

Review

Psychological and inflammatory outcomes associated with tai chi interventions in cancer patients: a systematic review

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Abstract: Cancer survivorship often includes persistent psychological distress and heightened inflammation that may be interrelated. This systematic review examined whether Tai Chi benefits both domains and explored the potential psycho-immune associations that may connect them. Following PRISMA 2020, we applied Population, Intervention, Comparison, Outcomes, Study design (PICOS) criteria to identify studies of adult patients with cancer that used Tai Chi as the primary intervention and reported psychological outcomes and/or inflammatory biomarkers. Searches and screening yielded 14 eligible records, including randomized trials, controlled clinical trials, and cohort studies. Across breast, lung, and mixed oncology cohorts, Tai Chi was generally associated with improvements in resilience, anxiety, depressive symptoms, and quality of life, with frequent concurrent gains in sleep and fatigue. Several trials reported biologic changes suggestive of reduced physiological stress load, including lower or altered interleukin-6 and tumor necrosis factor, decreased C-reactive protein in some studies, healthier diurnal cortisol rhythms, and improved heart rate variability. Studies that measured both psychological and biological outcomes suggested that symptom relief and biomarker shifts may occur together; however, the available evidence does not establish bidirectional causality or mediation. These findings suggest potential psycho-immune mechanisms in which improvements in resilience, autonomic balance, inflammatory activity, fatigue, and sleep disturbance may be interrelated. Feasibility was high in nurse-led, center-based, and telehealth formats. Heterogeneity in Tai Chi style, dose, and biomarker panels, along with modest sample sizes and limited follow-up, remains the main constraint. Current evidence suggests that Tai Chi appears to be a safe, feasible adjunct based on current evidence for supportive oncology that may be associated with improvements in psychological outcomes and, in some studies, immune-related outcomes, warranting larger, protocol-standardized trials with prespecified mediation analyses.

Keywords: Tai Chi; cancer survivorship; mind-body intervention; psychological resilience; inflammatory biomarkers; quality of life

1. Introduction

Cancer is a multifaceted disease that extends beyond its biological underpinnings, encompassing significant psychological and social challenges impacting patients' quality of life. Following advancements in early detection and treatment, numerous cancer survivors experience chronic psychological distress, which frequently manifests as anxiety, depression, and existential dread long after initial treatment [1,2]. Studies in psycho-oncology have demonstrated the profound effects of psychological factors on treatment adherence, rehabilitation, and long-term survival for cancer patients [1,2]. For instance, research reveals that patients grappling with high levels of fear of recurrence and existential distress report diminished quality of life and greater difficulty in managing their illness [1,3]. In addition to these

psychological challenges, the role of systemic inflammation in cancer progression and patient outcomes has garnered increasing attention. Inflammatory cytokines such as interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF- α), and C-reactive protein (CRP) are often elevated in cancer patients and have been associated with adverse effects such as tumor growth, fatigue, and poor treatment responses [2–4]. Chronic inflammation affects physical health and has significant implications for mental health, impacting mood, energy levels, and cognitive function [5]. Evidence suggests a bidirectional relationship between inflammatory cytokines and depression, whereby dysregulation of the immune system can exacerbate mental health difficulties among cancer patients [5,6]. This interplay suggests that addressing both psychological and inflammatory factors may be crucial in the holistic management of cancer patients.

Psychological resilience, defined as the capacity to adapt, recover, and thrive in the face of adversity, is a crucial protective factor influencing how cancer patients cope with their illness. It is well-documented that high resilience correlates with lower levels of depression and anxiety, better quality of life, and improved adherence to treatment regimens [7,8]. Resilience is not a static trait; rather, it can be cultivated through psychosocial interventions, coping strategies, and structured mind-body practices [9,10]. Interventions such as meaning-making approaches have been shown to enhance optimism and self-efficacy among patients, thereby contributing to greater resilience [7,11]. Emerging evidence indicates that resilience also interacts with immune function, highlighting its importance beyond psychological well-being. Stress and low resilience are associated with heightened inflammation and dysregulation of neuroendocrine pathways, including the activity of the hypothalamic-pituitary-adrenal (HPA) axis [12,13]. Conversely, resilient individuals often demonstrate a more balanced immune profile, characterized by lower circulating levels of pro-inflammatory markers [14,15]. This relationship supports a psycho-immune model in which resilience serves both as an outcome and a mediator of biological health, facilitating a healthier response to the stresses associated with cancer diagnosis and treatment [16,17].

Given the dual psychological and biological challenges of cancer, supportive care has increasingly turned toward integrative therapies. Pharmacological interventions remain essential, yet they are often insufficient for addressing the full scope of patient needs, particularly in long-term survivorship. Non-pharmacological strategies such as mindfulness meditation, yoga, and exercise have shown promising effects on mood regulation, fatigue, and immune parameters.

