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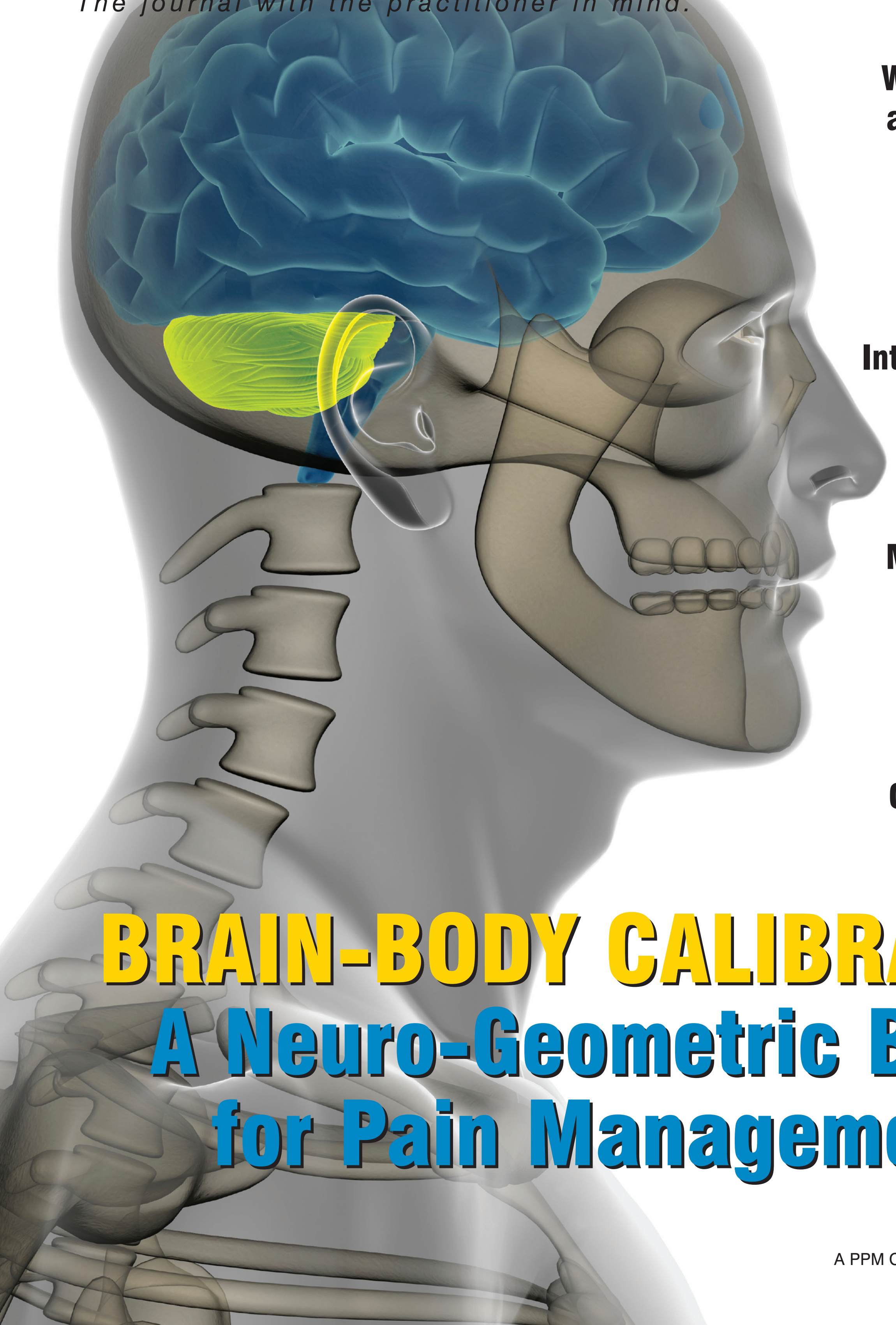

