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REVIEW ARTICLE

The Science of Tai Chi and Qigong as Whole Person Health-Part I: Rationale and State of the Science

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Abstract

Background: The emerging paradigm of whole person health shares many core principles with traditional complementary and integrative health frameworks, including Tai Chi and Qigong (TCQ).

Methods: In the Fall of 2023, the Harvard Medical School Osher Center for Integrative Health hosted the inaugural international conference on *The Science of Tai Chi & Qigong* as *Whole Person Health*: *Advancing the Integration of Mind-Body Practices into Contemporary Healthcare* held at Harvard Medical School. A two-part white paper was written to summarize key conference topics, findings, and issues.

Results and Discussion: Part I presented here summarizes the rationale for the conference and synthesizes the state of evidence for TCQ as rehabilitative and preventive tools for a range of clinical conditions, including falls and balance, cognition, mental health, sleep, cardiorespiratory health, musculoskeletal health, cancer, as well

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as translational evidence related to the neurophysiology, brain and immune function, and biomarkers of inflammation. The state of science of TCQ, viewed through the lens of traditional East Asian health constructs, is also discussed. Part II of this white paper outlines evidence gaps and opportunities and discusses strategies to address challenges in TCQ research, dissemination, and implementation.

Keywords: mind–body, integrative health, movement, whole person health

Introduction

The emerging paradigm of whole person health, a framework underlying strategies for health care research and delivery in the U.S. Veteran's Health Administration,[1–3] National Center for Complementary and Integrative Health (NCCIH) at the National Institutes of Health,[4] and many other international programs and institutions,[5–8] shares many core principles with traditional complementary and integrative health frameworks, including mind–body movement (MBM) practices. Core principles underlying both whole person health and MBM practices include the following: (1) health emerges from complex and multilevel cross-systems interactions, including psychophysiologic processes that link mind and body; (2) health and health care need to address both pathogenesis (i.e., disease) and salutogenesis (i.e., wellness), including primary and secondary prevention across the lifespan; and (3) health and wellness must consider patient-centered values (what matters to individuals practically, emotionally, socially, spiritually), as well as biologic symptoms and markers of disease. Addressing these holistic tenets is especially relevant in the context of declining population health and the U.S. Health care system, in which costs are increasing yet with worse clinical outcomes compared with other countries and without benefit to lifespan.[9] Causal links between deteriorating global trends in population health and noncommunicable diseases (NCDs), which are known to be preventable and (potentially) well-managed with mind–body and behavioral strategies, make exploring the ties between whole person and mind–body health even more germane.[10,11]

Tai Chi and Qigong (TCQ) are two increasingly popular MBM therapies that show promise for integration on a large scale in Western health care systems. On September 18–19, 2023, the authors convened an inaugural international conference entitled, *The Science of Tai Chi & Qigong as Whole Person Health: Advancing the Integration of Mind-Body Practices in Contemporary Healthcare* in Boston, MA, USA. The goals of the conference were as follows: (1) to provide an international forum for researchers and practitioners to disseminate scientific findings relevant to TCQ and related mind–body practices, assess the evidence base in the context of whole person health, and shape and inform the future research agenda, and (2) to foster interdisciplinary dialog and collaboration aimed at developing innovative strategies that address current challenges in mind–body movement research, dissemination, and implementation. With this in mind, this white paper is intended to articulate the rationale for the event, to synthesize and summarize the state of evidence for TCQ as rehabilitative and preventive tools for a range of clinical conditions, and to sketch a road map of current knowledge gaps in evidence and strategies for addressing them. Part 1 of this white paper directly reflects the five major plenary sessions of the conference covering the overarching topics (Whole Person Health—Integration Across Physiological Systems, State of the Science in Tai Chi & Qigong Research 1 & 2, Implementation of Mind–Body Practices in Contemporary Healthcare, Explorations in Body Intelligence—Examples from Western and East Asian Medicine Research). The keynote speakers were engaged in teleconference in preparation for the conference and to contribute to this white paper based on conference presentations and discussions.

Background

Defining Tai Chi and Qigong

TCQ share a common history that includes elements of Traditional Chinese Medicine, martial arts conditioning, and Asian holistic lifestyle philosophy.[12] Recent historic literature links Tai Chi's origin to martial arts lineages practiced in the 16th century AD, whereas Qigong-like practices have been identified in documents dating as far back as the 4th century BC.[13–15] Both TCQ are inherently multimodal, and training typically integrates flowing movements, dynamic and static postural control, and breath instruction, along with a variety of cognitive skills including heightened somatic awareness, imagery, and focused mental attention.[16–19] The "active ingredients" of Tai Chi have been previously described to include multiple shared therapeutic components, including awareness, mindfulness, and focused attention; intention, belief, and expectation; structural integration; active relaxation strength and flexibility training; natural freer breathing; social support, interaction, and community; and embodied spirituality, philosophy, and ritual.[17,19] While there is great heterogeneity within and between these practices, traditional Tai Chi training typically emphasizes relatively longer choreographed sequences of movements (forms or sets) with a focus on functional martial applications, whereas Qigong typically uses a more simplified and repetitive choreography, with greater emphasis on health and spiritual well-being.[12] Both TCQ are considered forms of "Meditative Movement"[20] and movement-based embodied contemplative practices.[21] In part, to adapt to replicable protocols suitable for academic and biomedical research community, over the past 50 years highly simplified Tai Chi forms have been developed centering around shorter, repetitive movement phrases and emphasizing nonmartial mind–body therapeutic principles.[22,23] Moreover, in clinical trials, even when more traditional Tai Chi forms are evaluated, they are often combined with Qigong-inspired "warm-up" and "cool-down" calisthenics, which reinforce mind–body training and practice principles common to both TCQ. For these reasons, during their conference and in this white paper, TCQ are grouped together and considered comparable interventions from both conceptual and therapeutic perspectives, as articulated in multiple recent reviews.[18,24–27] For practical purposes

in this white paper, they are jointly referred to as "TCQ." This approach is being taken with full awareness that future research may wish to evaluate these practices with greater granularity. This may include studies to evaluate if there are optimal styles, protocols, doses, and teaching approaches for Tai Chi and/or Qigong that match the needs of specific populations (e.g., older vs. younger adults; cardiovascular vs. pain conditions) and desired health outcomes (e.g., physical function, inflammatory markers, spiritual well-being).

Prevalence of TCQ use and integration with modern healthcare

Estimates of the prevalence of use of TCQ worldwide are not readily available. One recent survey based in the United States estimates that in 2017, 1.7% or approximately 4.05 million individuals, reported practicing Tai Chi or Qigong in the past 12 months for health purposes.[28] This estimate is approximately 64% higher than estimates obtained using similar methods in 2007.[28] Estimates from Asia,[29] Canada, Europe, Australia,[30] and Central and South America are not well established. However, nonsystematically collected data, such as the number of countries that have adopted formal national proclamations acknowledging World Tai Chi and Qigong Day, suggest that prevalence of use (and popularity) is growing worldwide.[31] Data from one U.S. national survey suggest that individuals using TCQ for medical reasons are more likely to be older than 30 years, of an Asian, African American, or ethnic origin other than White, and college educated. Health-related engagement in TCQ is related to wellness/disease prevention and to improving energy, immune function, athletic performance, or memory/concentration. Stress, arthritis, and joint problems are the most frequent specific health problems attributed to starting practice. However, survey results vary, and patterns and reasons attributed to the use of TCQ have varied over time.[28,32–35] One noteworthy and important finding from a recent review of survey data in the United States concluded as follows: "*Given that the greatest increases in use of TCQ from 2007 to 2017 were in older adults, females, low-income individuals, [those with limited access to health care], and people who were physically inactive, TCQ may serve as an age-appropriate, cost effective, mind-body exercise for these groups of populations to help ameliorate health disparities*."[28]

Approaching TCQ research from a systems biology and whole person health perspective

The remarkably broad constellation of therapeutic effects attributed to TCQ—including positive impacts on falls, mobility, musculoskeletal disorders, cognition, cardiorespiratory and metabolic function, immunity, affect, sleep, mood, cancer-related symptoms, and multiple higher level behavioral processes (e.g., perceived self-efficacy)—likely reflects two key concepts central to the field(s) of whole person health and complementary and integrative care. First, outcomes across the multiple systems impacted by TCQ training are typically not independent. Changes in one system (e.g., pace and depth of respiration) directly and indirectly impact other systems (e.g., blood pressure, neuroendocrine, and emotional regulation). This systems approach or "ecological" framework in which health emerges from cross-systems interactions,[36] including those broadly attributed to mind and body, is resonant with healing models of East Asian medicine from which TCQ originates.[19] Second, the broad multisystem health impacts of TCQ likely result from the multicomponent nature of these interventions, which have evolved to include a complex mixture of "therapeutic ingredients and components" (e.g., aerobic and weight-bearing activity, breath training, mental focus, bodily awareness, imagery and visualization, and social support).[16,17] This systems perspective is supported by a broader literature, which demonstrates that for many chronic conditions, multimodal therapeutic interventions that combine multiple elements (e.g., manual therapies, exercise, cognitive skills, education, health coaching) are more effective than unimodal ones.[37–45] Appreciating and better characterizing the suite of therapeutic components implicit in TCQ training protocols and how they can be synergistically combined to manage symptoms and alter underlying biologic features of various chronic health conditions will thus require novel experimental designs and synthetic cross-systems outcomes. The insight resulting from these novel approaches will both inform how TCQ clinically impacts diverse patient and healthy populations and afford insight into the psychophysiologic mechanisms and processes underlying observed therapeutic effects. To set the context for interpreting the broad impact of TCQ across multiple psychophysiologic outcomes and populations, Box 1 provides a brief summary of three examples of cross-system psychophysiologic interactions known to impact health and that are targets of TCQ training.

Box 1a-c. Examples of cross-system interactions that are likely to be influenced by multimodal mind–body interventions such as TCQ

a. Cognitive, affective, and sensorimotor interactions

One example of cross-system interactions relates to fundamental connections between cognition, mood, and movement. There is robust evidence indicating that how we think and feel impacts how we move, and conversely, how we move impacts how we think and feel. Epidemiologic research shows that in older adults, even subtle deficits in high-level cognitive "executive" functions (e.g., self-monitoring, planning, task switching) are associated with reduced walking speed and heightened risk of falling.[46,47] The interdependence of cognition and locomotor control, in particular, is directly supported by "dual task" studies demonstrating that for most individuals, performing an unrelated cognitive task (e.g., verbalized serial subtractions) while walking disrupts performance in one or both tasks as they compete for shared brain resources.[47] The relationships between the integrity of brain networks subserving cognition and walking performance in older adults support the importance of cognitive–motor interactions for health.[48] Similarly, recent evidence indicates that mobility can be improved via noninvasive brain stimulation targeting the dorsolateral prefrontal cortex, a primary node of the brain's frontoparietal executive control network.[49,50] At the same time, it is now understood that affect also impacts motor performance. Anxiety related to falling (i.e., fear of falling), ironically, is one of the strongest predictors of falls,[51] and both epidemiologic and experimental studies have linked depression to impaired gait and postural control.[52–54] Finally, there is mounting evidence that movement is critical to both cognition and affect. Large-scale prospective studies have linked adult walking speed to dementia risk in later life,[55] and clinical trial evidence indicates that regular

exercise supports positive affect[56] and protects against age-related cognitive decline.[57]

As the hyphen in mind–body intervention implies, these interventions explicitly aim to enhance awareness of, and practically facilitate connections between, what are broadly described as cognitive, affective, and motor processes. The focus of TCQ on these deeply wired mind–body links underscores the value of evaluating TCQ's effectiveness on function using multimodal assessments (e.g., dual-task walking) and likely underlies the reported benefit on complex outcomes such as mobility, fall risk, fear of falling, and cognitive function.[58–60]

b. Connective tissue

As the term connective tissue implies, it involves links or connections across multiple systems that are integral to health, including the musculoskeletal, nervous, and immune systems.[61,62] At the macro level, the rich networks of connective tissues ranging from bone, ligaments, tendons, fascia, and interstitium collectively represent a scaffolding, which supports biomechanical and physiological integration and adaptability. At the relatively local scale or level, *ex vivo* and *in vivo* studies support that connective tissue is highly sensitive to mechanical forces that could be influenced by the loads and shear forces encountered by TCQ.[63] *Ex vivo* studies have shown that stretching impacts fibroblasts, which triggers a cascade of molecular changes that include gene regulation and metabolic dynamics linked to inflammatory processes.[64] *In vivo* animal studies also suggest that stretching of connective tissues is associated with dynamic changes in immune markers and wound healing,[65,66] and may have potential to impact the growth of connective tissue-rich cancer tumors.[67] Observational studies in humans suggest that chronic low back pain (cLBP) may be associated with dysfunctional shear strain dynamics in the thoracolumbar fascia,[68] which in turn may be associated with gait abnormalities.[69] Other studies with cLBP suggest that tissue-level abnormalities may be comorbid with dysfunctional higher level behaviors, including kinesiophobia, catastrophizing, and rumination.[70–72] Of note, Tai Chi classics and East Asian medical texts emphasize that health requires body-wide connectivity, and some research has implicated connective tissues and the interstitium as one of the substates of meridians and acupoints.[73–75] Moreover, phrases from the Tai Chi classics such as—"*flow like water*" and "*every joint in your body must be strung together. . ..(which) allows Qi to pass smoothly through your body and benefits both form and application*"—point to principles of within and cross-system integration supported by emerging connective tissue and interstitium research. Not surprisingly, TCQ research has shown that training impacts all systems associated with connective tissue, including inflammatory processes,[76–78] musculoskeletal pain,[79] and kinesiophobia[80] and rumination,[71] positively impacting range of motion, mobility, and overall function.[81,82]

c. Cardiovascular stress, inflammation, and heart–brain connections

A third example of cross-system physiology is the link between cardiovascular stress and the brain. While links between psychosocial stress or depression and cardiovascular disease (CVD) have long been recognized, mechanisms linking the brain to the cardiac function have only recently been delineated. Murine studies have shown that heart–brain connections involve more than the activation of the hypothalamic–pituitary–adrenal axis. Such studies demonstrate that stress, through brain stem–derived sympathetic neurons, triggers the mobilization and release of immune cells that potentiate arterial inflammation and drive atherosclerosis.[83] In addition, animal studies identify neural loops that involve the amygdala and, via sympathetic nerves, terminate on blood vessel walls.[84] When stimulated, these circuits upregulate inflammation around the arteries, further driving atherosclerosis.

Human studies have likewise shown the impact of stress on CVD risk. The INTERHEART Study of nearly 25,000 individuals around the world has found that psychosocial stress carries an attributable CVD risk that is on par with that of traditional CVD risk factors such as smoking.[85] More recently, brain imaging studies have shown that heightened amygdalar metabolic activity (relative to activity in regulatory regions in the cerebrum) is associated with an elevated future risk of CVD, largely by serially upregulating immune activity and arterial inflammation, as predicted in animal models.[86] This neural-immune-arterial mechanism has been repeatedly shown to represent an important mechanism by which chronic stressors increase the risk of CVD.[87] Notably, individuals with lower stress-associated neural activity, despite exposure to chronic stress (i.e., those who are neurobiologically resilient), have a lower risk of CVD.[88] Thus potential methods to improve neurobiologic resilience, such as TCQ, are important. Indeed, TCQ have been shown to improve inflammatory markers implicated in cardiovascular, cognitive, and affective disorders, although explicit causal links between these processes have not been quantified.[89]

In addition, interrelationships between the heart and brain are illustrated by measures such as heart rate variability (HRV) and complexity, which provide important information about the autonomic nervous system and its impact on cardiorespiratory function, among other systems, while also serving as indices of whole system health.[19,90,91] Multiple studies have examined HRV to evaluate the physiological effect of Tai Chi.[92,93] While some evidence supports that compared with wait-list controls, Tai Chi positively impacts frequency (e.g., low frequency and very low frequency power) and time domain (e.g., standard deviation of the heartbeat intervals) measures of HRV associated with improved autonomic tone, comparisons with active interventions do not support Tai Chi-related benefits.[92] More generally, limitations in study design and HRV analytic methods limit conclusions that can currently be drawn regarding the impacts of TCQ on HRV.[93]

Summary of research evidence

Bibliometrics, meta-analyses, and scoping reviews

A bibliometric analysis of clinical studies of Tai Chi published between 1958 and 2013 identified 507 peer-reviewed studies,[94] and a 2010 to 2020 update identified an additional 987 studies.[95,96] Most recently, a critical overview identified and synthesized the findings of 210 systematic reviews of controlled clinical trials of Tai Chi.[97] With important caveats regarding research methodological quality and heterogeneity, the findings support that Tai Chi has multisystem effects, including physical, psychological, and quality of life (QOL) benefits, for a wide range of conditions. Clinically important benefits have been consistently reported for Parkinson's

disease, falls risk, musculoskeletal disorders (e.g., knee osteoarthritis, low back, and neck pain), and cerebrovascular and cardiopulmonary diseases, including stroke, hypertension, and chronic obstructive pulmonary disease (COPD), with less robust but promising evidence for mood, cognition, sleep, and cancer symptoms. A growing body of basic and physiological research, including brain imaging and neurophysiology, musculoskeletal biomechanics, cognitive–motor interactions, autonomic regulation, and immune function, add additional evidence and provide insight into plausible mechanisms underlying observed clinical effects.[77,92,98–106] At the other end of the translational spectrum, Tai Chi for fall prevention research has been shown to be effectively implementable in community-based programs and is cost-effective.[107–111] Additional bibliometric studies, including both TCQ as part of "Traditional Chinese Exercises," have summarized publication trends for specific health conditions.[112–115] Of note, most literature has supported the overall safety of these practices in multiple chronic disease populations. However, musculoskeletal pain and injury are possible with TCQ, as with any physical exercise, and there have been reports of psychological adverse effects with Qigong, similar to meditation. Nonetheless, a recent systematic review of Tai Chi trials across a broad range of conditions found Tai Chi to be safe and not resulting in more adverse events than either active or inactive control conditions.[116,117]

Not surprisingly, the broad promise of TCQ has attracted the attention of, and led to research funding from, multiple NIH institutes, including the NCCIH, National Institute on Aging, National Cancer Institute, National Institute of Mental Health, National Institute of Nursing Research, National Institute of Arthritis and Musculoskeletal and Skin Diseases, and National Institute of Neurological Disorders and Stroke. This rapid growth in research evidence and implementation in community and clinical practice, along with the increasing popularity and relative safety in the use of TCQ and related MBM practices to support whole person health and health care initiatives, underlies the motivation for the 2023 conference.

Clinical domains of evidence

Falls and balance. Falls in older adults are the leading cause of injury and injury deaths in adults aged 65 or older[118,119] and impose a significant economic burden on the health care system.[120] There is now an array of proven exercise-based fall prevention interventions that can be applied by public health and clinical practice communities to reduce the risk and incidence of falls.[121,122] Tai Chi has been shown to be especially effective in improving strength and functional balance,[6] thus reducing fear of falling and falls in populations of older adults.[60,123]