Tai Chi, a practice originating from traditional Chinese martial arts, combines slow, flowing movements with controlled breathing and focused attention, often referred to as "meditation in motion" [18,19]. This approach emphasizes relaxation, balance, and internal awareness rather than physical exertion, which renders it highly accessible for older adults and patients with compromised health [20]. From a psychological standpoint, Tai Chi promotes mindfulness, stress reduction, and enhanced emotional regulation. Numerous studies have demonstrated its effectiveness in reducing anxiety, depressive symptoms, and cancer-related fatigue among practitioners [21–23]. Biologically, Tai Chi engages in moderate aerobic activity, muscle engagement, and postural control, all contributing to improved cardiovascular health, enhanced sleep quality, and better functional mobility [24,25]. Furthermore, Tai Chi has been linked to decreases in circulating inflammatory cytokines, improved autonomic regulation, and enhanced immune surveillance, suggesting a dual impact where it may strengthen psychological resilience while concurrently modulating

inflammatory pathways [26]. This integrated mechanism is particularly relevant in oncology, where psychosocial stress and systemic inflammation often exacerbate one another [27]. Thus, Tai Chi may represent a promising supportive care intervention for cancer patients, with potential benefits for both psychological well-being and selected physiological outcomes. However, current evidence should be interpreted cautiously, as most studies have not been designed to establish causal or bidirectional psycho-immune mechanisms.

2. Literature review

The role of Tai Chi in supporting cancer patients has drawn increasing scholarly attention in recent years, as researchers attempt to integrate traditional mind-body practices into evidence-based supportive oncology care. A growing body of research suggests that Tai Chi may influence both psychological and physiological outcomes through interconnected biological and behavioral pathways. This literature review synthesizes evidence on Tai Chi interventions with a focus on their effects on psychological resilience and inflammatory biomarkers in cancer populations, highlighting the mediating and moderating variables that shape these outcomes.

2.1. Tai Chi as an intervention

Tai Chi, a traditional Chinese martial art characterized by slow, flowing movements, combines physical postures, controlled breathing, and meditative focus. The practice emphasizes balance, flexibility, and relaxation, making it particularly suitable for populations with chronic conditions, including cancer [28,29]. Intervention studies vary considerably in frequency, duration, style, and intensity, but most involve sessions of 45–90 minutes, practiced two to five times per week [30–32], over 8 to 24 weeks. Chen and Yang styles are the most commonly studied, although modified forms tailored for clinical populations have also been adopted [33].

Evidence from systematic reviews indicates that longer interventions and higher adherence are associated with greater therapeutic benefit, underscoring the importance of dosing and fidelity when evaluating Tai Chi outcomes [34,35]. In cancer settings, Tai Chi is often compared to standard care, health education, or light physical exercise. The appeal of Tai Chi lies in its accessibility; it requires no equipment, can be adapted to varying fitness levels, and integrates a meditative component that may target both mental and physical health simultaneously [36,37]. These characteristics make it an appropriate intervention to explore within the context of complex cancer-related symptoms and psychosocial burdens.

2.2. Psychological and physiological outcomes

2.2.1. Psychological outcomes

Resilience, anxiety, depression, and quality of life are key psychological domains affected by Tai Chi practice in cancer patients. Resilience, defined as the capacity to adapt positively in the face of adversity, is a protective factor against psychological morbidity [38]. Evidence suggests that Tai Chi fosters resilience by enhancing self-efficacy, encouraging mindfulness, and promoting social connectedness [33,39]. In a randomized trial among breast cancer survivors, participants who practiced Tai Chi reported significant improvements in resilience scores, which were associated with reduced depressive symptoms and improved life satisfaction [33].

Anxiety and depression are highly prevalent in cancer patients, often exacerbated by treatment side effects and uncertainty about prognosis. Several clinical trials report reductions in anxiety and depressive symptoms following Tai Chi interventions, with

effect sizes comparable to other mind–body therapies such as yoga and mindfulness meditation [40,41]. Mechanistically, the meditative aspects of Tai Chi appear to reduce rumination and enhance emotion regulation, while the physical activity component contributes to stress relief and improved sleep quality, both of which are closely tied to mood regulation [42].

Quality of life, a multidimensional construct encompassing physical, emotional, and social well-being, is frequently used as an endpoint in supportive oncology studies. Tai Chi interventions consistently report positive effects on quality of life, particularly in the domains of vitality, emotional functioning, and social participation [26]. Improvements are not uniform across all subscales, however, suggesting that Tai Chi may be especially effective in addressing fatigue, sleep disturbance, and emotional distress, rather than purely physical functioning [43].

2.2.2. Physiological outcomes

Tai Chi's influence extends beyond psychological health, with evidence pointing toward measurable changes in inflammatory biomarkers. Chronic inflammation has been implicated in cancer progression and treatment-related complications, making it a critical physiological target [44]. Key markers include C-reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor alpha (TNF- α), and interleukin-10 (IL-10). Several studies demonstrate that Tai Chi practice is associated with reductions in pro-inflammatory cytokines such as IL-6 and TNF- α , alongside increases in the anti-inflammatory cytokine IL-10 [34,35]. These changes suggest a shift toward an anti-inflammatory profile, which may support immune surveillance and tissue repair. For example, in a study of older adults with cancer-related fatigue, participants in a Tai Chi program exhibited decreased CRP levels compared to controls, correlating with subjective improvements in fatigue and sleep. These findings indicate that Tai Chi may exert systemic effects on the immune system through psychoneuroimmunology pathways [36].

2.3. Mediators of the Tai Chi–outcome relationship

Understanding how Tai Chi exerts its effects requires exploration of mediating mechanisms. Three primary mediators are commonly implicated: psychological resilience, autonomic regulation, and the broader mind–body connection through neuroendocrine–immune modulation.

