Motor Control: Unseen Cause of Persistent Tension and Pain

By Howard Nemerov

In my practice, clients generally don't call until they have musculoskeletal issues: "My low back hurts" or "I have knee pain walking stairs." These are often accompanied by negative medical findings: "The doctor found nothing wrong."

The motor control system can be the unseen cause of persistent non-pathological symptoms, creating abnormal movement we can visually assess, and tension we can palpate. The Nemerov Method gives you the tools to resolve these hidden causes.

Motor Control Primer

"*Motor control is an interface between the neurosciences, kinesiology, and biomechanics." —* Vernon B. Brooks

Motor control is a sensorimotor system, gathering *sensory* input from the body and then deciding which muscle (*motor*) functions work best in response to this input. A simple example would be the nearly instinctive withdrawal when your hand touches open flame. Motor control sends and receives via the nervous system, and individual nerves often include "wiring" for both sensory (input or afferent) and motor (output or efferent) signals. For example, the radial nerve—one of the five terminal branches of the brachial plexus, provides motor innervations to numerous muscles, including the triceps, and muscles sharing the common extensor tendon attached to the lateral epicondyle (e.g. brachioradialis, extensor digitorum, extensor carpi ulnaris). The radial nerve also provides sensory innervations to the posterior upper arm, dorsal forearm, and back of hand from thumb to 4th finger.[1] If somebody dropped a weight on the back of their hand, motor control would receive pain signals via the radial nerve, and almost simultaneously would send motor signals—also via the radial nerve—to the triceps and brachioradialis (humerus extension and elbow flexion) to save the hand from further injury.

Our motor control system contains both "hardware" and "software" similar to a programmable computing system, consisting of components governing learning, remembering, and performing posture and movement. Since we're born with only rudimentary movement programs—infants must learn to crawl, stand and walk—nearly everything we do in gravity must be learned.[2] This learning process focuses upon selecting and coordinating muscle "teams" and their related joints to create effective function.

This brain-related process of assembling musculoskeletal components for new movement patterns is called **motor learning**.[3] Using bicycling as an example, remember how unstable it felt at first? We had to learn a new posture—sitting on a narrow seat—while mastering bilateral balancing and contralateral pedaling movement. During this learning process, motor control auditioned various muscle recruitment sequences. We wobbled, and perhaps fell, until learning more efficient sequences that made riding easier; steering and speed improved, until biking became fun.

Sensory "hardware" is vital to this process. Muscle spindles tell the motor learning center, via sensory nerves, which muscles are contracting or lengthening, and at what rate.[4] Golgi tendon mechanoreceptors input load levels on related joints. Joint receptors report speed and direction of movement.[5] Visual feedback plays an important role in motor learning, reporting how well current movement sequences steer the bike.

The "software" aspect of motor learning involves the decision-making process that sifts and measures sensory input, ready to alter muscle activation and sequencing in response to changing conditions. Are you heading towards a tree? Motor control engages more hardware, changing muscle output, to produce the needed course correction. This "programming" process answers one vital question: *Am I getting the results I want?*

Motor control then stores this optimized motor pattern so it can be accessed as needed. **Motor memory**—how it felt and what result was achieved—is like a movement-related hard drive in the brain.[6] Once motor control experiences success while bicycle riding, it "compiles" muscle/joint sequences into motor "programs," storing them in motor memory. This is why you can ride after several months' hiatus without having to relearn the skill.

Motor skill is also part of motor control: refining and improving stored motor programming. Training to race means investing time and effort to build skill beyond what's needed to bike to the store. Consider the difference between platform pedals on a town cruiser, and racing bike pedals which clip racing shoes to pedal hardware. With the former, a rider presses the pedals down to create power; in the latter, a skilled rider pulls one pedal up while pressing the opposite pedal down.[7] While the former produces power using hip extensors and quadriceps, the latter adds hip flexors and hamstrings to generate more power and greater speed. Each new movement pattern requires new muscle sequencing, resulting in new motor programming (motor learning). Therapy isn't a substitute for motor skill, where practice makes progress, though tuning your racing client's motor programming can help.

Existing motor programs work until injury occurs, compensation begins, and riding becomes slower and more difficult.

How Does Compensation Occur?

"*When an overall program fails, the brain reverts to composing multijoint movements once more from sequential simple movements*."—Vernon B. Brooks[8]

Muscles weaken from trauma, blunt force impact (e.g. bike crash) or repetitive strain (e.g. intense training with insufficient recovery or postural imbalance). Trauma produces a response similar to an overloaded circuit: Motor control acts like a circuit breaker and disengages injured muscles to protect against further damage. Compensation is a survival mechanism.