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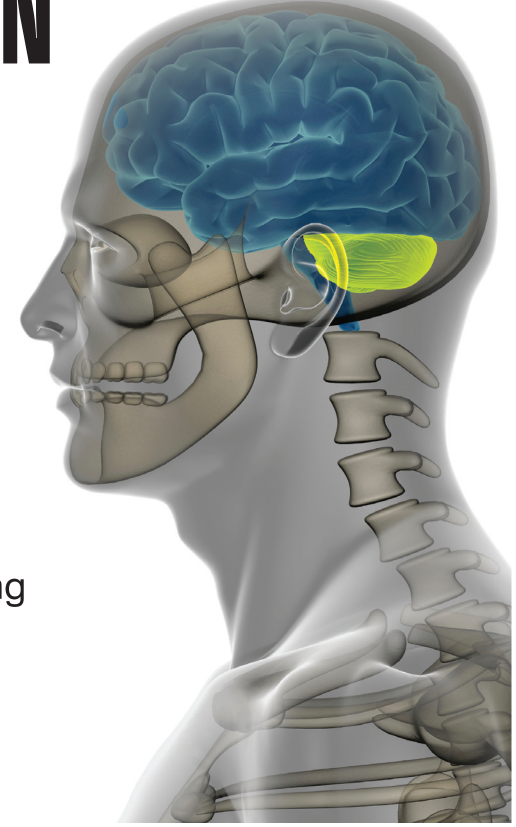

Kinesthetically-induced fractionated motion—using precise manual resistance—approaches pain testing and treatment from the perspective that brain and cerebellar functions may be involved as causal elements in musculoskeletal pain and pathologies.

By David Rubenstein, PhD

It is well understood that muscle imbalances or dysfunctions have high corollaries to pain, joint erosion, and pathologies.[1] I will introduce a newer and duplicatable pain treatment method called Brain-Body Calibration (BBC) and provide three examples at the end of this paper for clinicians to begin implementing this technique for patient pain relief. BBC is based primarily upon the intentional inducement of fractionated motion using newly discovered motion protocols called micro-exercises (MEs). MEs provide a basis to numerically evaluate cerebellar functional performance that heavily influences muscle and joint dynamics that have a bearing on non-cancer musculoskeletal pain. These same MEs simultaneously stimulate cerebellar learning thus effectively optimizing muscle tone, reducing pain and improving cognitive functions.

MEs have demonstrated effectiveness for both acute and chronic pain and having provided a noteworthy relief effect of a durable and lasting nature.[2,3] MEs have also demonstrated to be effective for inflammation which implies an effect on the CNS. Similarly, BBC is effective on compression-based pathologies through direct relief of either the lack of muscle support or hyperactive musculature—both of which are known to cause collapse of joint spaces. Typically in musculoskeletal pain management, we utilize a "site-specific" perspective of muscle dysfunctions such as injury, spasm, trigger points, hypotonicity, imbalances, etc., and treat the body at the site where the pain is located—or referred from other points—with medication and a array of physical therapies. This paper explores muscle and joint pain from a "non-site-specific perspective" exploring the role of specific brain regions and functions in the development, maintenance and resolution of musculoskeletal pain.

There are other elemental observations of aberrant motion—such as *angular vector* of applied force—that reveal errors in cerebellar function. In the latter case, if the angular vector is less than or greater than 90 degrees to the axis of rotation, a failure in radial functional applied force is a further manifestation of fractionated motion. Although execution of anatomically-incorrect motion, end-range performance abnormalities and fractionation of motion all represent significant failure at the cerebellar level to maintain proper control of the motion envelope, only fractionation of motion is focused upon in this article.

