Focal Muscle Vibration: An Overlooked Tool for Diagnosing and Managing Musculoskeletal Injuries

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Initially discovered in the 1960s by Eklund and Hagbarth (1), a surprising body of research has shown that placing small vibrating motors over the belly of a muscle can produce presynaptic inhibition of the muscle's spindles, which can reduce muscle tone by as much as 50% (2) (Fig. 1). Lee et al. (3) suggest that muscle vibration reduces tone by changing the intracortical inhibitory circuit. Best results are achieved with motors that oscillate at 60 cps with 0.4 mm displacements. The sharp reductions in muscle tone associated with focal vibration provides a useful clinical tool for managing a range of musculoskeletal conditions. The small motors can be strapped to the rotator cuff for 5 minutes before mobilizing a frozen shoulder. The rate of tone reduction is startling to both the practitioner and the patient. Muscle vibration can also be used to treat ankle equinus, which causes a myriad of forefoot injuries, including metatarsal stress fractures, interdigital neuritis, and hallux abductovalgus. Simply strapping the motor on a patient's calf for 4 hours a day can reduce tone within a few weeks.

Fig. 1. Muscle spindles attach in parallel series along muscle fibers. Spindles supply sensory information along annulospiral nerve endings providing detailed information regarding muscle movement. When information from the annulospiral nerve endings is inhibited, muscle tone is greatly reduced.
While early research on focal vibration focused on treating muscle spasticity, more recently, Kurt Claeys and his colleagues from Belgium (4,5) came up with a novel diagnostic use for muscle vibration. These authors published a series of papers showing that while standing with eyes closed, the muscle spindles in our calves and core muscles share information allowing us to balance properly. Apparently, the calf muscles send information to the central nervous system regarding forward/backward sway while core proprioceptors give information regarding the position of the torso relative to the pelvis. The shared information regarding position sense is vital for injury-free activity, since muscle spindle input tells your central nervous system exactly where you are in space and what speed your joints and muscles are accelerating/decelerating. Of course, this information is vital for injury prevention as it allows for the smooth, controlled motion necessary to participate in most daily activities. Perfectly functioning proprioceptors is especially important in preventing sports-related injuries.

In their clever studies, the Belgian researchers decided to use muscle vibration to evaluate the sensitivity of an individual’s core proprioceptors. To do this, Claeys et al. (4) placed vibrating motors on the soleus muscle while subjects stood on force platforms with their eyes closed. When these motors were turned on, the sudden vibration caused presynaptic inhibition of the muscle spindles (specifically the annulospiral nerve endings), producing the false sensation that the soleus muscle was lengthening. In subjects with perfectly functioning core proprioceptors, the core muscles ignored the faulty information from the vibrating soleus muscles, and the subjects easily managed to balance with eyes-closed. Conversely, subjects with poor core proprioception immediately shifted their entire body back to counter the illusion that they were falling forward. The degree of posterior sway readily measured with a laser centimeter scanner (Fig. 2). This simple test takes less than 20 seconds to perform and provides information regarding core proprioception that until recently, was impossible to obtain.

**Fig. 2. Vibrating motors placed on the soleus muscle (A) gives the illusion that the calf muscles are lengthening.** Individuals with good core proprioception can sense the calf muscles are not lengthening and remain stationary. Conversely, subjects with poor core proprioception are overreliant on ankle spindles and respond to the vibrating motors by leaning backward (B). The distance of posterior sway is readily measured with a laser scanner (C).
To determine if muscle vibration can distinguish between asymptomatic and chronic low back pain patients, Claeys et al. (4) performed the 20-second muscle vibration test on 106 nonspecific low back pain patients and 50 healthy controls. The researchers confirmed that the low back pain patients had significantly greater backward sway when their calves were vibrated, which the authors relate to reduced “lumbosacral proprioceptive.” Claeys et al. (4) theorize that the low back pain patients were unable to process proprioceptive signals from their low back muscles and they were forced to become overreliant on calf proprioceptors. This study was fascinating in part because so few clinical tests can distinguish low back pain patients from non-low back pain patients; e.g., arthritis and herniated discs are considered normal variants in individuals with low back pain.

In a follow-up study, Claeys et al. (5) again performed the 20-second vibration test on more than 100 asymptomatic subjects. In addition to evaluating vibration-induced sway, the authors also evaluated spinal posture along with various psychosocial behaviors known to correlate the development of future back pain; e.g., fear avoidance behavior. The subjects were followed for 2 years and while posture and fear avoidance behavior in no way predicted the development of low back pain during that period, individuals who swayed excessively when their calf muscles were vibrated were almost 4-times more likely to hurt their backs over the 2-year follow-up period. As with differentiating low back from non-low back pain patients, this finding is significant since so few factors predict future injury.