2.3.1. Psychological resilience

Resilience acts both as an outcome and as a mediator in the Tai Chi–health relationship. By cultivating acceptance, flexibility, and positive coping strategies, Tai Chi enhances resilience, which in turn buffers the negative effects of stress and psychological distress on immune functioning. Patients with higher resilience are less likely to experience chronic elevations in cortisol or maladaptive inflammatory responses to stress [33]. Thus, resilience serves as a psychological resource that links mind–body practices to improved physiological health [38].

2.3.2. Autonomic regulation

Autonomous regulation represents another mediating pathway. Tai Chi practice has been shown to improve heart rate variability (HRV), a marker of parasympathetic activity and stress resilience. Higher HRV reflects better autonomic balance, associated with lower sympathetic arousal and reduced systemic inflammation [41]. Cortisol, a key stress hormone, also decreases following Tai Chi interventions, indicating attenuation of hypothalamic–pituitary–adrenal (HPA) axis activation [45]. These changes suggest that Tai Chi fosters physiological calmness, translating into

downstream improvements in both psychological and immune outcomes.

2.3.3. Neuroendocrine–immune modulation

The mind–body connection inherent in Tai Chi involves coordinated regulation of the neuroendocrine and immune systems. Meditation-like components of Tai Chi engage brain regions associated with emotion regulation and interoception, including the prefrontal cortex and insula. Through these neural pathways, Tai Chi may downregulate pro-inflammatory gene expression and modulate immune cell activity [42]. This integrative mechanism bridges psychological and physiological domains, supporting the conceptualization of Tai Chi as a holistic intervention.

2.4 Moderators influencing Tai Chi effects

While Tai Chi demonstrates broad benefits, its effects are not uniform across all populations or contexts. Several moderators influence the strength and direction of outcomes, including cancer type and treatment stage, patient demographics, and intervention characteristics.

2.4.1. Cancer type and treatment stage

Different cancers and treatment modalities present unique symptom burdens that may shape responsiveness to Tai Chi. For instance, patients undergoing chemotherapy often experience fatigue and immunosuppression, which may be particularly amenable to Tai Chi's restorative and immune-supporting effects. In contrast, those receiving radiotherapy may benefit more in terms of emotional well-being and sleep regulation [43]. Moreover, survivors in remission may engage more fully with Tai Chi practice, whereas patients with advanced disease may face physical limitations that reduce adherence. These contextual factors highlight the need for tailored intervention design [46].

2.4.2. Patient demographics

Age, gender, and cultural background also moderate Tai Chi's effectiveness. Older adults often report higher adherence to Tai Chi, possibly due to its gentle nature and alignment with traditional cultural practices [33,40]. Gender differences have been observed, with women often reporting greater psychological benefits, though physiological changes appear less dependent on gender [36]. Cultural familiarity with Tai Chi may enhance motivation and perceived credibility of the intervention, which in turn influences adherence and outcomes [39].

2.4.3. Training intensity and adherence

The frequency, intensity, and style of Tai Chi practice are critical moderators. Evidence suggests that at least two sessions per week are necessary to achieve measurable benefits, with greater improvements observed in interventions lasting 12 weeks or longer [32,34]. Adherence plays a decisive role; participants who practice consistently outside of supervised sessions demonstrate the largest gains in resilience and biomarker changes [30]. Training intensity is also relevant, as moderate-intensity practice appears to optimize both psychological and physiological outcomes, while excessively light or strenuous forms may be less effective for vulnerable cancer populations [47].

2.4.4. Potential psycho–immune pathways

Synthesizing these findings, Tai Chi may be associated with parallel changes in psychological resilience, symptom burden, autonomic regulation, and inflammatory processes in cancer patients. Rather than confirming a bidirectional causal pathway, the available evidence suggests a potential psycho–immune framework in which psychological and biological outcomes may influence one another. For example,

improvements in fatigue, sleep, and emotional regulation may be accompanied by changes in HRV, cortisol rhythms, or inflammatory markers. However, most included studies did not test temporal sequencing or mediation; therefore, these associations should be interpreted as hypothesis-generating rather than confirmatory. In one direction, Tai Chi enhances resilience, which lowers psychological distress, subsequently reducing inflammation through psychoneuroimmunology mechanisms. In the reverse direction, Tai Chi directly reduces inflammation, leading to improvements in physical well-being and fatigue reduction, which then strengthen psychological resilience [44]. This reciprocal relationship underscores the integrative nature of Tai Chi, wherein psychological and physiological benefits reinforce one another. For example, reduced IL-6 and CRP levels may alleviate fatigue and physical discomfort, allowing patients to engage more actively in daily life and social roles, which in turn fosters greater resilience [43]. Conversely, improved resilience may decrease maladaptive stress responses, lowering HPA axis activation and dampening inflammatory signaling. Thus, Tai Chi operates through a feedback loop in which mind and body continuously influence each other [34].

2.5. Summary of evidence

The literature indicates that Tai Chi is a promising adjunctive therapy for cancer patients, with demonstrated benefits across psychological and physiological domains. Its effects are mediated by resilience, autonomic regulation, and neuroendocrine-immune mechanisms, and moderated by cancer type, demographics, and training characteristics [26,40]. The proposed bidirectional pathway highlights Tai Chi's unique potential to bridge psychological resilience and immune function, offering a holistic model of care. While evidence continues to accumulate, gaps remain in understanding the optimal dosing, long-term sustainability, and differential effectiveness across diverse patient populations. Addressing these gaps will be critical to fully realizing the potential of Tai Chi in oncology.