Early randomized controlled trials (RCTs) showed that Tai Chi can effectively reduce falls[124] and the risk of falls[125] among community-dwelling older adults. Subsequent RCTs demonstrated that Tai Chi helps reduce the incidence of falls and injurious falls among older adults at high risk of falling.[126,127] Studies of economic evaluation indicated that Tai Chi interventions can provide a net return on investment of 509%[128] and are cost-effective (i.e., lower cost and clinically more efficacious) compared with multimodal and stretching exercises with regard to cost per additional fall prevented.[111] From a practical perspective, Tai Chi interventions have been broadly implemented in diverse populations involving different race/ethnicities and various community settings for primary prevention of falls among community-dwelling older adults.[108,129–132] Currently, the literature specifically on Qigong for falls and balance is limited, but preliminary findings show some promise.[133–135] With regard to mechanism, many studies have investigated biomechanical, physical, perceptual, and psychological outcomes that may be applied to understand TCQ's effect on falls and balance. As described in Box 1 above, cognitive, affective, and sensorimotor interactions are highly relevant.[58–60] Studies have also reported on positive changes with Tai Chi on gait stability, neuromuscular control/coordination, proprioception, lower extremity strength, as well as impact on cognitive–emotional factors, directly addressing fear of falling and enhancing self-efficacy.[60,136–143]

Despite promising progress made in transforming traditional TCQ training into fall prevention interventions, there remain major clinical gaps in fall prevention research and intervention delivery.[144] One of these gaps is a critical lack of effective fall prevention interventions that can be delivered remotely to reach millions of high-risk older adults at home, where the majority of falls occur.[145] In response, two nationwide remote digital RCTs (NCT05822466, NCT05725668) are being conducted that are aimed at clinically evaluating the effectiveness of a completely remote delivery approach (including subject recruitment, clinical data collection, intervention, and data and safety monitoring) for reducing the incidence of falls in older adults with and without cognitive impairment who are at risk of falling. This approach has the potential to greatly expand the reach and impact of evidence-based, in-person TCQ interventions from locally situated community facility settings to home-based settings, where access is not weather limited, transportation dependent, or geographically bound.

Cognition. Emerging research underscores the significance of TCQ in enhancing cognitive function, with particular emphasis on the preventative potential against mild cognitive impairment (MCI) and dementia. Systematic reviews and meta-analyses provide robust evidence supporting the positive impact of TCQ on various cognitive domains, including improvements in executive function and global cognitive function among both cognitively healthy adults and those with cognitive impairments.[146,147] One recent RCT reported enhanced processing speed, sustained attention, increases in hippocampal volume, and reductions in inflammatory markers such as interleukin-6 (IL-6), which were correlated with cognitive performance in older adults after a 12-week Qigong intervention.[101]

Neurobiologic changes such as increased cortical thickness[148,149] and brain-derived neurotrophic factor levels[150] have been observed in practitioners, suggesting enhanced neuroplasticity and brain health. One study in older adults[151] reported that Tai Chi practitioners demonstrated faster eye–hand coordination movement times in complex tasks compared with a Tai Chi-naïve group. Neuroimaging studies have observed increased activity in the prefrontal lobe of older adults practicing Tai Chi compared with those performing arm ergometry using noninvasive functional infrared

spectroscopy.[152] In addition, Tai Chi may improve sensory integration and balance control, essential for cognitive function, by enhancing input from vestibular, visual, and somatosensory systems.[153] A recent systematic review provides similar neuroimaging data to describe Qigong's effect in healthy and cognitively impaired populations.[154]

Despite these promising outcomes, the optimal dosage of TCQ for cognitive benefits remains unclear.[146,155–158] Furthermore, the durability of cognitive improvements postintervention is a critical area of focus, with some studies[159] indicating a return to baseline levels after a period of inactivity, highlighting the importance of ongoing practice. Research into MCI and dementia utilizing TCQ is growing with ongoing clinical trials targeting, for example, subjective cognitive impairment and the prevention of MCI conversion to dementia.[160–163] Multiple new studies addressing the impact of TCQ on cognitive function are underway and listed in ClinicalTrials.gov (e.g., NCT05540613, NCT05573490).

Mental health. Findings from RCTs suggest that Tai Chi can be effective in reducing depressive symptoms, stress, anxiety, and mood disturbances across a wide range of clinical populations seen in primary or specialty care settings, with less evidence supporting the use of Tai Chi as promising intervention for neuropsychiatric symptoms, such as in patients with substance abuse, history of trauma, and attention-deficit and hyperactivity disorder (ADHD).[164–176] The majority of evidence to date focuses on the benefits of Tai Chi in reducing symptoms of depression, anxiety, and stress in individuals without a psychiatric diagnosis (e.g., Major Depressive Disorder [MDD] or Generalized Anxiety Disorder [GAD]). A recent review and meta-analysis of 23 studies comparing Tai Chi to nonmindful exercise that involved 4370 participants (mixed population: anxiety, depression, general mental health) showed significant small-to-moderate effects of Tai Chi versus nonmindful exercise on measures of anxiety and depression and on general mental health, which was moderated by baseline general mental health T-score and study quality.[176] Modest evidence supports benefits of TCQ for MDD with evidence that Tai Chi augments the benefit of escitalopram treatment,[177–179] whereas the literature of TCQ for GAD is rather limited. Overall, the literature specifically examining Qigong for reducing mood disturbances is less available; however, there is no evidence that Tai Chi or Qigong would differ substantially in addressing mental health.[174,180–182]

Several potential mechanisms of Tai Chi on mental health have begun to be explored. A handful of studies have shown correlations between clinical and neuroimaging findings for depressive disorders[98,183] and emotional health.[184] Some research has suggested that the combination of slow movements in TCQ with slowing of breath frequency can attenuate stress related to hypothalamus-pituitary-adrenal axis reactivity and modulate the balance of the autonomic nervous system toward parasympathetic dominance, which counters stress pathways implicated in mood disorders.[89,92,185,186] Other research suggests that sensory and cognitive components of TCQ, such as the cultivation of interoceptive awareness and nonreactivity to aversive thoughts and impulses, can lead to reduced negative ruminations and emotional responses.[183,187] Direct neuroplastic effects on emotion regulation have been proposed through changes in the brain's prefrontal regions, the limbic system, and the striatum, in neural connectivity,[98,188] and in the expression of genes linked to inflammatory responses[77,103,150,189] and stress-related pathways.[183,184,190] Reducing the chronic stress response can impact the risk and severity of stress-mediated disorders such as anxiety and depression. New directions in TCQ research for mental health involve applications to multiple neuropsychiatric disorders, including anxiety disorders,[191] and to improve overall brain health and symptoms in autism spectrum disorder, post-traumatic stress disorder,[169,170,192,193] and ADHD.[171–173]

Sleep. There is a growing body of literature that examines TCQ for the improvement of sleep symptoms and sleep quality, as well as treatment for insomnia. These studies have reported on TCQ's impact on varied sleep outcomes (including subjective and objective traditional sleep measures of sleep quality and efficiency, as well as more novel indices of sleep stability from high-frequency cardiopulmonary coupling analysis). Studies have included both healthy and clinical populations.

