Muscles at Rest

A line I use in many of my talks is the old army aphorism; "Never stand when you can sit, never sit when you can lay down, never stay awake when you can be asleep." This succinctly summarizes the Darwinian concept of least energy expenditure and survival of the fittest. Biology will always take the easiest (least energy) way to perform a task, and all we have to do is compare which of our concepts of bodily functions is least energy requiring and that will be the most likely path of evolution.

Fig. 1. Limp wrist. Ligaments alone do not stabilize a wrist, muscle input is necessary.

Let your wrist limp, now shake it (Fig.1). This demonstrates that most joints when supported by ligaments alone, (wrist, ankle, neck, foot, etc.), are unstable. There are exceptions, most notably the SI joint, and we will get back to it latter. It is the muscles that stabilize most of the joints and keep us from falling in a heap. Masi and Hannon (2008) believe that there is an inherent resting muscle tone (RMT) that exists independent of CNS input. However, take a rhinoceros standing in a field and shoot it with a curare dart, and it will collapse. Standing humans are EMG silent, that is their EMG of the 'postural' muscles record no activity, and I would think the same is true of a standing rhinoceros. (No, I have not done EMGs on a Rhino!) It will be the RMT that keeps him standing. Curare works at the neuro-muscular synapse, so it is the CNS that maintains the muscle tone, including the resting muscle tone (RMT). In my many years of doing surgery, I have never cut a muscle that did not retract unless it was curare-ized, (and even then there is some contraction), so it is a primitive function, maybe some of it spinal, present in deeply anesthetize creatures. Live muscles (and all biologic structures) always have a level of tension, often called "pre-stressed" but is really "intrinsic stress", that are part of the nonlinear mechanics common to all biologic tissue, and the stress/strain curve in nonlinear biologic structures never zeros out (fig 3). There is always some residual tension in the system, but it doesn't seem sufficient to maintain standing posture.

Knowing this, we then know that an EMG is not indicator of muscle tension. EMGs only inform of active contraction of a muscle. EMGs are like torque wrenches that tell you when you are in the process of increasing tension, but give no information unless you are actively increasing the torque. They do not show relaxation, lengthening, or when a muscle stays isometric and isotonic. Since we must conform to stand-sit-lay (S/S/L) philosophy of least energy, our best bet is to use our muscle isometrically and isotonically, as that require the least amount of energy. If that is so, muscles - all muscles, are functioning all the time, and EMGs need to be better understood. Active muscle contraction as expressed by an EMG is an inefficient use of muscle, (a concept exploited in biofeedback).

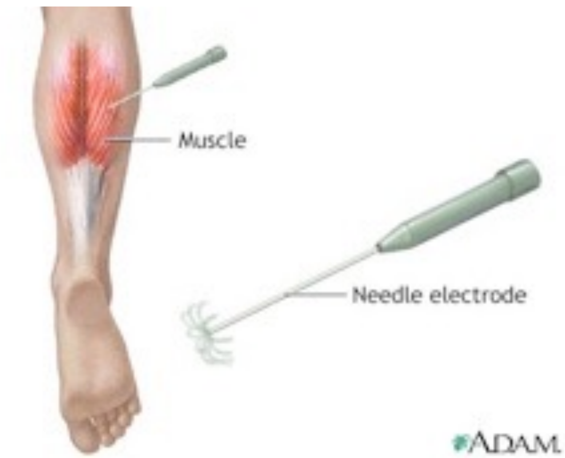


Fig 2. EMGs only respond to active contraction

Fig. 3. Stress/Strain curves

The non-linear near-flat part of the stress/strain curve is referred to as the 'toe'. In biology, you 'set' the toe (ready- get set -go), to the level that will adequately maintain whatever posture requires. Once you reach this point you are EMG silent, and we can call this the Resting Muscle Tension (RMT). RMT then, is activity dependent, as muscle tone is different when you are standing, lying down or sleeping, but it is always present to some degree in every muscle. To maintain a suitable and coordinated RMT, there has to be some communication amongst the muscles. It might be possible to do this by mechano-transduction, the transfer of information mechanically (Levin 2002), but the response to curare, the fact that decorticated muscle, as after a spinal cord injury, has tone, but no purposefulness, no coordination, and the flaccid paralysis that follows motor neuron death from poliomyelitis, indicates to me some level of CNS input.

There is a continuous tension in the system and when you add up all the tension in the system, including the stored tension in the fascial elements, it can add up to quite a bit. The body seeks the most efficient level of muscle tone for that posture, your RMT, and when possible, the body wants to function at the 'toe', since it requires the least amount of energy to stay there. Upright posture is remarkably stable once the RMT is set, but there are continuous oscillations in the muscles that are not EMG evident and you are not frozen rigid, (Gracovetsky, ch 19, MS&LPP). Even at rest, when EMG silent, there are oscillations of the heart, respiratory, GI, GU, eyes, and every cell in the body. As noted by Gracovetsky, collagen is never at rest for more than 20 seconds. Does that mean we are unstable? Not at all. It is like a swing, always seeking its lowest energy point.

If you pump, you can get the swing going, and it does not take much to keep it swinging. It actually takes a lot of energy to destabilize the system. So ‛pump up’ the muscles and bring it to the next level. For movement, you just pump it up to a higher level of 'tone', (a better word than 'pre-stress'), and it just keeps oscillating away, a symphony of bodily oscillations (Fig 4). In Gracovetsky's 'Spinal Engine', this is exactly what happens when walking, or for that matter, any rhythmic patterned motion, and the stored energy in the SI ligaments, (see above), just keep you swinging. In this system, all you need is some one-joint muscle to pump the swing and that can get the whole system oscillating at a higher frequency. If you look at Inman's book on walking, he shows that muscles seem to contract unexpectedly and often at the 'wrong' time. That is because muscles are not agonists and antagonists, (Huijing), but feeding into the tensegrity system, changing the oscillations and the shape of the whole structure.

