



Review Article

The effects of tai chi mind-body approach on the mechanisms of gulf war illness: an umbrella review

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ARTICLE INFO

Article history:

Received 16 April 2019

Received in revised form 10 May 2019

Accepted 13 May 2019

Available online 30 May 2019

Keywords:

Gulf War Illness

Mechanisms

Tai Chi.

ABSTRACT

Gulf War illness (GWI) is a chronic and multisymptom disorder affecting military veterans deployed to the 1991 Persian Gulf War. It is characterized by a range of acute and chronic symptoms, including but not limited to, fatigue, sleep disturbances, psychological problems, cognitive deficits, widespread pain, and respiratory and gastrointestinal difficulties. The prevalence of many of these chronic symptoms affecting Gulf War veterans occur at markedly elevated rates compared to nondeployed contemporary veterans. To date, no effective treatments for GWI have been identified. The overarching goal of this umbrella review was to critically evaluate the evidence for the potential of Tai Chi mind-body exercise to benefit and alleviate GWI symptomatology. Based on the most prevalent GWI chronic symptoms and case definitions established by the Centers for Disease Control and Prevention and the Kansas Gulf War Veterans Health Initiative Program, we reviewed and summarized the evidence from 7 published systematic reviews and meta-analyses. Our findings suggest that Tai Chi may have the potential for distinct therapeutic benefits on the major prevalent symptoms of GWI. Future clinical trials are warranted to examine the feasibility, efficacy, durability and potential mechanisms of Tai Chi for improving health outcomes and relieving symptomatology in GWI.

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1. Introduction

Gulf War illness (GWI) is a chronic and multisymptom disorder estimated to affect almost one third of military veterans deployed to the 1991 Persian Gulf War.¹ The overall profile of reported symptoms is consistent across populations of Gulf War veterans, with many individuals reporting some combination of fatigue, widespread pain, cognitive and memory problems, sleep disturbances, and respiratory and gastrointestinal difficulties attributable to their military service.^{1,2} The prevalence of many of these chronic

symptoms affecting Gulf War veterans occur at markedly elevated rates (~25–32%) compared to nondeployed contemporary veterans.¹

Despite a growing body of research on GWI over the past two decades, the underlying etiology of GWI remains poorly understood. Moreover, to date, no effective treatments for this complex multisymptom disorder have been established. Recent reports from the Institute of Medicine (IOM) committees on Gulf War and Health have emphasized a distinct need for new research to examine the integrated role of the brain and body for advancing the treatment and knowledge on the underlying pathophysiology of GWI.³

Tai Chi, an increasingly popular mind-body therapy, is a traditional Chinese martial art that incorporates physical, cognitive, social, relaxation and meditative components in the same activity.^{4–6} Among the general population, Tai Chi has been shown to induce numerous physiological and psychological health improvements, including benefits on cardiorespiratory, neurological and immune function, musculoskeletal pain, anxiety,

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Table 1
Most Common Gulf War Illness Case Definitions based on CDC and Kansas Gulf War Veterans Health Initiative Findings ^{2,13}

Fatigue/Sleep Problems
Psychological Health
Cognitive Function
Pain/Musculoskeletal Pain
Respiratory Problems

depression, and other outcomes including fatigue, sleep and health-related quality of life.^{7–11} Considering its clear potential for wide ranging health benefits, Tai Chi, a mind body therapy, may be a promising intervention for improving symptoms and health outcomes for veterans with GWI.

The overarching goal of this umbrella review was to evaluate the evidence supporting the potential for Tai Chi to improve the health of veterans with GWI. To better understand the strength of this evidence, we performed an umbrella review of published systematic reviews and meta-analyses. We summarized the evidence for the effects of Tai Chi on the most prevalent GWI symptoms. We also describe the potential mechanisms through which Tai Chi could benefit GWI and suggest future research directions.