For example, in one study, older adults (59–86 years) with at least moderate sleep complaints were randomized to group Tai Chi Chih or health education. Compared with controls, the Tai Chi group showed significant improvements in PSQI global score, as well as in sleep quality, habitual sleep efficiency, sleep duration, and sleep disturbance.[194] In another 3-arm RCT, including older adults with chronic and primary insomnia,[195] participants were randomly assigned to 4 months of group cognitive behavioral therapy (CBT), Tai Chi Chih, or sleep seminar education control. While CBT performed better than Tai Chi and education in remission of clinical insomnia, Tai Chi was associated with significant improvements in sleep quality, fatigue, and depressive symptoms compared with education.[195] Most recently, in a larger trial of older adults with chronic insomnia randomized to 12 weeks of group Tai Chi, conventional exercise, or no-intervention control,[196] both Tai Chi and conventional exercise improved sleep efficiency, reduced wake time after sleep onset, and the number of awakenings as assessed by actigraphy. Effects were sustained for 24 months.[196] Secondary analyses in these and other studies indicate that biologic processes related to inflammation may contribute to Tai Chi's positive effects on sleep.[78,103,195] A recent systematic review and meta-analysis of Qigong in the English and Chinese language literature reported improvements in subjective sleep quality among a mixed healthy and chronic disease population.[197]

Overall, in insomnia populations, studies have shown that Tai Chi may be effective with moderate-to-large effect sizes for sleep improvement.[198–201] One recent trial reported Tai Chi Chih to be noninferior to CBT for insomnia (CBT-I, the gold standard for insomnia treatment) for breast cancer survivors with chronic insomnia.[78,202] Both Tai Chi and CBT-I showed robust improvements in sleep quality, sleep diary measures, and related symptoms, with durable and noninferior effects over one year follow-up (also see Hong Kong based study in progress[203]).

Other clinical populations for which TCQ has demonstrated promise for sleep include patients with fibromyalgia,[204,205] MDD,[206] cognitive impairment,[207] chronic heart failure (HF),[208] cancers other than breast (lung, prostate),[201,209]

obstructive sleep apnea,[210] Parkinson's disease,[211,212] and chronic fatigue.[213]

Cardiorespiratory health. There is a robust and growing literature of TCQ for chronic cardiorespiratory conditions, including coronary disease, cardiovascular risk factors, as well as chronic HF, and COPD. Perhaps the most studied area within Tai Chi for CVD is the domain of blood pressure and hypertension. Most of the literature is from China. To date, there have been at least 12 systematic reviews and/or meta-analyses of RCTs investigating the impact of Tai Chi on essential hypertension.[214,215] The methodological quality of studies has been improving. One recent meta-analysis[215] reported reductions in systolic blood pressure of 14.7 mmHg with Tai Chi (compared with health education or no treatment), 7.9 mmHg (compared with active exercise such as walking or aerobics), and 9.0 mmHg (compared with antihypertensive medication, particularly in those younger than 50 years).[215] In one recent study, Tai Chi was also found to be more effective than aerobic exercise for reducing blood pressure in prehypertension, supporting its role in CVD prevention.[216]

For other common cardiovascular risk outcomes, there is supportive evidence for Tai Chi's effect on waist circumference/body weight, lipid profiles, and glycemic indices, but the impact differs by population studied.[217] Differential outcomes when studying those with obesity versus those with elevated blood glucose or type 2 diabetes versus those with hypertension suggest that the field need a more nuanced look at Tai Chi's effect on individual cardiovascular populations. For example, 12 weeks of Tai Chi has been shown to reduce waist circumference and body weight and to increase high-density lipoprotein in patients with central obesity compared with no exercise control—similar to aerobic exercise plus strength training—with benefits maintained over 38 weeks.[218] Another frequently studied outcome in cardiopulmonary patients is exercise capacity/endurance. In a recent systematic review/meta-analysis of patients with established coronary heart disease from 13 studies, Tai Chi was shown to improve aerobic endurance measured by maximal oxygen uptake and 6-min walk test.[219]

There has been a fast-growing literature examining TCQ for both HF and COPD.[97,168,220,221] Recent meta-analyses in patients with HF have concluded that TCQ versus both active and nonactive controls can improve exercise capacity, depression, QOL, and B-type natriuretic peptide. For COPD, a recent equivalence study reported similar improvements in QOL, dyspnea, quadriceps strength, and exercise capacity compared with an active exercise control, but no changes in either group with respect to actual lung function.[222] One explanatory model for some of Tai Chi's effects in these cardiopulmonary populations focuses on body awareness, decreased stress reactivity, and self-regulation through the impact on the anxiety–breathlessness cycle. In this cycle, shortness of breath triggers and feeds an emotional anxiety response, which prevents engagement in physical activity, leading to further deconditioning, worsening disease, and shortness of breath.[223,224] Together with improved physical function and endurance from the physical aspects, Tai Chi may facilitate the uptake of physical activity.[223–226] There may be a role for TCQ as an alternative or adjunct to conventional exercise or rehabilitation in sedentary cardiopulmonary populations, but high-quality studies are needed.[227–229]

Interesting research in chronic cardiopulmonary disease has begun to probe mechanistic biomarkers at the molecular level, including studies of genetic and epigenetic changes in response to Tai Chi.[230] In addition, virtual delivery of TCQ to improve access in less mobile, multimorbid chronic disease populations is burgeoning.[231]

Musculoskeletal pain. Chronic musculoskeletal pain, including osteoarthritis, rheumatoid arthritis, fibromyalgia, and other musculoskeletal disorders and pain syndromes, consists of a complex interplay between biological and psychological aspects. In the past two decades, clinical trials and observational studies have provided encouraging evidence that the use of integrated mind–body therapies, including TCQ, has multiple clinical benefits for patients with chronic musculoskeletal pain conditions, including back and neck pain.[79,97,232–236] A small number of studies support Qigong for chronic nonspecific neck pain.[237–239]

For osteoarthritis, numerous RCTs, systematic reviews, and meta-analyses have examined the clinical efficacy of Tai Chi in patients with knee osteoarthritis. The most updated literature has consistently recognized that Tai Chi, delivered two to four times weekly for 8 to 52 weeks, reduces pain and improves function, with the potential to slow disease progression and disability for older adults with symptomatic knee osteoarthritis and comorbid conditions.[240–250] The physical component provides exercise consistent with current recommendations for arthritis (muscle strength, balance, and aerobic cardiovascular exercise), and the mental component could address the chronic pain state through effects on psychological well-being, life satisfaction, and perceptions of health for symptomatic osteoarthritis.