Fractionated Motion

Early in 2003, I noticed a curious phenomenon during the rehab of a dance patient with a four-year history of moderate-to-severe painful injuries to the hamstring muscles and upper tendon. MRI ruled out any tearing or ruptures even though scar tissue was visible and palpable. A tremor-like response of the entire leg under very light loads—particularly during eccentric active motion—caught my attention. Although fractionated motion is similar in appearance to muscle tremor, it does not stem from neuro-degenerative pathology. Instead, as I later discovered, the muscle tremor was likely caused by corrupted data pattern templates emanating from the cerebellum.[4] Since we know that a primary function of the cerebellum is to smooth out motion, the emergence of fractionated or stuttered motion implies a decline in neural-cerebellar perform-

Table 1. Fractionated Motion Definitions and Magnitudes in Cerebellar Insufficiency

Fractionation Magnitude	Kinetically observed calibration (felt in the hands of the practitioner) during one micro-exercise cycle—including one concentric followed by one eccentric movement	'Index of Errors' Value
Very Large	Characterized by sudden high static tension followed by collapse and loss of control, "stops in space"	-4
Large	Large stutters in motion but does not stop in space	-3
Medium	Moderate stutter deviations from smooth motion	-2
Velocity Variance	Variances in velocity comprised of acceleration and deceleration during movement—with or without fractionation	-1.5
Small	Slight stutter deviations from smooth motion	-1
Vibration	Kinesthetically felt as a vibration at approximately 15–20 cycles per second	-0.5

Table 2. Assessment of Fractionated Motion

Index of Calibration
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 00 Target
Improvement ⟶
-7 is the average score for the first attempt of any micro-exercise (ME) motion. Expect improvement of 5 points, on average, (to -2) for the first of two calibrations one week apart. These metrics are derived from over half-a-million repetitions and represent approximately 4,000 hours of brain-body calibration experience.
Successful calibration (index of '00') is achieved when two consecutive repetitions under convincing power are smooth, crisp, initiate and finish strong—especially at end ranges of motion.

ance.[5] This decline in brain performance can be measured creating a new "index of errors" of non-performance of the motor system propagated by the CNS. The correlation of musculoskeletal pain and eccentric fractionated motion has been shown to be extremely high in 264 documented cases. With smoothening of motion by way of the cerebellar controls over the motor system, pain abates in a clinically significant manner—both in timeliness and magnitude.

Because the cerebellum's role in motion is smoothness and accuracy, errors in it's functional definitions are revealed by stuttered (fractionated) motion, accelerations and decelerations and, occasionally, as either complete loss of strength or its opposite of a sudden, brief, hypertonic spastic freeze in motion.

Clinical Observations

Clinical observations of 264 patients—presenting with a variety of musculoskeletal pain symptoms and subjectively measured pain intensities using a VAS—found the following top three items commonly observed in a variety of limb, extremity, spinal segments and TMJ motions:

1) Patients are initially unable to precisely position or execute a given ME motion even when demonstrated to the patient while in a passive mode and guided verbally and visually by the practitioner.

2) Patients' performance of micro-exercises were particularly inefficient at the proximal and distal end ranges of any given motion. Notable collapse of strength at end ranges of motion were common.

3) Fractionated motion, characterized by a stutter or tremor-like neuromuscular behavior in six explicitly distinct magnitudes, were recorded using the criteria in Table 1.

Inducing Fractionated Motion

Fractionation of motion is observable only under specific circumstances of kinetic behavior. For example, the *velocity* must be 4 cm/sec ± 1 cm/sec. Also, the necessary *force* limit is only ten percent of the one repetition maximum (1RM) to reveal the fractionated motion or error in movement. This is established by asking the patient to approximate how much force equates to ten percent and is surprisingly consistent in actual force production regardless of patient disposition or age. Outside these 'tolerances' or parameters, the aberrations of fractionated motion do not occur or decrease dramatically. In this way, muscle dysfunctions can be masked but continue to create musculoskeletal pain and biomechanical inefficiencies. This last note is critical for the practitioner as it instructs us that cerebellar insufficiency may be present but can only be identified within the above stipulations.

