excessive compressive loads to the spine. Activation of global muscles in the presence of dysfunction may actually increase the challenge on the local muscles to provide segmental stability.^{2,22}

Table 1. Motor control tests for local muscles: transversus abdominis and multifidi

Test	Procedure
Activation of the TA in quadruped position: Abdominal drawing-in test	To facilitate activation, “draw in your abdominal wall without moving your spine or pelvis and hold for 10 seconds while breathing normally.” ²² Skill should be repeated until mastered. Once the patient qualitatively demonstrates proficiency in this position, he or she progresses to the prone test.
Abdominal drawing-in test performed in prone position	Patient prone. Performance of the TA contraction is assessed using a stabilizer (Chattanooga, Vista, California) or pressure biofeedback device. The bladder of the device, with the navel positioned in the center, is inflated to 70 mmHg. The patient is instructed to perform the drawing-in maneuver. Successful performance of the maneuver results in a 6- to 10-mmHg drop in pressure, with each contraction held for 10 seconds. Richardson recommends having the patient perform 10 repetitions to assess muscular endurance capacity. ²² This test may be prescribed as an “exercise” if the patient demonstrates poor performance or limited muscular endurance. ²²
Abdominal drawing-in test for lumbopelvic control (Figure 1)	Patient supine in hooklying position (patient’s torso supine with hips and knees flexed and feet in contact with surface). The biofeedback device is placed in the lumbar spine (distal portion of bladder at S2 level) and inflated to 40 mmHg. The patient is instructed to perform a drawing-in maneuver, which will likely increase the pressure 2 to 4 mmHg. ²² The test is performed by having the patient extend the lower extremity, sliding the heel on the table top. Maintaining pressure during the leg slide demonstrates a level of lumbopelvic control (ability to stabilize the trunk on the pelvis during extremity movement). ²² Lumbopelvic control can be further challenged in supine by performing unsupported leg extensions.

TA, transversus abdominis.

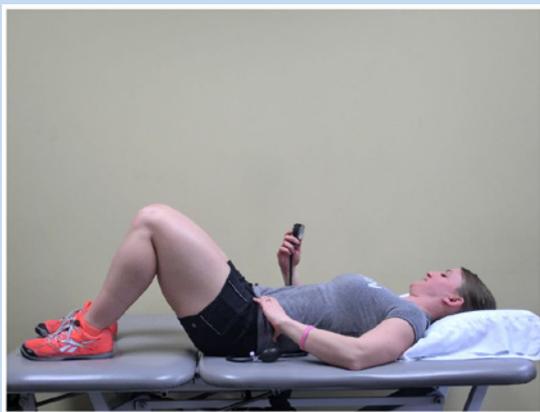


Figure 1. Abdominal drawing-in test: Lumbopelvic control.

A new 3-stage rehabilitation protocol for local muscle dysfunction has been described.^{22,23} The first consists of exercises targeted at improving neuromuscular function of the local muscles. During this stage, the motor control of

local muscles is assessed (Table 1), and specific exercises to promote co-contraction of local muscles are emphasized. Patients are progressed to a second stage (closed-chain segmental control exercises) once normal motor control is achieved during a local muscle co-contraction test. During the second stage, a series of weightbearing exercises in flexed and upright postures is performed on stable or unstable surfaces to improve neuromuscular control and joint stabilization when local and weightbearing muscles are activated.²³ The third stage consists of open kinetic chain exercises that promote distal mobility. Nonweightbearing exercises are performed to continue segmental stabilization and highlight any remaining local deficits.²³ Progression from one stage to the next is not quantified, thus requiring the rehabilitation professional to make clinical decisions as to exercise prescription based on continual assessment of a patient’s motor control tests (Table 1).²³

TESTING AND REHABILITATION STRATEGIES FOR GLOBAL MUSCLES

McGill proposed an alternate assessment and rehabilitation strategy that incorporates all of the core muscles, supported by an in-depth biomechanical rationale for this strategy.¹⁶ All

Table 2. Muscular endurance tests for the core

Test	Procedure
Back extensors test (Figures 2 and 3)	Patient prone on a treatment table with the lower body braced against it using straps or the tester's body weight. The torso is positioned off the table, above the anterior superior iliac spine, with the upper extremities weightbearing on a chair to support the body before the start of the test. The test begins when the patient assumes the test position: torso parallel to the ground and arms placed across the chest.
Lateral musculature test (Figure 4)	Patient places 1 elbow, flexed 90°, below the shoulder. The legs are extended in line with the torso, with 1 foot positioned in front of the other. The hand of the nonweightbearing upper extremity is placed on the opposite shoulder. The test is stopped when the patient is no longer able to maintain the position.
Flexion endurance test (Figure 5)	Patient reclines against a bolster (60° from table top), arms positioned across the chest, with hips and knees in 90°-90° alignments. The test starts when the bolster is slid 10 cm (4 in) away from the patient's back. The test is stopped when the patient's back touches the bolster.



Figure 2. Back extensor starting position.



Figure 3. Back extensor test position.

muscles, not just the TA and the multifidi, provide stability to the lumbar spine, and failure to address global dysfunction limits the effectiveness of a rehabilitation program. Muscular activation delays occur in all muscles, not just the TA and multifidi, after low back injury.⁴ Performing exercises that activate the TA with contributions from other abdominal muscles is impossible.¹⁶ Assessment of muscular contributions to stabilize during a variety of exercise positions^{10,11} found that a muscle's relative contribution to spine stability depended on the activity. As such, a rehabilitation program should develop stability by performing exercises that challenge the muscles of the core in a variety of positions.^{10,11} Performing an abdominal bracing contraction is superior to drawing in for enhancing stability.¹⁶

The first component of McGill's rehabilitation strategy is to enhance the muscular endurance capacity of the core.¹⁶ There are 3 muscular endurance tests for the core (the lateral musculature test is performed bilaterally); each is measured in seconds until failure (Table 2, Figures 2-5). The test ratios may indicate muscular imbalance. The flexion or lateral scores should be less than the extension score (flexion/extension < 1.0 and lateral/extensor < 0.75), and the lateral tests should be nearly symmetrical (< 0.05).^{16,17}

Injured athletes typically present with 1 or more imbalances. McGill described a "big 3" exercise program to enhance core muscular endurance: the side bridge, the bird dog, and the curl-up.¹⁶ As muscular endurance capacity is increased and balance restored between the ratios, the rehabilitation program can be progressed to functional exercises for the core.



Figure 4. Lateral musculature test.



Figure 6. Prone bridge test.



Figure 5. Flexor endurance test.



Figure 7. Supine bridge test.

ADDITIONAL FUNCTIONAL TESTS FOR THE CORE

Specific tests are used to assess function of the core musculature; some may not be appropriate for certain patients. For example, the tests for TA and multifidi function will not be able to assess core muscular endurance. The core muscular endurance tests may assess function in injured and healthy athletes, but some patients may not be able to assume testing positions because of the severity of the symptoms. The prone and supine bridge tests (Figures 6 and 7) may serve as alternate assessment tools for muscular function in the lumbar spine.²⁶ Athletes without low back pain were able to hold the prone bridge 72.5 ± 32.6 seconds, whereas those with low back pain were able to hold the position for only 28.3 ± 26.8 seconds.²⁶ During the supine bridge test, those without pain held the position for 170.4 ± 42.5 seconds, compared with those with pain, who lasted for only 76.7 ± 48.9 seconds.²²

CONCLUSION

Controversy exists as to the optimal strategy for rehabilitating the core musculature in patients with low back pain. Clinicians have 2 rehabilitation strategies to choose from: local muscle assessment with motor control exercise or global muscular function assessment with a general exercise approach.

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