Despite favorable results in several small trials for rheumatoid arthritis, recent Cochrane and other reviews evaluating two decades worth of published literature were unable to draw firm conclusions on the role of Tai Chi for treating rheumatoid arthritis. These conclusions are consistent with the findings of recent systematic reviews and a meta-analysis of 9 randomized trials and nonrandomized studies.[251–255] Discrepancies among these studies may be related to the complexities and severity of the disease, the lack of standardized treatment protocols for types of Tai Chi, dose and treatment duration, and choice of comparison.

Multiple systematic reviews have summarized the impact of TCQ on chronic back and neck pain.[79,233,239,256–258] The evidence on Tai Chi for back pain is based on smaller, lower quality studies primarily conducted in China, which report moderate-to-large effect sizes when it is compared alongside or in combination with other therapies to usual care.[236] Two moderate-sized wait-list controlled RCTs (one in Australia and one in the United States) also support Tai Chi's ability to reduce pain and disability, compared with usual care.[259–261] Parallel evidence of TCQ exists for neck pain, again, with nearly all studies based in China.[239] One larger RCT conducted in Germany supports that Tai Chi is noninferior to the gold standard neck pain-specific physical therapy, but superior to usual care.[262]

For fibromyalgia, the results from a series of studies consistently demonstrated that Tai Chi may be a useful treatment for

this challenging disorder, accompanied by psychosocial stress, anxiety, and depression, with limited treatment options.[24–30] These studies suggest that Tai Chi may improve patients' emotional health and well-being. Longer duration of Tai Chi demonstrated greater beneficial effects for fibromyalgia symptom management.[25] In summary, the encouraging findings have changed existing clinical guidelines for the management of musculoskeletal pain. Tai Chi is now strongly recommended as first-line therapy for arthritis-related chronic musculoskeletal pain.[31]

Explanatory mechanisms from Eastern and Western biological theories have provided a plausible rationale for the effectiveness of TCQ in treating musculoskeletal disorders related to chronic pain.[32–35] However, the pathophysiologic basis of TCQ for chronic pain is complex and multifaceted, and musculoskeletal disorders and pain syndromes are heterogeneous. Further work is needed to understand the underlying mechanisms by which TCQ can slow disease progression and disability associated with chronic musculoskeletal pain.

Cancer. Over the past three decades, numerous studies have highlighted the positive impact of TCQ on alleviating cancer-related symptoms such as anxiety, depression, fatigue, insomnia, hot flashes, joint pain, and chemotherapy-induced cognitive impairment.[201,263–270] Recent studies also indicate that TCQ positively influences immune function and related inflammatory biomarkers, potentially enhancing immunotherapy.[265,271,272] To date, more than 35 systematic reviews and meta-analyses of RCTs have explored TCQ's impact on the QOL for cancer survivors.

A systematic review involving 22 RCTs with 1410 participants reported significant improvements in physical health and mental health among cancer survivors practicing Tai Chi.[273] Subanalyses from this review of five studies with 465 breast cancer survivors showed enhanced limb and muscular function, whereas analyses of three RCTs, including two on breast cancer and one on lung cancer, revealed significant improvements in both fatigue and sleep quality.[273] Further subanalyses of studies examining IL-6 and cortisol levels suggest potential reductions in IL-6 in breast cancer patients and cortisol in female cancer survivors. However, the strength of the evidence remains moderate, primarily due to small sample sizes.[273] Similarly, the latest systematic review of 26 studies with various cancer groups consistently supported Tai Chi's improvement of fatigue and sleep quality, recommending a prescription of 30–60 min thrice a week for cancer survivors.[274] Moreover, a recent meta-analysis of 17 trials with 1236 subjects evaluated Qigong's effectiveness on overall QOL in women with breast cancer, showing significant effects on QOL, depression, and anxiety.[275] The latest umbrella review of 19 review articles confirmed Qigong's impact on overall QOL, cancer-related fatigue, and cognitive function and established its safety for frail patients.[276] While the abovementioned reviews reported outcomes of either Tai Chi or Qigong interventions, a meta-analysis of 15 RCTs with 1283 participants across various cancer groups combining TCQ revealed significant benefits on fatigue, sleep difficulty, depression, and overall QOL with small–medium effect sizes.[25] A recent study involving 17 studies of TCQ corroborated these findings, demonstrating consistent effects on anxiety and depression among adult cancer survivors.[277]

Despite these promising results, the biological mechanisms underlying TCQ's health benefits remain speculative, with several hypotheses focusing on immune response and inflammation.[271,278,279] Furthermore, there are noticeable gaps in the evidence; few studies have addressed TCQ's role throughout the cancer care continuum, particularly during pretreatment and end-of-life phases. In addition, trials assessing cancer-specific outcomes such as lymphedema, cardiotoxicity, chemotherapy-induced neuropathy, nausea, sexual function, or treatment tolerance are scarce. There is a need for more rigorous study designs and larger, diverse sample sizes to investigate these new areas and explore the mechanisms driving benefits.

Physiological/mechanistic domains

Neurophysiology and brain imaging. In recent decades, advanced brain imaging tools such as MRI, fMRI, PET, EEG, and MEG have been widely applied to investigate the underlying neural mechanisms of mind–body interventions. More recently, neuroimaging studies of TCQ have provided significant insights into central mechanisms, as well as potential neuromodulation targets associated with TCQ, highlighting involvement of multiple interconnected brain networks.[184,280–283]

Cross-sectional studies that compared long-term TCQ practitioners/experts with controls were the first to suggest salient brain structures and functions implicated in the practice. For example, in an early study,[149] Tai Chi expert practitioners, compared with age, sex, and education matched controls, showed significantly thicker cortex in right precentral gyrus, insula sulcus, and middle frontal sulcus in the right hemisphere and left superior temporal gyrus and medial occipitotemporal sulcus and lingual sulcus in the left hemisphere. Thicker cortex in left medial occipitotemporal sulcus and lingual sulcus was associated with greater intensity of Tai Chi practice. In a later study,[284] Tai Chi experts were found to have better functional connectivity in the right postcentral gyrus (PosCG) and less in the left anterior cingulate cortex (ACC) and the right dorsolateral prefrontal cortex. Better connectivity in the PosCG was linked to Tai Chi experience. Improved functional specialization in the left ACC and better functional integration in the right PosCG both predicted better performance on attention tests.

