Osteopathic Family Physician (2011) 3, 239-245

ELSEVIER

acofp Osteopathic Family Physician

The anatomical "core": a definition and functional classification

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KEYWORDS:
Core;
Static function;
Dynamic function;
Sensory-motor control

The anatomic core is important in the functional stabilization of the body during static and dynamic movement. This functional stabilization is an integral component of proprioception, balance performance, and compensatory postural activation of the trunk muscles. The structures that define the core and its functions are presented here. By understanding the contributing components and responsibilities of the core, it is hoped that the physician will have a better understanding of core function as it relates to the performance of their patients' activities of daily living.

Core training has found its way into the lexicon of countless exercise regimens. However, clinically there has been little comprehensive definition and even less practical characterization of this "core." The word *core* derives from the Greek word *kormos*, which loosely translates to "trunk of a tree." An additional word origin comes from the Spanish word for heart, *corazon*. George Lucas selected "Corazon" as the name for the planet at the center of his "Star Wars" universe. All of these expressions allude to the center of a structure. The core is in essence exactly that, the central portion of the body, and is composed of the torso, pelvic and shoulder girdles and their musculature, connective tissues, and osseous structures.[1-5]

An important relative concept when discussing the core is "center of mass." The center of mass is a dynamic point around which balance is maintained and it is dependent on the position of the body at a given moment in time.[1] As the extremities are extended, or are in various positions within their normal range of motion, a shift of the focal center of mass is effected.[6] As the center of mass changes its relative position within the body, the core operates as an integrated functional unit, synergistically adjusting the entire body to maintain balance, postural stabilization, and mobility. These abilities are essential in the performance of basic activities of daily living (ADLs).[7]

Neurologic and musculoskeletal impairments can alter these normal biomechanical relationships.[8-10] Such impairment effects a functional shift of the structural burden to the components of the core.[1] The resultant alterations impose specific distinctive demands, resulting in applied adaptations that often lead to somatic dysfunction.[8-10] These dysfunctions manifest in both the osseous framework and their supportive muscle groups.[7-10] Defining these distinct inert and active core components is the objective of this article.

Anatomy– overview

The core is composed of the torso, or trunk, and the pelvic and thoracic girdles.[1,3-5] Factors contributing to stability and function, and therefore the biomechanical integrity, include an osseous scaffolding, multiple dynamic muscle groups, cartilaginous and ligamentous structures, and a varied and diverse set of joints. The alignment of underlying boney frame has a direct relationship to the effectiveness of the applied forces from the relative motor unit.[5]

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doi:10.1016/j.osfp.2011.07.001

The musculature of the core in turn aligns the spine, ribs, and pelvis, allowing for the absorption and dispersal of externally applied forces, whether static or dynamic, to a controlled direction. Appropriate muscle recruitment and timing is extremely important in providing stability.[5,11] These muscles consist of both local and global stabilizing systems that must work coherently to achieve this dispersement. Alteration of the relationship between any of these components can result in proprioceptive imbalance, undue wear, and potential disruption of ligamentous or cartilaginous structures.[6] The core, as described, is composed of inert and active structures. These distinct yet symbiotic subsets each have further divisions that are responsible for a particular function.

The inert skeletal frame is what delineates the shape of the torso.[4,10] Defining the "normal" relationship of the interconnected bones is important when contemplating their functional responsibilities. The base of the core lies within the pelvis and therefore the pelvic girdle, which is composed of the right and left innonimates, and is conjoined posteriorly via syncytial joints to the sacrum.[3] Medial, anterior, and inferior, the pubic symphysis joint functions as a point of stabilization within this closed system. The pelvic girdle is loaded via the lumbar-sacral joint transmitting weight from the axial spine. The thoracic spine lies stacked on the five lumbar vertebrae. The ribs arise from the thoracic spine and frame the thoracic cage, anchoring anteriorly to the sternum. The sternum articulates via a hyaline cartilaginous interface, completing the cage.

With the exception of the pubic symphysis (cartilagenous articulation) and the first rib articulation to the sternum (synchondrosis), all of the relevant joints of the core are plane or gliding joints. These gliding joints allow only a slight slipping or sliding of one bone over the other and are formed by the apposition of plane surfaces—one slightly concave and the other slightly convex. These joints articulate between processes of the vertebrae, at the costovertebral and sternocostal juncture, and are enveloped by capsules lined by synovial membrane. The amount of motion between the surfaces is limited by the ligaments or by the articulating bones.

