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REVIEW ARTICLE

The effects of Tai Chi on quality of life of cancer survivors: a systematic review and meta-analysis

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Abstract

Purposes To assess the effects of Tai Chi on quality of life (QOL) of cancer survivors.

Methods The following databases were searched: PubMed, Cochrane CENTRAL, EBSCO (including MEDLINE, CINAHL, and other databases), ScienceDirect, CNKI, Wangfang Data, and CQVIP until April 25, 2018. Randomized controlled trials (RCTs) published in English or Chinese examining the effects of Tai Chi intervention for cancer survivors were included. The primary outcome was QOL; the secondary outcomes were limb function/muscular strength, immune function indicators, cancer-related fatigue (CRF), and sleep disturbance. Methodological quality was assessed using the Cochrane Risk of Bias tool. Results of RCTs were pooled with mean difference (MD) or standardized mean difference (SMD) with 95% confidence intervals (CI). Quality of evidence for each outcome was assessed with the GRADE system.

Results Twenty-two RCTs were included in this review. Tai Chi improved the physical (SMD 0.34, 95%CI 0.09, 0.59) and mental health (SMD 0.60, 95%CI 0.12, 1.08) domains of quality of life. The intervention improved the limb/muscular function of breast cancer survivors (SMD 1.19, 95%CI 0.63, 1.75) and in mixed samples of cancer survivors reduced the levels of cortisol (MD − 0.09, 95%CI − 0.16, − 0.02), alleviated CRF (SMD − 0.37, 95%CI − 0.70, − 0.04), and promoted sleep (SMD − 0.37, 95%CI − 0.72, − 0.02).

Conclusion There is low-level evidence suggesting that Tai Chi improves physical and mental dimensions of QOL and sleep. There is moderate-level evidence suggesting Tai Chi reduces levels of cortisol and CRF and improves limb function. Additional studies with larger sample sizes and with higher-quality RCT designs comparing different regimens of Tai Chi are warranted.

Keywords Tai Chi · Cancer survivors · Quality of life · Cancer-related fatigue · Limb function · Sleep

Introduction

While the incidence of cancer has increased in many countries, there has been a decrease in cancer death rates [1]. These changes have resulted in a growing population of cancer survivors. Studies indicate that many cancer survivors experience adverse effects relating to physical function, mental health, physical disability, and difficulty in maintaining social activities [2]. These effects have significant impacts on quality of life (QOL) and in some cases survival. A 2011 systematic review reported that more than half of cancer patients use complementary therapies to manage these adverse effects and to promote physical and psychological health, with mind-body exercise as commonly reported approaches [3].

Tai Chi (Chuan) is an ancient Chinese mind-body fitness regimen, which has been widely studied to explore its benefits on human health [4, 5]. Tai Chi is considered a moving meditation, in which practitioners are guided to be mindful of their postures, movements, and breathing, with an intensive inwardly directed focus [6]. For the body, Tai Chi is a form of moderate-intensity aerobic exercise (less than 55% of maximal oxygen intake), leading to more efficient breathing, better capacity to control posture, and enhanced cardiovascular function [7].

In recent years, there have been an increasing number of trials assessing the effects of Tai Chi as a non-pharmacological

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intervention among cancer patients [8]. A number of systematic reviews have been published since 2010 [9–15] and mostly focused on examining the benefits for breast cancer patients [9–11, 14, 16]. These reviews report non-significant effects of Tai Chi on most domains of QOL, except for the mental health domain [9–11, 16]. Moreover, inconsistent results have been reported in terms of the effect of Tai Chi on muscle strength [14]. One of the earliest systematic reviews explored the combined effects of Tai Chi and Qigong for all types of cancer patients [17]. Tai Chi and Qigong share some commonalities, including the use of Ying and Yang as guided theory. Nevertheless, they differ in many ways [18]. Tai Chi was originally developed for martial purposes with a focus on body movement and exercise, while Qigong was developed for fitness regimen with an emphasis on body relaxation and mindfulness meditation [19]. As such, the combination of both therapies in an evidence review makes it difficult to isolate the effects of Tai Chi. Further, some of these reviews [15] did not include studies published in the Chinese language or included studies of patients both during and post-cancer treatment [9–12, 17], making it difficult to identify the efficacy of Tai Chi for patients finished treatment. In one study focused on breast cancer patients post treatment, results indicated a lack of benefits from Tai Chi on QOL [13, 14]. Given the limitations of the existing reviews, the aim of this current systematic review and meta-analysis was to assess the effects of Tai Chi exercise in the population of cancer survivors.

Methods

The review was conducted and reported in accordance with the Cochrane Handbook for Systematic Reviews of Interventions [20] and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [21].

Data sources and search strategy

The following databases were searched electronically up to 25th April, 2018: MEDLINE (via PubMed, from 1997), Cochrane CENTARL (from 1996), EBSCO (from 1975), ScienceDirect (from 2006), Wanfang Data (from 1989, Chinese, 万方), VIP (from 1989, Chinese, 维普网) and CNKI (China National Knowledge Infrastructure, from 1994, Chinese). The search terms included "Tai Chi," "Tai Chi Chuan," "Tai Ji," "Tai Ji Quan," "cancer," "tumor' and "carcinoma," "太极拳," "太极," "肿瘤," and "癌症," "癌."

Selection of studies

All search results were imported into the NoteExpress software and screened for duplication. Two reviewers (NXs and HWy) independently pre-screened all articles (title and abstract) according to the inclusion criteria. Those identified for inclusion either by one reviewer or two reviewers were subject to a full-text review. Independent assessments of the included articles were conducted by the same two reviewers against the inclusion and exclusion criteria. Discrepancy was resolved by discussion and consensus.

Inclusion criteria

Eligibility criteria were detailed using the Participants, Interventions, Controls, Outcomes, and Studies (PICOS) framework. Participants were adults aged 18 years or older with a diagnosis of cancer (solid and hematologic); of any race, nationality, or language background; had previously received cancer treatment; and without major concomitant chronic disease or mental illness that precluded them from participating in Tai Chi. The studies must have examined Tai Chi movement of any type as the only intervention, compared to usual care, or other standard interventions including health education, spiritual growth, psychological support, and daily exercise. The primary outcome of this review was QOL. Secondary outcomes included limb function, fatigue, sleep disturbance, and immune function indicators. Only randomized controlled trials (RCTs) were included.

Data extraction

Two reviewers (NXs, HWy) independently extracted data from each included study using a pre-designed Microsoft Excel data extraction form. Disagreements were settled with a discussion with a third reviewer (LY).

Risk of bias assessment and quality level of evidences

The methodological quality of the studies was evaluated according to *the Cochrane Handbook for Systematic Reviews of Interventions* [20] (RevMan version 5.1.0, The Cochrane Collaboration, 2011). The risk of bias assessment included generation of the allocation sequence, allocation concealment, blinding of the participants and personnel, blinding of outcome assessors, selective outcome reporting, incomplete outcome data, and other potential sources of bias. Each risk of bias item was assessed as low, unclear, or high risk of bias based on the trial reports. Two review authors (NXs, HWy) assessed the risk of bias for each study independently, with discussion in the presence of any disagreements to reach consensus. Further disagreement was resolved by discussion with a third reviewer. In addition to bias assessment to each study, we assessed the quality of evidence for each outcome variable using the Cochrane Collaboration Network GRADE (the Grading of Recommendations Assessment Development and Evaluation).

Data synthesis and analysis

A meta-analysis was conducted using Review Manager (version 5.3 for Windows, Cochrane Collaboration, http://tech.cochrane.org/revman). Statistical heterogeneity was determined using Q test and the I^2 statistic. For cases in which $P < 0.10$ and $I^2 \geq 50\%$, a random effects model was applied. Otherwise, a fixed-effects model was used. Sensitivity analysis was applied to test the stability of the results if there was large heterogeneity. For continuous variables, weighted mean difference (WMD) was calculated when outcomes were measured using the same scale across studies, and the standardized mean difference (SMD) was applied when different scales were used in different trials. Publication bias was not assessed with a funnel plot since the number of studies included for each meta-analysis did not reach 10 [22].

Results

Study selection

In total, 476 citations were identified from the electronic database searches. Of these, 160 were removed for duplication. After screening the titles and abstracts, 51 studies were retrieved for full-text review. Of the 51, 22 [23–44] met the inclusion criteria and were included in this review (see Fig. 1 for reasons of excluded studies), of which 15 studies [23–31, 34–39] were quantitatively synthesized. The remaining 7 studies [32, 33, 40–44] reported varied outcome indicators making it insufficient for meta-analysis.

Study characteristics

Of the 22 included studies ($N = 1410$), eight were published in Chinese (all conducted in China) and 14 were published in English (three conducted in China and 11 in the USA). Most studies ($n = 18$) were published after 2010 (see Table 1).The largest sample size in the included studies was 185 and the smallest was 16. Only one study [39] reported the method for sample size calculation. A variety of cancer diagnoses were recruited in the included studies, with breast cancer ($n = 1054$) and lung cancer ($n = 248$) as the most common cancer types.

Of the 22 studies, 13 studies reported the use of 24-form Tai Chi based on Yang style, two studies with Tai Chi Chih Movements, one study with 24-form Tai Chi based on Chen style, and one with 10-form Tai Chi qigong based on simplified Tai Chi. Different forms of Tai Chi vary in the number of movements, the pace, and power (see Table 2).

In the majority of studies, Tai Chi was instructed and guided by a professional coach, with the period of intervention

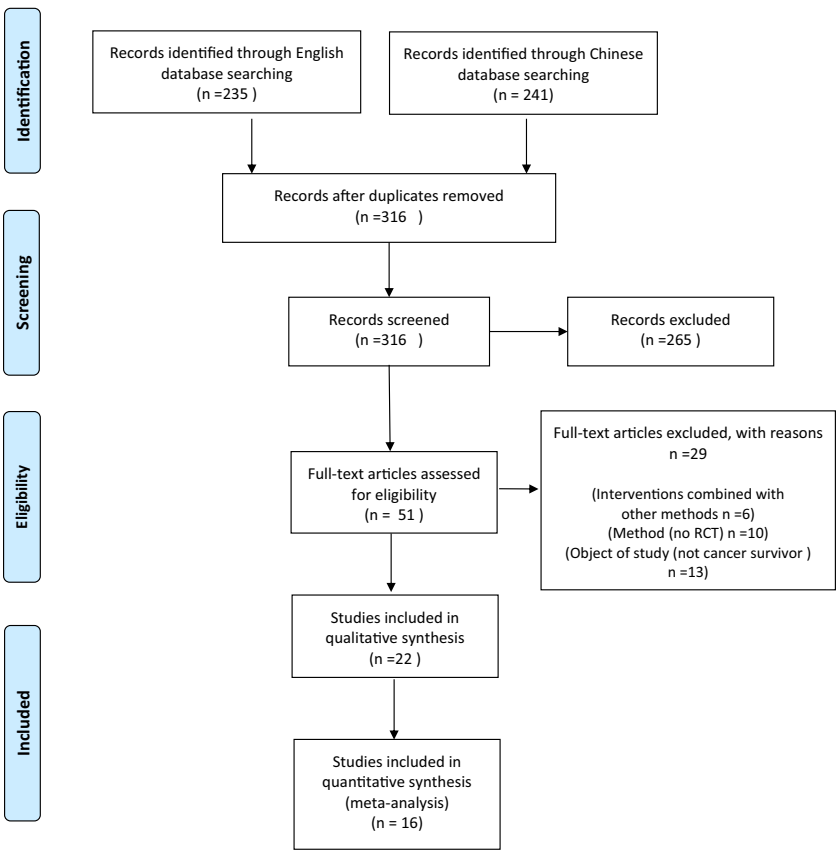

Fig. 1 PRISMA flowchart

Table 1 Characteristics of the included studies

Authors/year/country	Cancer type	Current status	Arms		Duration for each session/frequency/period	Outcome measures/results
			Intervention group (number/age)	Control group (number/age)		
Li YQ et al., 2013, China [23]	Breast cancer	After modified radical mastectomy	Taiji cloud hand (three nurses instructed by a Tai Chi expert) $N = 29$ (29~68)	Routine rehabilitation training $N = 28$ (29~68)	20–30 min; 3 times/day; 6 months	Significant improvements in muscle strength (Lovett grading method) ($P < 0.01$) and QOL (WHOQOLBREF) ($P < 0.05$)
Sun XY et al., 2012, China [24]	Breast cancer	After extended latissimus dorsi Flap and reconstruction of stage I after modified radical mastectomy for breast cancer	24-Form Yang Tai Chi touch by professional coach $N = 41$ 39.18 (28~53)	Routine rehabilitation training/ fitness yang dance exercise $N = 42/35$ 39.18 (28~53)	20 min; 2 times/day; 6 months	Significant improvements in shoulder function (Constant-Murley shoulder function evaluation standard) ($P < 0.05$) and Subjective Feeling with Quality of Life, Subjective Feeling with Health, Physiological, Psychological and Social Relationship of QOL (WHOQOL-BBEF) ($P < 0.05$)
Wang YL et al., 2012, China [25]	Breast cancer	After modified radical cure surgery	24- Form Yang Tai Chi $N = 63$ (28~65)	Yangge dance/routine rehabilitation training $N = 51/71$ (28~65)	20 min; 2 times/day, 6 months	Significant improvements in shoulder function (Constant-Murley shoulder function evaluation standard) ($P < 0.05$) and Subjective Feeling with Quality of Life, Subjective Feeling with Health, Physiological, Psychological and Social Relationship of QOL (WHOQOL-BBEF) ($P < 0.05$)
Wang HY et al., 2016, China [26]	Breast cancer	After modified radical mastectomy	Taijiquan (taught by Tai Chi coach and patrol supervisor nurse on time) $N = 48$ (53.64 ± 7.1)	Routine rehabilitation training $N = 48$ (51.74 ± 7.67)	20–30 min; 2 times/day; 3 months	Significant improvements in shoulder function (Neer shoulder function scoring system) ($P < 0.05$) and Physical Well-being, Emotional Well-being, Functional Well-being, Additional Concerns of QOL (FACT-B) ($P < 0.05$)
Xiao H et al., 2013, China [27]	Breast cancer	After unilateral breast cancer modified radical surgery	24- Form Yang Tai Chi $N = 33$ (70.5 ± 4.2)	Aerobic exercises (arm walking preparation activities, the limb help movement, neck-assisted movement, chest movement, joint movement, the arm shake activity) $N = 33$ (70.3 ± 3.6)	20 min; 2 times/day, 6 months	Significant improvements in shoulder function (Neer shoulder function scoring system) ($P < 0.05$) and Social/Family Well-being, Emotional Well-being, Functional Well-being, Additional Concerns of QOL (FACT-B) ($P < 0.05$)
Lv F et al., 2015, China [28]	Breast cancer	After unilateral breast cancer modified radical surgery, undergone surgery, chemotherapy therapy	24-Form Yang Tai chi (the State Sports General Administration by Tai Chi coach to conduct live teaching and play Tai Chi video) $N = 50$ 48.61 (32–65)	Ba Duan Jin/routine rehabilitation training $N = 50/49$ 48.61 (32–65)	Over 60 min; 3 times/week; 6 months	Significant improvements in upper limb function (Constant-Murley shoulder function measurement standard) ($P < 0.05$) and RP, SF, RE, Vt, MH QOL (SF-36)
Campo et al., 2013, USA [29]	Female cancer patients	≥3 months since completing treatment (exception of hormone therapy), with no detectable cancer	Tai Chi Chih Movements (20 min warm-up, 30 min of Tai Ji with 19 movements and one standing pose and 10 min of closing movements) $N = 29$ (67 ± 7.15)	Health education (topics relevant to successful aging, pain, nutrition, sleep changes, social roles, and relationships), with the majority of topics spanning two classes by a variety of health specialists	60 min; three times/week; 12-week period	Significant improvements in the mental component summary score in TCC (SF-36v1) ($P = 0.01$), but not in HEC

Table 1 (continued)

Authors/year/country	Cancer type	Current status	Arms		Duration for each session/frequency/period	Outcome measures/results
			Intervention group (number/age)	Control group (number/age)		
				$N = 25$ (67 ± 7.15)		
Sprod et al., 2012, USA [30]	Breast cancer	Treatment completed more than 1 month prior but less than 30 months prior	24- Form Yang Tai Chi (10-min warm-up, 40 min of Yang-style Tai Chi Chuan using the 15-move short form and 10 min of guided breathing) $N = 11$ (54.33 ± 3.55)	Standard support therapy control (emphasis on behavioral coping skills, group cohesion, and peer support) $N = 10$ (52.70 ± 2.11)	60 min; 3 times/week; 12 weeks	The TCC group improved in total HRQOL (T1–T2: CS = 8.54, $P = 0.045$), physical functioning (T1–T2:CS = 1.89, $P = 0.030$), physical role limitations (T1–T2 CS = 1.55, $P = 0.023$), social functioning (T1–T3:CS = 1.50, $P = 0.020$), and general mental health (T1–T2:CS = 2.67, $P = 0.014$; T1–T3: CS = 2.44, $P = 0.019$). Cortisol changes were associated with changes in physical role limitations ($r = 0.74$; $P < 0.05$) and health perceptions ($r = 0.46$; $P < 0.05$)
Larkey et al., 2016, USA [31]	Breast cancer	6 months to 5 years past primary treatment (including surgery, radiation, or chemotherapy)	10 QG/TCE exercises based on Tai Chi Easy $N = 42$ (57.7 ± 8.94)	Sham Qigong (i.e., similar movements as QG/TCE without the meditative focus) $N = 45$ (59.8 ± 8.93)	At least 30 min; 5 days/week; 12 weeks	Both groups demonstrated pre-to-post-intervention improvements in physical and mental health, level of PA(SF-), self-reported cognitive function, and cognitive performance tests (FACT-COG), though without significant differences between QG/TCE and SQG
Mustian et al., 2004, USA [32]	Breast cancer	1 week and 30 months after treatment	24-Form Yang Tai chi (10 min of warm-up stretching and basic Chi Kung, a 15-move short form of Yang style) $N = 11$ 52 ± 9 (33~78)	Psychological support (teaching behavioral coping strategies, peer support, and group cohesion by a graduate exercise psychology student) $N = 10$ 52 ± 9 (33~78)	60 min; 3 times/week; 12 weeks	Significant improvements in HRQL (FACIT–F) ($P < 0.05$) and self-esteem, while (RSE) ($P < 0.05$) the PST group reported declines in HRQL and self-esteem
Mustian et al., 2006, USA [33]	Breast cancer	1 week and 30 months post treatment	24-Form Yang Tai Chi (10 min of warm-up stretching and basic Chi Kung, a 15-move short form of Yang style) $N = 11$ 52 ± 9 (33~78)	Psychological therapy (teaching behavioral coping strategies, peer support, and group cohesion by a trained counselor and an exercise psychology graduate student) $N = 10$ 52 ± 9 (33~78)	60 min; 3 times/week; 12 weeks	The TCC group demonstrated significant improvement in functional capacity (specifically aerobic capacity, muscular strength, and flexibility), whereas the PST group showed significant improvement in flexibility only
Mustian et al., 2008, USA [34]	Breast cancer	Between 1 week and 30 months after treatment	24-Form Yang Tai chi (10 min of warm-up stretching and basic Chi Kung, a 15-move short form of Yang style) $N = 11$ 52 ± 9 (33~78)	Psychological therapy (teaching behavioral coping strategies, peer support, and group cohesion by a trained counselor and an exercise psychology graduate student) $N = 10$ 52 ± 9 (33~78)	60 min; 3 times/week; 12 weeks	Significant improvements in functional capacity, including aerobic capacity, muscular strength, and flexibility, as well as QOL (FACIT–F) ($P < 0.5$)
Janelsins et al., 2011, USA [35]	Breast cancer	Treatment completed more than 1 month previously but less than 30 months previously	Tai Chi Chih Movements (10-min warm-up, 40-min 15-move short form of Yang-style TCC, 10 min	Psychological therapy (behavioral coping strategies, peer support, and group cohesion by a trained	60 min; 3 times/week; 12 weeks	Levels of insulin are significantly different in TCC and PST groups; levels remained stable in the TCC group but increased in the PST control