2. Methods

We performed this review in accordance with recently established guidelines for the development and reporting of umbrella review research.¹² To be included in this overview of systematic reviews, reviews were required to meet the following eligibility criteria: 1) Study Type: Systematic reviews with or without meta-analysis were eligible. We included studies claiming to be systematic reviews as well as reviews with a systematic literature search while performing a comprehensive evidence review. 2) Participants: We included reviews examining any disease condition which had symptoms similar to the specific GWI symptom domains, adapted from recommendations by the IOM³ and based on the most prevalent chronic symptoms and case definitions established by the Centers for Disease Control and Prevention (CDC)¹³ and the Kansas Gulf War Veterans Health Initiative Program² (Table 1). There were no restrictions based on the disease, age, gender or race. 3) Interventions: Only reviews on the effects of Tai Chi were included. Studies examining the effects of mind body interventions similar to Tai Chi such as Quigong were also eligible. No restrictions were placed on style, dose, duration and intensity of Tai Chi. 4) Comparisons: No restrictions based on the comparison interventions were employed. 5) Outcomes: We included reviews that assessed at least one of the outcomes related to GWI symptom domains. 6) Only full-text articles published in peer-reviewed English language journals were included. We included the most updated version of a review for each outcome.

We systematically searched PubMed/MEDLINE, Cochrane Library, EMBASE, Scopus, CINAHL, SPORTDiscus, and PsycINFO from their inception to December 18, 2017. The search included various terms “Tai Chi”, OR “Quigong”, AND GWI symptom domains such as “pain”, “fatigue”, “sleep” etc. We also hand searched the reference lists of all included studies.

Two reviewers (KR, RB) screened the abstracts and the full-text articles of the potentially eligible studies. The same two reviewers independently extracted the data on the study characteristics such as number of studies and patients, types of included studies, interventions, comparators, risk of bias assessments, results, and conclusions. Disagreements were resolved by consensus and if required were adjudicated by the third reviewer (CW). Effect sizes are reported as the standardized mean difference (SMD) or weighted mean difference (MD) where specified. An effect size

of <0.20 was considered a small effect, 0.20–0.50 moderate effect and >0.50 a large effect.^[14]

3. Results

3.1. Effects of Tai Chi on Fatigue and Sleep

We identified one recent systematic review and meta-analysis that synthesized the evidence from all RCTs that have examined the effects of Tai Chi on fatigue as a specific primary outcome (Table 2).¹⁵ From ten RCTs and 689 participants, which included individuals with specific health conditions such as lung/breast cancer, multiple sclerosis, rheumatoid arthritis, chronic obstructive pulmonary disease, and age-related fatigue, Tai Chi interventions that ranged in duration from 4 to 24 weeks improved fatigue more than control interventions that included stretching, low impact exercise, health education and conventional nursing (SMD: -0.45, 95% confidence interval (CI): -0.70, -0.20).

Raman and colleagues conducted the first systematic review and meta-analysis to examine the effects of Tai Chi on sleep related outcomes in healthy subjects and in patients with chronic health conditions.¹⁶ The authors synthesized the findings of 9 RCTs and 2 non-randomized trials totaling 994 subjects, which included 632 healthy individuals and 362 patients with chronic conditions that included fibromyalgia (3 studies), heart failure (1 study) and cerebrovascular disorder (1 study). From meta-analysis of the 9 RCTs, the authors concluded that a Tai Chi dose of 1.5 to 3 hours per week for a duration of 6 to 24 weeks significantly improved overall sleep quality and insomnia in healthy persons and among individuals with fibromyalgia or cardiovascular disease (SMD: 0.89; 95% CI: 0.28 to 1.50). The two non-randomized comparative studies were not included in the meta-analysis due to lack of sufficient quantitative data. However, these studies reported that a 50 minute, twice a week, Chen-style Tai Chi intervention (of 15 weeks duration) significantly improved sleep quality in healthy college students.

