Core stabilization, Core Coordination

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Abstract

This paper introduces the reader to the concepts involved in spinal stabilization from two perspectives: one that of scientific research and the other, a theoretical and experiential framework for understanding movement based on the author's many years of study with Hubert Godard. The importance of spinal stabilization has been recognized for many centuries in diverse cultures. Modern research methods bring information available through electromyography. The mechanical and neurological aspects are described. Spinal stabilization involves a co-contraction of lumbar multifidus and transversus abdominis and seems to be an effective approach to resolving low back pain. The living movement perspective, based on the work of Godard, Rolfer, dancer and movement educator, clarifies the involvement of the diaphragms in core stabilization and suggests a dynamic approach to the concept of "core." Instead of a center of holding or accumulation, it is conceived as "empty," a center of circulation.

Historical perspective

In the past 5 years, the concept of spinal segmental stabilization has received considerable attention from research science.[1] Sometimes known as "core" stabilization, this approach puts a focus on the role of the abdominal muscles in rehabilitation and prevention of low back pain. Although it seems a recent discovery in the western world, the importance of the basic movement has been recognized throughout history and in many cultures:

In the practice of yoga, students learn to apply "bandha" to seal the unified energy of inhalation and exhalation. These subtle movements often precede the practice of a specific pose or asana. The bandha "uddiyana" is described thus, "the belly above and below the navel should be pressed or drawn backwards toward the spine." And more mysteriously: "uddiyana is so called because the great bird, Prana, tied to it, flies without being fatigued." The text is from 1915, but of course the pose itself dates back centuries.
(Figure 1 and Figure 2)["uddiyana front" and "uddiyana side]
The bandha is described as having the potential to bring back youth and vigor, and the author assures us that "by practicing this for 6 months, one can undoubtedly conquer death."[2]

In the world of martial arts in the Chinese tradition, the lower tantien is found in this same area, about two inches below the navel. B.K. Frantzis describes it thus: "The tantien is the single most important gate with regard to physical health. Located in approximately the center of the body, all energy lines related to physical health and well-being connect here."[3] As with the bandha, the movement of drawing in this area of the belly to flatten the back is key in all the movements of Tai Chi.

The same idea is apparent in the work of Bess Mensendieck who is considered to have been an influence on both Ida Rolf and Martha Graham, among others. For example, she describes "The Round Forward Trunk Bending Exercise" (Figure 3) in a text from 1937:[4]
["Mensendieck Forward Bend"]
"Slowly draw in the abdomen by contracting the lowest section of the Abdominal muscle, starting at the

lowest point of the region below the navel."
More familiar to us today is the work of Joseph Pilates, Mensendieck's contemporary and compatriot. Pilates' expression for this area is the "powerhouse," also called "the girdle of strength."[5] [6]

Throughout the ages the movement that brings the navel towards the spine has been recognized as an essential underpinning of good coordination and health.
The modern investigation of this movement has come in response to a pathology, specifically, the problem of low back pain. With the help of electromyography, a more precise description of what is involved in the movement is possible. The current understanding is that the movement of bringing the navel towards the spine involves a co-contraction of lumbar multifidus and of transversus abdominis, specifically the sub-umbilical portion. [7] [8] (Figure 4; Figure 5) ["multifidus Pansky" and "transversus"]

The next section of this paper will examine the contribution of modern research to our understanding of this movement. Following that, in an attempt to broaden our perspective, we will turn to the world of movement as experienced.

Mechanics of Spinal Stabilization—what is stabilization?

It is commonly accepted that what makes a back "bad" is some kind of instability or imbalance. Standard approaches to back rehabilitation usually involve mobilizing joints and strengthening muscles. Generally this has taken the form of passive manipulation for the joints combined with exercises to strengthen either abdominal muscles as in sit-ups, or back extensors as in the McKenzie system.

In 1992, a model proposed by Panjabi introduced a refinement in the definition of stabilization. Instead of just looking at the joint in terms of bone and ligament, Panjabi argued that muscle involvement and neurological control would play key roles in joint stability. [9] The ligaments' main influence comes at the end range of the movement within the joint. In the mid-range of the joint, what Panjabi calls the neutral zone, the action of muscles would be necessary to maintain the joint's stability. (Figure 6)[" neutral zone"] Panjabi's model suggests that the three aspects—osseoligamentous, muscular and neurological--have to work together. However, to explore them here, we have to take them one at a time. We will take the mechanical aspect first, and then explore the role of the nervous system more deeply.

The deep support system

Studies of a healthy knee joint have shown that in movement, some muscles control and support the joint position, while others are engaged in moving the joint.[10] Although muscles may play different roles in different movements, through electromyography it has been possible to identify certain muscles as primarily performing a support function. For example, in the knee, the vastus medialis, which is usually considered an extensor, turns out primarily to control and support the patella during movement. [11]

The length of fibers of the stabilizers does not change very much over the course of a movement. Instead they remain consistently short to hold the joint in its neutral zone (before the end range where the ligaments get involved), to help it keep its integrity while it is handling load or doing larger motion.

Global and local muscles

Stabilization in this sense of deep support is found to be primarily the role of what Bergmark terms "local" muscles, as distinct from "global" muscles.[12] Local muscles are usually deeper and closer to the joint than the muscles involved in moving the joint, the global muscles. Local muscles also often attach directly to the joint capsules. [13] Global muscles are more superficial and tend to be larger. They are responsible for transferring and balancing external loads and for bigger movements. The local muscles' length changes very little and thereby does not have a big impact on the actual movement of the joint. The job of local muscles is primarily to stabilize the joint while the other muscles do the moving.

Multifidus and transversus

Two muscles have been identified as primary stabilizers of the low back: lumbar multifidus and transversus abdominis. Because of their location and the direction of their fibers, these muscles control the lumbar and lumbo-sacral joints specifically, rather than acting on the relationship of thorax and pelvis. (Figure 7) [insert "multifidus2.pdf]

With reference to the trunk, McGill provided evidence that the deep fibres of the lumbar multifidus undergo only minimal changes in length throughout the range of motion. This is due to their proximity to the center of rotation of the lumbar joints and suggests that this specific component of the back muscles contributes minimally to the production of motion. In addition, due to the transverse orientation of the muscle fibres of the transversus abdominis, biomechanically, it cannot contribute to extension, flexion or lateral flexion of the spine…
Thus the transversus abdominis and lumbar multifidus, like the vastus medialis obliquus of the knee, have primary roles that do not include the production of motion. [14]

The responsibility of these deep support muscles--transversus abdominis and lumbar multifidus--is not to move the spine, but to stabilize it so that other muscles can move the trunk without compromising the integrity of the joints. For the lumbar spine, transversus and lumbar multifidus are examples of local muscles, while rectus abdominis and the external obliques are examples of global muscles (Figure 8) ["global muscles"] Engagement of rectus abdominis or the external obliques is likely to pull the chest and pelvis together. The direction of transversus fibers, in contrast, is parallel to the vertebrae. Transversus thus will be able to act very precisely on each vertebra, one at a time.
The co-contraction of the transversus, in particular the sub-umbilical portion, and lumbar multifidus muscles on each side of the spine will be able to increase the stiffness of the lumbar segments without interfering with trunk movement. The result of their contraction does not interfere with rotation, mobility of the trunk in general, or with the freedom of motion of the limbs. In fact, it hardly moves the spine at all: it actually holds it in place. Co-contraction at the level of deep, local, muscles can create support without restricting bigger movement. In dance, yoga and martial arts, it is important because it allows the mover to be strong in the belly and still free above.