Table 1 (continued)

Authors/year/country	Cancer type	Current status	Arms		Duration for each session/frequency/period	Outcome measures/results
			Intervention group (number/age)	Control group (number/age)		
			of structured breathing, imagery, and meditation) *N* = 9 53 (43–78)	counselor and exercise psychology graduate student) *N* = 10 53 (43–78)		group ($P = 0.099$). Bivariate analysis revealed novel and significant correlations (all r 0.45, all $P < 0.05$) of both decreased fat mass and increased fat-free mass with increased IL-6 and decreased IL-2 levels
Campo et al., 2015, USA [36]	Elderly women with cancer	≥3 months since cancer treatment completion (exception of hormone therapy), with no detectable cancer	24-Form Yang Tai chi (20-min warm-up, 30 min of TCC movements consist of 19 non-strenuous movements and one standing pose and 10 min of closing movements) *N* = 29 65.9 (55–82)	Health education (topics relevant to successful aging, pain, sleep changes, and social roles), with the majority of topics spanning two classes each) *N* = 25 66.7 (59–84)	60 min; 3 times/week; 12 weeks	TCC group had significantly lower systolic blood pressure (SBP, $P = 0.002$) and cortisol area under curve (AUC, $P = 0.02$) at post-intervention than the HEC group. There was no intervention effect on inflammatory cytokines ($P > 0.05$)
Jiang MY et al., 2013, China [37]	Lung cancer	Patients with advanced lung cancer	24-Form Yang Tai chi (when hospitalized led by a full-time nurse or when discharged with 24-form Tai Chi VCD) *N* = 30 64.4 ± 2.8	Usual care *N* = 30 65.6 ± 2.5	30 min; 2 times/day; 30 days	Significant improvements in CRF (BFI) ($P < 0.05$) and sleep (SRSS) ($P < 0.05$)
Larkey et al., 2015, USA [38]	Breast cancer	Six months to 5 years past primary treatment (including any of the following: surgery, radiation, or chemotherapy)	Tai Chi Easy *N* = 42 57.7 ± 8.94	Sham Qigong (SQG) *N* = 45 59.8 ± 8.93	60 min, 2/week for the first 2 weeks; 16 weeks	Fatigue decreased significantly in the QG/TCE group compared to control at post-intervention ($P = 0.005$) and 3-month follow-up ($P = 0.024$), but not depression and sleep quality; improvement occurred over time for both interventions in depression and sleep quality (all $P < 0.05$)
Irwin, MR. et al., 2017, USA [39]	Breast cancer	≥6 months since cancer treatment completion (surgery, radiation, and/or chemotherapy)	TCC *N* = 45 59.6 ± 7.9	CBT *N* = 45 60.0 ± 9.3	Weekly 120-min sessions	Tests of noninferiority showed that TCC was noninferior to CBT-I at 3 months ($P = 0.02$). Between-group differences in change of fatigue from baseline to 3 months were not significant
Fan Y et al., 2014, China [40]	Lung cancer	After lung cancer surgery	Tai Chi *N* = 22 55 (43–75)	Walking/yoga/rehabilitation gymnastics 25/29/31 55 (43–75)	60 min; every day; 8 weeks	Significant improvements in carcinogenin secretion and rehabilitation index
Peppone et al., 2010, USA [41]	Breast cancer	Treatment completed more than 1 month previously, but less than 30 months before enrollment	24-Form Yang Tai chi (10 min warm-up exercises, stretches, and Chi Kung; 40-min 15-move short form of Yang style, 10 min of regulatory breathing) *N* = 7 53.8 (43–78)	Standard support therapy (behavioral coping strategies, cohort support, and group unity by a trained counselor and exercise psychology graduate student) *N* = 9 52.6 (43–78)	60 min, 3 times/week; 12 weeks	TCC group experienced a greater increase in levels of bone formation (BSAP [μg/L]: before, 8.3; after, 10.2; change, 1.9 μg/L and 22.4%) and in bone resorption (NTx [nanomoles bone collagen equivalent; nmBCE]: before, 17.6; after, 11.1; change, − 6.5 nmBCE; − 36.9%)
Wang et al., 2013, China [42]	Lung Cancer	After lobectomy	24-Form Chen Tai Chi (10-min warm-up, 10-min cool-down) *N* = 13 63.1 ± 7.9	Usual care *N* = 14 59.3 ± 7.7	60 min, 3 times/week from 7 to 8 AM; 16 weeks	The T1/T2 and Tc1/Tc2 ratios show significant time-by-group interactions (both $P = 0.001$); the catecholamine level decreased over time in the Tai

Table 1 (continued)

Authors/year/country	Cancer type	Current status	Arms		Duration for each session/frequency/period	Outcome measures/results
			Intervention group (number/age)	Control group (number/age)		
						Chi group ($P < 0.05$); no significant changes in theβ-EP levels
Liu et al., 2015, China [43]	Non-small cell lung cancer	Two or more years after completion of surgical intervention	24- Form Yang Tai Chi (15-min warm-up, 35-min practice, 10-min cool-down period) $N = 14$ 62.64 ± 8.35	Usual care $N = 13$ 60.46 ± 7.08	60 min; 3 times/week; 6:30 am to 7:30 am; 16 weeks	Significant improvements in cell proliferation, cytolytic/oncolytic activity against A549 cells and NK cell percentage ($P < 0.05$)
Zhang et al., 2013, China [44]	Non-small cell lung cancer	Had survived the surgery for more than 2 years and had not received chemotherapy	24-Form Yang Tai chi (a senior instructor with 20 years of teaching experience, 10-min warm-up, 10-min cool-down) $N = 13$ 63.07 ± 7.89	Usual care (not to modify their daily life activity routine, including diet and physical activity) $N = 14$ 59.27 ± 7.68	60 min; 3 times/week; 16 weeks	The TCC participants showed a significantly lower increment in the expression of CD55 ($P < 0.05$) as compared to the control group. No significant between-group differences were found in the $CD4^+/CD8^+$ ratio or CD59 expression. There were also no significant correlations among the changes in CRPs or T lymphocyte subpopulations, either

being from 3 to 6 months, with a frequency of 3–5 sessions per week. All studies lasted less than 60 min for each session, with 10 to 20 min of warm-up inclusive. No adverse events were mentioned from the included studies, and the overall exercise compliance was good. Control groups included usual care, routine rehabilitation training, sham Tai Chi, aerobic exercise, health education, support group, psychological support, or cognitive behavioral therapy.