Because increased postural sway both differentiates low back from the low back pain patients and predicts future injuries in asymptomatic populations, the next phase of vibration research focused on identifying which factors can impair core proprioception and then evaluating which, if any, interventions can improve core proprioception. To that end, Lotta Janssens et al. (6) show that a weak diaphragm can impair core proprioception by decreasing sensitivity of spindles located in the low back muscles. Apparently, because oxygen is necessary for our survival, the central nervous system prioritizes the delivery of blood to the diaphragm over other skeletal muscles. When the diaphragm fatigues with exercise, the central nervous system deliberately decreases blood flow to spinal and peripheral muscles in order to shunt as much blood as possible to the diaphragm (Fig. 3).

Fig. 3. When the diaphragm is fatigued, the central nervous system shuttles blood away from neighboring muscles into the diaphragm (arrows).
If an individual’s diaphragm is weak, it prematurely fatigues and blood is redirected away from peripheral muscles to enhance diaphragmatic circulation. Several studies have shown significant reductions in blood flow to the erector spinae and lower extremity muscles when the diaphragm is deliberately exhausted (7,8). Where this gets interesting is the effect that decreased spinal and peripheral muscle circulation has on muscle spindles. Because muscle spindles are highly vascular structures that exist almost exclusively in slow twitch muscle fibers (9), even a slight reduction of blood flow to a spindle, as would occur with premature fatigue of the diaphragm causing a reflex reduction in blood flow to the low back musculature, would markedly impair muscle coordination in the spine and extremity muscles.

Janssens et al. (6) prove the diaphragm can redirect blood flow from the erector spinae thereby reducing core proprioception by evaluating back muscle oxygenation using near-infrared spectroscopy before and after fatiguing the diaphragm in individuals that had excessive posterior sway when their calf muscles were vibrated. Their detailed evaluation confirmed that individuals who swayed excessively when the calves were vibrated had significant reductions in back muscle oxygenation and blood volume with inspiratory fatigue. In contrast, individuals who did not sway excessively had no reduction in back muscle oxygenation when their muscles of inspiration were exhausted. These authors claim a fatigued diaphragm steals blood from the spinal stabilizers, decreasing reliance on core proprioceptors, greatly increasing the risk of injury.

To see if the impaired core proprioception could be reversed with diaphragm exercises, Janssens et al. (10) performed another study in which they had individuals with low back pain undergo inspiratory muscle training. The test subjects performed 3 sets of 20 repetitions at either 60% full effort (high intensity group) or 20% full effort (low intensity group). After 8 weeks of training, individuals treated with the high intensity training exhibited smaller responses to ankle muscle vibration, improved core proprioception, higher inspiratory muscle strength, and most importantly, reduced low back pain severity. The authors note that these changes were not seen after low intensity inspiratory muscle training.

Over the past year, I’ve had patients with excessive vibration-induced posterior sway perform a series of different exercises, including diaphragm and various lower extremity exercises. I’ve also used hip mobilization, spinal manipulation, and deep tissue massage of the erector spinae musculature to see what, if anything, can improve core proprioception. While spinal mobilization and deep tissue massage will occasionally increase core proprioception, without doubt the most significant improvements in posterior sway occur when performing exercises to increase endurance to the lumbar paraspinal muscles. My favorite exercises for restoring low back proprioception are summarized in figure 4. It is not uncommon to have full restoration of core proprioception within the first 8 weeks of performing these exercises. Of course, a weak diaphragm should always be strengthened and a hypomobile spine and/or hips should always be mobilized.

Evaluating posterior sway with the application of calf vibration allows you to take a snapshot of your patient’s spinal proprioceptive system, providing invaluable diagnostic information that allows you to potentially prevent future injury. The attached video reviews just how simple it is to perform this test. In my 35 years of clinical practice, I’ve never seen anything like these small motors. Putting aside the obvious benefits of safely reducing tone in spastic muscles, the ability of focal vibration to predict future injury makes these small vibrating motors an indispensable diagnostic tool that should be utilized by every musculoskeletal practitioner.
**Fig. 4. Low back exercises for increasing endurance in the erector spinae musculature.** The multifidi muscles are exercised by flexing and extending the lumbar spine through a small range of motion (arrow) while positioned on a 65 cm physioball (A). Side plank exercises (B) should be held for 30 seconds and repeated 4 times. To increase difficulty, raise the top leg for 10 seconds each cycle. Bird-dog exercises (C) are performed by resting on all fours and extending the opposite arm and leg. In this position, slowly move the extended arms and legs through 4-inch squares for about 30 seconds (arrows). Repeat twice on each side. The plank pose (D) is typically held for 30 seconds. To increase difficulty, alternate raising one leg than the other for 5 seconds each time (arrow).
References: