Gracovetsky on Walking

by Aline Newton, Certified Advanced Rolfer

The author would like to acknowledge the extraordinary movement teacher Hubert Godard.

INTRODUCTION

Without it necessarily coming to consciousness, each of us carries an idea of biomechanics, a model, that reveals itself in our manner of moving. As practitioners, these assumptions will inevitably shape our interventions. The structural perspective is one of the most common of models. It implies that, like a building, the body is built from the ground up. In a movement such as walking, this will mean an emphasis on the ground, feet and legs, and a tendency to see problems as moving from the bottom up.

Serge Gracovetsky's work presents an alternative model of human locomotion that he calls the "spinal engine."[1] I would like to describe this model in the following pages and show how it can be useful for practitioners engaged in working with human structure and movement.

Gracovetsky takes an evolutionary approach.[2] He takes the human being in the context/environment in which we find ourselves - upright, bipedal, in gravity, using locomotion as a fundamental action. From there, certain questions follow: if this is how we ended up, what evolutionary advantages might that give us? Locomotion is basic to survival. As with uprightness, we can assume that the most adaptive situation will be one in which locomotion doesn't expend a lot of the organism's energy. In the course of evolution the spine has not become a rigid column. Instead it has kept the capacity to compress and twist even though it makes the spine vulnerable to injury. What evolutionary advantage might this provide?

THE SPINAL ENGINE

A lordotic spine is one of evolution's contributions to bipedalism.[3] Gracovetsky's thesis is that

> ...the evolutionary pressures for efficient locomotion on land forced the spine of our fish ancestors to evolve into our curved spine. The lordotic spine converts the primitive piscine lateral bend into an axial torque driving the pelvis. This theory neatly explains the need for spinal compression and torsion in locomotion. It also clarifies the central role played by the earth's gravitational field in walking and running, and suggests that the human species exploits the constancy of that field to move anywhere on the planet with a minimum expenditure of energy. A prediction of the theory was that the legs were simply following pelvic motion.[4]

In most models of gait, pelvic rotation is basic to walking; but instead of the pelvic motion being driven from the leg, in the "spinal engine" model, it is the spine's lordosis, which by converting a side-bend into an axial torque drives the pelvic rotation.

GAIT: STEP BY STEP

Taken as a whole, human locomotion involves a careful orchestration of the whole body. From the toes on the ground to the cervicals, each part plays its role in the rotational movement. At the same time, all this is organized in such a way as to leave the head free from the torquing forces below.

To understand the process step by step, let's start with the left leg (see diagrams):

-As the toes push off the ground, the hip extensors fire, and with the help of the fascial connections, extend and raise the trunk, decompressing the spine as it bends to the left. The spinous processes rotate to the right (clockwise looking from above). The rotating pelvis brings the acetabulum forward.

-Then, as the trunk falls back to the ground, the heel contacts the ground. The pelvis tilts and the right ilium is lowered. The compressive pulse generated at heel strike travels back up the spine. The pulse stiffens the fascial lines and increases the spine's torque strength. In this way, the power from the leg muscles and fascial connections attached to the transverse and spinous processes will be effective in derotating the spine.

-The compressive pulse generated by the heel strike continues upwards. The intervertebral joints extend and derotate. At the thoracic spine the pulse helps counter-rotate the pelvis and shoulders, which is the basis of the contralateral movement of gait that we see in the arms and legs.[5] Latissimus dorsi and the inertia of the arms play an important role here: the good development of the upper extremities is a key element in the chain of rotation.