Anchored upon this thoracic core are the scapulas, providing a stable articulation for the upper extremities and allowing for effective locomotor function of the appended extremities. The scapular-thoracic articulating surfaces form what is termed a *false joint*. The components of this "articulation" are married in their form and function because of the shared muscular support and not a true osseous interface.[10]

The connective tissues within the framework simultaneously provide both stability and flexibility. Between any two adjacent vertebrae rests a tough but elastic fibrocartilaginous intervertebral disk. These intervertebral cushions contribute to the stability of the spinal column because they are strongly bound to the vertebrae, yet allow for considerable movement between the adjoining bones. Furthermore, they allow the spinal column to absorb significant weight-bearing loads. A soft gelatinous center, the nucleus pulposus, lends resilience to the joint.

Anterior and posterior to the spine lie the longitudinal ligaments. Ligaments are composed of collagenous fibers that are pliant and flexible. It is this elasticity of the ligament that in the correct biomechanical position can act as a contributor to or a substitute for muscle power. These ligaments, along with the apposition of the boney articulation at their anatomic endpoint, limit movement.

Sensory-motor control

An established relationship has been demonstrated among core stability, balance performance, and activation characteristics of the trunk muscles.[1] Sensory-motor control is an integral component because it relates to postural response, stability, mobility, and proprioception. All skills are both innate and yet trainable. The role of sensory-motor control is much more important than the role of strength or endurance of the core musculature. For example, anxiety associated with a position the individual has not experienced or is uncomfortable with results in a reactive response, placing the body into a posture in which the muscles of record have control of balance.[6,12,13]

The central nervous system (CNS) then creates a stable foundation for movement through co-contraction of particular muscles. The contributions and sequence of the various trunk muscles involved in recovery depend on the task being performed.[6] This "muscle memory" of the position, to which balance confidence is reacquired, is a learned skill that can be effected with repetition. This appropriate muscle recruitment and timing is an extremely important tenet in providing core stability.[13]

Functional responsibilities

Static function

Postural stability—standing and seated—is a function of low-level co-contraction of the trunk muscles.[14] A degree of stiffness is maintained, giving sufficient stability against minor perturbations. A combination of local and global stabilizers must work coherently to achieve core stability. To remain static and move unnecessarily the core muscles must provide support to the axial skeleton (skull, spine, and tailbone) and maintain alignment to provide a steady, solid base.[4] The kinematic- and kinetic-associated behavior of the trunk in postural response cannot be overlooked. There are constant minute multisegmental movements performed by the core musculature in the duties of maintaining these "static" postures.[6,13,14]

A secondary, but equally important, static function is autonomic. The core muscles provide stabilization of the thorax and the pelvis during internal pressure necessary to expel an internal substance (Valsalva maneuver).[1-3,12] All normally involuntary, and sometimes voluntary, actions are accomplished with the assistance of the pelvic floor. Practical examples include but are not limited to micturition, continence of both bowel and bladder, and in the performance of labor and delivery.[3,12,13,15]

Dynamic function

Dynamic functional activities are multiplanar and require deceleration, dynamic stabilization, and acceleration.[6] These actions take into account the inert skeletal structure (as a lever) in addition to the force of external resistance, and consequently incorporate a complex combination of muscle activation to optimize joint positioning with the goal of dissipating force.[4] A motion may appear to be in a single plane, but other planes need to be stabilized to allow for the primary activity. During dynamic movement there is more dependence on core musculature than just skeletal rigidity, as in a static situation. This is because the purpose of movement is not to resist a static, unchanging resistance, but to resist the force that changed its plane of motion.[6] By incorporating movement, the bones of the body must absorb the resistance in a fluid manner and thus tendons, ligaments, muscles, and innervations take on different responsibilities. Sequential muscles are recruited in advance of the focal movement to contribute to the stability of the motion. These responsibilities include postural reactions to changes in speed (quickness of a contraction), motion (reaction time of a contraction), and power (amount of resistance over a period of time).[6,13]

