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Tai Chi exercise for psychological well-being among adults with cardiovascular disease: A systematic review and meta-analysis

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Abstract

Background: Regular exercise is beneficial for adults with cardiovascular disease to improve psychological well-being. Tai Chi is a mind–body exercise thought to promote psychological well-being.

Aim: Examine the efficacy of Tai Chi in improving psychological well-being among persons with cardiovascular disease.

Methods: An electronic literature search of 10 databases (AMED, CINAHL, Embase, OpenGrey, PsycARTICLES, PsycINFO, PubMed, Scopus, SPORTDiscus, and Web of Science) was conducted. Clinical trials that examined one or more aspect of psychological well-being, incorporated a Tai Chi intervention among cardiovascular disease participants, and were published in English or German languages were included. Comprehensive Meta-Analysis version 2.0 software (Biostat, Inc.) was used to calculate the effect sizes (i.e. Hedges' *g*) and the 95% confidence intervals using random effects models.

Results: A total of 15 studies met the inclusion criteria, enrolling 1853 participants (mean age = 66 years old, 44% women). Outcomes included: quality of life (QOL), stress, anxiety, depression, and psychological distress. When Tai Chi was compared with controls, significantly better general QOL (Hedges' *g* 0.96; p=0.02, I^2=94.99%), mental health QOL (Hedges' *g*=0.20; p=0.01, I^2=15.93) and physical health QOL (Hedges' *g*=0.40; p=0.00, I^2=0%); with less depression (Hedges' *g*=0.69; p=0.00, I^2=86.64%) and psychological distress (Hedges' *g*=0.58; p=0.00, I^2=0%) were found.

Conclusions: Few Tai Chi studies have been conducted during the past decade examining psychological well-being among older adults with cardiovascular disease. Further research is needed with more rigorous study designs, adequate Tai Chi exercise doses, and carefully chosen outcome measures that assess the mechanisms as well as the effects of Tai Chi.

Keywords

Cardiovascular disease, meta-analysis, older adults, psychological well-being, quality of life, Tai Chi

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Introduction

Cardiovascular disease (CVD) is the leading cause of mortality globally, accounting for approximately one-third of all deaths.[1] In the United States, the prevalence of CVD comprising coronary heart disease, chronic heart failure, hypertension and stroke among adults of all ages is 48%, though among older adults, defined as 60 years and older, this increases significantly among both men and women.[2] However, when excluding hypertension, CVD prevalence among United States adults is estimated to be 9%.[2] Psychological well-being was reported to be associated with a 29% reduced risk of cardiovascular-related mortality.[3] However, psychological distress is prevalent among adults with CVD and includes decreased quality of life, along with increased symptoms of stress, anxiety, and depression.[2,4] Despite the availability of pharmacological and behavioral interventions, CVD patients continue to experience these undesirable psychological symptoms, which lead to poor quality of life.[5–7] For example, depressive symptoms are

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prevalent among 20% of coronary heart disease patients, 20% of chronic heart failure patients, 27% of hypertensive patients, and 35% of stroke survivors.[2,4,5,8] On the other hand, effective mind–body interventions, such as Tai Chi, that foster psychological well-being among CVD patients lead to better outcomes.[9]

Tai Chi exercise is a promising, relatively low cost, and easily accessible option for holistic CVD management.[10–12] Originating in China, Tai Chi (also called taiji or tai chi chuan) is a mind–body exercise combining a series of meditative, synergistic dance-like movements that promote energetic (Qi) balance, relaxation, and diaphragmatic breathing.[13] Tai Chi is generally considered a safe, low-impact, moderate-intensity exercise, making it a feasible option for individuals with CVD, including those with low exercise tolerance.[14–16] Previous studies demonstrate physiologic benefits of Tai Chi leading to reduced CVD risk such as lower systolic and diastolic blood pressure, resting heart rate, triglycerides, low-density lipoproteins, and inflammatory markers, and improved overall exercise capacity.[17] Prior research conducted across various chronic diseases indicates that Tai Chi leads to better psychological well-being, such as reducing symptoms of anxiety and depression and enhancing quality of life.[13,18]

In the past decade, there has been substantial research interest in Tai Chi evidenced by an increasing number of randomized clinical trials and reviews.[17,19] However, prior studies conducted among patients with CVD are exceedingly fragmented, and a collective assessment of Tai Chi impacting psychological well-being indicators such as quality of life, stress, anxiety, and depression among adults with CVD has not been conducted. This systematic review and meta-analysis seeks to add to the scientific literature by systematically collecting and assessing the efficacy of Tai Chi interventions published during the past decade, for improving quality of life, and reducing stress, anxiety, and depression among adults with coronary heart disease, chronic heart failure, hypertension, or stroke.

Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items of Systematic Reviews and Meta-analysis (PRISMA) guidelines,[20] and conforms with the principles outlined in the Declaration of Helsinki.

Literature search

An electronic literature search was conducted using the following databases: Allied and Complementary Medicine Database, Cumulative Index to Nursing and Allied Health Literature, Embase, OpenGrey, PsycARTICLES, PsycINFO, PubMed, Scopus, SPORTDiscus, and Web of Science. The following terms were utilized in the search: tai ji OR tai chi OR tai chi chuan AND coronary disease OR coronary artery disease OR cardiac rehabilitation OR myocardial infarction OR heart failure OR diastolic heart failure OR systolic heart failure OR hypertension OR stroke OR stroke rehabilitation OR cerebrovascular disorders AND quality of life OR psychological stress OR anxiety OR depression OR emotions. The search was limited to humans, clinical trials, full text articles, published in English or German languages between 11 July 2009 and 10 July 2019. An example of the search in PubMed can be found in Supplementary Material Appendix A online.