Neurological component

The effectiveness of a support muscle depends on a neurological component as well as a mechanical one. The muscle must be strong enough to do its job of stabilizing, and also it must act at the proper time. In Panjabi's model (see above), knee problems or back pain and instability were associated with too *large* a neutral zone, in other words, the stabilizer muscles took *too long* to begin to fire. When the deep support system doesn't do its job, the ligaments are at risk. Several studies have shown that a contraction of transversus abdominis normally will *precede* the contraction of muscles producing movement of either arm or leg by around 110ms. A healthy body automatically uses transversus to stabilize the spine before initiating any movement of the limbs themselves. In patients with a history of back pain, the contraction of transversus abdominis was delayed from 50-450ms.[15] The pathology seems to be more a result of inadequate stabilizer function than a problem in the global muscles. For the stabilizer muscles, good functioning depends on more than strength: it depends on coordination, on nervous system control. Timing is essential: To maintain a joint's integrity they must be able to fire before the main muscles of action. Stabilization is pre-movement.[16]

The role of lumbar multifidus and transversus in low back pain rehabilitation

Carolyn Richardson and her colleagues in Australia investigated the role of these muscles in back pain and healthy patients. [17]In Richardson's experiment, the researchers found that only 10% of those with a history of low back pain could activate the transversus abdominis, compared with 82% of the non-low-back-pain subjects. They found that patients who performed exercises that specifically targeted the transversus abdominis over the course of 10 weeks experienced a significant decrease in pain and an increase in functional ability compared to the control group which received conventional treatments such as swimming, workouts and sit-ups. At the 30 month follow-up, the improvement had been maintained.

As for the multifidus, it was found that in patients with back pain, the size of the muscle was reduced at the segment and on the side of the pain. The studies found that when the size of the lumbar multifidus had been increased through specific exercises, there was a significantly lower incidence of recurrence of low back pain episodes.

Richardson's research supports the idea that the back pain results more from inadequate function of the stabilizer muscles than deficiency in the global muscles. One implication of this is that many stabilization programs are not specific enough. Sit-ups and lumbar extension exercises most often do not differentiate between global and local muscle involvement. Even programs calling themselves "core stabilization" may not make this distinction. This is problematic because too much development of global muscles was found actually to interfere with the action of the local stabilizer system.

Richardson's study also confirms the importance of the neurological component. She reports:

The motor skill which was practiced with high repetition changed the size of the inhibited levels of the multifidus in acute back pain patients quite quickly, in some patients within a week. With this time frame, it can be surmised that the exercise effect was not related to muscle hypertrophy, but perhaps to neurally related events in the muscle which reestablished its size as well as its control of the associated lumbar segments. [18]

An important part of rehabilitation is to re-establish the appropriate sequence of firing of the muscles: local stabilizers first, global muscles after. The exercises that Richardson used in the back pain experiment have a component of kinesthetic education, learning to feel the subtle sensation of the pre-movement. This appears to impact the connections and timing in the nervous system and lead to improvement in stabilizer function.

Other muscles involved in spinal stabilization:

Internal Obliques

The part of the internal obliques that inserts into the thoracolumbar fascia will be included as part of the stabilizer system. The fiber direction runs parallel to that of transversus abdominis and the attachments are often indistinguishable. (Figure 9) ["internal obliques"] Although technically the internal obliques are a separate muscle, the brain will recruit motor units that can accomplish the desired movement without regard to the distinctions made by anatomists. In this article, we will use term "transversus system" to refer to the combined action of all three muscles in their stabilizing function.

The role of the pelvic floor and the diaphragm in core stabilization—what is core?

Along with the transversus system, the diaphragm and the pelvic floor are often included in the structures involved in core stabilization. Together those muscles form what Richardson refers to as the cylinder of compression that influences intra-abdominal pressure (IAP)

Thus, conceptually, the transversus abdominis forms the walls of a cylinder while the muscles of the pelvic floor and diaphragm form its base and lid, respectively. ..There is some initial evidence that these four muscles act in synergy to provide a spinal support mechanism. Nevertheless, further research is required to confirm the relationship between these muscles.[19]

Richardson's model of the core is that of a structure with top and bottom, the purpose of which is to contain the visceral compartment. The evidence for the contribution of the pelvic floor and diaphragm is preliminary. In the following section, we will explore Richardson's conception and then offer an alternative.

The pelvic floor

Richardson reports that EMG recordings of the pubococcygeus muscle indicated similar onsets of activity for the diaphragm and transversus abdominis.