3.2. Effects of Tai Chi on Psychological Health

We identified two systematic reviews with meta analyses that have examined the effects of Tai Chi on psychological health. Wang et al.,⁸ reviewed the effects of Tai Chi on stress, anxiety, depression and mood disturbance in eastern and western populations (41 studies (n = 3817)). The authors also conducted a meta-analysis on the 21 randomized studies in each psychological subcategory and reported that regular Tai Chi (up to 48 weeks in duration) significantly reduced stress (SMD: 0.66; 95% CI: 0.23 to 1.09), anxiety (SMD: 0.66; 95% CI: 0.29 to 1.03) depression (SMD: 0.56; 95% CI: 0.31 to 0.80) and enhanced mood (SMD: 0.45; 95% CI, 0.20 to 0.69) in community-dwelling healthy participants and in patients with chronic conditions. Seven observational studies that were not included in the meta-analysis, but had large sample sizes (totaling > 1100 participants) and long term interventions (ranging from 0.5 to 14 years), further supported evidence for a beneficial association between Tai Chi practice and psychological health. More recently, Wang et al.,⁹ conducted a systematic review and meta-analysis of 37 RCTs and 5 quasi-experimental trials that studied the effects of Tai Chi on psychological well-being from both Chinese- and English-language databases. Their systematic review revealed that Tai Chi interventions (ranging from 1 month to 5 years in duration) had beneficial effects for various populations on a range of psychological measures, including depression, anxiety and general stress management. Their meta-analysis was performed on three RCTs that used depression (Center for Epidemiological Studies of Depression scale) as an outcome measure, and Tai Chi was found to have significant benefits on depressive symptoms when compared

Table 2
Summary of Systematic Reviews on Mechanisms of Effects of Tai Chi

Domain	Reviews (author year, type)	Number & Type of included studies	Main Results
Fatigue/Sleep	Xiang 2017, systematic review and meta-analysis ¹⁵	10 RCTs (cancer, MS, RA, chronic and primary insomnia, COPD, age-related fatigue)	Tai Chi achieved better gains in relieving fatigue compared to the control interventions
	Raman 2013, systematic review and meta-analysis ¹⁶	11 (9 RCTs, 2 NRS)	Tai Chi improves sleep in healthy adults and patients with chronic conditions
Psychological Health	Wang C. 2010, systematic review and meta-analysis ⁸	40 (17 RCTs, 16 NRS, 7 observational)	Tai Chi reduces stress, anxiety, depression, and mood disturbance, and increases self-esteem in healthy adults and patients with chronic conditions
	Wang F. 2014, systematic review and meta-analysis ⁹	42 (37 RCTs, 5 quasi-experimental)	Tai Chi is beneficial for various populations with chronic conditions on psychological well-being measures, including depression, anxiety, stress management, and exercise self-efficacy
Cognitive Function	Wayne 2014, systematic review and meta-analysis ¹⁰	20 (11 RCTs, 1 NRS, 4 observational, 4 cross-sectional)	Tai Chi shows potential to enhance cognitive function in older adults, particularly of executive functioning and in individuals without significant impairment
Pain/ Musculoskeletal Pain	Kong 2016, systematic review and meta-analysis ¹⁷	18 RCTs (8 OA, 3 LBP, 2 osteoporosis, 2 fibromyalgia, 3 other)	Tai Chi showed improvements in chronic pain for patients with OA, LBP, and osteoporosis.
	Wang C. 2012, Descriptive review ⁷		Tai Chi appears to be associated with reductions in pain in patients with fibromyalgia, OA, and RA
	Wang C. 2011, Descriptive review ²⁹		Tai Chi may be highly suited to the management of symptoms of common chronic rheumatic conditions by reducing pain and improving physical and psychological health and wellbeing
Respiratory Function	Zheng 2015, systematic review and meta-analysis ¹⁸	20 (2 RCTs, 8 NRS, 3 self-controlled, 7 cohort)	Tai Chi may be effective in improving respiratory function in healthy adults

RCT: randomized controlled trial; NRS: non-randomized controlled trial; OA: osteoarthritis; LBP: low back pain; RA: rheumatoid arthritis; COPD: chronic obstructive pulmonary disease; MS: multiple sclerosis

to interventions of wellness education and stretching (MD: -5.97; 95% CI: -7.06 to -4.87).