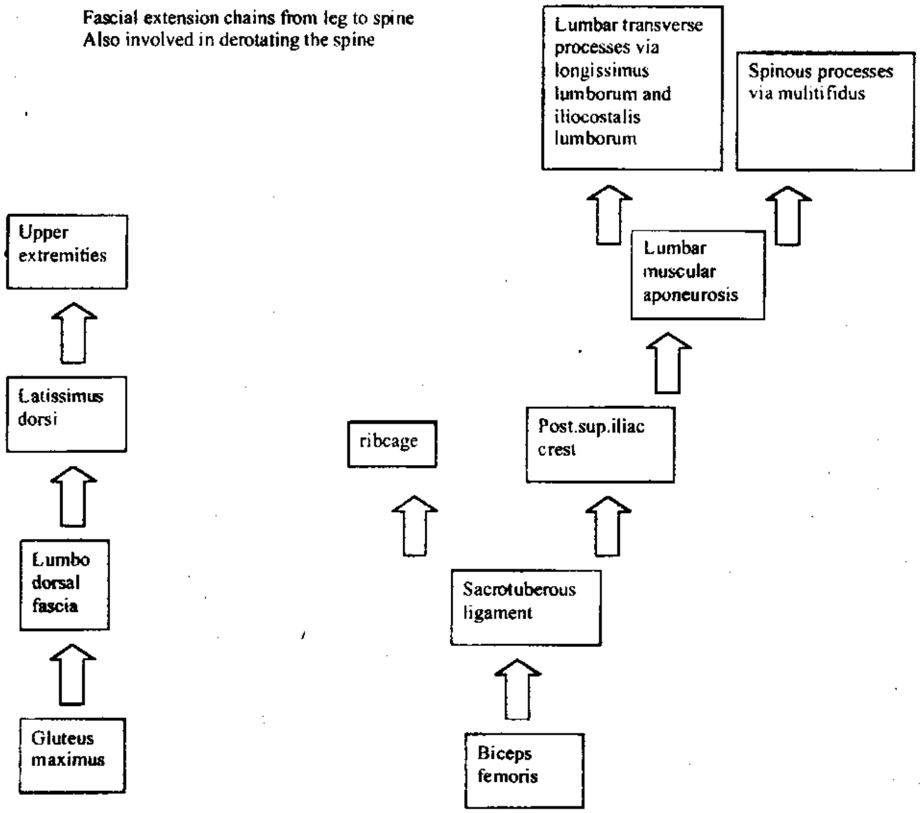
-At the level of the cervicals, again the pulse generates an axial torque which is reversed due to the organization of the facets. The effect of this is to cancel the motion of the shoulders so that the head can remain stable. While the body is involved from toe to pelvis through the whole interlocking mechanism of spinal facets and intervertebral discs in creating rotation, it stops at the head, preserving the need for stabilization of the eyes in a creature that interacts visually with its environment.

-As the pelvis returns to horizontal, and the spine to vertical, the facets get aligned and the torque continues to be transmitted through the annulus fibrosus. The spinal facets and intervertebral disks are a complementary system; they work together, spelling each other to transmit the torque with maximum efficiency:

> ...the annulus fibrosus, made of viscoelastic collagen fibers, responds particularly well to changes in angular rotation velocity. Hence, the torque transmitted by the annulus is maximum when the velocity is maximum (double-stance), which corresponds precisely to the instant when the facets' transmission is minimum.[6]

Just as the facets cease to be effective, the discs take over.

Unlike the image of the trunk sitting passively on legs that carry it along in walking, or of legs pushing the pelvis into rotation, Gracovetsky's model shows that the



Fascial extension chains from leg to spine
Also involved in derotating the spine

power goes from the leg to the spine directly. Gluteus maximus and the hamstrings are hip extensors, and also capable of directly or indirectly derotating the spine.

> Transforming the variable (raw) heel strike impulse into a well-conditioned pulse to feed the spinal engine is the basic role of the leg-pelvis system.[7]

> The legs have the required muscle mass to release enough chemical energy for running or walking. The legs also provide contact with the ground and modulate the timing, duration, and amplitude of the energy pulses generated at heel strike before transmitting them to the spine. The spine capitalizes on this energy to fuel its axial rotation, which in turn rotates the pelvis. Thus the legs perform these functions to assure gait modulation and velocity for a wide range of ground condition.[8]

The legs play an important role, but it is in providing fuel for the dynamic spine which is the true engine of locomotion.

VISCO-ELASTIC TISSUES

Gracovetsky describes the crucial role of what he calls "visco-elastic" tissues in the orchestration of walking. We are used to thinking of connective tissue as the organ of support, which suggests a structural scaffolding. Gracovetsky is looking from a movement point of view - in walking, he suggests, the connective tissues play a *dynamic* role:

> The visco-elastic nature of biological material prevents it from sustaining constant loads for extended periods of time. A constant blood pressure would deform and damage the arteries, and prevent the heart from resting. Similarly, the regular sagittal oscillating motion of the spine of the hiker carrying a backpack coupled with the anterior posterior motion of the pelvis prevents the lumbodorsal fascia form continuously transmitting forces. During the double stance, the lordotic spine switches on the erector spinae muscles and slackens the posterior ligamentous system. Conversely, at heel strike, the posterior ligamentous system being tightened can transmit forces, thereby permitting the erectors to relax and rest. Hence, muscles and ligaments alternatively time share the forces transmitted across the SI joint, delaying onset of fatigue of the back.[9]

When subjected to an energy pulse, the visco-elastic tissues can stiffen very quickly. After heel strike, the pulse stiffens the fascia that will be used to support the spine as it twists. Because of this organization, the spine is able to be strong and stable at some moments and delicate and responsive, free to make subtle adjustments, at others.[10]

ENERGY

From the point of view of evolution, the most effective walk is the most efficient one, one that leaves the organism most free to perform the functions necessary for survival. In Gracovetsky's model, walking is a *transformation* of energy rather than an energy expenditure:

> The spine-pelvis-leg system is optimized to permit locomotion at minimal energy expenditure. This entails a delicate exchange between the three basic forms of energy existing at any given moment: that is, kinetic, potential and elastic. The term elastic is used to describe the ability of ligaments to store energy by being deformed and then to restore (most) of that energy at the appropriate time.[11]

From the arch of the toes to the sub-occipital joint, legs, pelvis, spine and arms work as one system in a great work of energy transformation that lets us walk with minimal energy expenditure. The bones and soft tissues are involved in an elegant interplay that has the potential to transmit the forces with optimum ease. Far from the image of a passive trunk carried by strong legs, in this model walking transforms into a kinetic symphony:

> At each step, energy flows freely as the spine deforms in space, a view inconsistent with the concept of the disk operating as a "shock absorber" [or the spine as a column].[12]

As Gracovetsky describes it in the conclusion of his presentation:

> Gait is the result of a sequential transformation of energy intended to redirect the quasi-vertical pull of the hip extensors to a horizontal pull capable of rotating the pelvis. Beginning with the legs, muscular chemical energy is first used to lift the body into the earth's gravitational field, where the chemical energy is stored in potential form. When the body falls downwards, this potential energy is converted into kinetic energy that is in turn stored into a com-

pressive pulse at heel strike. The pulse properly filtered by the knees and the massive ligamentous structures across the SI joint travels upwards and reaches the spine with the proper shape and timing. The energy is then distributed to each spinal joint to counter-rotate pelvis and shoulder, while derotating the shoulders stabilizes the head.[13]

IMPLICATIONS FOR PRACTICE

Contralateral

In traditional gait analysis, one of the hallmarks of normal human gait is "arm opposition", i.e., opposite arm and leg moving at the same time.[14] The spinal engine model proposes that the contralateral motion is generated in the spine. If we look only at the arm and leg, we may miss the more subtle and important level.

COMPENSATORY CONSEQUENCES

Compensations for problems in the whole gait mechanism may show up where the contralateral spinal movement is missing or inhibited:

> For instance, a damaged knee will obviously [have] impacts on the efficacy of the leg forcing the muscles to compensate for the corresponding energy losses. What is perhaps less obvious is the mechanism by which the damaged knee ends up reducing the overall energy efficiency. Indeed, the chemical energy liberated by the powerful hip extensors is contained in the pulse generated at heel strike. That energy must be recovered and returned to the oscillating structure. If not, then the energy cost of gait increases significantly, as can be demonstrated by running on soft sand. As the foot sinks into the soft sand, energy is lost at the foot/ground interface. The obliques must fire to induce proper spinal motion and control of the pelvis, and the runner exhausts himself rapidly.[15]

Too much development of superficial abdominal muscles (rectus and external obliques) may limit the spine's freedom of movement in rotation. In its stead, there will be a visible homologous (head to tail) or homolateral (lateral flexion) spinal motion.

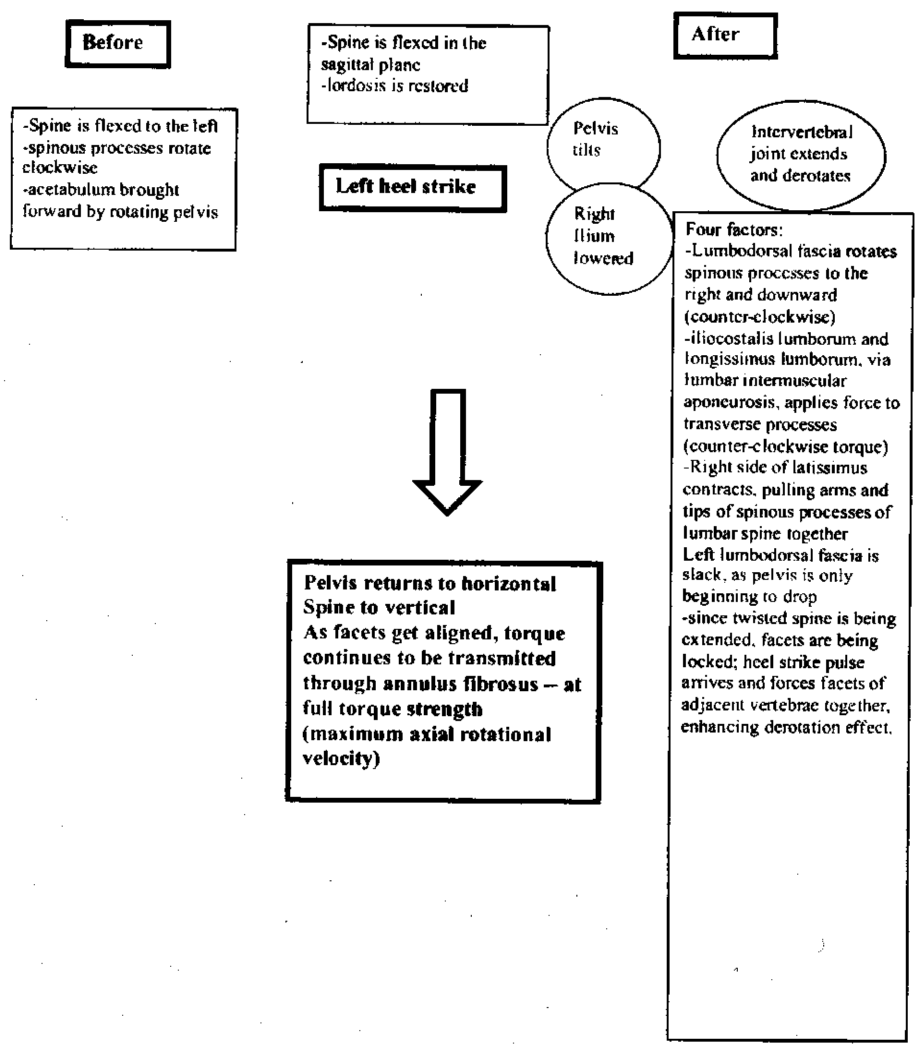
Therefore in practice, to promote a contralateral gait pattern, we will work directly with the spine and we will see the consequences also in the pattern of movement of arm and leg. Evoking two directions in the spine through both tissue work and perceptual cues leads to a better contralateral movement of the spine.

ARMS

The arms have several important roles to play in this model of locomotion. Their inertia provides a key element in the counter-rotation of the shoulders and pelvis. Through the latissimus dorsi muscle, they also help to stabilize the spinous processes, and to derotate the spine after heel strike. Problems in the freedom of movement of the arms and shoulder girdle will eventually show up in gait.8 Among other things, this gives meaning to Ida Rolf's idea of rhomboids/psoas balance: if the rhomboids hold a chronic contraction (as in shoulders braced back), it will interfere with the ability of the hip to extend, thus preventing the psoas from being stretched and lessening the effectiveness of its function (see below: "hip extension"). Again, this provides a different perspective from the structural, one in which lesions can be descendant as well as ascendant.

LOADING AND UNLOADING

For the spinal engine model as described by Gracovetsky to be effective requires loading and unloading of the spine in well-orchestrated alternation. Both are key. Loading occurs in compression, as in heel strike, and loading also occurs in tension/extension, as in push off. Here again we are encountering a difference between the structural model, in which manipulation takes place with the patient passive, in which we look at joint function but outside of a functional context. The latest terminology to describe this issue, quoted by Diane



Lee, is the contrast between form closure, how a joint operates in a passive state, and force closure:

> This functional requirement has been called effective load sharing, effective force closure or effective load transfer. In short, how well can the individual stabilize their bones and joints during both static and dynamic activities. Optimal stabilization requires accommodation to each specific load demand, through adequate, tailored joint compression, by muscles, fascia and ligaments (Vleeming, Lee, Ostgaard, Sturesson, Mens).[16]

Force closure, how all the elements involved create a coordinated movement, can only be observed in a dynamic context. It can't be seen in a dissection or addressed in a passive manipulation. It may be that some chronic back problems are not structural *per se*. Instead, the problem may be in the pattern of coordination that occurs in each moment of the actual process of walking, in the relationship of upper and lower girdles, in the moment of push off and the moment of landing.