Subsequent prospective studies have investigated the effects of TCQ using longitudinal designs. For example, one study in healthy older adults that utilized data from two randomized cohorts found a significant increase in gray matter volume in the insula, medial temporal lobe, and putamen with 12 weeks of TCQ compared with health education control.[285] In additional studies, investigators reported that 12 weeks of TCQ could modulate the resting-state functional connectivity of cognitive control networks,[286] default mode network,[287] and hippocampus (a critical brain structure noted for memory formation)[288] and improve the fractional amplitude of low-frequency fluctuations.[289] Another recent study in healthy older adults utilizing whole brain network analysis compared participants randomized to Tai Chi (vs. an aerobic brisk walking group vs. a no-exercise control) and reported that Tai Chi alters brain functional network plasticity (specialization and

efficiency), and changes were predictive of greater cognitive flexibility.[99]

More recently, investigators have begun to probe the application of TCQ as a neuromodulation strategy in specific patient populations. For instance, in pain patients with knee osteoarthritis, changes were seen in the resting-state functional connectivity of periaqueductal gray (a key region of the descending opiodergic pain modulation system), ventral tegmental area (a pivotal brain structure of the dopaminergic reward network),[290] and bilateral amygdala (a key hub for emotion regulation).[291] The functional connectivity change was associated with clinical improvement in pain. In addition, investigators reported that Tai Chi can decrease resting-state functional connectivity of the dorsal lateral prefrontal cortex (DLPFC)-supplementary motor area (SMA) and increase resting-state functional connectivity between the DLPFC and ACC compared with the control group. Baseline DLPFC-SMA resting-state functional connectivity can significantly predict pain improvement in knee osteoarthritis.[243]

A distinctive feature of TCQ is its comprehensive integration of physical, psychological, emotional, spiritual, and behavioral components, which enables simultaneous modulation of multiple brain circuits and networks.[184,280–282] For example, as a mindful exercise, TCQ has the potential to directly affect the motor-sensory network.[292] During practice, participants' attention is directed toward posture, body movement, and internal bodily changes, thereby activating the executive control network (i.e., the prefrontal cortex, parietal cortex, and ACC),[184,286] the default mode network,[287] and the interoception network. Moreover, interactions between the brain and body modulate peripheral nervous system activity such as in the autonomic nervous system with the vagus nerve, as well as other physiological systems like the immune system,[293,294] which may be implicated in the profound physiological changes and widespread whole person effects observed with TCQ practice.

Future research may further evaluate brain functional and structural changes with clinical improvements and identify specific neural circuits associated with particular benefits. Mapping neuroimaging findings to clinical outcomes may provide insight into enhancing TCQ's effects, for example, through personalization or targeting specific individuals/disorders (or subtypes of particular disorders) most likely to respond. In addition, synergizing therapies like the use of noninvasive neuromodulation techniques, such as transcranial electrical stimulation, to target critical regions associated with TCQ practice may be a new frontier.[295–297]

Immune function and biomarkers of inflammation. While NCDs outpace infectious diseases in most developed countries, infection still poses a global public health challenge.[298,299] Efforts to prevent infection have focused on primary prevention strategies and vaccination.[299] Yet, there is substantial individual heterogeneity in response to a vaccination, due to recipient characteristics, as well as modifiable factors.[300] Among the most studied modifiable factors are sedentary physical activity,[301,302] psychological stress,[303] and poor quality of sleep,[304] all of which adversely impact the immune system and contribute to an attenuated immunologic response to a vaccine and a blunted protective response.[305]

Recent research has examined whether Tai Chi can improve immune responses and boost infectious disease resistance, either directly or indirectly via targeting psychological stress or insomnia. A recent meta-analysis of 17 RCTs with 1686 participants evaluated the effects of Tai Chi on a number of different immune cells and found an overall small effect for Tai Chi or Qigong to increase overall immune cell numbers, with increases in innate immune cells (i.e., dendritic cells, natural killer cells, monocytes), as well as adaptive immune cells (i.e., T helper cells, memory specific T cell).[271] One study found that administration of Tai Chi boosted the response of memory T cells to varicella zoster virus (VZV) in older adults who are known to have an age-related attenuation of memory T cell function that is associated with increased risk and severity of herpes zoster.[306] Furthermore, when Tai Chi was coupled with administration of a VZV vaccine, the memory response was greater than that induced by vaccine alone, achieving a level of response similar to those 30 years younger.[306] These effects of Tai Chi on adaptive immunity may generalize to memory T cells specific for antigens of other pathogens that cause severe disease in older adults, such as influenza viruses and *Streptococcus pneumoniae*.

In addition to the adaptive immune response, Tai Chi has robust effects on inflammatory outcomes, which are elevated in association with aging, stress, depression, and insomnia.[307–309] The first comprehensive meta-analysis of controlled trial evidence, including 39 different trials and 2219 participants, found that various mind–body therapies (i.e., Tai Chi, meditation, yoga) were associated with significant reductions in the circulating level of the inflammatory marker, C-reactive protein.[189] In a more recent meta-analysis focused solely on Tai Chi, no effect on a diverse number of inflammatory markers was found,[271] although a subgroup analysis found that Tai Chi reduced the transcriptional factor, nuclear factor (NF)-κB;[271] activation of NF-κB initiates the inflammatory cascade with increases in inflammatory transcripts, monocyte cellular production of inflammatory cytokines, and the downstream of inflammatory cytokines into the circulation.[310] Indeed, in RCTs that have provided a comprehensive evaluation of inflammation, including systemic, cellular, and transcriptional outcomes, Tai Chi is found to reverse insomnia-related activation of cellular- and transcriptional inflammatory outcomes in older adults,[103,195] as well as in breast cancer survivors.[78,311] Furthermore, while both Tai Chi and CBT-I can effectively treat insomnia,[202] Tai Chi preferentially reduces systemic- and cellular inflammation in breast cancer survivors with insomnia, and these benefits are maintained over one-year follow-up.[311] Given that Tai Chi acutely decreases sympathetic outflow,[312] it is thought that repeated practice of Tai Chi cumulatively downregulates sympathetic outflow, which in turn induces decreases in inflammatory outcome, especially upstream sources of inflammation which are more sensitive to changes in sympathetic output and binding to the β-adrenergic receptor in immune cells.[294] Alternatively, given that Tai Chi can improve insomnia, and insomnia drives decreases in antiviral immunity and increases in inflammation, the benefits of Tai Chi may be indirect or related to improvement in sleep.[308] The literature specifically on Qigong and immune function is more limited.[101,271,313]

The science of TCQ through the lens of traditional East Asian health constructs. A comprehensive review of TCQ research would be incomplete without addressing the concept of "qi" and other subtle phenomena central to TCQ principles, practice, and mastery. Despite the fundamental role these concepts play in traditional understanding and training, scientific investigation in this area remains limited.[314] Several factors contribute to this research gap, including the operational challenges in defining and measuring qi,[315] the ability of existing biomedical frameworks to explain many therapeutic outcomes of TCQ, the limited funding available, and the academic career implications of studying scientifically marginal and/or esoteric topics, which are typically labeled as high risk high reward.