3. Methodology

3.1. Eligibility criteria

This review followed the PRISMA 2020 guidelines. Studies were eligible if they met the Population, Intervention, Comparison, Outcome, Study Design (PICOS) framework: the population consisted of adult patients with cancer, regardless of stage or cancer type; the intervention involved Tai Chi in any form, frequency, duration, or style; the comparator was usual care, other exercise interventions, or no intervention; and the outcomes included psychological measures (resilience, anxiety, depression, quality of life) and biological markers (C-reactive protein, interleukin-6, tumour necrosis factor-alpha, or other inflammatory biomarkers). Eligible study designs included randomized controlled trials, cohort studies, and controlled clinical trials. We included peer-reviewed studies published in English between 2018 and 2025. Exclusion criteria were non-cancer populations, interventions not centered on Tai Chi, absence of relevant psychological or biological outcomes, case reports, qualitative narratives, protocols, and secondary analyses without original data. Protocols, narrative reviews, systematic reviews, and meta-analyses were not counted as original intervention evidence for efficacy; when relevant, they were used only for background, methodological context, or discussion of future research.

3.2. Search strategy and study selection

The search strategy was implemented in the Web of Science Core Collection and

was supplemented by searches in PubMed, Scopus, Embase, CINAHL, the Cochrane Library, CNKI, and Wanfang using the following Boolean string:

TS = (("tai chi" OR taichi OR "tai ji" OR taiji OR taijiquan OR "tai chi chuan")
AND (cancer OR neoplasm* OR tumor* OR tumour* OR carcinoma OR oncology
OR malignan*))
AND (resilienc* OR "psychological resilience" OR anxiety OR depression OR
"quality of life" OR fatigue OR sleep
OR "C-reactive protein" OR CRP OR "interleukin-6" OR IL-6 OR "tumor necrosis
factor" OR "TNF-alpha" OR cytokine* OR biomarker* OR inflammat*)
AND (random* OR "controlled trial" OR "cohort study" OR "clinical trial"))

The final search was completed on March 3, 2026, and covered studies published between 2018 and 2025. Search terms were adapted as needed for each database. The initial search retrieved 271 records. After applying the publication year limit (2018–2025), 126 records remained. Restricting to English reduced this to 125 records, and filtering for articles and reviews resulted in 124 records eligible for screening. Titles and abstracts were screened for relevance, during which 76 records were excluded. The remaining 48 full texts were assessed for eligibility. Of these, 30 were excluded (wrong study design $n = 12$, absence of relevant outcomes $n = 10$, duplicate or secondary analyses $n = 8$). A total of 14 studies met all inclusion criteria and were included in the review. Titles, abstracts, and full texts were screened independently by two reviewers, and disagreements were resolved through discussion. **Figure 1** illustrates the PRISMA 2020 flow diagram for study selection, showing the number of records identified, screened, excluded, and ultimately included in the review.

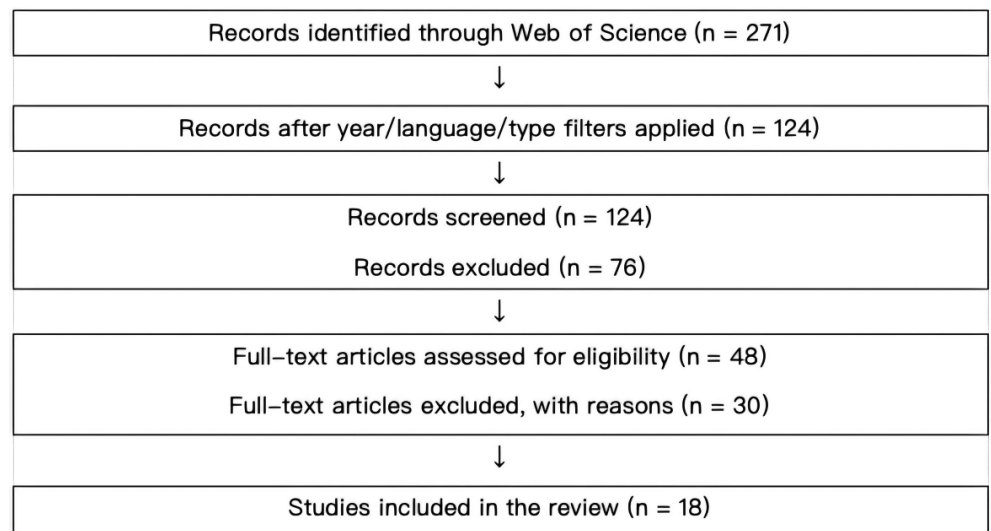


Figure 1. PRISMA 2020 Flow Diagram of Study Selection

Note. The 14 included records comprise 10 original intervention studies as well as 4 non-original records (protocols and reviews) retained for background and contextual discussion only. Only original intervention studies were used as evidence for intervention effects.

Data extraction, quality assessment, and evidence synthesis. Data were extracted using a standardized form, including author, year, study design, cancer type, sample size, Tai Chi style, intervention duration, comparator condition, adherence, follow-up duration, psychological outcomes, biological outcomes, biomarker assessment methods, and main findings. The methodological quality of randomized controlled

trials was assessed using the Cochrane Risk of Bias 2 tool, while non-randomized and cohort studies were assessed using ROBINS-I. The certainty of evidence was considered narratively according to study design, risk of bias, consistency, directness, and precision. Because the included studies differed in Tai Chi style, intervention duration, cancer population, comparator condition, psychological outcomes, biomarker panels, and assay methods, findings were synthesized narratively rather than quantitatively.