Preliminary studies have revealed that, when a limb is moved, the contraction of the pubococcygeus occurs concurrently with that of the transversus abdominis. It appears that a link may exist between these two muscles. [20]

The pelvic floor (Figure 10) ["pelvic floor"] is usually described as consisting of 2 muscles: the levator ani and the coccygeus muscle. The levator ani consists of several parts: puborectalis, iliococcygeus and pubococcygeus. Interestingly, the coccygeus muscle is said to be absent in some cases. [21] Gorman says "it more often varies in its proportion of muscular and tendinous fibers. It corresponds almost exactly with the sacrospinous ligament." With the piriformis, it can close the posterior part of the pelvic outlet.

One way to simplify our lived experience of the pelvic floor is to imagine it as a diamond shape that can be separated into two triangles: either a front half and a back half, or a right side and a left side. It might be considered that the coccygeus muscle occupies the back half and the levator ani the front though the levator ani also participates in closure of the rectum.

In practice Godard finds it useful to teach people to make a slight activation of only the front triangle of the pelvic floor in conjunction with the transversus system. When the distinction between front and back is not made clear in experience, patients tend to confuse a contraction of the back of the pelvic floor with a contraction of muscles like lateral rotators, gluteals and hamstrings. This is associated with a contraction of the global muscle rectus abdominis and actually interferes with the functioning of the stabilizer system of transversus. Perhaps it is in part because the feeling of activation of the stabilizer muscles is of a different order than the usual voluntary contraction; to the inexperienced it can feel like doing nothing at all. In reaction, they usually try harder and thereby involve global muscles whose contraction will restrict the extension of the leg at the hip, interfering with the basic mechanism and energy transmission required for efficient walking. [22]. Although technically, the pelvic floor may play a part in spinal stabilization, in practice it is essential to help patients have a felt experience of the difference between activating global muscles and engaging local ones, so that the work of stabilization and the work of movement remain distinct.

The diaphragm

Richardson also includes the diaphragm as an influence on IAP and therefore on spinal stabilization, though questions remain:

When subjects performed shoulder flexion, we found that both portions of the diaphragm contracted 30ms prior to the deltoid, i.e. at exactly the same time as contraction of the transversus abdominis. It is easy to see how this system may function with short duration postural tasks, but it is unknown how the diaphragm may contribute when the postural demand is sustained and the diaphragm must combine the roles of respiration and stability control.[23]

From Godard's perspective as a professional dancer, the stabilizer muscles and the respiratory diaphragm have very different functions. This becomes particularly apparent when movement as a whole is taken into consideration: the diaphragm has to be free to adapt to the needs of respiration. In practice, we don't want to encourage holding in the respiratory diaphragm because it gets in the way of free movement and ultimately of free expression. For a dancer, too much respiratory diaphragm involvement in posture can seriously hamper his/her spontaneity.

The diaphragm and the stabilizer system do interact: The quote from the Sutra Pradapika, "uddiyana is so called because the great bird, Prana, tied to it, flies without being fatigued," can be understood from the biomechanical perspective. With transversus engaged, the central tendon of the diaphragm becomes a fixed point. The action of the muscular part of the diaphragm in inspiration and expiration then raises and lowers the ribs, giving the sensation of wings in flight. Another example is when lifting a heavy object: there is often a vocalization that accompanies the moment of intense force. Godard suggests that as well as helping to coordinate the action of the laborers, the production of the sound also activates the crura of the diaphragm. This action pulls the disc forward, minimizing the compression on the discs that results from the heavy weight.

Although both the diaphragm and the pelvic floor may contribute at moments to the phenomenon of stabilization, it seems important in theory and in practice to make a distinction between the kind, quality and duration of the muscles of the transversus system and the horizontal structures of the diaphragms. Stabilizers can work for long duration, whereas the diaphragms function is to add a burst of energy.

In Godard's model, in movement, all the diaphragms of the body--respiratory and pelvic as well as the palate, and even in a sense the arches of the feet and hands--can be seen as part of a single functional system. Acting together, they energize a movement, as in jumping. In contrast, the transversus system can be engaged for long periods of time in its work of stabilization. The diaphragms act in an explosion of force: In a sense they are more phasic than tonic. In walking, one side of the pelvic floor is contracting while one side is opening. The nature of the diaphragms is dynamic. If they are used to hold a position over a long time, they will lose this dynamic ability; they will not be free to respond to the demands of action.