Motor programs fail when muscles within those programs can't activate on demand to perform their normal workload. To maintain as much structural integrity as possible, motor control switches to motor learning, surveys the musculoskeletal system via sensory feedback (e.g. nociceptors, Golgi tendon, spindle cell), and compiles a list of remaining available muscles. Piecing these functions together, motor control assembles a new program as similar as possible to the original pattern, compiles it, and stores it in motor memory. The resulting program recruits other muscles to assist the weakened ones (compensation). Since recruited muscles must still perform their normal functions, this added workload presents as persistent tension: Recruited muscles have less opportunity to relax, since their workload extends beyond the normal agonist/antagonist relationship that allows them to lengthen while reciprocal muscles contract.

Resolving Compensation in Motor Control

Restoring a “deleted” muscle function in motor control is more involved than flipping a circuit breaker. After injury-related deactivation of a muscle, motor control often deletes it from related programming stored in motor memory, and can only reintegrate it by therapeutically engaging the motor learning process. Until this happens, the muscle remains unable to participate in normal, multi-joint motor programs.

You can accomplish effective reprogramming of compensated muscles by restoring normal motor programs. This shortens rehabilitation, making the process easier for both you and your client. For this to occur, the therapist must interact with the motor control system in its native, movement-related language.

Florence Kendall was a pioneer in developing functional muscle testing to improve posture and function.[9] Her discipline has been a manual therapy “gold standard” since the mid-1900s.[10] Applying this form of direct, functional muscle testing enables a kinesthetic conversation with the client’s motor control system, acting as a catalyst to restore lost muscle function.

In one case history, a cyclist strained their left gluteus maximus from over-training. Focusing on an upcoming race, they kept training without letting the gluteus maximus heal and return to full capacity. Though at the time they felt no symptoms, motor control recruited the left semitendinosus to compensate for lost gluteus maximus power during hip extension. It was only after the race they began experiencing hip pain, especially when climbing stairs.

The semitendinosus is primarily a knee flexor. However, due to its origin on the ischial tuberosity, it’s also a hip extensor, making it a synergist with the gluteus maximus. The semitendinosus “grain” is primarily superior/inferior, making it a more effective hip extensor when moving in sagittal plane of leg, as happens during the power phase of the pedal stroke. These two factors—synergy and sagittal position during bike riding—makes the semitendinosus an ideal muscle for motor control to recruit if the gluteus maximus weakens.

The gluteus maximus "grain" follows an inferolateral direction, especially noticeable from its posterior iliac crest and sacral origins, to insertions on femur and Iliotibial tract. Nevertheless, its primary movement is hip extension. Abducting the hip about 30° aligns your muscle test with the gluteus maximus muscle's grain, while also deemphasizing semitendinosus involvement as a hip extensor. This enables you to better isolate and assess gluteus maximus function separate from the hamstrings (Figure 1).

Figure 1—Abduct hip 30° to emphasize gluteus maximus during muscle test

Beyond the assessment process, functional muscle testing provides an opportunity for motor control to reintegrate lost muscle functions into motor memory.

How Muscle Testing Helps Reprogram Motor Control

Your client reported left hip pain. Palpation indicated left semitendinosus tension, and visual assessment indicated your client wasn't fully extending their left knee. (These assessment skills should already exist in your toolbox.) Now, functionally test their left gluteus maximus. If it tests fair or poor—less than normal function—release their left semitendinosus and retest the left gluteus maximus. If it now tests normal, motor control "reprogrammed" the left gluteus maximus.

The internal process—what their motor system experienced—during the first test was "failure." Motor control didn't get the results it expected: ease in meeting your gentle testing pressure. This "failure" initiated motor learning. If motor control could speak, it would say after the initial test, "That didn't work; how can I make it work?"

During the motor learning phase, release the compensating muscle with whatever mobilization technique works for you and your client, the left semitendinosus in this case. Retesting the left gluteus maximus provides motor control an opportunity to activate the left gluteus maximus with the left semitendinosus more relaxed. Motor learning also enables motor control to compare the first testing experience to this one. A normal response now shows motor control that it *can* isolate and activate the left gluteus maximus without first recruiting the left semitendinosus. This "success" results in motor control saying, "That worked. I want to remember this, so I will overwrite the existing compensated motor program with this more efficient program." Motor control reintegrates the left gluteus maximus into motor memory. The "overwrite" phase of motor re-programming results in long-lasting, more fluid movement and enhanced injury resistance.

While instructive, this synergist example is the least common type of compensatory relationship. Going forward, remember that *synergists* contract concurrently to perform a single-joint action.

The next case study involved a left quadriceps spasm along with left hip pain. All intake and assessment were the same as the above example, except this time there was persistent tension in the left vastus lateralis instead of the left semitendinosus.

During the power phase while pedaling, both the ipsilateral hip and knee joints extend. Their muscles contract concurrently like synergists, but they operate different joints to accomplish more global, *functional* movement. This makes the ipsilateral gluteus maximus and vastus lateralis *functional synergists*. The Oxford English Dictionary defines “synergistically” as, “cooperative, interacting, mutually reinforcing…” [11] This is a useful concept to remember when identifying functional synergists: Muscles operating more than one joint, that cooperate, interact, and mutually reinforce each other to create a multi-joint movement, enabling the limb to execute a required function, in this case powering a bicycle.