4. Result and discussion

This chapter presents the results of the systematic review, with a particular focus on the impact of Tai Chi interventions in oncology. Structured in accordance with the PRISMA 2020 guidelines, the findings encompass both psychological and physiological outcomes across diverse cancer populations. A total of fourteen records were ultimately included following the screening and eligibility process. Of these, ten were original intervention studies, including randomized controlled trials, controlled clinical trials, or cohort/intervention studies, and were used as the primary evidence base for intervention effects. The remaining four records, including protocols and reviews, were retained only for methodological context, theoretical interpretation, or discussion of future research directions, and were not counted as independent patient-level evidence for intervention efficacy.

4.1. Summary and classification of included records

Table 1 presents a summary of the 14 included records that employed Tai Chi as an intervention. Each study is outlined with its key findings for clarity and comparison.

Table 1. Classification of Included Records and Evidence Type

Author(s) & Year	Study Design	Cancer Type	Tai Chi Protocol	Comparator	Psychological / Symptom Outcomes	Biological / Inflammatory Outcomes	Evidence Type
Mohammed & Attia (2021)	Controlled clinical trial	Breast cancer (on chemotherapy)	Tai Chi exercise (modified)	Usual care	Psychosocial well-being, fatigue	Not assessed	Original intervention
Zhou et al. (2018)	RCT	Nasopharyngeal carcinoma (on chemoradiotherapy)	24-form Yang-style Tai Chi, 5×/week	Usual care	Cancer-related fatigue, vigor	Not assessed	Original intervention
Irwin et al. (2024)	RCT (3-arm)	Breast cancer survivors with insomnia	Tai Chi (Yang style)	CBT-I; Waitlist	Insomnia, mood, fatigue	IL-6; TNF- α ; cellular & genomic markers	Original intervention
Takemura et al. (2024a)	RCT (3-arm)	Advanced lung cancer	Tai Chi (simplified)	Aerobic exercise; Usual care	Dyspnea, physical fatigue	Not assessed	Original intervention
Cheung DST et al. (2021)	RCT (3-arm feasibility)	Advanced lung cancer	Tai Chi (modified)	Aerobic exercise; Usual care	Balance, well-being	Diurnal cortisol rhythm	Original intervention
Cheng et al. (2021)	RCT	Middle-aged & elderly mixed cancer	Tai Chi (simplified 24-form)	Resistance training	Cancer-related fatigue, QoL	Not assessed	Original intervention

Continuation Table:

Author(s) & Year	Study Design	Cancer Type	Tai Chi Protocol	Comparator	Psychological / Symptom Outcomes	Biological / Inflammatory Outcomes	Evidence Type
Yao LQ et al. (2022)	Preliminary RCT	Breast cancer	8-form Yang-style Tai Chi	Usual care	Fatigue–sleep–depression cluster	Not assessed	Original intervention
Takemura et al. (2024b)	RCT (3-arm) + mediation	Advanced lung cancer survivors	Tai Chi (simplified)	Aerobic exercise; Usual care	Cognition, anxiety, depression, fatigue, sleep	Not assessed	Original intervention
Li et al. (2023)	Systematic review of RCTs	Breast cancer	Tai Chi Chuan (various)	Various	QoL, psychological well-being	Not consistently reported	Non-original (review)
You et al. (2025)	Narrative review	Breast cancer	Tai Chi Chuan (various)	Various	Physical function, health-related QoL	Not assessed	Non-original (review)
Cheung MNB & Loo TY (2021)	Interventional study	Post-chemotherapy breast cancer	Tai Chi Chuan (standardized)	Pre–post (no control)	Quality of life	IL-2, IL-4, IL-6, IL-10, TNF- α , IFN- γ ; hematological indices	Original intervention
Yao LQ et al. (2021)	Protocol	Female breast cancer	Evidence-based Tai Chi (8-form Yang)	N/A (protocol)	Fatigue, sleep, depression (planned)	Not assessed (planned)	Non-original (protocol)
Oh et al. (2021)	Service report	Mixed cancer (telehealth)	Tai Chi & Qigong (telehealth)	N/A (descriptive)	Well-being, engagement (feasibility)	Not assessed	Original intervention
Wang CC et al. (2022)	Protocol for RCT	Breast cancer	Nurse-led Tai Chi programme	Usual care (planned)	QoL, mental well-being (planned)	Not assessed (planned)	Non-original (protocol)

Note. Ten original intervention studies (RCTs, controlled clinical trials, and interventional studies) were used as the primary evidence base for intervention effects. Four non-original records (protocols and reviews) were retained only for methodological context, theoretical interpretation, or discussion of future research directions and were not counted as independent patient-level evidence for intervention efficacy. Numbers in brackets [] correspond to the reference numbering in the main text and reference list. RCT = randomized controlled trial; CBT-I = cognitive behavioral therapy for insomnia; IL = interleukin; TNF = tumor necrosis factor; IFN = interferon; QoL = quality of life.

