



Human Physiology

Elixir Human Physio. 53 (2012) 11914-11917

Elixir
ISSN: 2229-712X

Core stability – an overview

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ARTICLE INFO

Article history:

Received: 13 October 2012;

Received in revised form:
20 November 2012;

Accepted: 5 December 2012;

Keywords

Core stability,
APA,
Neuromuscular control of core.

ABSTRACT

Core stability is a foremost important thing when the discussion of spinal stability comes into light. The TrA is amongst the first trunk muscles to fire when limb activity is initiated. Core stability is a umbrella term covering aspects like core strength, balance, power etc. core stability is a complex interplay between active/passive and neural subsystem. Communication between musculature and the neuromuscular system is what enables the body to regain the equilibrium state. This is also termed as the APA (anticipatory postural adjustments) where postural adjustments allows body to increase proximal stability. Over the last several years the evidence on correlation between performance and core stability has remained inconclusive. It appears that focus of research must be directed to determine whether tests of core stability are related to athletic performance or not.

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1. Introduction

Leonardo da Vinci explained the concept of muscle grouping around the spine. He suggested that the small muscles of the neck stabilized the spinal segments, whereas the more global muscles acted as guide ropes supporting the vertebrae¹. Core muscles around lumbar spine are positioned in the same way. "The core musculature can be defined generally as the 29 pairs of muscles that support the lumbo-pelvic-hip complex in order to stabilize the spine, pelvis, and kinetic chain during functional movements"². Some studies have suggested that "The core musculature includes muscles of the trunk and pelvis that are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from larger torso to smaller extremities during many sports activities."

Professor Anders Bergmark (1989) of Sweden classified the muscles acting on the lumbosacral spine as either "local" or "global". The local and global muscles can be understood according to the varying demarcating features between them.

The "local" system: The "local" system is composed of all the muscles that originate and insert at the vertebrae, with the exception of the psoas muscles which flex the hip joints⁴. The local system can be divided into primary and secondary stabilizers. The primary stabilizers are the TrA and multifidi, because they do not create movement of the spine. As these muscles have shorter muscle lengths, attach directly to the vertebrae, and generate sufficient force for segmental stability of the spine^{5,2}. The purpose of the "local" system is to control the curvature of the lumbar spine, help in the coordination and motion control of segments, and provide sagittal and lateral stiffness to maintain mechanical spinal stability⁴. These muscles are primary stabilizers because they do not create movements in the joints through which they pass⁶. Secondary local stabilizers include the internal oblique, medial fibers of the external oblique, quadratus lumborum, diaphragm, pelvic floor muscles, iliocostalis and longissimus (lumbar portions) all play a secondary role in the "local" stabilizing system⁶.

The "global" system: - the "global" system functions to transfer forces from the thoracic cage and the pelvis out to the extremities⁴. Global muscles or the "slings" possess long levers

and large moment arms, helping them in producing high outputs of torque, with focus on speed, power, and larger arcs of multiplanar movement^{2, ;}.

These muscles include the external oblique, rectus abdominis, erector spinae and the psoas major. The muscles of the "global" system have longer moment arms of force, and larger physiologic cross-sectional areas than the muscles of the "local" system, making them suited for force production⁷. The "global" system is responsible for providing movement of the trunk⁴.

2. Core Stability

Different definitions of core stability exist according to the context in which they are used. In sports it is used in dynamic terms. Kibler, et al⁸ in reference to dynamic movement patterns defined core stability as being "the ability to control the position and motion of the core over the pelvis to allow ideal production, transfer, and control of force and motion to the terminal segment". Core stability is dependent on three subsystems: the passive spinal column, active spinal muscles, and a neural control unit⁹. Further, it was viewed that spinal stability is the result of passive stiffness, which is due to the bony and ligamentous structures, and active stiffness, which is produced by muscular activity¹⁰.

i) Passive subsystem: Passive core stability is the domain of the osseous and ligamentous structures of the lumbar spine. The primary role of these structures is proprioception rather than support¹⁰. The passive subsystem consists primarily of the vertebral bodies, zygapophyseal joints and joint capsules, spinal ligaments, and passive tension from the musculotendinous units⁹. The passive subsystem has a vital function in the elastic zone of spinal ROM (ie, near endrange)⁹. When the spine moves in flexion the stabilizing structures are posterior ligaments of the spine (interspinous and supraspinous ligaments) along with the zygapophyseal joints and joint capsules and the intervertebral disks^{11,12}. End-range extension is stabilized primarily by the anterior longitudinal ligament, the anterior aspect of the annulus fibrosus, and the zygapophyseal joints^{13,14}. zygapophyseal joints help in stabilizing the rotational movement. Side-bending movements have not been studied extensively, but

intertransverse ligaments may play an important role in segmental stability for movement occurring in the frontal plane⁹

(ii) **Active subsystem:** the spine is inherently unstable. Structure. The ligamentous spine (stripped of muscle) will fail or buckle under compression loads of as little as 2 kg or 20 N^{5, 15}. This inherent instability along with tremendous demand required during different activities necessitates the role of active subsystem. Because the spine is inherently unstable, an important role of the muscles is to stiffen the spine during movements that elicit instability¹⁶. Therefore, the active spinal muscles of the trunk and pelvis are responsible for maintaining core stability as well as providing and transferring energy from proximal to distal body parts¹⁷.

The link between muscle activation and stiffness is an established concept. Activating muscle increases stiffness, both within the muscle and to the joint(s) it crosses. Activating a group of muscle synergists and antagonists in the optimal way now becomes a critical issue.^{18, 19} it is noted that that motor control and muscular capacity create core stability. It is well established fact now that core muscles provide an important role in stabilizing the spine⁹

(iii) **Neural subsystem:** The NM input provides the two way system to control the trunk during movement in regard to forces generated from distal body segments and from expected/unexpected perturbations^{20, 11} McGill, et al. found that spine stability is the resultant from well coordinated muscle activation patterns that include many muscles and that recruitment patterns must continually change, depending on the task.¹⁸ The stability of the core, depends on the body ability to integrate sensory, motor-processing, and biomechanical strategies along with learned responses to detect and anticipate change²¹. The body must control the trunk in response to internal and external perturbations, which embody forces produced by the distal extremities as well as expected/unexpected challenges to stability²².

Core stability components: Core stability is composed of following components such as core strength, endurance, power, balance, as well as the coordination of the spine, abdominal, and hip musculatures²³. The strong and endurable core muscles stabilize the spine by providing greater passive support with mechanical integrity and neurological recruitment patterns; including appropriate activation of these muscles when forces and loads are applied²⁴.

Core Strength vs. Core Stability: These two terms are often used interchangeably, although, Core stability and core strength differ based on their functions, the contexts in which they are used, and the anatomy involved²⁵.

Core stability is achieved when the intervertebral range of motion is maintained within a safe limit on exposure to internal and external perturbations⁹. The core stability is also defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities¹⁷ Panjabi makes an anatomical reference to core stability as the integration of the passive spinal column, active spinal muscles, and neural control unit all working together to stabilize the spine during activities of daily living⁹ Core stability requires coordination, strength, and endurance for effective control of the spinal column²⁶

Core strength is responsible for producing the muscular force around the lumbar spine to maintain functional stability¹⁰.

Neuromuscular control of core

Perturbation and instability of core: Perturbations can be expected or unexpected and occur due to internal and external forces due to distal body segment motion²² The stability to protect the spine from perturbations, input from the passive, active, and neural subsystems is required.. These conceptually separate but functionally interdependent systems work together to provide core stability⁹.

Success in a majority of sports is dependent upon producing external forces while maintaining dynamic stability. Balance is maintained by keeping the body's center of gravity over its base of support. External forces can disrupt balance by altering the center of gravity²⁷. While external loads are acting on the body, internal forces, particularly in the lumbo-pelvic-hip complex, help in maintaining equilibrium of the body²⁸. Feedback system between the musculature of the core and the neuromuscular system helps the body to regain this new equilibrium state, and paves the way for core stability to happen.²⁹

Once above mentioned mechanism of core stability fails instability results. Instability of the core during athletic tasks leads to an increase in co-contractions of antagonistic muscles, which negates the production of external forces. The loss of core stability would lead to a suboptimal production of external forces. When instability is present, there is a failure to maintain correct vertebral alignment, or a failure in the musculature to apply enough force to stabilize the spine. The core instability could be caused by deficiencies in muscular strength, muscular capacity, coordination of limb movement, or a combination of any of these.³⁰

Anticipatory postural adjustments- When maintenance of equilibrium is the target in presence of quick, localized voluntary movements then the feed forward adjustments occurs in the postural muscles which negate the expected perturbing forces. Anticipatory postural adjustments (APS) are produced by the higher centers³¹. Voluntary arm movements by standing subjects have been most frequently used to study anticipatory postural adjustments. This approach, however, has its pitfalls in particular; slow movements do not usually involve anticipatory postural adjustments³² Thus, differences in anticipatory postural adjustments in different subjects may reflect both differences in their central mechanisms of anticipatory postural control and the ability to move fast³³.