During the BBC process, the practitioner *counts the number of fractionations* in real time during a single cycle or repetition, beginning with the concentric and ending with the eccentric phase of motion. That number is a sum of each occurrence of fractionation and the value assigned to its magnitude (see Table 1 for values). The total is recorded as a matter of course and listed in negative integers. Also, the practitioner needs only to estimate the sum total number since the trend toward smoother function is the critical criteria. As each cycle of motion—such as opening and closing of the mandible—is consecutively repeated, the fractionation lessens and the decreasing scores are noted indicating improved

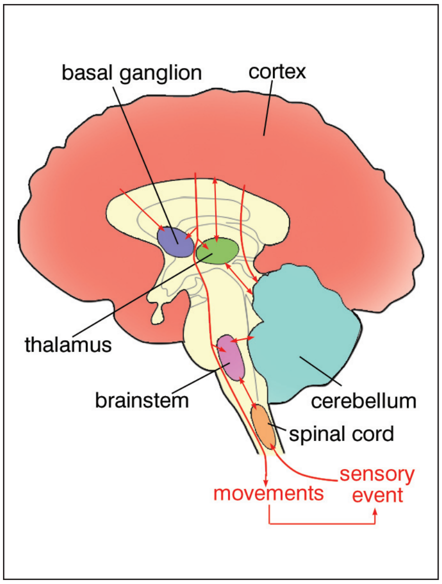

FIGURE 1. *The location and relative mass of the cerebellum versus the cortex.*

cerebellar internal modeling of the motion templates. Pain generally abates immediately and it correlates to smoothness in motion. Pain may abate after the patient performs a three-minute walk to integrate the cerebellar changes (see Table 3 for "concluding activity"). In this way, a compelling correlation of the absence of fractionation and pain emerges. It is important to note that severely high scores can also accompany no discernable pain.

Table 2 displays the numerical scale as read from left to right beginning with the negative number "-9" and ending at "00." Scores are often in excess of "-9" but it is of no clinical value to count beyond that point. The average first-repetition ME value is "-7." This scale has been in clinical use for greater than six years.

The primary tool of the practitioner is tactile feel with their hands to provide an external resistance needed to trigger the calibration process. Humans cannot self-calibrate due to the neurological phenomenon of colloidal discharge—the same neuro-reflex that makes it unlikely that a person can induce laughter by tickling themselves. The remaining practitioner tools consist of a massage table, office chairs, doctor's stool, a visual analogue scale (VAS), mirror, examination light and gloves. Calibrating a muscle, muscle group, or a motion can be achieved in as little as six minutes but sessions are frequently about fifty minutes while treating various areas or body segments.

MEs Merge Testing and Treatment into a Single Activity

As cerebellar errors smooth out or resolve through the process described above, musculoskeletal pain abates with a documented success rate of 94.7%[2] forming the basis for a new methodology to treat chronic and acute pain. This process provides a unique sensory-motor feedback loop that combines testing and treatment into a one activity. MEs are similar in application to Travells' method of "rolling taut bands" which reveal both the diagnosis of trigger points' existence/location and simultaneous patient relief.[1]

Background on the Cerebellum

The cerebellum is the super-computer of the brain possessing more neurons than the rest of the cerebrum combined, even though it possesses only ten percent of the mass of the brain (see Figure 1). It is connected to the cerebrum by 40 million nerve fibers as compared to the visual system which has one million. The cerebellum is responsible for greater than 65 trillion calculations of data per second—fully half the brains' processing power—and informing many regions of the brain about optimization of motor and non-motor performance.[4,6]

Cerebellar Functions

The cerebellum, located inferior to the cerebrum and posterior to the brain stem, was viewed decades ago as having the singular role of refinement of all motor functioning. This included speed (velocity), acceleration, smoothness of motion (i.e., lack of stuttered or fractionated motion), precision of motion, and ambulation or walking gait pattern generator and maintainer.[7] Fractionated motion constitutes a breakdown in cerebellar function and is easily observed kinetically under light resistance.

As research has continued—and in particular over the last decade—scientists have been surprised to discover that the cerebellum is also involved in almost every brain region of non-motor cognition. It supports other brain regions in doing their work more effectively. This includes cognitive thinking and emotional processes to promote optimal outcomes through the calculations of future possibilities, improved mental dexterity, and language—by using internal templates of stored memory (motor or non-motor) as a reference.[8] These new scientific observations both support brain-body calibration processes and provide important connections in understanding the mechanism by which this new modality can attenuate pain in clinically-significant ways as well as simultaneously improve overall cognition. I include these newer findings of cerebellar function because these non-motor activities are also affected by the brain-body calibration process. For example, mood, focus, concentration, and cognitive functions all appear to be enhanced as a side-effect of the treatment.