4.2. Discussion and future directions

4.2.1. Evidence synthesis

For clarity, the findings were interpreted separately according to psychological outcomes and biological outcomes. Psychological outcomes included resilience, fatigue, anxiety, depression, sleep disturbance, cognitive symptoms, and quality of life, whereas biological outcomes included inflammatory cytokines, C-reactive protein, cortisol rhythm, heart rate variability, hematological indices, and other immune-related markers. Only a smaller subset of studies measured both psychological and biological outcomes within the same trial, and these studies were used to discuss

potential psycho-immune associations rather than to confirm causal pathways. In interpreting the evidence, original intervention studies were distinguished from protocols and secondary literature to avoid duplicating evidence or attributing efficacy to sources without independent patient-level outcome data. In addition, statistically significant findings were distinguished from nonsignificant trends where reported, and primary outcomes were considered separately from secondary or exploratory outcomes. Greater interpretive weight was given to original randomized or controlled intervention studies with clearer sample size, cancer type, disease stage or treatment context, control condition, Tai Chi dose, adherence reporting, follow-up assessment, and biomarker assay methods. Findings from small pilot studies or exploratory biomarker analyses were interpreted cautiously, particularly when cytokine changes were limited, mixed, or nonsignificant.

The psychological benefits of Tai Chi are among the generally reported findings across oncology populations. Interventions reduced cancer-related fatigue, anxiety, and depression, while enhancing resilience and quality of life. Zhou et al. demonstrated that patients with nasopharyngeal carcinoma undergoing chemoradiotherapy reported significant improvements in fatigue and vigor following a 24-form Yang intervention [48]. In breast cancer survivors, Irwin et al. found Tai Chi to be comparable to cognitive behavioral therapy for insomnia, with additional benefits for mood and fatigue [49]. Similarly, Yao and colleagues reported that an eight-form Yang program could alleviate the fatigue-sleep disturbance-depression symptom cluster, indicating that Tai Chi may not only address single symptoms but may also improve interrelated symptom clusters that undermine wellbeing [50]. These outcomes were therefore treated as psychological or symptom-related outcomes rather than biological outcomes.

The evidence for biological outcomes, including inflammatory and immunological effects, while promising, is less consistent. Some studies documented meaningful changes in circulating biomarkers. Irwin et al. reported reductions in interleukin-6 and tumor necrosis factor expression, while Cheung and Loo found normalization of cytokine profiles—including increases in IL-2, IL-4, IL-6, TNF- α , and IFN- γ —together with improved hematological indices in breast cancer survivors [49]. These findings may suggest a potential association between Tai Chi and selected inflammatory or immune-related changes, which is important given the impact of chronic inflammation on cancer progression and survivorship. However, other reviews, such as Li et al., did not observe consistent biomarker changes despite psychological improvements [51]. This inconsistency may reflect heterogeneity in intervention style, biomarker choice, assay methods, cancer population, intervention duration, or study power, underscoring the need for more rigorously designed biomarker-focused trials.

A smaller group of studies simultaneously measured both psychological and biological outcomes, offering valuable insights into mind-body mechanisms. Irwin et al. showed that reductions in psychological distress co-occurred with decreases in inflammatory markers, pointing to a psych neuroimmune mechanism [52,53]. Takemura et al. further demonstrated that cognitive improvements in lung cancer patients were mediated by reductions in anxiety, depression, fatigue, and sleep disturbance, emphasizing the centrality of psychoneurological symptom control to Tai Chi's impact [54]. Cheung et al. added to this evidence by linking high adherence to both improved balance and better circadian cortisol rhythms, alongside psychological benefits [51]. Together, these integrated studies suggest that Tai Chi-

related psychological and biological changes may occur in parallel, rather than through isolated symptom relief. **Figure 2** depicts the conceptual framework of Tai Chi intervention in cancer patients. Tai Chi influences both psychological pathways, including fatigue, anxiety, depression, resilience, and cognition, and physiological pathways, including autonomic regulation, inflammatory cytokines such as IL-6 and TNF- α , and immune recovery. These potentially associated effects converge to enhance quality of life and survivorship outcomes.