Risk of bias assessment

The risk of bias assessment for each study is presented in Fig. 2. The majority of studies were rated as low risk in the selective outcome reporting domain ($n = 21$). Around half of included studies were rated as low risk in the random sequence generation ($n = 13$) [23–26, 30, 31, 33, 35, 38, 39, 41, 43, 44], allocation concealment ($n = 9$) [23, 30, 31, 35, 38, 39, 41, 44], and incomplete outcome data reporting domains ($n = 10$) [30, 32–36, 38, 39, 42, 44]. Due to the nature of Tai Chi intervention, only a few studies reported blinding of participants and personnel ($n = 3$) [31, 38, 39], and blinding of outcome assessment ($n = 6$) [29, 31, 36, 38, 39, 44]. Therefore, most studies were rated as high-risk for these two domains.

Data synthesis

Effects on quality of life

Ten studies [23–32] assessed QOL, and one study [32] was not included for statistical pooling due to insufficient data provided. The meta-analysis found a significant improvement in physical functioning (random effects model, SMD = 0.34, 95%CI (0.09, 0.59); $P = 0.007$) and mental functioning (random effects model, SMD = 0.60, 95%CI (0.12, 1.08), $P = 0.01$), but not in social functioning (random effects model, SMD = 0.26, 95%CI (− 0.25, 0.77); $P = 0.32$] for the Tai Chi group compared to the control group (see Table 3 and Supplementary Fig. 1.1–1.3). Studies were removed one by one in sensitivity analysis for physical and mental functioning domains, but no significant improvement was detected. For the social functioning dimension, sensitivity analysis identified a significant improvement after the removal of two studies with small sample sizes (Supplementary Fig. 1.4) [29, 30]. In light of the low methodological quality of the included studies and high level of heterogeneity, there is low-level evidence suggesting that Tai Chi could improve the physical, mental, and social domains of QOL (Table 4).

Effects on upper limb function and muscular strength

A meta-analysis of five trials [24–28] including 465 breast cancer survivors for measures of upper limb function demonstrated

Table 2 Type of Tai Chi used in studies

Type of Tai Chi	Main postures	Characteristics	Studies
24-Form Chen	(1) Commencing, (2) warrior pounds the mortar, (3) tie the coat leisurely, (4) six sealing and four closings, (5) single whip, (6) white crane spreads wings, (7) walk obliquely, (8) brush knees, (9) twist steps, (10) pat on the foot with both hands, (11) golden rooster stands on one leg-left and right, (12) inverted flower dance sleeves, (13) overturn the ocean waves, (14) kick twice, (15) girls shuttling, (16) smooth elbow, 17) wrapping fire crackers, (18) fist protects heart, (19) wear elbows, (20) tie the coat leisurely, (21) cloud hands, (22) cannon over the head, (23) warrior pounds the mortar, (24) closing References: (1) Guo Chuanguang. Chen Tai Chi simple 24-style [M]. Chengdu: Chengdu Times Press. 2010. (2) Wushu ed. Taijiquan teaching and training English-Chinese bilingual teaching [M] Beijing: Beijing Sport University Press. 2009.	Emphasizes strong explosive power and quick movements	Wang et al., 2013, China [42]
24-Form Yang	(1) Commencing, (2) splitting the wild horse's mane on both side, (3) white crane spreads wings, (4) brush knee and twist steps on both side, (5) playing the pipa, (6) repulse monkey, (7) grasp the bird's tail-lift, (8) grasp the bird's tail-right, (9) single whip, (10) clouds hands, (11) single whip, (12) patting a high horse, (13) kicking with the right heel, (14) strike ears with both fists, (15) turn and kick with left heel, (16) push down and stand on the left foot, (17) push down and stand on the right foot, (18) working with a shuttle, (19) needle to bottom of the sea, (20) flashing the arm, (21) turn, deflect, parry, and punch, (22) withdraw and push, (23) crossing hands, (24) closing References: (1) Li Huilin. Yang Taiji simple 24-boxing [M]. Chengdu: Chengdu Times Publishing House. 2008. (2) Zhou Qingjie. Taiji Taiji sword practice guide [M] Beijing: Chinese People's Public Security University Press. 2010.	gentle and soothing, emphasizing the coordination between breath and movement.	Sun XY et al., 2012 [24]; Wang YL et al., 2012 [25]; Xiao H et al., 2013 [27]; Lv F et al., 2015 [28]; Sprod et al., 2012 [30]; Mustian et al., 2006 [32]; Mustian et al., 2008 [33]; Janelsins et al., 2011 [35]; Jiang MY et al., 2013 [37]; Peppone et al., 2010 [40]; Liu et al., 2015 [43]; Zhang et al., 2013 [44]
10-Form Yang	Including movement 1 to 10, and 24 of 24-Form Yang, with the ninth and tenth movement order reversed References: (1) Su Jianming, Xian Hui. College Wushu bilingual tutorial [M]. Kunming: Yunnan University Press. 2012. (2) Zhou Qingjie. Taiji Taiji sword practice guide [M] Beijing: Chinese People's Public Security University Press. 2010.	Gentle and soothing, emphasizing the coordination between breath and movement	Larkey et al., 2016 [31]
Tai Chi Chih Movements	(1) Rocking motion, (2) bird flaps its wings, (3) around the platter, (4) around the platter variation, (6) bass drum, (7) daughter on the mountaintop, (8) carry the ball to the side, (9) push pull, (10) pulling in the energy, (11) pulling taffy, (12) pulling taffy–anchor, (13) pulling taffy–wrist circles, (14) pulling taffy–perpetual motion, (15) working the pulley, (16) light at the top of the head, (17) joyous breath, (18) passing clouds, (19) six healing sounds, (20) cosmic consciousness pose References: Campo et al., 2013 [24], Campo et al., 2015 [39]		Campo et al., 2013 [29]; Campo et al., 2015 [36]

significant heterogeneity ($I_2 = 87\%$, $P < 0.00001$). The pooled results from the random effects model demonstrated significant differences in upper limb function scores between the Tai Chi intervention group and the control group, with the Tai Chi group having better limb function (SMD = 1.19, 95%CI [0.63, 1.75]; $P < 0.0001$) (see Supplementary Fig. 2.1).

Except for an intervention period of 3 months in Wang et al.'s study [26], the remaining four studies all had an intervention period of 6 months. Sensitivity analysis was conducted after removing Want et al.'s study, resulting in statistical significance and consistency in the forest plot (see Supplementary Fig. 2.2).

Four trials [24, 25, 28, 34] measured muscular strength of upper limbs of breast cancer survivors. There was no statistically significant heterogeneity among different trials ($P = 0.13$, $I^2 = 47\%$). In a fixed-effects meta-analysis, a significant improvement (SMD = 0.49; 95%CI (0.16, 0.81); $P = 0.003$) in muscular strength scores was found for the Tai Chi group compared to the control group (see Supplementary Fig. 2.3). In the presence of heterogeneity, sensitivity analysis was conducted but did not change the result. Due to low methodological quality, the level of evidence for the positive effects of Tai Chi on limb function and muscular strength was moderate (see Table 4).