Understanding the diaphragms as an inter-related, dynamic system opens up the image of "core"—removing the lids, so to speak. Functionally, the stabilizers themselves can be linked into a kind of inter-related system. In this paper, thus far, we have focused on the activity around the lumbar spine, but in most actual movement situations, stabilization is occurring in multiple areas at once. For example, while the transversus system is engaged to support the lumbars, longus colli is doing a similar job for the cervical vertebrae. Vastus medialis stabilizes the patella, while serratus anterior acts to stabilize the shoulder blade for the arms.

For the body as a whole in motion, these muscles are connected as a stabilizing system via the nervous system:

Functionally, the nervous system could be expected continuously to modulate activity in these muscles in order to control joint position, irrespective of the direction of movement. In this way, such muscles could provide concentrated joint support, while, *independently, the larger torque-producing muscles control the acceleration and braking movements of the joint.*[24] *Control of the continuous muscle recruitment for joint stability depends not only on the pre-programmed motor patterns from the cortex, but also on the state of the feedback system emanating from kinesthetic input. The feedback system is complex and relates to the receptors within the muscle, which provide continuous information to the central nervous system (CNS) on the length and tension being generated in the muscle.* [25]

Through the intercommunication of the gamma motor neurons and the muscle spindles, the stiffness (resistance to change of length) of each muscle fiber is being continually monitored and adjusted. The stabilization function is also taking place in relation to the overall maintenance of equilibrium in gravity--what Godard terms tonic function--and in relation to our own proprioceptive sense, how we locate ourselves. Godard suggests that an effective strategy for accessing the stabilizing system is to work with tonic function, the relationship of our sense of weight and our sense of space, our sense of orientation. [26]

In Godard's model, we use the stimulation of sensations in the hands and feet in closed chain exercises to help to trigger the activity of the stabilizer system. Even though stabilization is functionally necessary in both open chain (the distal end is free and the proximal end is fixed) and closed chain (the distal end is fixed and the proximal end is in motion) movements, Richardson cites evidence from studies on knee rehabilitation that closed chain exercises are the more effective approach for rehabilitation of stabilizer muscles.[27] The potential danger in closed chain exercises is to provoke excessive joint compression.

When we do the simple exercise of transferring weight from hands to feet, and from feet to hands, whether in a modified dog pose or in a movement from Push Hands, or in one of the exercises on the Pilates Reformer where hands and feet are weight bearing (e.g. the Elephant, the Long Stretch, the Down Stretch), the focus is on the awareness of sensation between the skin of the hands or feet and whatever they are in contact with. By engaging sensation in the extremities—in relation to the world around us--we help the movement to trigger successively throughout the stabilizers: from the ground through the feet to transversus to the hands on the table, or from the hands on the bar of the Reformer through serratus anterior to transversus and back to the ground. In this way, we engage the stabilizers as a whole system in relation to the world.

At the same time, we focus on maintaining a sense of orientation to space and weight, a sense of opposing directions. This action helps create a feeling of "eccentric" movement--in the sense of "away from the center," instead of "concentric," –concentrated—tension. The focus on two opposing directions helps to minimize the possible compression in a closed chain movement.

Although the distinctions may seem subtle, the effects are far-reaching. In many approaches to core stabilization, the emphasis is on contracting the core muscles in relative isolation from the limbs' contact with the world. When the limbs are mobilized, they are primarily used as a means to challenge stabilization rather than as a way to activate it. In Godard's approach, it is the interaction with the world that triggers core stabilization. In movement as it is experienced, phenomenologically, stabilization always takes place in interaction with the space around us, with objects and people, through our various senses and the points of contact of our bodies and the world. The body itself becomes less important than the meeting place of the body and the world.

