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).

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) is usually described as consisting of two 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. 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.[21]

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.

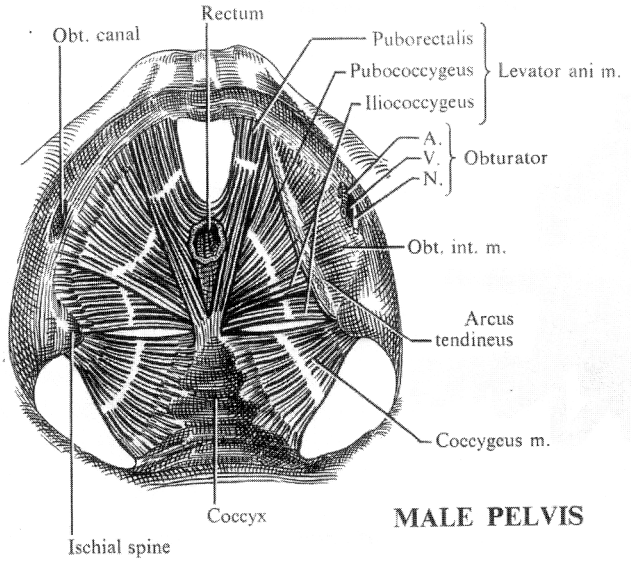

Figure 10

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 interrelated, 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 add 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 Ch'i. ❑

NOTES

[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 and 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 that transversus abdominis predominates in pulling the belly in.

[8] Richardson,1999, op. cit., p.130.

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

[10] Richardson, 1999, op cit., p. 3.

[11] Ibid, p. 81.

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

[13] Richardson, 1999, op. cit., 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] Ibid, p. 95,

[20] Ibid, pp. 52, 134.

[21] Platzer, W., 1986, *Locomotor System, 3rd ed.* Thieme Verlag, Stuttgart, New York, 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, op. cit., p. 50.

[24] Ibid, p. 81.

[25] Ibid, p. 82.

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

[27] Richardson, 1999, op. cit., p. 86.

Image titles and captions and credits

Figure 1, Figure 2
Caption: The action of drawing the navel toward the spine is emphasized in the bandha "uddiyana"

Figure 3
Caption: We find the emphasis on the movement drawing the navel toward the spine again in Mensendieck's "Round Forward Trunk Bending Exercise"

Figure 4 Multifidus,**Figure 5** Transversus Abdominis
Caption: Electromyography confirms that the co-contraction of the sub-umbilical fibers of transversus abdominis and the lumbar fibers of multifidus is the basis of lumbar spinal stabilization.

Figure 6 The neutral zone

Figure 7 The deep fibers of lumbar multifidus are close to the center of rotation of the joints. Rather than producing motion, their function is to stabilize the joints.

Figure 8 Engagement of rectus abdominis (white)or the external obliques (gray) is likely to pull the chest and pelvis together: they are examples of "global" muscles. The direction of transversus fibers(black), in contrast, is parallel to the vertebrae. It is considered a "local" muscle.

Figure 9 The part of the internal obliques (gray) 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 10 The pelvic floor can be conceptualized as a diamond consisting of two triangles, one anterior and one posterior.

Illustration Credits
Figures 1, 2 Iyengar, BKS, Light on Yoga, revised edition Schocken Books NY 1979
Figure 3 Mensendieck, Bess, The Mensendieck System of Functional Exercises, Vol. I, Southworth-Anthoensen Press, Portland, Maine 1937 Illustration 64
Figure 4 Pansky, Ben. Review of Gross Anatomy 4th ed. Macmillan Publishing Co. Inc. NY 1979, p. 157.
Figure 5 Kapandji, I A The Physiology of the Joints vol. 3 Churchill Livingstone NY 1974, p.97.
Figure 6 Richardson, Carolyn, et al, Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain. Churchill Livingstone, Edinburgh, 1999 p.23.
Figure 7 Pansky, Ben. Review of Gross Anatomy 4th ed. Macmillan Publishing Co. Inc. NY 1979, p.159.
Figure 8 Kapandji, I A The Physiology of the Joints vol. 3 Churchill Livingstone NY 1974, p.97.
Figure 9 ibid p.99
Figure 10 Pansky, Ben. Review of Gross Anatomy 4th ed. Macmillan Publishing Co. Inc. NY 1979. p.377.