FIGURE 2. *Supine Diaphragmatic Calibration.*

FIGURE 3. *Seated Diaphragmatic Calibration.*

Cerebellar Automation Enlarges Cognition

According to Leiner, et al: "Experimental evidence has shown that the cerebellum is involved in the process by which… motor tasks can…be performed automatically. Through such automation, the performance can be improved: sequences of

TABLE 3. Calibration Example: Instructions for Diaphragm Calibration

Position	Instructions	Parameters
Supine (easier, safer for patients pre-disposed to light-headedness or balance issues, but less effective than seated diaphragmatic calibration)	**Before Test:** After the patient is in a comfortable lying position, ask them to inhale and exhale deeply. You observe and comment on the (1) shoulder movement toward the head and (2) lack of abdominal motion which indicates non-diaphragmatic breathing. With the patient on a flat comfortable table, sit to the side at waist level of the subject. Place one hand on the upper abdomen, two finger-widths below the solar plexus (so as not to place direct force on the xiphoid process) and one hand on the shoulder (see Figure 2). The shoulder hand is to generate sensory feedback for the patient and the other hand is to apply about 10 lbs of constant downward resistive force for the diaphragm muscle to work against. **Sets x Reps Protocol** 4 sets (inhale and exhale) of 4–5 breaths. **Reminder:** This is a learned process and may take some patience and practice for both practitioner and patient.	The shoulders should not move during diaphragmatic breathing (this must be learned by the patient as they will likely be 'chest breathing' as indicated by the elevation and falling of the shoulders during inspiration and exhalation respectively). Picture how an infant breathes while supine. Two inches of upward abdominal motion should occur with shorter body heights, three inches for taller heights (above 5' 6" or more). The patient should purse their lips into a whistle posture. This provides resistance to the airflow and hence to the diaphragm. It also creates an audible swoosh sound which will match the fractionated kinetic motion stutters, creating an audible connection of motion and sound for maximum learning. Breaths should be constant in motion and sound at the maximum inhale/exhale volume. Perform four to five sets of four to five breaths. Tell the patient to aim for the smoothest motion possible and to refrain from moving their shoulders.
Seated	Sitting directly behind the patient, separated by a bolster for spinal support and maintenance of separation between you and the patient (non-encroachment), interlock fingers just below the solar plexus with your forearms at the sides just below the ribcage to provide circumferential resistance (see Figure 3). 4 sets (inhale and exhale) of 4–5 breaths. **Post Test:** Once the 4 sets of 4 to 5 breath repetitions are completed, note to what degree the breathing pattern has become more dominant with greater abdominal motion and less shoulder motion. Ask the patient how he/she feels, i.e., pain, clarity of mind, peacefulness. **Caution:** The patient will typically be slightly lightheaded following this procedure, so have them wait 10–20 seconds for this to pass before standing or moving.	
Walking	**Concluding Activity:** The patient should finish the session with a three-minute barefoot walk (a hallway will suffice). Allow the patient about one minute to become familiar with how they feel. In the first minute they will feel a slight unstable sensation in their legs. The second minute will reveal changes. First, ask the patient how their feet feel on the ground, then ask how their mind feels as well as low back or other areas of presenting complaint. In the third minute, the patient will begin to feel a 'leveling-out' and reach a new stable state. I recommend using a timing device so that these predictable responses can be tracked accurately.	

movements can be made with greater speed, greater accuracy, and less effort…and to the extent that an individual can perform some mental activities without conscious attention to detail, the conscious part of the brain is freed to attend to other mental activities, thus enlarging its cognitive scope."[6]

Cognitive scope relates to what mental tasks, how many, and how deeply they can be performed competently. Although male and female brains are set up differently in relation to the number of tasks—with females generally having better multitasking abilities—the actual number of consciously-processed pieces of information per second is limited in both genders to approximately two thousand. To the extent that physical pain is experienced, for example, greater effort is required to maintain the rate of two thousand consciously-processed pieces of information per second. Pain may also distract an individual by occupying part of that conscious limit and thus lowering their overall concentration or focus. This is not uncommon in pain populations.[9,10]

Automation and refinement of motor activities does not necessarily mean *optimal* and may, in fact, automate motor functions wherein errors also become embedded into the automation patterns. In this way, errors might go unnoticed by the brain and may continue to spawn new errors because the memory matrix is built progressively over time.[11] These errors are located in the internally-represented templates which reside in the cerebellum. BBC is a process by which specific stimulation mechanically alerts the brain to reprocess the data comprising the templates and thus improve bio-mechanical efficiency by eradicating errors. This process commonly results in the attenuation of pain and enhanced mental state as the removed errors free up more cognitive processing capacity. The reduced pain can be explained by the intelligent animation of muscle fibers toward a more optimal state wherein the tone of muscle tissue is more balanced and optimized.

Table 4. Calibration Example: Instructions for TMJ Calibration

Posture	Instructions	Parameters
Semi-Reclined	The patient should be in a semi-reclined position with the practitioner on a doctor's stool such that the patients' head is at the height of the practitioners solar plexus. This positioning provides optimum stability for this delicate calibration. The practitioner must be in a very stable position with forearms supported. A tongue depressor is centered flat over the cuspid and bicuspid teeth of the mandible. (For illustration purposes, I used a smaller depressor to show proper position of the depressor in Figure 4).	Begin with measuring the MIO using a VAS with patient in a semi-reclined posture and record the reading. Next have the patient start by opening the mandible to maximum without pain. Using a tongue depressor as the means of resistance, hold the thumbs just outside the incisors on top of the depressor (see Figure 4 "Closing" and Figure 5 "Opening"). Ask the patient to use 10% of their maximum effort to close their mouth slowly against the resistance you provide with the depressor. It is key that you provide the same light and slow (4 cm/sec) resistance in both concentric and eccentric movement of the mandible. Ask the patient to make the movement of their jaw as smooth as possible. You will need to give several spoken clues to reduce the amount of power they use. **Caution:** Never use overpowering force to open or close the mandible!
Walking	**Concluding Activity:** The patient should finish the session with a three-minute barefoot walk (a hallway will suffice). Allow the patient about one minute to become familiar with how they feel. In the first minute they will feel a slight unstable sensation in their legs. The second minute will reveal changes. First, ask the patient how their feet feel on the ground, then ask how their mind feels as well as low back or other areas of presenting complaint. In the third minute, the patient will begin to feel a 'leveling-out' and reach a new stable state. I recommend using a timing device so that these predictable responses can be tracked accurately.	

Results

By balanced and optimized, I mean that a greater number of muscle fibers become active (called "activation protocol" in BBC) in the contraction process—both concentrically and eccentrically. This event displaces greater load to more fibers thereby 'lifting' load from a given joint and lowering the compression forces so common in the musculoskeletal system.[12] It is a consistent finding that more than half, and up to 70%, of total muscle fibers for a given area do not contract at all and are essentially "offline." This may be the most significant finding regarding muscle and joint pathologies of a non-cancer origin. Consider the Greek Parthenon and its many columns: the fewer the columns supporting the loads of the upper structures, the greater the weight is supported by the columns still standing. Muscle fibers (analogous to these columns) are overloaded causing them to overwork, go into spasm, eventually becoming painful and finally failing altogether.

Again using the Parthenon as analogy, the more strategically placed the columns are, the more sound the structural integrity becomes. In this case, I am referring to "calibrating" muscle tissue after it is "activated." The effect of calibrating a muscle or group of muscles for a more complex motion is that the synaptic firing pattern threshold of 20 milliseconds is reached and the neuro-geometric shape of this pattern becomes far more precise and organized. This optimization is theoretically generated by the ability of the brain to learn new data patterns (plasticity) or find forgotten templates, or some combination. In this way, agonist/antagonist muscular relationships are re-balanced causing a synergistic effect of strength and support—absent of much or all compensatory reactions so common in the musculoskeletal system.[13,14]

Important Note on Compensation Versus Adaptation

I have seen a consistent misunderstanding in clinical environments of the word 'compensation.' Anytime we observe musculoskeletal compensation, it is *a failure of the brain-body to adapt*. Period. On countless occasions, I have observed in journals and in clinical conversations these two words—compensation and adaptation—used interchangeably. This is patently incorrect as their meanings, as defined by both medical text and standard dictionaries, put them at opposite ends of the functional performance spectrum of the musculoskeletal system.[15] Compensations are the body's best means to "offset" a given problem such as a dysfunctional muscle. For example, when the diaphragm muscle is not producing adequate mechanical force (should be approximately 70% of total force of the breathing apparatus[16]), the secondary breathing muscles, sternocleidomastoid (SCM) and scalene groups, *compensate* by attempting to make up for the failure of the primary breathing apparatus. This carries severe consequences:

- overload of the SCMs and scalenes,
- site-specific and referred pain induced from that overload,
- cervical compression arising from these relatively small-mass muscles lifting the large-mass thoracic complex, and
- pulling of the cranium downward thereby contributing to compression-based pathologies such as disk degeneration and postural degradation such as straightening of the cervical curvature.

The pain in this most common case is generally chronic and long-term and creates an environment for initiating the release of the stress hormones cortisol, adrenaline, and norepinephrine—also known as the C.A.N.E. group.[17]

By contrast, an adaptation (i.e., an improvement, adjustment in which an organism becomes more suited to its conditions, environments[18]) in this scenario

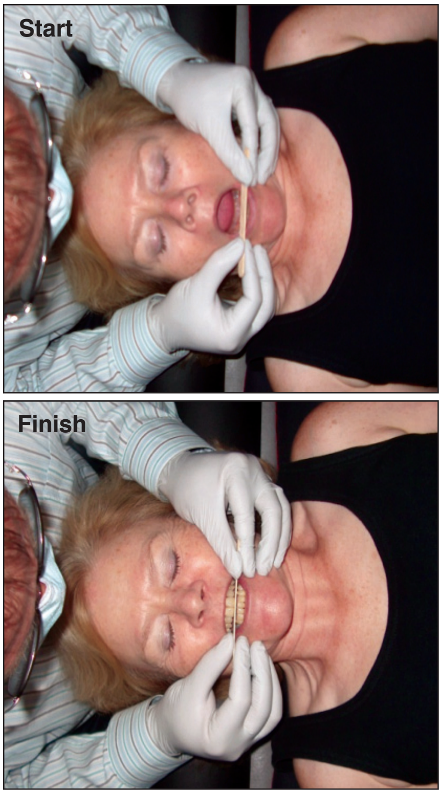

FIGURE 4. *Jaw calibration of mandibular closing muscles (masseter, temporalis, medial pterygoid).*

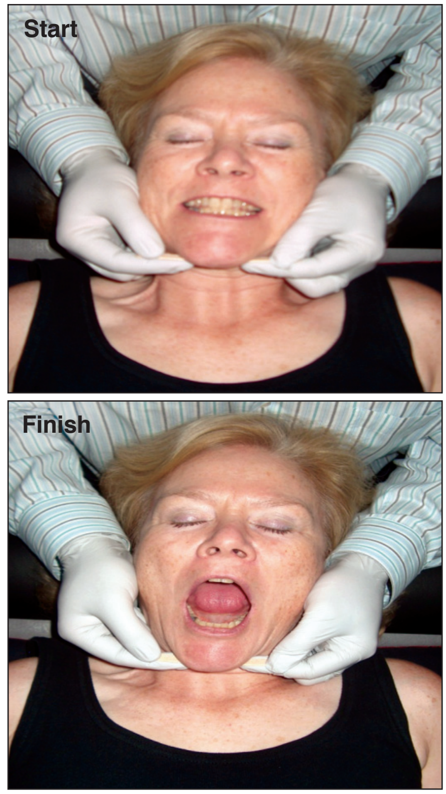

FIGURE 5. *Jaw calibration of mandibular opening muscles (lateral pterygoid, digastric, mylohyoid and geniohyoid muscles).*

would be to restore diaphragmatic breathing and thus release the cervical compression derived from secondary breathers and the pain they generate. This reliably produces pain relief by restoring the natural balance of proper breathing. Diaphragmatic calibration also improves relaxation—implying the release of serotonin—presumably from improved brain oxygenation and the relief of pain.