3.3. Effects of Tai Chi on Cognitive Function

We identified one systematic review and meta-analysis that has examined the effects of Tai Chi on age-related cognitive decline in older adults. Wayne et al.,¹⁰ systematically evaluated twenty studies (total of 2,553 participants), eleven of which were RCTs. A total of 11 studies evaluated the effect of Tai Chi on cognitive function in older adults that had no reported cognitive impairment, and 9 studies in populations that reported varying degrees of cognitive impairment, ranging from mild cognitive impairment to irreversible dementia. In cognitively healthy adults, meta-analyses of executive function outcomes in RCTs revealed small to moderate improvements after Tai Chi interventions ranging in duration from 26–52 weeks when compared with nonintervention controls (SMD: 0.39; $P = .004$), and a positive moderate effect size when compared with exercise controls (SMD: 0.51; $P = .003$). Meta-analyses of outcomes related to global cognitive function (mini-mental state examination) in RCTs of adults with cognitive impairment that ranged from mild to dementia, showed small but statistically significant and clinically meaningful improvements after Tai Chi interventions (ranging from 12 weeks–52 weeks) compared with nonintervention controls (SMD: 0.35; $P = .004$) and other exercise and cognitive training interventions (SMD: 0.30; $P = .002$).

3.4. Effects of Tai Chi on Chronic Pain and Musculoskeletal symptoms

We identified one systematic review and meta-analysis that has examined the effects of Tai Chi for chronic pain condition. Kong et al.,¹⁷ reviewed 18 RCTs that ranged in duration from 6–26 weeks and totaled 1260 participants. Eight of these RCTs assessed the effectiveness of Tai Chi for reducing chronic pain in osteoarthritis, 3 for low back pain, 2 for osteoporosis, 2 for fibromyalgia and 3 for other chronic pain associated with conditions such as herpes zoster, chronic stroke and rheumatoid arthritis. Meta-analysis results indicated that Tai Chi showed positive evidence for relieving chronic pain from osteoarthritis (SMD, -0.54; 95% CI, -0.77 to -0.30) and there was some beneficial evidence for the effects of Tai Chi in relieving chronic low back pain (SMD, -0.81; 95% CI, -1.11 to -0.52) and osteoporosis (SMD, -0.83; 95% CI, -1.37 to -0.28). However, the authors found insufficient evidence to support or refute the value of Tai Chi for reducing chronic pain associated with fibromyalgia.

3.5. Effects of Tai Chi on Respiratory Function

We identified one systematic review and meta-analysis that has examined the effects of Tai Chi on respiratory function in healthy adults. Zheng et al.,¹⁸ evaluated 20 studies that involved a total of 1783 healthy community-dwelling adults (age from 45 to 75

years old). Of these studies, 2 were RCTs, 8 were non-randomized controlled trials, 7 were cohort studies and 3 were self-controlled trials. The results of meta-analysis indicated that Tai Chi had a positive effect on indices of respiratory function: lung capacity (Forced Vital Capacity: $n = 1272$, MD = 359.16 mL, 95% CI 19.57 to 698.75 for less than one year of intervention, and MD = 442.46 mL, 95% CI 271.24 to 613.68 for more than one year of intervention); and respiratory efficiency (Maximal Minute Ventilation, MD = 2.09 L/min, 95% CI 0.90 to 3.28 for < 2 years of intervention or MD = 7.02 L/min, 95% CI 0.40 to 3.27 for > 2 years of intervention). While the results of this systematic review and meta-analysis suggest that Tai Chi may benefit respiratory function, the authors only evaluated the effects of Tai Chi vs. inactive control groups, had a limited number of RCTs, and substantial statistical heterogeneity existed for a number of the reported outcomes.

4. Discussion

This umbrella review represents the first summary of available evidence to suggest that Tai Chi mind-body exercise may have important clinical benefits for veterans with GWI. Our findings indicate that Tai Chi may have distinct therapeutic effects on the major prevalent symptoms of GWI, namely: 1) fatigue and sleep problems; 2) psychological health; 3) cognitive function; 4) chronic pain; and 5) respiratory function.