Despite these challenges, it is important to note that significant progress has been made in establishing biomedical mechanisms that elucidate important subtle concepts foundational to TCQ, without directly measuring qi and related concepts—often referred to as "subtle energy" or "biofields."[316,317] One such concept is the relationship between mental intent and functional response, encapsulated in the Daoist principle "when the yi (intent) arrives, the qi (life force) arrives." This idea finds parallel in the well-researched field of motor imagery, where mental rehearsal of actions without physical performance has been shown to significantly improve rehabilitation outcomes and athletic performance.[318–323] A notable early study conducted at Harvard used transcranial magnetic stimulation to investigate the effects of both physical and mental practice of a five-finger piano exercise.[324] The study found that over five days of practice, the cortical motor areas targeting the muscles involved in the task enlarged and their activation threshold decreased. Interestingly, mental practice *alone* led to similar changes in cortical motor outputs as physical practice, although to a lesser extent. These findings suggest a neurophysiologic basis for the effectiveness of mental practice, providing scientific support for understanding the role of intention in TCQ practice.

Another concept, controversial even within the Tai Chi and martial arts community, that has begun to receive scientific attention is "fajin"—sometimes translated as "intelligent power" developed through the integration of body and mind.[325,326] Some experts emphasize that what looks like supernatural power (e.g., explosive outcomes following imperceptible movements) can be completely explained by honed biomechanical skills, whereas others emphasize the exchange of more subtle psychophysiologic forces. A study from Australia involving Kung Fu practitioners, who included Qi-building practices, provides insights into the biomechanical basis of this phenomenon. Using sophisticated measurement techniques, including nasogastric tubes with EMG electrodes and pressure sensors, the study found that Kung Fu practitioners generated significantly more mass-normalized force compared with control groups (who were matched for age, gender, and physical activity).[327] These practitioners demonstrated greater generation of abdominal pressure and earlier onset of abdominal pressure rise, both suggesting more refined biomechanical efficiency. While these findings support conventional biomechanical explanations for a significant proportion of observed force generation, they do not necessarily exclude the possibility of additional psycho-biophysical forces that transcend current scientific understanding.

Recent novel physiological discoveries are opening new avenues for understanding traditional TCQ concepts within a scientific framework. The exploration of biofields, defined as biologically generated fields that might influence tissues, represents one such avenue. A comprehensive review in 2014 assessed the quality and outcomes of RCTs involving non-physical contact biofield therapies such as external Qigong, Healing Touch, Johrei, Reiki, and Therapeutic Touch.[317] This review included 28 trials with 1775 participants and found that 12 of the 18 higher quality trials reported statistically significant therapeutic outcomes. However, the pilot nature and small sample sizes of these studies preclude robust conclusions, suggesting the need for further research. More recent studies with provocative findings also support the value of further research on the therapeutic effects of biofields.[328]

Research into the pathways through which information, including bioelectrical energy, occurs across the body has revealed intriguing correlations with traditional concepts in Chinese medicine. Studies have shown that acupuncture meridians correspond with intermuscular fascial-tissue planes,[73] exhibit higher electrical conductivity,[329,330] and may function as special hydraulic conduit pathways, as demonstrated by experiments using fluorescent dyes injected at acupuncture points.[331] One exploratory study reported that heterogeneity in the strength of bioelectric signals at the 24 terminal acupoints on fingertips and toes (Jing-well Points) was correlated with severity of symptoms in endometriosis, and abatement of symptom severity following acupuncture treatment was associated with greater homogeneity in electrical signals across points.[332] These discoveries suggest a potential physical basis for the energy pathways long described in traditional TCQ practices, bridging the gap between ancient wisdom and modern scientific understanding.

Increasingly, electrical and magnetic fields are seen as prime candidates for explaining fundamental human phenomena, from morphogenesis in healthy and abnormal development to cancer tumor growth, metastasis, and treatment.[333–336] Based on the groundbreaking work of Dr. Michael Levin's group, bioelectric signals, mediated by ion channels and pumps, were shown to play a crucial role in controlling cell behaviors such as proliferation, differentiation, and apoptosis. These signals are not only intrinsic to individual cells but also involve intercellular communication through gap junctions, forming bioelectrical networks that influence tissue and organ patterning. For instance, bioelectric gradients have been shown to regulate processes such as limb regeneration, eye induction, craniofacial patterning, and head-tail polarity. These gradients act as instructive cues that can trigger specific morphogenetic outcomes.[337,338] In addition, bioelectric signals are implicated in the establishment of left-right asymmetry during embryogenesis, a fundamental aspect of vertebrate development.[339] Bioelectric signaling has also been linked to metastatic transformation and tumorigenesis where changes in membrane potential can influence gene expression and cellular behavior, contributing to cancer progression.[337,340] Given the critical role these bioelectrical dynamics play in body regulation, it is plausible that they may contribute to the physiological effects observed in TCQ practice, potentially offering a scientific framework for understanding these traditional, subtle energy concepts.

Conclusion

The past two decades has seen a remarkable growth in research on TCQ as rehabilitative treatment and prevention across a wide range of populations and conditions. Notably, over the last decade, the quality of studies has significantly improved, with a growing proportion of RCTs and many systematic reviews and meta-analyses that represent the expanding volume of the available literature. More studies are using innovative designs to not only examine clinical outcome but also probe a deeper understanding of psychosocial and physiological mechanistic processes that might be at play. The evidence summarized here present TCQ as exemplary and promising tools to address whole person health, highlighting the state of the science in the domains of falls and balance, cognition, cardiorespiratory health, musculoskeletal pain, mental health, and cancer. Although there is a substantial body evidence, in many areas, the research is far from conclusive. Given the multicomponent and cross-system effects of TCQ, it is not surprising that there is support for TCQ's broad spectrum impact across physiological systems, diseases, and patient populations. This makes TCQ a very good fit for a whole person health framework. However, despite these successes to date, there are still multiple gaps in the evidence, and a clearer road map for future priorities in mind–body movement research and clinical care is now needed. The Part 2 companion article to follow outlines these evidence gaps and opportunities to inform the future research agenda and discusses strategies to address challenges in research, dissemination and implementation.

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Authors' Contributions

P.M.W., G.Y.Y., and W.M. were responsible for this project's conceptualization. P.M.W. and G.Y.Y. wrote the first draft of the overall article and were responsible for funding acquisition. All authors contributed written content in their areas of expertise and reviewed and edited subsequent drafts.

Author Disclosure Statement

P.M.W. has a financial interest in the Tree of Life Tai Chi Center, a Tai Chi teaching center. The interests of P.M.W. were reviewed and are managed by Brigham and Women's Hospital and Mass General Brigham in accordance with their conflict-of-interest policies. J.K. has holding equity in two start-up companies (MNT, BTT) and a patent on applying neuromodulation, but declares no conflict of interest. No other authors report any competing interests.

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