The Internal/External Neuro-Geometric Model

Pellionisz et al states that "The general hypothesis of the geometrical interpretation of brain function hinges on the assumption that the relation between the brain and the external world is determined by the ability of the CNS to construct an internal model of the external world using an interactive relationship between sensory and motor expressions."[19] These neuro-geometries have the task of "transforming covariant intention (groups of pre-formed templates of data in the cerebellum combined with objectives and goals) into contravariant execution" (actual motion results).[19]

Neural (cerebellar template) model execution equals muscle activity and/or motion results. Thus, motion results are the expressed motor behavior of the muscle systems derived from internally-modeled templates—whether accurate or not, painful or not. The implication here is that a painful muscle spasm, for example, is a template being expressed at the level of the kinetic chain but is, in fact, sourced from CNS influences and, in particular, the cerebellar templates. Further, the muscle is following CNS-sourced instructions and to that end, no error exists in the muscle per se, but rather in the brain. It also implies that muscle imbalances or dysfunctions which can lead to muscle pain can also lead to joint erosion as seen, for example, in many TMJ cases. Moreover, this newer view of brain-generated body pain seems to create a portal of study to further our understanding of pain issues.

Calibration Equals Precision

The *degree* of precise measurement and of forming internal metrics (covariant intention) appears to correlate in the data regarding pain and movement. During the BBC process, two to three sets of seven different motions creates a learning window for the cerebellum to learn to refine motion and thereby attenuating causal elements of pain. For example, at the ME motion level, the smoother a given motion can be attained, the less the accompanying pain. This means the internal neuro-geometric program has been improved in its precision and thereby 'updated' to reflect greater biomechanical efficiency (contravariant execution) in the motion. It is 'calibrated' to a higher tolerance and therefore operates better. It's similar to starting with a tape measure that is marked only at each inch or centimeter but lacks the smaller measurement markings making it difficult if not impossible to measure accurately. Since stuttered motion directly indicates a force magnitude error, this implies a lack of internal accuracy in cerebellar modeling of muscle activation. As with any system that requires calibration for proper function—e.g., tools, machines, electronic devices, etc.—cerebellar modeling operates in certain and sometimes very unforgiving and tight tolerances. An error that occurs outside that tolerance yields corruption in the operational capacity of the system.

For simplicity, the easiest calibrations are presented in Tables 3 and 4. There are more than 350 MEs currently in daily clinical use but this article is designed to provide a practical introduction to this technique for the clinician. Calibration of the breathing (diaphragm) musculature and the TMJ tend to offer some degree of clinically significant, body-wide pain relief and substantial stress reduction. In the clinical environment, these calibrations are typically 'front-line' treatments due to their global impact on pain and stress states.

Practitioner Note

Although calibration is safe because it is so gentle, it is still possible to injure a patient using this process. First, remember that this is a delicate, gentle and slow-paced procedure. Second, use common sense and consider any medically-applicable contraindications which may preclude the use of this technique.

Summary

Pain Management is not often reflective about brain function—particularly from the perspective that brain and cerebellar functions may be involved as causal elements in musculoskeletal body pain and pathologies. This article introduces this concept using fractionated motion induced under highly specific parameters of kinetic behavior. In so doing, the fractionated motion appears to be a function of cerebellar influences, has been present for indeterminate time frames, and has therefore remained masked as a possible and plausible source of pain. There is very limited, if any, detailed research on fractionated motion and further investigation is warranted. However, in the application of brain-body balibration techniques, a high corollary to pain and fractionated abatement has been identified with some reliability. ■

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