A pertinent question for GWI clinicians and researchers is what are the underlying mechanisms and pathways through which Tai Chi may elicit benefits for veterans with GWI? Given its multi-component nature, Tai Chi exercise may possess unique potential to target multiple physiological and psychological processes and impact the complex constellation of symptoms that characterize GWI. We propose that this mind-body intervention may benefit GWI through a diverse, interrelated, reciprocal and potentially synergistic set of mechanistic pathways (Figure 1). For example, there are a number of possible interrelated mechanisms underlying how Tai Chi may improve sleep quality, fatigue and respiratory function. Tai Chi may improve sleep by promoting a deep state of relaxation and restoring the homeostatic balance of sympathetic/parasympathetic function by reducing sympathetic activity and stimulating the parasympathetic nervous system.¹⁶ The meditative component inherent in Tai Chi may also contribute to increased sleep stability, through related improvements in respiratory function. A reduced respiratory chemoreflex sensitivity and increases in baroreflex sensitivity have been described in practitioners of meditation.¹⁹ These direct improvements in respiratory control could lead to improvements in sleep-disordered breathing. Similarly, Tai Chi also incorporates a component of respiratory rhythm training with slow, deep, diaphragmatic breathing, which could play a role in retraining breathing patterns during sleep.²⁰ It is also highly plausible that the global improvements in sleep quality, respiratory function, and the promotion of