Functional synergists:

- Operate different joints (gluteus maximus moves hip; vastus lateralis moves knee).
- Reside in different anatomical planes (gluteus maximus is primarily posterior to coronal plane; vastus lateralis primarily anterior).
- Move different body parts in different directions (gluteus maximus moves femur posterior; vastus lateralis moves tibia anterior).
- Work together to perform multi-joint movement (power phase of bicycle pedaling).

This client’s motor system perceived weakness in the gluteus maximus, and compensated by recruiting the vastus lateralis to perform greater workload when pressing the bike pedal. While the compensatory relationship is different than simple synergy, the reprogramming protocol remains identical. Test the left gluteus maximus, release the left vastus lateralis, and retest the left gluteus maximus. If the gluteus maximus tests normal—or at least noticeably improved—motor control responded to this proprioceptive process by deleting the left vastus lateralis as a compensator, restoring gluteus maximus function, and storing new programming in motor memory where the gluteus maximus and vastus lateralis work together as a team.

Compensatory patterns can be complex. For example, motor control might recruit both the semitendinosus and vastus lateralis to assist the gluteus maximus. In gait, every muscle has a job, stabilizing the entire structure while moving through gravity. The same is true for bike riding: While primarily a lower body activity, attempting a hill climb with one arm held behind your back will demonstrate the need for integrated core and upper body function in cycling.

Another client had spasms in their right quadriceps muscles, along with pain in the left anterior hip region. They were using their right quads to compensate for their left hip flexors.

Skilled bike racers know they risk losing power after the power phase (downstroke), if they allow that leg to become dead weight during recovery (upstroke). This is why racers practice single-leg drills on stationary bikes, to practice pulling up after completing the downstroke. Efficient pedaling requires normal hip flexor function while the contralateral leg is in power phase. The more adept the rider gets at reducing this drag, the more power gets transferred to the drive chain, resulting in greater speed.

Such complex patterns are a little beyond this discussion, but serve to highlight motor control’s motto: “Recruit whatever works to get the job done.”

Regardless of the type of compensatory patterns, all of your tissue mobilization skills remain just as helpful after reprogramming. The difference is that where motor control resisted your release and stretching before, it will be easier now—on both you and your client—to attain new length and suppleness during mobilization. Before reprogramming, motor control essentially was saying: "Don't do that; I need that muscle to do these extra activities." After reprogramming, motor control's saying: "Go ahead; I don't need that tension anymore." The examples above highlight motor control's ability to compensate for lost muscle function by recruiting other muscles, though the result isn't as efficient as normal programming. At some point, compensation presents as persistent tension and recurring issues that resist resolution by traditional manual therapy alone.

Most importantly, these examples highlight the motor control system's neuroplasticity. With the right skills, you can help your client's motor control restore lost function, enabling them to move more efficiently post-treatment, while also providing long-lasting relief for the persistant symptoms that previously resisted other treatment modalities.

About the Author

Howard Nemerov has been researching and teaching the Nemerov Method for over 25 years. His articles have been featured in *Massage & Bodywork* and *Triathlete Magazine*. His Nationally-certified training is available to qualified manual therapists.

Endnotes

[1] Joseph E. Muscolino, DC, The Brachial Plexus and Thoracic Outlet Syndrome, *Massage & Bodywork*, November/December 2017, pages 60-69.
[2] Vernon B. Brooks, The Neural Basis of Motor Control, Oxford University Press, 1986, page 5.
[3] Vernon B. Brooks, The Neural Basis of Motor Control, Oxford University Press, 1986, page 5.
[4] Christy Cael, Muscle Spindles, *Massage & Bodywork*, March/April 2016, pages 45-46.
[5] Christy Cael, Joint Mechanoreceptors, *Massage & Bodywork*, September/October 2016, pages 43-44.
[6] Vernon B. Brooks, The Neural Basis of Motor Control, Oxford University Press, 1986, page 6.
[7] Loren Mooney, Get the Perfect Pedal Stroke, *Bicycling*, April 30, 2010. http://www.bicycling.com/training/fitness/perfect-pedal-stroke
[8] Vernon B. Brooks, The Neural Basis of Motor Control, Oxford University Press, 1986, page 7.
[9] Florence Peterson Kendall et al, *Muscles: Testing and Function, Fourth Edition*, Williams & Wilkins, 1993.
[10] Florence Peterson Kendall, Maryland Women's Hall of Fame. http://msa.maryland.gov/msa/educ/exhibits/womenshall/html/kendall.html
[11] The New Shorter Oxford English Dictionary, Thumb Index Edition, 1993 Edition, Clarendon Press, page 3190.