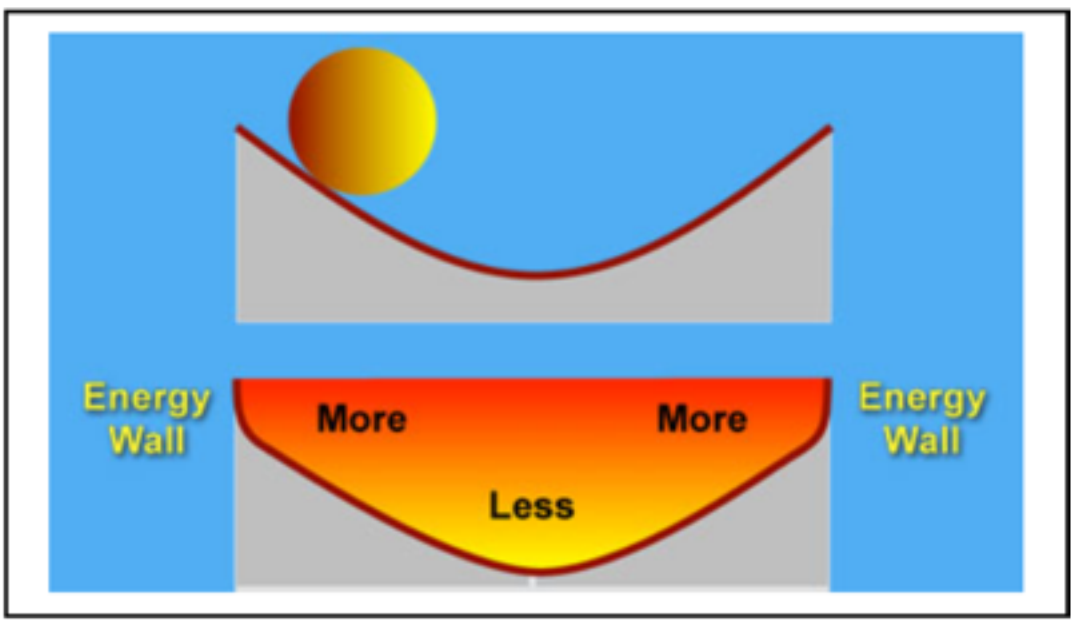
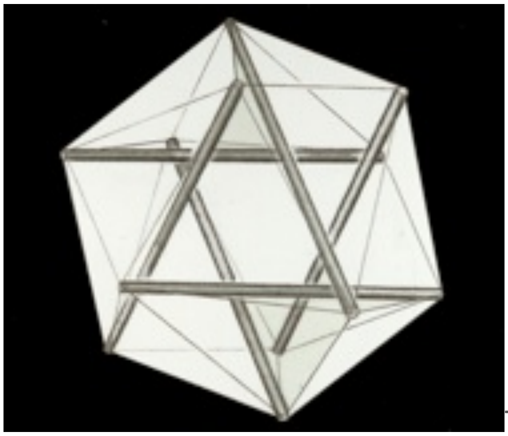


Fig. 4 Energy and stability. Courtesy - S. Gracovetsky

Now here is where biotensegrity comes in. By now you know that I model the body as a tensegrity. Tensegrities are lowest energy constructions. They use the least amount of material and energy enclosing and maintaining the space they occupy. Tensegrities are natural oscillators. Their mechanics are nonlinear and the toe is a low energy point that is its most stable shape - the symmetrical, omnidirectional icosahedron and its subset, the contracting tensegrity icosahedron (Fig 5). Tensegrities are stable oscillators, almost like pendulums; except they do not depend on gravity and are self-contained and the stored energy in the system just keeps it swinging. However, it is not a perpetual motion machine and does need infusions of energy, just less than other structures, a lot less. As in Grecovetsky's chapter showing energy points, tensegrities can be moved from their lowest energy point, and in the toe region it is easy to do as the bottom of the pit is almost flat, but they will then oscillate back to the lowest energy point. Since it takes minimal energy when in the toe region, it just keeps oscillating in a stable configuration, its own self-contained, gravity independent pendulum. Even when there is a large perturbation, the configuration is remarkably stable and will move back toward its toe region, swinging widely at first, like a swinging door pushed by a hurried waiter, and then quickly come to a non-linear, soft rocking, back to its RMT and stable tensegrity. The RMT then, is what maintains the tensegrity and is essential to the stability and efficient use of the body in both the static state, S/S/L, or in rhythmic, patterned movement, walking, running, swimming, etc..


Icosahedron


Tensegrity icosahedron
Oscillating vector equilibrium (Wolfram)
Fig. 5

Changing the tone of the RMT allows you to dance to a different drummer. If you want me to get into pathology- I usually stick to normals and leave pathology speculation to others–an abnormal RMT can increase energy needs, affect performance, whatever...

The fact that there is always tension in so-called 'resting' muscles, and that tension is present to varying degrees, depending on the activity level of the organism, is inconsistent with the methods used in conventional biomechanics to measure, or even approximate, muscle forces, joint forces, moments about joints, etc..

I haven't discussed reciprocal two joint muscles and the role they play in rhythmic patterned movement, that is the next paper, but it is all part of the same concept.