Effects on interleukin-6 (IL-6)

Two trials [30, 35] compared the IL-6 levels of 18 participants in the Tai Chi group (combined) and 20 participants in the health education or standard support group (combined). There was no detected heterogeneity with the two trials ($Chi^2 = 0.00$, $P = 1.00$; $I^2 = 0\%$). The fixed-effects meta-analysis showed statistically significant difference between the Tai Chi and control group, with the control group associated with reduced IL-6 level (MD = 2.21; 95%CI (0.74, 3.68); $P = 0.003$) (see Supplementary Fig. 3.1). The evidence indicating effects of Tai Chi on IL-6 levels was low, because of the small sample size ($n = 38$) and low methodological quality (see Table 4).

Effects on cortisol levels

Two trials [30, 36] compared cortisol levels of participants with 38 participants in the Tai Chi group (combined) and 35 participants in the health education or standard support group (combined). There was no detected heterogeneity among the two trials ($Chi^2 = 0.25$, $P = 0.62$; $I^2 = 0\%$). The fixed-effects meta-analysis showed statistically significant difference between the Tai Chi and control group, with the Tai Chi group associated with reduced cortisol level (MD = − 0.09, 95%CI (− 0.16, − 0.02); $P = 0.01$) (see Supplementary Fig. 3.2).The quality of evidence for the benefits of Tai Chi for cortisol levels was moderate due to the small sample sizes in both studies (see Table 4).

Effects on cancer-related fatigue (CRF)

Three trials [37–39] compared CRF in the two groups as measured by fatigue symptom severity with 115 participants in the Tai Chi group and 119 participants in the usual care group or Sham Qigong group. There was heterogeneity among the trials ($Chi^2 = 10.21$, $P = 0.006$; $I^2 = 80\%$), and thus, sensitivity analysis was conducted with the exclusion of Michel et al.'s study. The fixed-effects meta-analysis suggests a significant difference between the Tai Chi and control group, with the Tai Chi group associated with reduced CRF level (SMD = − 0.37, 95%CI (− 0.70, − 0.04); $P = 0.03$) (see Supplementary Figs. 4.1 and 4.2). The quality of evidence was moderate, as the processes of blinding and randomization were not clearly described (see Table 4).

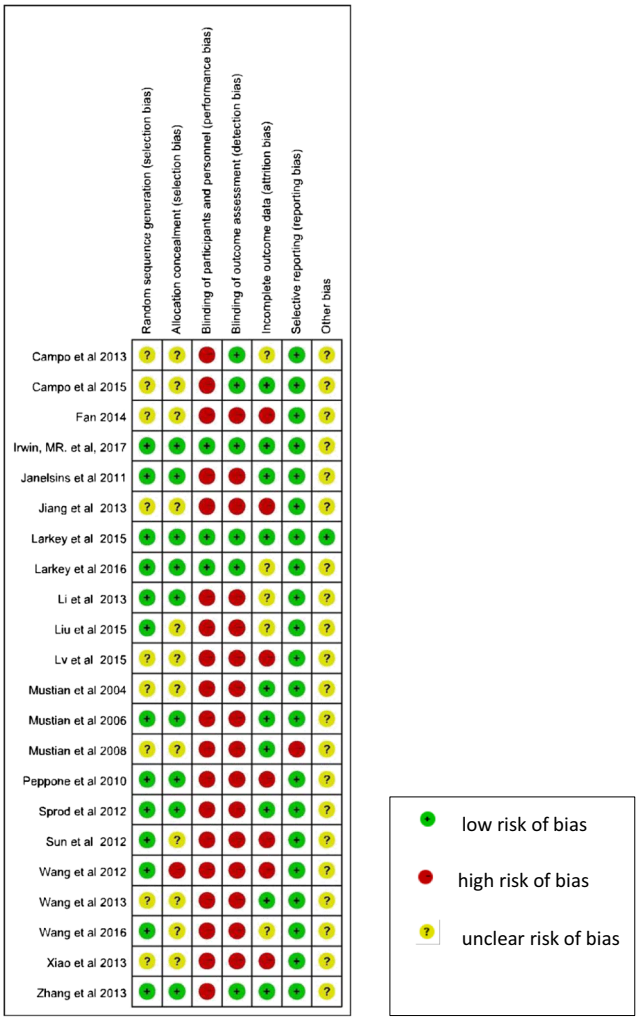

Fig. 2 Risk of bias summary

Effects on sleep quality

Three trials [37–39] compared sleep quality as measured by the Pittsburgh Sleep Quality Index and Self-Rating Scale of Sleep with 106 participants in the Tai Chi group and 112 participants in the usual care group or Sham Qigong group. There was heterogeneity among the trials ($Chi^2 = 33.82$, $P < 0.001$; $I^2 = 94\%$). Due to the significant heterogeneity,