Musculature

The musculature of the core can be divided into four distinct functional groups based on the movement that is produced. These groups are named based on the primary direction of movement when they are actively functioning as stabilizers. The four groups are anterior, posterior, medial, and lateral.[16-22]

The anterior core is composed of the internal and external obliques, transverse abdominus, rectus abdominus, levator ani, and diaphragm (Table 1).[17,19,20,22-26] The muscles as a group primarily perform the static function of stabilizing the spine and increasing intra-abdominal pressure.[17,19,20,22-25] This anticipatory function transpires as the pelvic floor, diaphragm, and transverse abdominus tensioning the transverse lateral fascia, creating a rigid cylinder.[27,28] Rectus abdominus contracture has a similar action upon the abdominal fascia.[16] This resultant increase in intra-abdominal pressure allows segmental unloading of the spine and increases trunk stability, minimizing displacement of the abdominal and pelvic contents when the abdominal and pelvic floor muscles contract.[29,30] The obliques

Table 1 Anterior Core Musculature

Muscle	Origin	Insertion	Innervation	Primary function
Anterior Musculature				
External Oblique	External surfaces of 5th-12th ribs	Linea alba, pubic tubercle, and anterior half of iliac crest	Thoracoabdominal (inferior 6 thoracic nerves) and subcostal nerve	Compress and support abdominal viscera, flex and rotate trunk
Internal Oblique	Thoracolumbar fascia, anterior two-thirds of iliac crest, and lateral half of inguinal ligament	Inferior border of 10th-12th ribs, linea alba, and pectenpubis via conjoint tendon	Thoracoabdominal (ventral rami of inferior 6 thoracic nerves) and first lumbar nerve	
Transverse abdominus	Internal surfaces of 7th-12th costal cartilages, thoracolumbar fascia, iliac crest, and lateral third of inguinal ligament	Linea alba with aponeurosis of internal oblique, pubic crest, and pectin pubis via conjoint tendon		Compress and support abdominal viscera
Rectus abdominis	Pubic symphysis and pubic crest	Xiphoid process and 5th-7th costal cartilage	Thoracoabdominal (ventral rami of inferior 6 thoracic nerves)	Flexes trunk (lumbar vertebrae) and compresses abdominal viscera
Levator ani	Body of pubis, tendinous arch of abturator fascia, and ischial spine	Perineal body, coccyx, anococcygeal ligament, walls of prostate or vagina, rectum, and anal canal	Nerve to levator ani (branches of S4) and inferior anal (rectal) nerve and coccygeal plexus	Helps to support the pelvic viscera and resists increases of intra-abdominal pressure
Diaphragm	Sternal: Posterior xiphoid process Costal: interior, inferior six costal cartilages and adjoining ribs on each side Lumbar: Medial and lateral aponeurotic arcuate ligaments, and anterior L1-L3)		Phrenic nerves (C3-C5), peripherally intercostal nerves (T5-Y11), and subcostal nerves (T12)	Inspiration, braces abdominal viscera