The concept in showing that other muscles contract before the limb agonist when stability is challenged due to limb movement. With these postural adaptations the proximal stability is increased in respect to increased distal mobility. . Advanced research which have analyzed the response of the superficial muscles in response to external perturbations have revealed a direction-specific activation pattern in order to maintain proper orientation of the spine³⁴

Transversus abdominis and core stability:

Transversus abdominis (Tr.A), the deepest of the abdominal muscles, is the first trunk muscle active irrespective of the direction of limb movement²⁴ TrA could contribute to control of lumbar spine stiffness between individual intervertebral segments which potentially may prepare the spine for contraction of superficial muscles. In theory, contraction of the transverse abdominis acts as a girdle by increasing intra-abdominal pressure and putting tension on the thoracolumbar fascia, which creates a rigid cylinder to reinforce lumbar spine stability.^{10, 17} Tr.A may achieve this by increasing tension in the thoracolumbar fascia¹⁰ or by increasing IAP³⁵. Previous

work has indicated that IAP generation is strongly associated with Tr.A contraction³⁵. Recent experiments have shown that IAP increases earlier (prior to movement) as the speed of trunk movement is increased, contributing to the control of the dynamic forces at the initiation of movement³⁶. Alternatively, the increase in IAP may be present to maintain the hooplike geometry of the abdominal muscles to allow them to produce a mechanical effect on the spine or simply be a product of the multiple influences on the abdominal cavity (including the abdominal muscles) without direct contribution to trunk control.

The multifidi and abdominal muscles require only 5% of a maximal voluntary contraction (MVC) for activities of daily living and 10% of a MVC for rigorous activities to stiffen the spinal segments³⁷. Therefore, a forced maximal contraction is not needed in order to increase core stability. Work done by Cholewicki et al. found that the quantity of stability provided throughout a given task relies upon the load and direction of the load placed on the core³⁸. Stability is greatest during the most difficult tasks and decreases during periods of low muscular activity³⁷.

Method of core assessment

It is very tedious task to assess the core with just one test, knowing that the musculature of the core consists of intricate, integrated elements that work synergistically to bring forth stability to the spine^{39,40}. It is not surprising then that researchers who have investigated the relationships between core stability and performance, or the effects of training the core musculature on performance, have used an array of tests to measure core stability and its components (i.e., strength, endurance, and power^{40, 41}). There is limited evidence on the assessment of core muscle system, that adds to some of the confusion related with this topic.

Clinically, core activation has been measured with ultrasound, MRI, and EMG²⁴. There could be possible advancements in these areas, but current analysis with the core muscle system is limited, to the authors' knowledge. Progress has been made toward simpler assessments of the core musculature. This focus on activating the stabilization system of the core is thought to carry into future prescription for athletes as well.

The most commonly utilized assessments and training are performed in the supine or prone position. They are formulated to assess or to train the stabilizing system with minimum activation of the movement system. However an issue crops up, when athletes do not typically require spinal stabilization in a supine or prone position. Due to dearth of evidence, there is no current, valid proof for the core muscular system in a plane or position apart from supine and prone. Assuming the law of specificity applies to the core musculature as well, it may be helpful for further analysis to assess and to quantify the activation of the stabilization system in more specific positions.

In a research study of which the main objective was to develop a activity pattern, allow quantification of core stability⁴². It was observed that coordination and balance are vital components in core stability training and so they chose to quantify core stability through balance tests in which actual core stability training postures were mimicked. For this purpose, a stability platform was used on which balance had to be maintained in three completely different postures, particularly kneeling arm raise, quadruped arm raise and also the bridging postures. The duration of balance tasks was 30 seconds and the tilt limits of balance board were set at 5° to either side.

Single arm raising experimental model

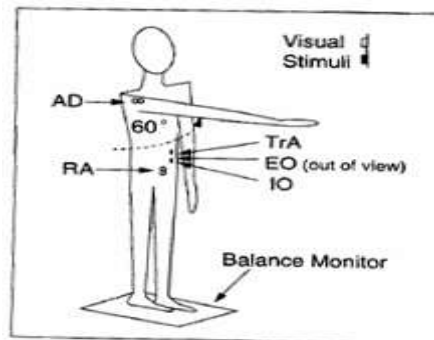


Figure 1. Single arm raising experimental model

A model for evaluation of motor control strategies for stabilization of spine would necessarily involve identification of the coordination of muscles contributing to spinal stiffness generation. On the basis of previous argument, Tr.A should be included. Evaluation of this system would be facilitated by identification of muscular responses to a controlled challenge to stability. Evaluation of the control strategy using a model in which the exact nature of the disturbance or perturbation can be anticipated by CNS would facilitate a more specific investigation of this complex system. Evaluation of the response of the body to movement of a limb provides such a model. Previously this test had been used in rehabilitation sector in low back pain population to see feedforward mechanism of response of sudden arm raising. This test consists of rapid arm flexion as fast as possible. In shoulder flexion, the centre of mass is moved anteriorly by the forward motion of the upper limb while reactive moments act backwards and downwards on the trunk producing trunk flexion and backward displacement of the centre of mass⁴³.

Conclusion

- 1) The transversus abdominis and multifidus form the deep stabilizing mechanism of the spine.
- 2) Core stability is an integral and intricate interplay between active, passive and motor control mechanisms.
- 3) Core stability is composed of strength, endurance, power, balance as well as fine contraction interplay between spine, abdominal, hip muscles.
- 4) TrA is the first trunk muscle to fire irrespective of direction of limb movement.
- 5) Due to limited clinical evidence future researches can correlate core stability with athletic performance.

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