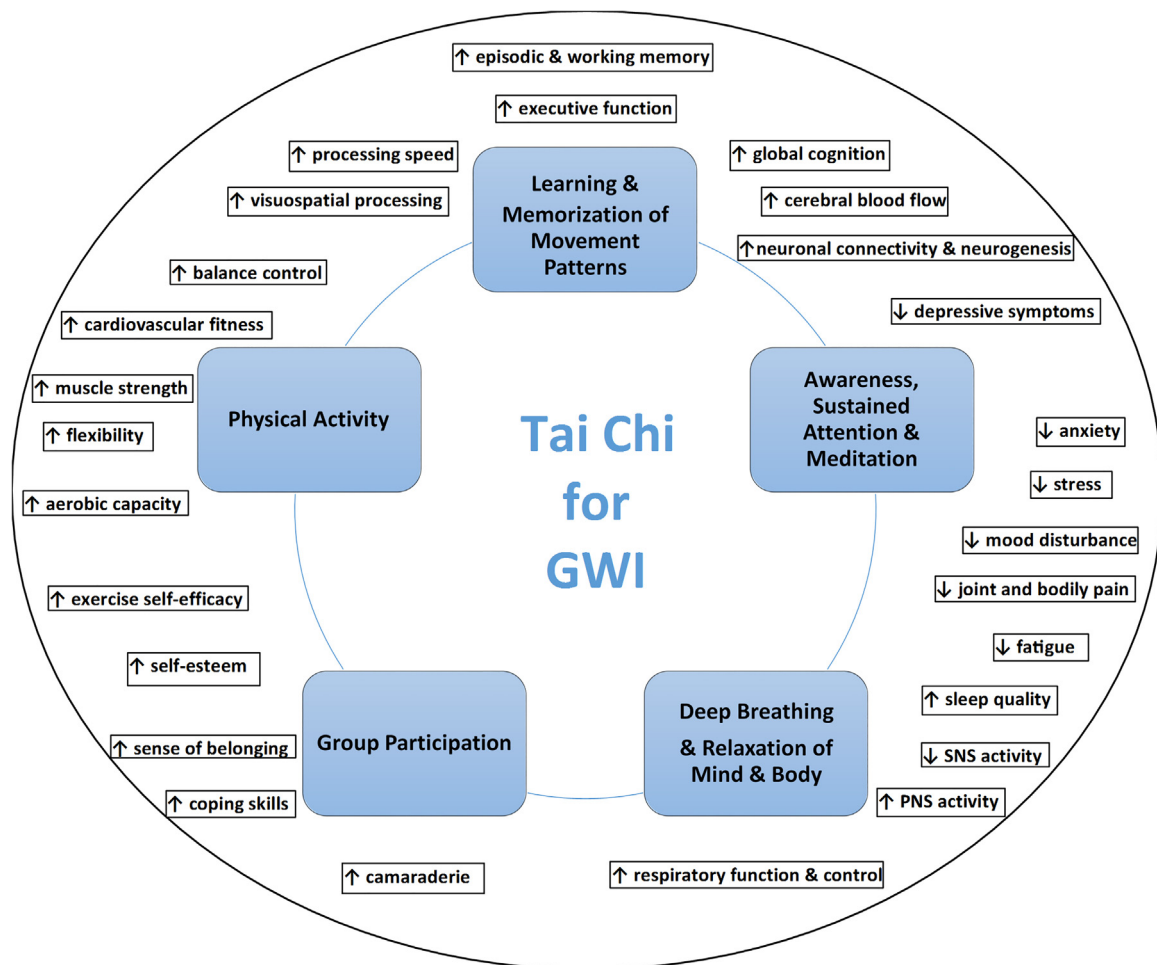


Figure 1. Tai Chi Mind-Body Exercise for GWI. Inner blue boxes represent the major integrated components of Tai Chi Mind-Body Exercise. Outer text boxes represent potential pathways and mechanisms of benefit from Tai Chi among veterans with GWI.

relaxation induced by Tai Chi, may directly lead to the alleviation of fatigue.

Similarly, the meditative component of Tai Chi has been hypothesized to negate the impact of pain, anxiety and depressive symptoms through stress-related pathways,^{8,10} which may also indirectly facilitate important benefits in cognitive function. Moreover, meditation has been shown to affect attention and executive functions by increasing the brain's ability to allocate attentional resources.²¹ Thus, the meditative component of Tai Chi may directly enhance attention and executive cognitive function. Tai Chi also involves the learning of choreographed movement patterns, which may directly lead to improvements in visuospatial processing, processing speed, and episodic memory.¹⁰

As a physical exercise, Tai Chi provides moderate aerobic activity as the flowing movements performed during Tai Chi can elevate heart rate to approximately 70% of the maximal heart rate, depending on the age of the individual and the intensity of practice.²² Thus it is possible that increases in cardiorespiratory fitness from Tai Chi interventions may relieve symptoms of fatigue. It is also physiologically plausible that the well-documented benefits of aerobic exercise on cognitive function, such as cerebral blood flow, neuronal connectivity, and neurogenesis, may be elicited in response to Tai Chi interventions.^{23–25} The physical movements of Tai Chi also promote muscle strengthening, improved balance control and joint flexibility, which have been reported to reduce joint pain and improve musculoskeletal health, which in turn are associated with improvements in psychological health, sleep quality, self-efficacy and body awareness.⁸

Finally, engaging in Tai Chi in a group setting may enhance mood and coping skills through social interactions and camaraderie. This social support aspect of Tai Chi may have particular relevance for veterans. A recent pilot study of Tai Chi among veterans with post-traumatic stress disorder (PTSD) reported a greater sense of camaraderie and belonging during group-based sessions.²⁶ Similarly, among veterans who may have traumatic associations with combat stances and postures, engagement in group-based Tai Chi exercise may lead to the development of positive associations with the warrior identity.²⁷

5. Limitations

There are several important limitations associated with this umbrella review. Firstly, we were unable to identify any studies or reviews summarizing the potential benefit of Tai Chi on gastrointestinal symptoms and skin symptoms, two other highly prevalent reported GWI symptoms.² Secondly, we did not focus our review on the effects of Tai Chi on immune function which may be of particular significance for veterans with GWI. Tai Chi may improve immune function through a reduction in stress-response inflammatory mechanisms.²⁸ Thirdly, many of the reviews and meta-analyses we summarized demonstrated a high degree of heterogeneity. The overall methodological quality of many studies reviewed was variable, with a large number of studies comparing the effects of Tai Chi to inadequate control groups or in some studies, no control groups. Also, the effects of Tai Chi on various parameters of health were often studied in healthy participants or among varying patient populations, which limits our ability to generalize our findings to veterans with GWI. Finally, in this review we primarily used a Western medical perspective for describing the potential of Tai Chi for alleviating individual GWI symptoms. However, given the complex and multisymptom etiology of GWI, it may be beneficial to consider a more holistic and integrated Eastern medical perspective focused on the potential of Tai Chi for restoring internal balance and harmony while regenerating the body's organs and systems in veterans with GWI.

6. Conclusions and Future Research Directions

This umbrella review has summarized positive evidence for the potential effects of Tai Chi for improving symptoms and health outcomes for veterans with GWI. Future studies should be conducted to directly examine the feasibility, efficacy and durability of Tai Chi for GWI. In addition, studies are warranted to identify and delineate the specific mechanisms underlying the potential benefits of Tai Chi within this population. Such knowledge would be highly informative and important for optimizing appropriate intervention and therapeutic management strategies for veterans with GWI.

Conflict of interest

Authors declare no conflict of interest.

Funding

This research was supported by the Boston Claude D. Pepper Older Americans Independence Center (1P30AG031679, K.R.) and based upon work supported by the U.S. Department of Agriculture, under agreement No. 58-1950-4-003 (K.R.). Any opinions, findings, conclusion, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. This study was also supported by the Veterans Administration Clinical Science Research and Development (SPLD-004-15S, B.N. and D.M.) and the National Center for Complementary and Integrative Health (NCCIH) (K23AT009374, R.B.; R01AT006367 and K24AT007323, C.W.). The investigators are solely responsible for the contents of the manuscript and they do not represent official views of the U.S. Department of Veterans Affairs, the NCCIH, or the United States Government.

Ethical statement

No ethical approval was required for this manuscript as this study did not involve human subjects or laboratory animals.

Data availability

The data supporting the findings of this study are available within the article.

Authors contributions

K.R. wrote the first draft of the manuscript. All authors contributed to revising the manuscript and approved the final draft for submission.

Acknowledgements

The authors wish to acknowledge Kimberly Sullivan, PhD, and Augustine Lee, MD, for their input in developing this research article.

References

1. White RF, Steele L, O'Callaghan JP, et al. Recent research on Gulf War illness and other health problems in veterans of the 1991 Gulf War: Effects of toxicant exposures during deployment. *Cortex* 2016;74:449–75.
2. Steele L. Prevalence and patterns of Gulf War illness in Kansas veterans: association of symptoms with characteristics of person, place, and time of military service. *American journal of epidemiology* 2000;152(10):992–1002.
3. In: Cory-Slechta D, Wedge R. *Gulf War and Health: Volume 10: Update of Health Effects of Serving in the Gulf War* 2016:2016. Washington (DC).
4. Li JX, Hong Y, Chan KM. Tai chi: physiological characteristics and beneficial effects on health. *British journal of sports medicine* 2001;35(3):148–56.