Table 2 Posterior Core Musculature

Muscle	Origin	Insertion	Innervation	Primary function
Posterior musculature				
Extrinsic back muscles				
Latissimus dorsi	Spinous processes of inferior 6 thoracic vertebrae, thoracolumbar fascia, iliac crest, and inferior 3 or 4 ribs	Floor of intertubercular groove of the humerus	Thoracodorsal nerve (C6, C7, and C8)	Extends, adducts, and medially rotates the humerus: raises body toward arms during climbing
Intertransversii lumborum	Transverse processes of lumbar vertebrae	Transverse processes of adjacent vertebrae	Dorsal and ventral rami of spinal nerves	Aid in the bending of vertebral column; acting bilaterally, they stabilize vertebral column
Intermediate Layer of intrinsic back muscles				
Erector spinae: *Iliocostalis Lumborum* *Longissimus*	Arises by a broad tendon from posterior part of iliac crest, posterior surface of sacrum, sacral and inferior spinous processes, and supraspinous ligament	Fibers run superiorly to angles of lower ribs and cervical transverse processes, fibers run superiorly to ribs between tubercles and angles to transverse processes in thoracic and cervical regions	Dorsal rami of spinal nerves	Acting bilaterally, they extend vertebral column and head; as back is flexed they control movement by gradually lengthening their fibers; acting unilaterally, they laterally bend vertebral column
Deep layer of intrinsic back muscles				
Multifidus	Arises from the sacrum and the ilium, transverse processes of T1-T3, and articular processes of C4-C7	Fibers pass superomedially to spinous processes of vertebrae above, spanning 2-4 segments	Dorsal rami of spinal nerves	Stabilizes vertebrae during local movement of vertebral column
Rotatores	Arise from the transverse processes of vertebrae; are best developed in thoracic region	Pass superomedially to attach to junction of lamina and transverse process of vertebrae above their origin, spanning 1-2 segments	Dorsal rami of spinal nerves	Stabilizes vertebrae and assist with local extension and rotary movements of vertebral column; may function as organs of proprioception
Minor deep layer of intrinsic back muscles				
Interspinales lumborum	Superior surfaces of spinous processes of lumbar vertebrae	Inferior surfaces of spinous processes of vertebrae superior to vertebrae of origin	Dorsal rami of spinal nerves	Aid in extension and rotation of vertebral column
Posterior abdominal wall				
Quadratous lumborum	Medial half of inferior border of 12th rib and tips of lumbar transverse processes	Iliolumbar ligament and internal lip of iliac crest	Ventral branches of T12 and L1-L4 nerves	Extends and laterally flexes vertebral column; flexes 12th rib during inspiration

Table 3 Lateral Core Musculature

Muscle	Origin	Insertion	Innervation	Primary function
Lateral musculature				
Gluteus medius	External ilium	Lateral greater trochanter	Superior gluteal L5, S1	Abducts and medially rotates thigh, keeps pelvis level when opposite leg is raised
Gluteus minimus	External ilium	Anterior greater trochanter	Superior gluteal L5, S1	
Piriformis	Anterior sacrum, sacrotuberous ligament	Superior aspect of greater trochanter	Anterior branch S1-S2	Laterally rotate extended thigh and abduct flexed thigh, steady femoral head in acetabulum
Superior gemelius	Superior ischial spine, Inferior Ischia tuberosity	Medial aspect of greater trochanter	N. to obturator L5, S1	
Inferior gemelius	Superior ischial spine, inferior ischia tuberosity	Medial aspect of greater trochanter	N. to quadratus L5, S1	
Obturator internus	Obturator membrane and surrounding bones	Medial aspect of greater trochanter	N. to obturator L5, S1	
Quadratus femoris	Lateral border of ischial tuberosity	Quadrate tubercle of femur	N. to quadratus L5, S1	Laterally rotates thigh, steadies femoral head in acetabulum
Quadratus lumborum	Medial half of inferior border of 12th rib and tips of lumbar transverse processes	Iliolumbar ligament and internal lip of iliac crest	Ventral branches of T12 and L1-L4 nerves	Extends and laterally flexes vertebral column, fixes 12th rib during inspiration

meanwhile are independent in unilateral movements and assist in trunk rotation and lateral flexion.[20,22,24]

The posterior core muscles include the latissimus dorsi, intertransversii lumborum, erector spinae, iliocostalis lumborum, longissimus, multifidus, rotators, interspinales lumborum, and quadratus lumborum (Table 2).[26,31-34] These muscles can be divided into extrinsic and intrinsic contributors. The intrinsic musculature can then be further stratified by intermediate, deep, and minor deep. The final posterior core layer is anterior to the deep intrinsic musculature, forming the posterior abdominal wall. As a group, the posterior core muscles function to provide trunk extension and shear force resistance. Globally, they work to stabilize spinal orientation, contributing to overall posture. Locally, their contributions are to control segmental "lever arms," countering redistributions of the center of mass. Individually, the posterior core muscles can act unilaterally by providing trunk rotation and lateral flexion.

The contributory role of the extrinsic latissiumus dorsi is controversial; however, it has been shown to assist in spinal stabilization through an increase in tension and distribution of forces by way of its insertion in the thoracolumbar fascia. The erector spinae, as it relates to the core, is subdivided into the iliocostalis lumborum and longissimus. Bilaterally, they act to extend the vertebral column and stabilize posture. As the back is flexed they eccentrically control movement by gradually lengthening their fibers, opposing the rectus abdominal musculature.[35] Acting unilaterally, they contribute to laterally bending the vertebral column.