Table 3 The effects of Tai Chi among cancer survivors

Domains	Intervention	Control	Assessment time point	Effect size (fixed/random effects)	Included studies		Conclusion (i.e., demonstrating benefits of Tai Chi)
					No. of studies	No. of participants	
Quality of life (QOL)							
Physical domain of QOL	Tai Chi	Rehabilitation training ($n = 5$)/aerobic exercise/sham Qigong/standard support/health education	3 months	SMD = 0.34 (95%CI 0.09 to 0.59) (RE)	9	679	Positive
Psychological domain of QOL	Tai Chi	Rehabilitation training ($n = 5$)/aerobic exercise/sham Qigong/standard support/health education	3 months	SMD = 0.60 (95%CI 0.12 to 1.08) (RE)	9	681	Positive
Social relationship domain of QOL	Tai Chi	Rehabilitation training ($n = 5$)/aerobic exercise/standard support/health education	3 months	SMD = 0.26 (95%CI − 0.25 to 0.77) (RE)	8	595	Inconclusive
Sensitivity analysis of social relationship	Tai Chi	Rehabilitation training ($n = 5$)/aerobic exercise	3 months	SMD = 0.56 (95%CI 0.10 to 1.03) (RE)	6	522	Positive
Subjective feeling with quality of life	Tai Chi	Rehabilitation training	3 months	MD = 0.47 (95%CI 0.15 to 0.80) (FE)	3	268	Positive
Subjective feeling with health	Tai Chi	Rehabilitation training	3 months	MD = 0.42 (95%CI 0.08 to 0.76) (FE)	3	267	Positive
Environment	Tai Chi	Rehabilitation training	3 months	MD = 0.50 (95%CI − 0.50 to 1.50) (FE)	3	267	Inconclusive
Functional well-being	Tai Chi	Rehabilitation training/aerobic exercise	3 months	MD = 2.74 (95%CI 2.03 to 3.45) (RE)	2	155	Positive
Additional concerns	Tai Chi	Rehabilitation training/aerobic exercise	3 months	MD = 1.58 (95%CI 0.92 to 2.24) (FE)	2	156	Positive
Role-physical	Tai Chi	Rehabilitation training/standard support/health education	3 months	MD = 4.56 (95%CI − 6.21 to 15.33) (RE)	3	172	Inconclusive
Body pain	Tai Chi	Rehabilitation training/standard support/health education	3 months	MD = 3.75 (95%CI − 1.37 to 8.86) (RE)	3	172	Inconclusive
General health	Tai Chi	Rehabilitation training/standard support/health education	3 months	MD = 0.05 (95%CI − 4.53 to 4.63) (RE)	3	172	Inconclusive
Vitality	Tai Chi	Rehabilitation training/standard support/health education	3 months	MD = 5.41 (95%CI − 5.06 to 15.87) (RE)	3	172	Inconclusive
Role-emotional	Tai Chi	Rehabilitation training/standard support/health education	3 months	MD = 1.38 (95%CI − 1.83 to 4.58) (RE)	3	172	Inconclusive
Limb function	Tai Chi	Rehabilitation training ($n = 4$)/aerobic exercise	3 months	SMD = 1.19 (95%CI 0.63 to 1.75) (RE)	5	465	Positive
Sensitive analysis of limb function	Tai Chi	Rehabilitation training ($n = 3$)/aerobic exercise	3 months	SMD = 0.87 (95%CI 0.66 to 1.09) (RE)	4	375	Positive
Muscular strength of upper limbs	Tai Chi	Rehabilitation training ($n = 3$)/psychological therapy	3 months	SMD = 0.49 (95%CI 0.16 to 0.81) (RE)	4	330	Positive
IL-6	Tai Chi	Psychological therapy/standard support	3 months	MD = 2.21 (95%CI 0.74 to 3.68) (FE)	2	38	Inconclusive
Cortisol	Tai Chi	Health education/standard support	3 months	MD = − 0.09 (95%CI − 0.16 to − 0.02) (FE)	2	73	Positive
CRF	Tai Chi	Usual care/sham Qigong/cognitive behavioral therapy	Mainly 3 months	SMD = − 0.04 (95%CI − 0.30 to 0.22) (FE)	3	234	Inconclusive
Sensitive analysis of CRF	Tai Chi	Usual care/sham Qigong	1 and 3 months	SMD = − 0.37 (95%CI − 0.70 to − 0.04) (FE)	2	144	Positive
Sleep quality	Tai Chi	Usual care/sham Qigong/cognitive behavioral therapy	Mainly 3 months		3	218	Inconclusive

Table 3 (continued)

Domains	Intervention	Control	Assessment time point	Effect size (fixed/random effects)	Included studies		Conclusion (i.e., demonstrating benefits of Tai Chi)
					No. of studies	No. of participants	
				SMD = 0.26 (95%CI − 0.02 to 0.53) (FE)			
Sensitive analysis of sleep quality	Tai Chi	Usual care/sham Qigong	1 and 3 months	SMD = − 0.37 (95%CI − 0.72 to − 0.02) (FE)	2	128	Positive

sensitivity analysis was conducted with the exclusion of Michel et al.'s study. The fixed-effects meta-analysis suggests a significant difference between the Tai Chi and control group, with the Tai Chi group associated with improved sleep levels (SMD = − 0.37, 95%CI (− 0.72, − 0.02); $P = 0.04$) (see Supplementary Figs. 5.1 and 5.2). The evidence rating was low because of the small sample size and low methodological quality (see Table 4).

Discussion

Several limitations of the available studies and notable risk of bias in many dimensions of assessment should be considered in the interpretation of these results. The current meta-analysis pooled results for 3 months following the intervention due to the insufficient data at 6 months. The long-term effectiveness of Tai Chi in cancer patients cannot yet be determined, although the results from several studies [23, 27] suggest better outcomes including shoulder function, postoperative upper limb edema, muscle strength, and psychological health among breast cancer patients at 6 months. Notwithstanding these limitations, this meta-analysis is unique in its focus on the effects of Tai Chi interventions on multiple outcomes for cancer survivors. Overall, the results indicate low to moderate level of evidence of the positive effects of Tai Chi.

Assessment of the effects of Tai Chi on cancer survivors

Quality of life

Quality of life is a subjective and multi-dimensional concept [45]. While measurement scales differ slightly in terms of the domains assessed, physical, psychological, or mental, social relationships and symptoms are the most commonly evaluated among cancer survivors [46, 47].

Consistent with the findings from the meta-analyses of Zeng et al. [12] and Lee et al. [15], the current meta-analysis identified low-level evidence that Tai Chi exercise has an overall positive effect on physical and psychological dimension of QOL among cancer survivors. There are several explanations for these findings. The 24-form Tai Chi based on Yang style was used most commonly in the studies included, which is considered more suitable for cancer survivors [48] for its ease of learning and smooth postures [49]. Importantly, Tai Chi might be beneficial for cancer survivors because of its impact on subjective perceptions of wellbeing. According to Li Y. et al. [50], Tai Chi practitioners often offer group sessions, in which people usually share a common interest, and this in turn can promote harmonious interpersonal relationships. While Campo et al. [29] did not report a significant effect of Tai Chi interventions on social functioning that was

Table 4 Risk of bias summary

Quality assessment							No of patients		Absolute effect (95%CI)	Quality	Importance
No. of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Tai Chi	Control			
Tai Chi for quality of life											
9	Randomized trials	Serious[a]	Serious[b]	No serious indirectness	No serious imprecision	None	331	348	SMD 0.34 (−0.59, −0.09)	⊕⊕OO Low	Critical
Tai Chi for limb function											
5	Randomized trials	Serious[a]	Serious[b]	No serious indirectness	No serious imprecision	None	225	240	SMD 1.19 (0.63, 1.75)	⊕⊕⊕O Moderate	Important
Tai Chi for IL-6											
2	Randomized trials	Serious[c]	No serious inconsistency	No serious indirectness	Serious[d]	None	18	20	MD 2.21 (0.74, 3.68)	⊕⊕OO Low	Important
Tai Chi for cortisol											
2	Randomized trials	No serious risk of bias	No serious inconsistency	No serious indirectness	Serious[d]	None	38	35	MD 0.09 (0.02, 0.16)	⊕⊕⊕O Moderate	Important
Tai Chi for CRF											
2	Randomized trials	Serious[c]	No serious inconsistency	No serious indirectness	No serious imprecision	None	115	119	SMD − 0.04 (−0.70, −0.4)	⊕⊕⊕O Moderate	Important
Tai Chi for sleep quality											
2	Randomized trials	Serious[a]	No serious inconsistency	No serious indirectness	Serious[d]	None	106	112	SMD 0.26 (−0.93, −0.07)	⊕⊕OO Low	Important

[a] There were no details on blinding and the randomization method. Although it was difficult to blind to patients and researchers, outcome assessors should be blinded

[b] There was high heterogeneity

[c] Details on blinding and randomization method were missing

[d] The sample size was too small

reported in other studies, they argued that the control group in their study also had more time for social interaction thus limiting the ability to detect significant differences. Such explanations for the positive effects of Tai Chi suggest that the Tai Chi format should not only focus on the performance of gestures but also the social supportive aspects. Other explanations for the positive effect of Tai Chi include the potential for Tai Chi, with its requirements for full attention to the exercise, to provide a distraction from cancer-related stress. Such explanations are consistent with the underpinning Taoism philosophy embedded in the practice, with its associated value on contentment, and life self-perception, human self-cultivation. Promoting such values could help promote calmness, relaxation, and peace, thereby explaining the positive impacts on QOL.