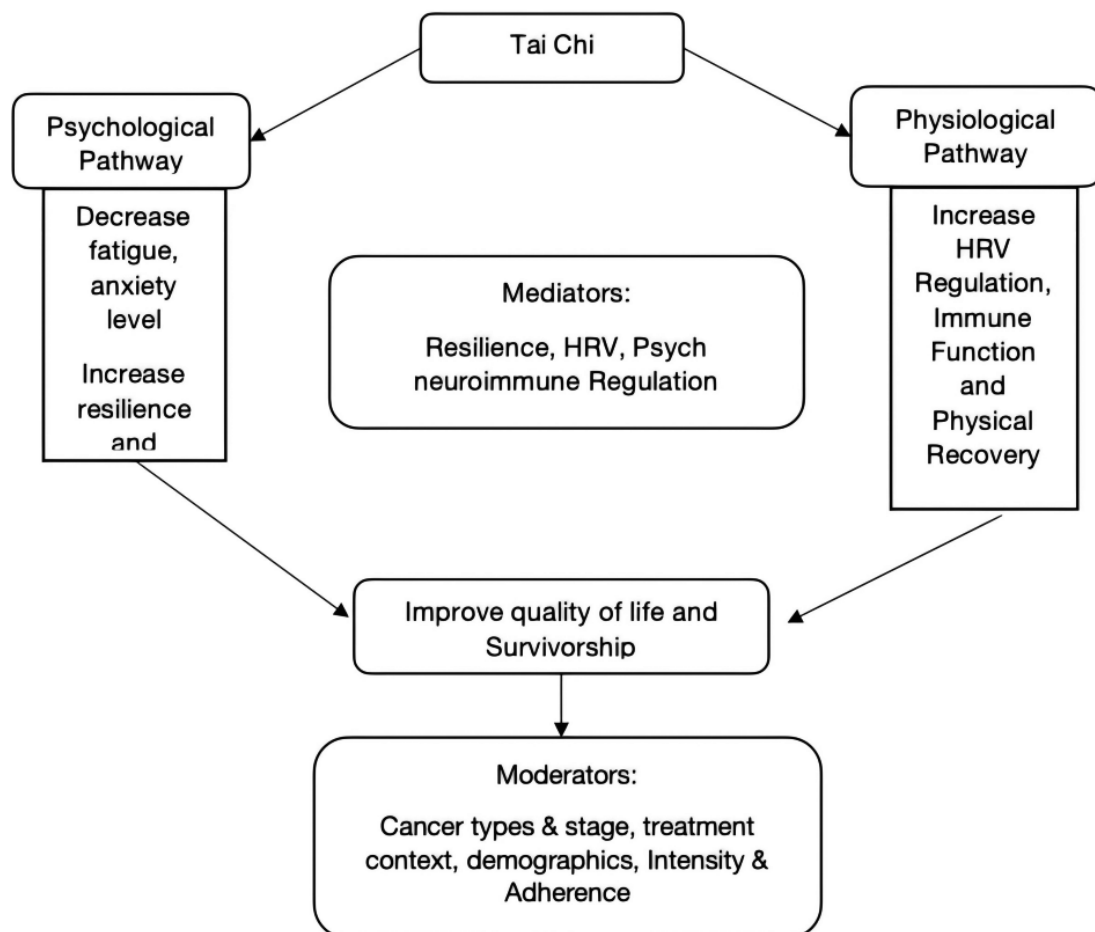


Figure 2. Conceptual Framework of Tai Chi Intervention in Cancer Patients

4.2.2. Interpretation of potential psycho–immune associations

The oncology evidence may be interpreted from a potential psycho–immune perspective in which Tai Chi may be associated with changes in both psychological and physiological outcomes. Practices that emphasize breath control, focused attention, and gentle movement were associated in several studies with reductions in fatigue, insomnia, and psychological distress while also improving autonomic regulation and, in some cases, inflammatory markers [48,49,52]. Improvements in mood and sleep appeared in some studies to occur alongside physiological adjustments, although the available evidence does not confirm whether psychological and immune systems co-adjust during practice. Cognitive benefits observed in lung cancer survivors also fit this pattern, emerging in parallel with relief of psychoneurological symptoms [54]. The available evidence should therefore be interpreted as showing parallel psychological and biological changes rather than confirmed bidirectional causality. Most included studies did not use longitudinal

mediation, temporal sequencing, or repeated biomarker measurements sufficient to determine whether psychological improvement preceded inflammatory change or whether inflammatory reduction preceded symptom relief.

4.2.3. Evidence that Tai Chi may improve resilience-related outcomes and selected biomarkers

Across breast, lung, and mixed cancer cohorts, Tai Chi was commonly associated with improvements in resilience-related outcomes, reflected in increased vigor, improved sleep quality, and quality-of-life gains [33,52,53]. These findings were not limited to subjective reports in some studies. Some studies reported lower or altered interleukin-6 and tumor necrosis factor levels, healthier diurnal cortisol rhythms, and improved heart rate variability, all markers of reduced physiological stress load [49,51]. Longer-term programs reported additional immune changes, such as improved blood counts and cytokine balance, suggesting that resilience training through Tai Chi may be associated with measurable immune-related changes [54]. However, biomarker findings should be interpreted cautiously because the available studies differed in sample size, cancer type, disease stage, intervention dose, follow-up duration, biomarker panels, sampling time, and assay methods. Therefore, the current evidence suggests possible associations between Tai Chi practice, resilience-related outcomes, and selected biological markers rather than consistent or confirmed inflammatory modulation.

4.2.4. Pathways

Resilience may be relevant to the potential psycho-immune interaction. By calming arousal, regularizing breathing, and strengthening attentional control, Tai Chi may enhance parasympathetic activity. Improved heart rate variability and stabilized cortisol rhythms may be associated with lower stress-related physiological load [48,49]. In this sense, psychological resilience may operate as a potential mediator of immune-related improvement, although this requires confirmation in future mediation studies. A reverse pathway is also possible but remains insufficiently established when inflammatory markers decrease and autonomic balance improves, sickness-behavior signals associated with fatigue, disturbed sleep, anhedonia, and cognitive dysfunction may diminish. Patients report clearer thinking and improved mood as immune tone normalizes. These potentially interconnected pathways may help explain why clustered symptoms sometimes improve together [49].