The multifidus muscles' principle action is posterior sagittal rotation of the lumbar vertebra.[20] However, in rotation their main action is not necessarily to produce rotation but to oppose the trunk flexion that is accompanied with the rotation. The multifidus muscles provide stabilization by increasing intra-abdominal pressure and are particularly active in sagittal plane movements as mentioned before. With these muscles actively contracting during rotation, thus preventing trunk flexion, they also increase the spinal stiffness through their co-contraction with the transverse abdominus.[26,31,32,36]

The medial and lateral core muscles provide medial and lateral stability to the entire core/lumboplevic complex. These muscle groups provide the integral link to transfer of force and support from the distal to proximal segments of the entire kinetic link system and provide support for the spine. Anteriorly, the force is redirected in part because of the relationship of the transverse lateral fascia-abdominals and their connection to the gluteal musculature and posteriorly via the connection between the multifidus muscles as they blend into the superior medial aspect of gluteus maximus.

The lateral core musculature includes the gluteus medius, gluteus minimus, piriformis, superior and inferior gemelli, obturator externus and internus, quadratus femoris, and the quadratus lumborum (Table 3).[10,24,31,36] The primary muscle of all the lateral core musculature is the gluteus medius. The gluteus medius is the primary stabilizer of the core in both open and closed kinetic chain activities. During open kinetic chain activities, the gluteus medius abducts the hip. Functionally acting as an abductor in open kinetic chain activities, the gluteus medius also functions as a major pelvic stabilizer when the kinetic link is closed. Although the main function of the gluteus medius is hip extension, it also assists with the lateral core stability while performing external rotation at the hip.

Table 4 Medial Core Musculature

Muscle	Origin	Insertion	Innervation	Primary function
Medial musculature				
Adductors brevis	Body and inferior pubic ramus	Pectineal line, proximal linea aspera	Obturator L2, L4	Adducts thigh
Adductors magnus	Inferior pubic ramus, ischial ramus	Gluteal tuberosity, linea aspera, medial supracondylar line	Obturator L2-L4	Adducts thigh and to some extent flexes
Adductors longus	Body and inferior pubic ramus	Middle 1/3 of Linea aspera	Obturator L2-L4	Adducts thigh adductor part: flexes thigh Hamstring part: extends thigh
Pectineus	Superior ramus of pubis	Pectineal line, just inferior to lesser trochanter	Femoral L2, L3	Adducts and flexes thigh; assists with medial rotation of thigh
Iliopsoas: *Psoas minor*	Sides of T12-L1 vertebrae	Pectineal line, iliopectineal eminence	Ventral rami of lumbars L1, L2	Acts conjointly in flexing thigh at hip joint and in stabilizing joint
Psoas major	Sides of the T12-L5 vertebrae	Lesser trochanter of femur	Ventral rami of lumbars L1, L2, L3	
Iliacus	Iliac crest, iliac fossa, ala of sacrum, anterior sacroiliac ligaments	Lesser trochanter and femur distal to, tendon of psoas major	Femoral L2, L3	

The medial core musculature that acts to stabilize the core is composed of the adductor brevis, adductor magnus, adductor longus, pectineus, illiacus, and psoas (Table 4).[26,31,32,37-39] The medial core musculature is a relatively strong set of muscles, often stronger than the lateral core musculature. However, when comparing the medial with the lateral core musculature, the role of the medial core and its contributions to overall core stability may be significantly less than that of the lateral core musculature.[26,31,32,37-39]

Conclusions

A basic precept of osteopathic medicine is the interrelationship between structure and function. The connection of the structure and function of the core is a reflection of this truism. The structural components outlined in this discussion function to reduce force load, dynamically stabilize, and generate strength against abnormal forces. An effective core allows for the maintenance of an optimal relationship of the functional agonists, which makes it possible for the body to maintain favorable biomechanical relationships. This biomechanical interconnectivity affects routine activities of daily living, which is, in essence, human performance.

The goal of this paper was to define the individual muscular contribution of core musculature. As research progresses, the definition may change with a few variations; however, the contribution of the muscles identified will assist by serving as a benchmark definition. By understanding the muscles contributing to core stability, it is hoped that the individual practitioner will take into consideration anatomical core function and postural activation when evaluating their patients.

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