In terms of effects on the physical domains, studies showed an improvement on physical functioning in those practicing Tai Chi, which is consistent with a qualitative study finding that Tai Chi can improve physical health for older people [51]. Tai Chi requires the coordination of gestures and balance, thereby positively influencing the functioning of the muscular-skeletal and central nervous systems. Tai Chi also focuses on the practice of slow and deep breathing, which increases movement amplitude of the diaphragm, chest, and abdomen, thereby potentially improving blood circulation and strengthening myocardial perfusion [52].

Upper limb function

Consistent with Yan et al.'s [9] systematic review, our results provide moderate-level evidence that Tai Chi can improve upper limb function and muscle strength for breast cancer survivors. However, our review included an additional two studies, increasing the sample size for the meta-analysis from 169 to 375. These additional studies provide insights into effects of longer-term intervention lasting for up to 12 weeks. For breast cancer survivors, surgical trauma can cause damage to the tissue in the affected side, which can directly lead to restriction of limb activity or even dysfunction [23]. Tai Chi has unique circular motions, which are performed in a way of being flexible, slow, coherent, and stable movements. These motions can greatly enhance limb function by promoting coordination between body muscles and joint activities, especially the upper limb joints [23]. Tai Chi movement may be conducive to the lymphatic return, thereby preventing further tissue damage and upper limb lymphedema [53].

Indicators of immune function

IL-6 is expressed at high levels in the tumor microenvironment during radiotherapy and chemotherapy treatment [54, 55], and it has a role in inflammatory regulation and metabolic processes, which is associated with symptoms such as fatigue, and survival in metastatic cancer [55–57]. The current meta-analysis did not identify a reduction in IL-6 levels among breast cancer survivors who used Tai Chi. This finding is inconsistent with Meneses-Echavez et al.'s [57] meta-analysis, which synthesized the reduction effect of aerobic, resistance training, Tai Chi, and Yoga on IL-6 in breast cancer survivors. Interestingly, our study demonstrated a higher level of IL-6 in the Tai Chi group. It has been reported in the literature that IL-6 has a dual effect of pro-inflammatory and inhibitory inflammation, depending on its source of cell production. IL-6 from adipose tissue can promote tumor cell infiltration and that from T cells can promote tumor cell survival [58], while regular exercise can induce muscle to secrete IL-6 and raise its level to trigger anti-inflammatory effects [59]. While the small sample size of included studies in the current meta-analysis may inhibit a definitive conclusion of the exercise effect of Tai Chi, it is of great interest for future study to explore the origin and effect of IL-6.

Our meta-analysis also showed moderate-level evidence that Tai Chi could reduce cortisol levels among cancer survivors. It has been reported that elevated cortisol levels in cancer survivors are associated with suppressed immune function, promoted tumor growth, and inflammation-related disease susceptibility [60, 61] and also can cause a variety of side effects, including fatigue [30]. Thus, Tai Chi may be helpful for cancer recovery via stabilizing or reducing the cortisol levels.

Cancer-related fatigue and sleep disorders

This meta-analysis found moderate-level evidence that Tai Chi relieves CRF, which is consistent with Song et al.'s recent meta-analysis [62]. Aistars [63] proposed physical, psychological, and situational etiologic factors associated with CRF. Tai Chi may have an effect on each of these etiologic factors. For example, Jin et al. [64] reported that Tai Chi increased the secretion of norepinephrine in the urine, reduce the concentration of salivary cortisol, and make the participants feel more energetic with less fatigue, confusion, anxiety, and other mental disorders. Lu et al. [65] also found that short-term Tai Chi decreased sympathetic modulation and lead to a relaxing state.

The current meta-analysis found low-level evidence that Tai Chi is associated with improved sleep, which in turn can reduce fatigue. This finding is consistent with results from a qualitative study, which qualitatively evaluated the effect of Tai Chi on older people [51].

Limitations and implications

There are several limitations to consider in the interpretation of results of this meta-analysis. First, the majority of included studies were subject to risks of bias and had small sample sizes. Methodological deficits included unclear description

of research design, the generation of random sequence, and the allocation of hidden and blindness. Although we aimed to evaluate the effect of Tai Chi for cancer survivors, the dominant types of cancer from original studies were breast cancer and lung cancer, which limit the generalizability of results to other cancer types. Second, the interventions included various types of Tai Chi, intervention dose, and frequency, as well as the outcome measures used, which impacted on the combined effect of the results. The optimal intervention dose for different types of Tai Chi needs further exploration. Further well-designed clinical trials with a larger sample size, evaluating different types and doses of Tai Chi interventions are warranted.

Third, the length of intervention and follow-up were short in most included studies, with few long-term effect evaluations. Fourth, there were different control groups across included studies, with most being active control groups, including routine rehabilitation training, sham Tai Chi, aerobic exercise, health education, support group, psychological support, or cognitive behavioral therapy. Four studies used usual care in the control group, which is arguably treated as an active control. In sensitivity analyses, the removal of study with cognitive behavioral therapy, health education, and standard support as the control group resulted in significant improvement in the positive effect of Tai Chi on the social domain of QOL, CRF, and sleep.

Conclusion

The current meta-analysis investigated the effects of Tai Chi on health outcomes of cancer survivors. There is low-level evidence suggesting a positive effect of Tai Chi on physical and mental functioning and sleep quality. This meta-analysis further identified moderate levels of evidence of the benefit of Tai Chi for upper limb function and muscle strength in breast cancer survivors. More well-designed trials with larger sample sizes comparing different Tai Chi types and doses are required to determine the most favorable Tai Chi regimens to improve limb function and muscular strength. The current study also identified moderate levels of evidence that Tai Chi could relieve CRF and reduce cortisol levels. More well-designed trials with larger sample sizes, with appropriate focus on social interaction and health education, are needed to verify these effects.

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Conflict of interest

Conflict of interest The authors declare that they have no conflict of interest.

Share of data We have full control of all meta-analysis data and we agree to allow the journal to review the data if requested.

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