4.2.5. Moderating factors shaping outcomes

Benefits of Tai Chi are shaped by contextual moderators. Lung cancer studies most often reported improvements in dyspnea and physical fatigue, reflecting the unique symptom burden of advanced pulmonary disease [50,52,54]. Breast cancer studies more consistently highlighted gains in mood, sleep, and upper-limb function, outcomes relevant to survivorship challenges such as lymphedema and body image [55-60]. Adherence also shaped outcomes; trials with high attendance and structured home practice reported larger and longer-lasting improvements [61]. Duration played a role as well: shorter programs of eight to twelve weeks reliably shifted psychological symptoms, while longer interventions produced more consistent biomarker and functional changes [59]. Feasibility was not limited to in-person classes—nurse-led community sessions and telehealth models achieved similarly strong engagement when supervision and safety were ensured [40,61]. These observations should be interpreted cautiously because intervention dose, Tai Chi style, instructor expertise, adherence monitoring, cancer type, and biomarker assessment

were not standardized across studies.

4.2.6. Clinical implications

Taken together, these findings suggest that Tai Chi may be a feasible and safe adjunct within psycho-oncology. Its low cost, minimal risk, and adaptability to patients with limited energy or mobility make it suitable for integration into supportive care [47,62]. A practical clinical model would involve two to three sessions per week of 45–60 minutes, emphasizing breath–movement coordination and mindfulness, supplemented by brief daily home practice. Tai Chi can be incorporated into outpatient rehabilitation, survivorship programs, and digital platforms, broadening accessibility for patients across diverse care settings [61]. However, because the evidence base remains heterogeneous, clinical recommendations should be framed as provisional rather than definitive, particularly for inflammatory and immune-related outcomes.

4.2.7. Gaps in the literature

Despite encouraging findings, limitations remain. Current trials suffer from heterogeneous outcome measures, small sample sizes, and inconsistent biomarker assessments [55,62]. Few studies specify intervention fidelity or instructor expertise, limiting reproducibility. Follow-up periods are often short, leaving uncertainty about the durability of effects, particularly for biological outcomes. This limited longitudinal follow-up also makes it difficult to determine whether psychological improvements and biomarker changes are sustained over time. Moreover, many control conditions lack adequate activity matching, making it difficult to isolate Tai Chi-specific effects from general social or physical engagement [57]. The variation in Tai Chi style, intervention duration, cancer population, treatment stage, psychological instruments, and biomarker assay methods also limits the ability to draw firm conclusions about consistency of effects across studies. Because this review used narrative synthesis rather than meta-analysis, publication bias could not be statistically assessed, for example through funnel plots. Nevertheless, the possibility that studies with positive findings were more likely to be published than those with null or negative findings should be considered when interpreting the results.

4.2.8. Future directions

Future progress will depend on greater standardization and methodological rigor. Harmonized Tai Chi protocols specifying style, intensity, frequency, and dose are essential, along with fidelity monitoring to ensure reproducibility [40,60]. Multi-site randomized controlled trials with larger samples and extended follow-up are needed to establish dose–response relationships and confirm durability of effects [57]. Mechanistic studies should integrate validated psychological outcomes with autonomic and immune biomarkers, including heart rate variability, diurnal cortisol, and cytokine assays, and apply prespecified mediation models to directly test the psycho–immune pathways [49]. Future studies should report statistically significant and nonsignificant findings separately, distinguish primary from secondary outcomes, and provide sufficient detail on biomarker collection and assay procedures so that consistency across studies can be evaluated more accurately. Finally, the use of digital delivery and adherence analytics offers opportunities to expand reach and scalability while maintaining scientific precision [61]. Future biomarker-focused studies should also consider broader inflammatory regulatory mechanisms, including immune-metabolic pathways and host–microbiota interactions, because recent evidence suggests that inflammatory activity may be shaped by resistin-related metabolic

signaling and short-chain fatty acid-related microbiota pathways [63-65].

5. Conclusion

This systematic review shows that Tai Chi appears to be a credible adjunct based on current evidence to supportive oncology for addressing psychological and immunological burdens in adult patients with cancer. Across fourteen eligible records, Tai Chi was associated with higher resilience, lower anxiety and depressive symptoms, better sleep, reduced fatigue, and improved quality of life. Trials that collected biological outcomes reported shifts consistent with reduced physiological stress load, including lower pro-inflammatory cytokines, healthier diurnal cortisol rhythms, and improved heart rate variability. When psychological and biological endpoints were measured together, improvements tended to occur in parallel, suggesting potential psycho-immune associations rather than confirming a bidirectional causal model. Current evidence indicates that resilience, autonomic balance, inflammatory activity, fatigue, and sleep disturbance may be interrelated, but most included studies were not designed to establish causality or mediation.

Clinical feasibility was high across nurse-led classes, center-based programs, and telehealth formats, which underscores scalability in real-world settings. At the same time, heterogeneity in Tai Chi style, dose, and biomarker panels, modest sample sizes, brief follow-up, and variable control conditions limit certainty about effect size and durability. These constraints point to clear priorities for the field. Future research should employ harmonized protocols that specify style, frequency, intensity, and total dose, include activity-matched controls, monitor instructor fidelity and adherence, and extend follow-up to test maintenance of benefits. Larger, multi-site randomized trials that integrate validated psychological measures with autonomic and immune biomarkers, alongside prespecified mediation and moderation analyses, are needed to clarify potential psycho-immune mechanisms and identify subgroups most likely to benefit.

In practice, a pragmatic pathway involves two or three supervised sessions per week for forty-five to sixty minutes, supported by brief daily home practice and safety oversight. Within such a framework, Tai Chi offers a low-risk, low-cost strategy that can be embedded in survivorship and rehabilitation services, with the potential to improve both mind and body through potentially interconnected psychological and physiological pathways.

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