5. Cheng J. Tai chi chuan: a slow dance for health. *The Physician and sportsmedicine* 1999;27(6):109–10.
6. Lan C, Lai JS, Chen SY. Tai Chi Chuan: an ancient wisdom on exercise and health promotion. *Sports medicine* 2002;32(4):217–24.
7. Wang C. Role of Tai Chi in the treatment of rheumatologic diseases. *Curr Rheumatol Rep* 2012;14(6):598–603.
8. Wang C, Bannuru R, Ramel J, Kupelnick B, Scott T, Schmid CH. Tai Chi on psychological well-being: systematic review and meta-analysis. *BMC complementary and alternative medicine* 2010;10:23.
9. Wang F, Lee EK, Wu T, et al. The effects of tai chi on depression, anxiety, and psychological well-being: a systematic review and meta-analysis. *Int J Behav Med* 2014;21(4):605–17.
10. Wayne PM, Walsh JN, Taylor-Piliae RE, et al. Effect of tai chi on cognitive performance in older adults: systematic review and meta-analysis. *Journal of the American Geriatrics Society* 2014;62(1):25–39.
11. Wang C, Collet JP, Lau J. The effect of Tai Chi on health outcomes in patients with chronic conditions: a systematic review. *Archives of internal medicine* 2004;164(5):493–501.
12. Aromataris E, Fernandez R, Godfrey CM, Holly C, Khalil H, Tungpunkom P. Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. *Int J Evid Based Healthc* 2015;13(3):132–40.
13. Fukuda K, Nisenbaum R, Stewart G, et al. Chronic multisymptom illness affecting Air Force veterans of the Gulf War. *JAMA: the journal of the American Medical Association* 1998;280(11):981–8.
14. Cohen J. A power primer. *Psychological bulletin* 1992;112(1):155–9.
15. Xiang Y, Lu L, Chen X, Wen Z. Does Tai Chi relieve fatigue? A systematic review and meta-analysis of randomized controlled trials. *PloS one* 2017;12(4):e0174872.
16. Raman G, Zhang Y, Minichiello VJ, D'Ambrosio CM, Wang C. Tai Chi Improves Sleep Quality in Healthy Adults and Patients with Chronic Conditions: A Systematic Review and Meta-analysis. *J Sleep Disord Ther* 2013;2(6).
17. Kong LJ, Lauche R, Klose P, et al. Tai Chi for Chronic Pain Conditions: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Sci Rep* 2016;6:25325.
18. Zheng G, Li S, Huang M, Liu F, Tao J, Chen L. The effect of Tai Chi training on cardiorespiratory fitness in healthy adults: a systematic review and meta-analysis. *PloS one* 2015;10(2):e0117360.
19. Bernardi L, Porta C, Spicuzza L, et al. Slow breathing increases arterial baroreflex sensitivity in patients with chronic heart failure. *Circulation* 2002;105(2):143–5.
20. Yeh GY, Mietus JE, Peng CK, et al. Enhancement of sleep stability with Tai Chi exercise in chronic heart failure: preliminary findings using an ECG-based spectrogram method. *Sleep Med* 2008;9(5):527–36.
21. Chiesa A, Calati R, Serretti A. Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clin Psychol Rev* 2011;31(3):449–64.
22. Bower JE, Irwin MR. Mind-body therapies and control of inflammatory biology: A descriptive review. *Brain Behav Immun* 2016;51:1–11.
23. Colcombe SJ, Erickson KI, Scalf PE, et al. Aerobic exercise training increases brain volume in aging humans. *The journals of gerontology Series A, Biological sciences and medical sciences* 2006;61(11):1166–70.
24. Kramer AF, Colcombe SJ, McAuley E, Scalf PE, Erickson KI. Fitness, aging and neurocognitive function. *Neurobiol Aging* 2005;26(Suppl 1):124–7.
25. Burdette JH, Laurienti PJ, Espeland MA, et al. Using network science to evaluate exercise-associated brain changes in older adults. *Front Aging Neurosci* 2010;2:23.
26. Tsai PF, Kitch S, Chang JY, et al. Tai Chi for Posttraumatic Stress Disorder and Chronic Musculoskeletal Pain: A Pilot Study. *Journal of holistic nursing: official journal of the American Holistic Nurses' Association* 2017;617, 898010117697.
27. Niles BL, Mori DL, Polizzi CP, Pless Kaiser A, Ledoux AM, Wang C. Feasibility, qualitative findings and satisfaction of a brief Tai Chi mind-body programme for veterans with post-traumatic stress symptoms. *BMJ Open* 2016;6(11):e012464.
28. Morgan N, Irwin MR, Chung M, Wang C. The effects of mind-body therapies on the immune system: meta-analysis. *PloS one* 2014;9(7):e100903.
29. Wang C. *Tai chi and rheumatic diseases. Rheumatic diseases clinics of North America* 2011;37(1):19–32.