Movement-informed Breathwork (MiB): Integrating Muscular Contractions with Circular Breathing for Therapeutic Application.

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Abstract

This paper introduces Movement-informed Breathwork (MiB), a novel theranostic approach that integrates circular breathwork with targeted neuromuscular contraction and relaxation cycles. Drawing from neuromuscular torque chain dynamics, fascial research, and sensorimotor trauma therapy principles, MiB aims to enhance autonomic regulation, interoceptive awareness, and somatic-emotional integration by bridging traditional breathwork, movement therapy, and clinical practice across diverse populations and therapeutic settings. MiB demonstrates immediate feedback mechanisms for both participants and practitioners, enabling real-time assessment of neuromuscular patterns whilst promoting nervous system regulation. The approach is scalable from brief 5–10-minute sessions for awareness and downregulation to extended 90-minute sessions for deeper somatic exploration and trauma integration, with the aim of offering a contraindication-free, accessible framework for addressing autonomic dysregulation, emotional trauma, and chronic pain through targeted neuromuscular retraining. Its integration of contemporary neuroscience with traditional breathwork provides a scientifically informed approach that may enhance precision and effectiveness of movement-based therapeutic interventions. We believe it presents a significant advancement in integrative health practice that addresses both psychological and physical aspects of healing through the interconnection between breathing, movement and wellbeing.

Keywords

Movement, Breathwork, Torque Chains, Autonomic Regulation, Trauma Therapy, Interoception, Somatic Integration

1. Introduction

The relationship between breathing, movement, and neuromuscular coordination has been recognised across traditional healing systems for millennia, yet modern healthcare has largely compartmentalised these interconnected systems. Recent advances in fascial research, interoceptive neuroscience, and movement analysis are revealing the profound connections between conscious breathing and optimal neuromuscular function. Movement-informed Breathwork (MiB), also known in practice as the Swami Method, emerges from this convergence, offering a novel framework that integrates breathwork with targeted neuromuscular activation to enhance embodied awareness and therapeutic outcomes.

Traditional breathwork practices, whilst beneficial for stress reduction and emotional regulation (1,2), often lack the specific neuromuscular feedback mechanisms necessary for identifying and addressing dysfunctional movement patterns. Conversely, movement assessments frequently overlook the foundational role of breathing in establishing optimal neuromuscular coordination and nervous system regulation. MiB bridges this gap by combining circular breathwork in the form of conscious-connected breathing techniques (inhales followed by exhales without pauses (3)) with systematic muscle activation patterns, creating a dynamic assessment and intervention tool that provides immediate feedback to both participant and facilitator.

This approach builds upon recent advances in torque chain theory (4), which suggests that muscles can be functionally categorised based on whether they generate tension toward (Internal Torque Chain, ITC) or away from (External Torque Chain, ETC) the body's centre. Clinical application of this model has shown remarkable success in addressing chronic pain previously considered a surgical candidate (5), with targeted ITC retraining producing immediate functional improvements and sustained pain relief. MiB represents the practical operationalisation of these theoretical principles, providing a standardised method for assessing and optimising torque chain function through breath-coordinated muscle activation.

The accessibility of MiB distinguishes it from many movement interventions and traditional psychotherapeutic approaches. Requiring only the ability to lie supine and breathe, this approach can accommodate individuals with mobility limitations, chronic pain conditions, or those intimidated by traditional exercise modalities. Unlike psychedelic-assisted therapies, which show promise but remain limited by regulatory constraints and accessibility issues (6), MiB offers an accessible alternative that leverages the body's inherent capacity for self-regulation without requiring clinical settings or substances.

Recent neuroscientific findings support the biological plausibility of MiB's approach. Synchronising breath with widespread somatosensory and motor engagement can globally influence brain activity (7), with nasal airflow and full-body respiratory synchrony enhancing the propagation of respiratory-linked brain signals. This suggests that consciously coupling movement and breath—as operationalised in MiB—may amplify brain-wide coordination and interoceptive signalling, providing a mechanism for improved emotional regulation and autonomic balance. Furthermore, evidence demonstrates that even elite athletes frequently exhibit dysfunctional breathing patterns, with nearly 45% showing thoracic or abdominal dominant patterns despite high conditioning levels (8). These dysfunctional patterns correlate with increased injury risk, poor

respiratory performance, and inefficient autonomic regulation—precisely the issues MiB attempts to address through targeted neuromuscular retraining coordinated with optimised breathing mechanics.

Sessions can be adapted from brief 5-10-minute protocols for neuromuscular awareness and nervous system downregulation to extended 90-minute sessions, potentially facilitating deeper somatic exploration and trauma integration. This scalability, combined with the immediate feedback mechanisms, might make MiB particularly valuable for trauma-informed practice, where traditional movement approaches may be too activating or inaccessible for individuals with autonomic dysregulation.

By providing a framework that bridges traditional breathwork with contemporary neuroscience, fascial research, and trauma-informed somatic approaches, MiB offers practitioners a scientifically grounded yet accessible tool for enhancing the precision and effectiveness of movement-based therapeutic interventions across diverse populations and clinical settings. Importantly, through detection and correction of imbalances, deficiencies and weaknesses, the approach ensures that everybody can yield benefit regardless of their level of athletic performance or baseline health state.

2. Theoretical Framework

2.1 Fascial Networks and Interoceptive Awareness

Contemporary fascial research has fundamentally shifted our understanding of connective tissue from passive structural support to an active, sensory-rich network integral to movement coordination and interoceptive awareness. The fascia contains abundant mechanoreceptors and interoceptors—sensory receptors that provide information about internal bodily states. Remarkably, interoceptive nerve endings outnumber proprioceptive endings by a ratio of seven to one, highlighting the profound sensory capacity of fascial networks (9).

The diaphragm exemplifies this fascial complexity, representing not merely a breathing muscle but a multifaceted fascial structure encompassing transversalis fascia, endothoracic fascia, thoracolumbar fascia, and contractile tissue—all derived from the same embryological origin (10). This fascial continuity extends throughout the body, creating what many describe as an "uninterrupted structure" capable of transmitting mechanical and electromagnetic information across distant regions.

2.2 Neuromuscular Torque Chains and Autonomic Regulation

Research in sensorimotor trauma therapy has established that emotional experiences, particularly traumatic ones, are stored in the body through procedural memory and autonomic imprinting (11). Individuals with unresolved trauma often experience heightened autonomic arousal (hypervigilance, panic) or dissociative hypoarousal (numbing, collapse) due to the nervous system's impaired self-regulation capacity (12). These dysregulated states may manifest in postural imbalances, restricted breathing patterns, and chronic muscular tension patterns that become self-reinforcing over time. Perhaps similar mechanisms are at play during catatonia and other movement-related conditions associated with mood and affective disorders?

Recent advances in movement science have revealed the limitations of traditional single-muscle analysis, leading to the development of integrated neuromuscular models (13). The torque chain framework represents a paradigm shift that categorises muscles based on their directional force generation rather than isolated anatomical function. We have recently proposed that the neuromuscular system operates through distinct and binarised torque chains, which organise muscular tension and postural alignment in ways that influence autonomic function (4).

Internal Torque Chain (ITC): Comprises muscles that generate tension toward the centre of the body, including core stabilising muscles such as the transverse abdominis, external obliques, psoas major, lower abdominals, teres major, anterior deltoids, sternocostal head of the pectoralis major, and related postural stabilisers. These muscles demonstrate direct connections to the diaphragm and pelvic floor, contributing not only to structural integrity but potentially also to autonomic regulation. The ITC can be engaged more effectively with continuous, cyclical movements and breathing patterns.

External Torque Chain (ETC): Includes muscles that generate tension away from the body's centre, such as the rectus abdominis, internal obliques, sternoclavicular head of the pectoralis major, latissimus dorsi, lumbar erectors, and muscles supporting explosive movements. ETC activation appears more closely associated with sympathetic nervous system activity, tends to fatigue more quickly, elevates heart rates more rapidly, and is characteristically more challenging to maintain in sustained, cyclical patterns.

This functional dichotomy provides a neurobiological basis for understanding how specific movement patterns influence autonomic regulation. The torque chain framework provides a contemporary lens through which to understand traditional yogic concepts of energetic channels and locks (nadis and bandhas). Where traditional yoga speaks of energy flow, the torque chain model identifies specific neuromuscular pathways that, when activated properly, might influence autonomic state and interoceptive awareness.

When ITC muscles are weak or poorly coordinated, compensatory patterns emerge that can manifest as chronic pain, dysfunctional movement, and altered emotional states. Sensorimotor trauma therapy suggests that habitual overactivation of certain muscles is linked to hyperarousal states (11). Notably, Svebak described how low-level, but enduring psychogenic muscle tension can become pathophysiological when sustained by stress or effort, creating a ‘vicious circle’ of tension, local ischemia, and pain (14). This insight supports the need for conscious retraining. The integration of breathing patterns with torque chain activation offers a practical means of assessing and optimising these fundamental neuromuscular relationships.

2.3 Breathing Patterns and Nervous System Regulation

Controlled breathwork practices have demonstrated efficacy for stress management, mood enhancement, and physiological regulation. Specific breathing patterns influence autonomic nervous system activity, with exhale-focused techniques particularly effective for promoting parasympathetic activation and respiratory rate reduction (15).

The integration of muscle activation with breathing patterns appears to enhance these regulatory effects whilst providing additional neuromuscular benefits. Circular breathwork in the style of conscious-connected breathing—characterised by continuous, circular patterns without breath holds—maintains consistent nervous system activation whilst allowing for sustained muscle engagement and interoceptive exploration. This approach disrupts breath-holding patterns associated with trauma responses and prevents sympathetic arousal while facilitating an increase in vagal tone.

3. Movement-informed Breathwork Protocol

3.1 Core Methodology

Before engaging in MiB, practitioners are encouraged to establish an environment of safety, which aligns with sensorimotor principles of dual awareness and grounding. This preparation is particularly relevant for trauma survivors, as acknowledgement bodily sensations without becoming overwhelmed may be essential for effective integration (11).

3.1.1 Breathwork Foundation

MiB integrates four fundamental elements that distinguish it from traditional breathwork approaches:

Circular Breathwork: Participants employ a circular breathing technique with inhalation through the nose combined with a gentle facial engagement that resembles a subtle smile or "smirk," reinforcing safety and interoceptive muscular engagement. Exhalation occurs through pursed lips, mimicking a whistling action without sound, to activate mechanoreceptors on the lips whilst maintaining gentle back-pressure. This is consistent with recent findings that the facial muscles and diaphragm are among the most stress-reactive regions in the body and likely benefit from targeted relaxation or activation during breathwork (16). This pursed-lip technique supports sustained exhalation and parasympathetic activation while regulating emotional response through controlled vagal engagement. The circular, connected nature of the breath cycle—without pauses between inhalation and exhalation—promotes continuous awareness and prevents breath-holding patterns associated with trauma responses or dysfunctional movement patterns.

Internal Torque Chain Activation: During inhalation, participants systematically contract specific muscle groups associated with the ITC, specifically those that generate tension toward the centre of the body. This includes the psoas major, vastus medialis obliquus, gluteus maximus, pectoralis major and teres major, and related core stabilisers that contribute to both structural integrity and autonomic regulation. This breath initiates activation of the ITC, promoting parasympathetic regulation.

Systematic Muscle Contraction and Relaxation: During exhalation, participants consciously release the activated muscles, creating alternating patterns of tension and relaxation that may enhance interoceptive awareness and identify areas of dysfunction. This process involves gentle movements coordinated with the breath cycle, allowing for the discovery of "blind spots" in muscular awareness, as a biofeedback loop.

Facilitator Assessment: Trained practitioners observe muscle activation patterns, breathing quality, and stress responses, providing real-time feedback about neuromuscular function and areas requiring attention. Practitioners may be able to sense asymmetries in muscle activation, identifying areas where tension might be excessive or lacking.

3.2 Session Variations and Structure

Brief Sessions (5-10 minutes): Designed for neuromuscular assessment, stress reduction, or integration into training sessions. These protocols focus on establishing basic breathing patterns and identifying primary areas of tension or weakness while providing immediate downregulation benefits.

Standard Sessions (20-30 minutes): Comprehensive protocols that systematically address multiple muscle groups whilst promoting deeper nervous system regulation. The practice begins with engagement of deep core stabilisers (transverse abdominis, pelvic floor, lower diaphragm) to increase interoceptive awareness and establish a foundation for subsequent movement. These sessions are suitable for therapeutic settings and regular practice.

Extended Sessions (45-90 minutes): Intensive protocols that have the potential to facilitate altered states of consciousness and profound somatic exploration. These sessions allow for deeper integration and emotional processing whilst maintaining focus on neuromuscular awareness. Contractions can be adjusted based on internal somatic feedback. As practitioners discover areas of excessive tension or inadequate activation, they can direct conscious attention to these regions or towards others, while maintaining the breath pattern.

3.3 Core Trauma-Informed Principles

MiB operates under two core trauma-informed principles that distinguish it from traditional breathwork approaches:

Continuous Breath Connection: Disrupting breath-holding patterns (which are usually tied to whole-body movement patterns) prevents sympathetic arousal and facilitates vagal tone activation, mitigating autonomic dysregulation. Unlike some traditional pranayama practices that incorporate breath retention, MiB emphasises continuous flow to maintain regulatory capacity and avoid potential triggering of trauma responses.

Somatic Compassion: The practice encourages non-judgemental engagement with bodily sensations, breaking fear-avoidance cycles common in trauma-related disorders and fostering a sense of embodied safety. This approach fosters sensorimotor reorganisation, potentially helping release trauma-related muscular tension and autonomic hyperactivity through conscious neuromuscular engagement and proactive agency rather than passive release.

3.4 Assessment Capabilities

MiB can provide immediate feedback regarding:

- Breath-holding patterns under stress

- Muscle activation capabilities and limitations
- Compensation patterns and asymmetries
- Nervous system regulation capacity
- Interoceptive awareness and embodied connection

This real-time assessment capability distinguishes MiB from static evaluation methods, providing dynamic information about how individuals respond to stress and challenge whilst offering pathways for immediate intervention and regulation.

4. Clinical Applications

4.1 Psychological Applications

MiB offers evidence-informed benefits for various psychological conditions where autonomic dysregulation plays a significant role:

Anxiety Disorders: By enhancing parasympathetic activation through ITC engagement, MiB may help reduce sympathetic dominance and associated anxiety symptoms. The continuous, cyclical breathing patterns combined with ITC activation might help interrupt anxiety-related tension patterns associated with mouth breathing (17).

Depression: The active engagement of core musculature may counteract the postural collapse and psychomotor retardation often seen in depressive states, potentially influencing mood through bottom-up processing. Additionally, the increased interoceptive awareness fostered by MiB may help reconnect individuals with sensations of vitality and embodied presence (9).

Trauma-Related Conditions: For individuals with PTSD or complex trauma, MiB provides a gentle pathway to reconnect with bodily sensations in a titrated manner, addressing somatic aspects of traumatic experience that may remain unresolved through cognitive approaches alone. This approach aligns with van der Kolk's recognition that trauma is "stored in the body" and requires somatic intervention for complete healing (18).

Stress-Related Disorders: The practice offers tools for autonomic regulation that may be beneficial in conditions characterised by allostatic load and chronic stress activation (19). The balance between ITC and ETC activation may provide a practical means to modulate stress responses for anybody looking to optimise their health and wellness.

4.2 Physical Applications

Beyond psychological benefits, MiB might address physical manifestations of dysregulation:

Chronic Pain: By altering tension patterns in the torque chains, MiB may help interrupt pain-tension cycles and restore more balanced muscular activation. One clinical observation suggests that many conditions diagnosed as structural problems (such as femoroacetabular impingement syndrome) often respond to neuromuscular retraining that focuses on proper activation of the ITC,

particularly the psoas major, producing immediate pain relief and functional improvement (5). This aligns with Alfvén's (1997) model of psychomuscular tension in children, which demonstrated that generalised stress can lower local pain thresholds by inducing chronic muscle tension—a pattern MiB aims to detect and re-pattern before it becomes a self-reinforcing source of pain (20).

Fatigue Conditions: For conditions like chronic fatigue syndrome, where autonomic dysregulation is often present, this approach may aid the return to physical activity with a subjectively guided approach that prevents excessive post-exercise malaise. Additionally, conditions with overlapping phenomena involving movement and the autonomic nervous system such as joint hypermobility, fibromyalgia, and postural orthostatic tachycardia syndrome may respond to targeted torque chain training, a potentially fascinating avenue of future research.

Functional Neurological Disorders: The emphasis on interoceptive awareness and neuromuscular precision may help address the disconnection between intention and movement seen in some functional disorders (21). By providing clear somatic feedback through breathwork-movement coordination, individuals can potentially rebuild disrupted sensorimotor pathways.

4.3 Integration with Existing Therapeutic Approaches

MiB serves as a complementary approach that can enhance traditional yoga therapy, physiotherapy, and psychotherapy interventions. Rather than replacing existing modalities, it offers a framework for understanding how movement and breath interventions affect both physical and psychological functioning, potentially increasing the precision and effectiveness of current practices.

Yoga Therapy Integration: Understanding torque chain dynamics can refine alignment cues and muscular engagement in traditional postures, particularly those involving core stability and dynamic movement. The continuous connected breath of MiB can complement traditional pranayama practices, offering an accessible entry point for those who find breath retention challenging or triggering.

Somatic Psychotherapy: MiB provides specific protocols for potentially addressing the neuromuscular aspects of trauma while maintaining the safety and titration principles essential to trauma-informed practice.

Clinical Settings: The accessibility and immediate feedback capabilities of MiB make it potentially suitable for integration into various healthcare settings, from primary care to rehabilitation facilities, requiring minimal equipment and offering contraindication-free application.

5. Implementation Guidelines

5.1 Practitioner Considerations

For healthcare providers, yoga therapists, and movement professionals integrating MiB into their practice:

Assessment: Begin with observing the client's natural breathing pattern and postural tendencies, noting signs of torque chain imbalance such as chest-dominant breathing, collapsed posture, or excessive tension in the upper shoulders which may be bilateral or lateralised.

Introduction: Start with simple awareness practices before progressing to more targeted activations, allowing clients to develop comfort with interoceptive sensing. Establish safety and explain the voluntary nature of all aspects of the practice.

Progression: Gradually increase complexity by adding more specific muscle activations and eventually incorporating dynamic movement while maintaining breath-muscle coordination. Progress from foundational awareness to more sophisticated neuromuscular patterns based on individual capacity and therapeutic goals.

Trauma-Sensitive Approach: Maintain awareness of potential trauma responses, offering options to modulate intensity and ensuring clients can self-regulate throughout the process. Emphasise client agency and choice in all aspects of the practice.

5.2 Session Structure

A typical MiB session might follow this structure:

Orientation and Safety (5-10 minutes): Establishing presence, explaining the practice, and creating a container for safe exploration. This includes assessment of current state and any contraindications or modifications needed.

Breath Awareness (5-15 minutes): Introducing the circular, connected breath pattern without muscle activation, allowing participants to establish the foundational breathing rhythm and assess baseline nervous system state.

Primary Activation (10-20 minutes): Beginning engagement of core ITC muscles in coordination with breath, starting with simple awareness and progressing to more sustained activation patterns.

Exploration and Integration (15-30 minutes): Exploring dynamic movement patterns while maintaining breath-muscle coordination, identifying areas of strength, weakness, or compensation patterns.

Regulation and Closure (5-15 minutes): Gradual transition back to normal functioning with retained awareness, integration of insights, and establishment of regulatory capacity for post-session stability.

The duration and emphasis can be adjusted based on client needs, therapeutic context, and practitioner experience.

5.3 Integration with Yoga Therapy

For yoga practitioners and instructors specifically, MiB enhances traditional practices in several evidence-informed ways:

Asana Enhancement: Understanding torque chain dynamics refines alignment cues and muscular engagement in traditional postures, allowing assessment of asana through the lens of effective muscle engagement rather than focusing solely on external alignment.

Pranayama Connection: Again, the continuous connected breath of MiB complements traditional pranayama practices, offering an accessible entry point for those who find breath retention challenging or triggering. The MiB method is designed to be accessible for beginners and individuals with medical or physiological contraindications to breath retention.

Philosophical Alignment: The focus on embodied awareness and somatic integration aligns with yogic concepts of pratyahara (sensory withdrawal) and dharana (concentration), supporting the progression toward meditative states through body-based awareness.

Therapeutic Applications: For yoga therapists working with specific populations, the torque chain framework provides a physiological rationale for adapting practices to address particular imbalances or conditions whilst maintaining connection to traditional wisdom.

6. Future Research Directions

6.1 Empirical Validation Opportunities

Future investigation into MiB should focus on several key research directions to provide robust quantitative validation:

Physiological Markers: Longitudinal studies measuring heart rate variability (HRV), electromyography (EMG) readings, and relevant cellular metabolites in participants before and after structured MiB interventions to establish objective measures of efficacy.

Standardised Assessment: Implementation of standardised assessment protocols and detailed case report templates across multiple practitioners to enable systematic documentation of interventions and outcomes in a comprehensive database.

Mechanistic Investigations: Utilisation of advanced imaging techniques, such as fMRI or fMRS, to observe real-time changes in neural activity during specific muscular contractions within the torque chains, whilst measuring interoceptive accuracy using established protocols during muscular tension modulation.

Cross-Disciplinary Validation: Partnerships with breathwork practitioners, sports scientists, psychedelic researchers, and mental health professionals to identify common physiological mechanisms and validate the torque chain model across different applications.

Clinical Trials: Structured investigation of efficacy in specific conditions such as PTSD, anxiety disorders, chronic pain, and conditions with overlapping movement and autonomic features like joint hypermobility and fibromyalgia.

Comparative Studies: Examining differences in outcomes between MiB and traditional yoga practices, conventional psychotherapeutic interventions, or other somatic approaches to establish specific therapeutic advantages.

6.2 Training and Implementation Framework

As MiB continues to develop, considerations for systematic training include:

Standardised Protocols: Development of core practice sequences for specific populations or conditions, with clear guidelines for progression and adaptation based on individual needs and therapeutic goals.

Integration Frameworks: Guidelines for incorporating MiB into existing yoga therapy, physiotherapy, or clinical practice settings, with particular attention to bridging traditional and contemporary approaches whilst maintaining safety and efficacy.

Assessment Tools: Creation of observational and self-report measures specific to torque chain function and balance, allowing practitioners to track progress and refine interventions based on objective feedback.

Practitioner Training: Development of structured training programmes that ensure competence in both the theoretical foundation and practical application of the torque chain framework, including trauma-informed principles and safety considerations.

The challenge facing further work in this area is to avoid reductionist perspectives and fragmentation of the neuromuscular system from the rest of the body and brain.

7. Conclusions

Movement-informed Breathwork offers a significant advancement in integrative health practice, providing a novel framework that bridges traditional breathwork, movement therapy, and clinical assessment through scientifically informed principles. By combining circular breathwork with systematic muscle activation based on torque chain theory, MiB provides immediate feedback about neuromuscular function whilst promoting nervous system regulation and embodied awareness.

The approach's accessibility and contraindication-free application (when applied correctly), may make it valuable across diverse populations and settings, from trauma recovery to athletic performance optimisation. Its foundation in contemporary fascial research, neuromuscular science, and trauma-informed practice provides credible theoretical grounding whilst maintaining practical applicability for both healthcare providers and movement professionals.

By recognising that the neuromuscular system—particularly the interplay between the Internal and External Torque Chains—mediates physical, emotional, and psychological health, we can deepen our understanding of how movement practices influence wellbeing. The torque chain framework provides a common language that can facilitate communication across traditionally separated fields such as neuroscience, orthopaedics, sports medicine, somatic therapy, and yoga therapy.

As healthcare increasingly recognises the importance of integrative approaches that address both psychological and physical aspects of healing, we believe MiB offers a valuable tool for

practitioners seeking evidence-informed methods that honour the interconnection between breathing, movement and wellbeing. Through continued research, refinement, and integration with existing practices, MiB may contribute significantly to the evolving field of movement-assisted psychotherapy and its applications for human health and resilience.

The integration of breathwork and movement assessment represents a natural evolution in our understanding of human function and healing. Movement-informed Breathwork offers a practical, accessible means of harnessing this integration for the benefit of individuals and communities seeking enhanced health, emotional regulation and somatic awareness. Ultimately, by recognising movement practices as the bridge between body and mind, we open the door to a new era of healing—one that transcends traditional boundaries and harnesses the full transformative power of the neuromuscular system to restore balance and resilience across innumerable aspects of human health.

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Competing Interests

R.A. is founder of Moved Academy and Movement Ayahuasca, two companies which teach and apply the concepts introduced in this paper. E.C. is a practicing movement specialist as well as an instructor at Moved Academy and facilitator at Movement Ayahuasca. G.W.F. is a qualified Breath Teacher with The Breath-Body-Mind Foundation, New York.

AI-Assisted Technologies Statement

Both Claude Sonnet 4 and ChatGPT-4o models were used to enhance the readability of the manuscript in the final drafting stages.

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