HIP EXTENSION AND THE PSOAS

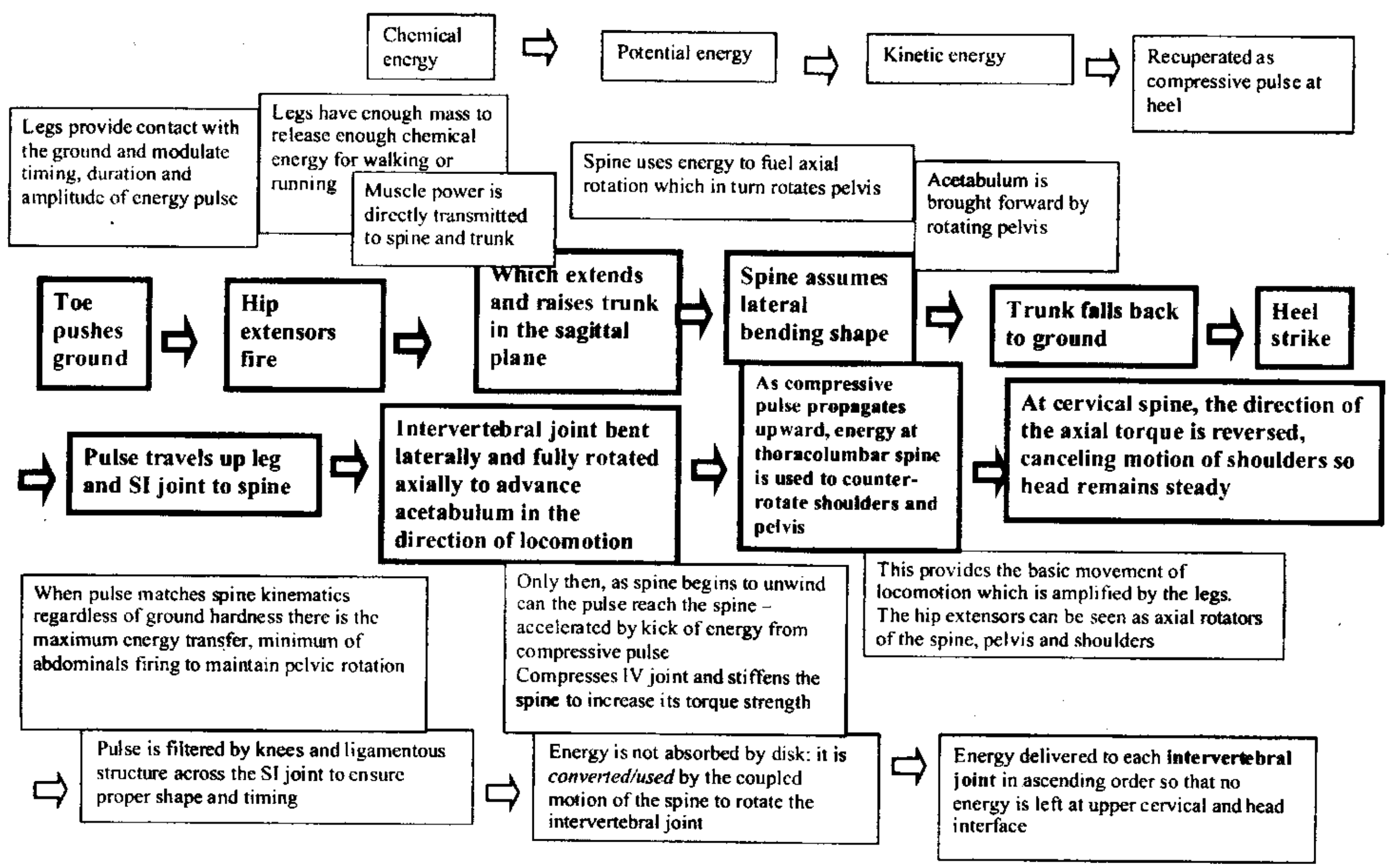
For the spinal engine to be charged with energy, the hip extensors have to be free to extend. The action of the hip extensors carries beyond the part into relationship with the movement as a whole. The hip extensors power the system by helping the spine extend and also by stretching the psoas (i.e., increasing the stored elastic energy) before it contracts to flex the hip:

> ...eccentric muscle contractions occur when the length of a muscle increases despite the contractile machinery being stimulated to shorten. In these types of contractions, the elastic tissues in the muscle and tendon are stretched. If the external load is then reduced so that a concentric contraction ensues, the potential strain energy stored in these elastic structures is available to do work. To what extent this potential energy is transformed into kinetic energy, and increases in efficiency consequently gained, depends on the type of activity and the skill of the performer.
>
> In running it has been reported that as high as 50% of the total energy requirement of running is available through elastic energy sources.
>
> The storage of elastic energy is short lasting. If a substantial delay occurs between the concentric and eccentric phases of a movement, the energy stored in the elastic structures is dissipated as heat.[17]

ENERGY TRANSFORMATION: DIFFERENT MODEL, DIFFERENT IMAGE

Even within the functional perspective, our conscious or unconscious assumptions about biomechanics are shaping what we look for, how we see, what we do. Seeing/experiencing locomotion as a coordinated sequence of rotations in relation to the ground and the arms can, in and of itself,

TAKING A STEP



change your experience in practice.

This perspective helps us to understand walking as a set of unfolding functional relationships, and the body in terms of interconnections instead of as parts.

The different premises lead to different conclusions: in the model legs-carry-trunk, the legs have to be picked up at each step, requiring the energy to hoist them against gravity: i.e., strong quadriceps. In the spinal engine model, rather than weight *lifting*, the image is of walking as a flowing transformation of energy, with minimal effort. In this model, the arms and legs need to be evenly developed, smoothly inter-related.

The spinal engine model emphasizes the complex coordination involved in locomotion. The next section of this paper will pursue this topic.

NOTES

1. Gracovetsky, Serge, *The Spinal Engine*. Springer-Verlag, NY, 1988. And: Gracovetsky, S., "Analysis and Interpretation of Gait in Relation to Lumbo-Pelvic Function", *Fourth Interdisciplinary World Congress on Low Back and Pelvic Pain.* Montreal, Nov. 2001. Posted on the website www. kalindra.com.

2. The evolutionary approach has an advantage in that it is idealized, i.e., it can look at "normal", not just "average." Although many things are possible for our human bodies, we don't necessarily exhibit their full potential, so studying how actual people move means studying compensations and less effective adaptations, and won't necessarily give us a guiding principle by which to see.

3. As Tobias points out, in *Man, the Tottering Biped: The Evolution of his Posture, Poise and Skill*, by Phillip Tobias. University of New South Wales, Kensington, NSW Australia, 1982.

4. "Analysis and Interpretation of Gait...", p. 46.

5. It may come as a surprise that there is virtually no torsion at the foot as it interacts with the ground. Gracovetsky suggests that this evolved from our fish ancestors' predicament: their pectoral fins might not have been able to transmit torque in the soft mud of their initial earthy environment.

6. "Analysis and Interpretation of Gait...", p. 61.

7. Ibid., p. 58.

8. Ibid., p. 55.

9. Ibid., p. 61.

10. Gracovetsky says that an unsupported spine collapses under 2kg of force.

11. "Analysis and Interpretation of Gait...", p. 57.

12. Ibid.

13. Ibid., p. 62.

14. Knudson, D., Morrison, M., *Qualitative Analysis of Human Movement*. Human Kinetics, Champaign, IL, 1997.

15. "Analysis and Interpretation of Gait...", p. 58.

16. Diane Lee, "An Integrated Model of 'Joint' Function and its Clincial Application", *Fourth Interdisciplinary World Congress on Low Back and Pelvic Pain.* Montreal, Nov. 2001. Posted on the website www. kalindra.com.

17. Abernethy, et al., *The Biophysical Foundations of Human Movement*. Human Kinetics Publishers, Champaign, Ill., 1997; p.171.

Aline Newton teaches movement workshops based on Hubert Godard's work, including an in-depth look at walking, in collaboration with Certified Advanced Rolfer Kevin Frank.