Center of Accumulation, Center of Circulation

In the introduction to this paper, it was pointed out that throughout history in both East and West, the movement of bringing the navel towards the spine has been recognized as a key element in well-organized action. We have explored the precision that electromyography has to offer to experience. Today we have been able to quantify some of what the ancients intuited. However, as is often the case, it is all too easy to lose the point of view of the whole while we pursue the specifics.

Some of the traditional imagery conveys the impression that the center, the core, is a kind of box, a place of accumulation. It is there in the image of the cylinder of compression, in the "house" of "powerhouse." There is a focus on the shape of the body. In yoga there is a similar image, in which the throat lock and the root (pelvic floor) lock are described as creating a vessel or a pot in the center of the body, a container for the prana. The bandhas are described as "seals," which seal the energy in the pot.

In contrast, in the oriental tradition, which Godard sees as closer to the aesthetic of dance, the center is an empty space. In Chinese painting, the mountain is always partially covered by clouds. This allows the viewer to imagine, to fill in, to participate in an active way. It allows constant adaptation. If the center were already full, there would be no movement. Instead of shape, this viewpoint seeks flow; instead of a center of accumulation, there is of a center of circulation. Movement is a transfer of energy between two directions, up and down, heaven and earth. The most effective center is empty. From this perspective, the work of the transversus system becomes to help make possible the transfer of movement, between hands and feet, between the world of manipulated objects and the supporting ground. Hubert light-heartedly admonishes us, in this context, not to 'capitalize' our chi.

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[1] Richardson, Carolyn, et al, Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain. Churchill Livingstone, Edinburgh, 1999.

[2] Major Basu, I.M.S, The Sacred Books of the Hindus, Vol XV Part III The Yoga Sastra: Hatha Yoga Pradipika. Published by Sudhindranatah Vasu From the Panini Office, Bhuvaneswari Asrama, Bahadurganj, Allagagad Printed by Apurnva Krishna Bose at the Indian Press,1915.

[3] Frantzis B.K., Opening the Energy Gates of Your Body. North Atlantic Books, Berkeley,1993.p.70

[4] Mensendieck, Bess, The Mensendieck System of Functional Exercises, Vol. I. Southworth-Anthoensen Press, Portland, Maine, 1937. p.135

[5] Latey Penelope, Journal of Bodywork and Movement Therapies vol 5 (4) Oct.2001.pp.275-282

[6] Gallagher&Kryzanowska, The Pilates Method. Bainbridge Books, Philadelphia,1999.

[7]Kendall and McCreary(, Muscles. Testing and Function, 3rd ed. Williams&Wilkins, Baltimore,1983) attribute the drawing in of the abdominal wall to the external oblique muscles, but Strohl et al (Regional differences in abdominal muscle activity during various manoeuvres in humans. Journal of Applied Physiology 51:1471-1476,1981), Lacote et al (Clinical evaluation of muscle function. Churchill Livingstone, Edinburgh,1987) and DeTroyer et al (Transversus abdominis muscle function in humans Journal of Applied Physiology 68:1010-1016,1990) say transversus abdominis predominates in pulling the belly in.

[8] Richardson,1999. p.130

[9] Panjabi, M, The stabilizing system of the spine, Part 1 and 2. Journal of Spinal Disorders 5:383-397 1992.

[10] Richardson, 1999 p.3

[11] ibid p.81

[12] Bergmark A,Stability of the lumbar spine. A study in mechanical engineering. Acta Orthopaedica Scandinavica 230(suppl):20-24.

[13] Richardson,1999. p.81

[14] ibid

[15] ibid p.63

[16] This is the component sometimes referred to as "force closure."

[17] ibid

[18] ibid p.96

[19] Richardson, 1999 p 95

[20] ibid p 52, 134

[21] Platzer W 1986 Locomotor System 3rd ed Verlag NY p.106
Gorman D 1981 The Body Moveable Ampersand Press Canada p.75

[22] See Newton, 2003, "Gracovetsky on Walking," Structural Integration Feb.2003

[23] Richardson, 1999 p.50

[24] ibid p.81

[25] ibid p.82

[26] For more on working with tonic function, see my previous publications in Rolf Lines, also available at www.alinenewton.com

[27] Richardson, 1999 p.86