Eligibility criteria

Full-text articles employing a clinical trial study design, such as a randomized clinical trial (RCT) or quasi-experimental study with a comparison group, incorporating a Tai Chi exercise intervention, examining one or more aspect of psychological well-being, such as quality of life, psychological distress, stress, anxiety, and/or depression, among individuals with a CVD diagnosis (i.e. coronary heart disease, chronic heart failure, hypertension, or stroke) were included. There were no limits according to age, gender/sex, the type of control/comparison groups, or the Tai Chi intervention frequency, intensity, time, or type.

Data extraction

Two reviewers (RTP and BF) extracted data independently in a standardized manner. Data pertinent to location, study design, participant population, intervention and control/comparison groups, psychological well-being outcomes measured, and challenges to scientific rigor were collected. Inclusion and exclusion of studies were conducted in accordance with the PRISMA guidelines.[20]

Data synthesis

Comprehensive Meta-Analysis Version 2.0 software (Biostat, Inc., Englewood, New Jersey, USA) was used to calculate effect sizes (i.e. Hedges' *g*) and 95% confidence intervals using random-effects models, to estimate the mean of the distribution of effects that could have been observed (e.g. different participants or intervention protocols). Effect sizes were defined as follows: small = 0.20, medium =0.50, and large =0.80.[21] Using the random effects model, the individual study weights are more balanced, thus the summary effect is more conservative. In the random effects analysis the study-to-study variance (tau-squared) is assumed to be the same for all subgroups. This value is computed within subgroups and then pooled across subgroups. The ratio of true heterogeneity to total observed variation was also calculated using the I^2 statistic, as the number of studies in the analysis does not directly affect I^2. I^2 is not scale dependent but is expressed as a ratio ranging from 0% to 100% (25% = low, 50% = moderate, 75% = high heterogeneity).[22]

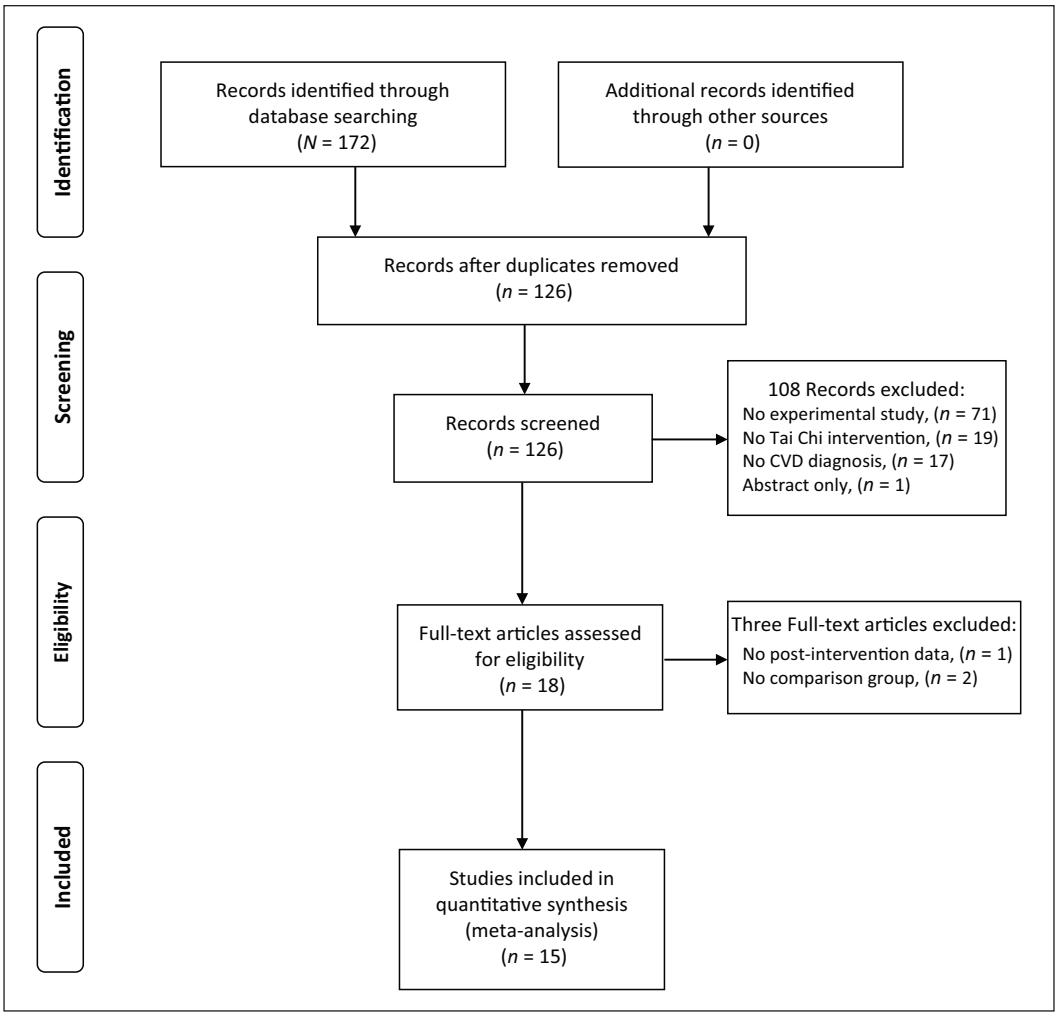

Figure 1. Preferred Reporting Items of Systematic Reviews and Meta-analysis flow chart.
CVD: cardiovascular disease

Risk of bias in individual studies

Two reviewers (RTP and BF) independently assessed the risk of bias of the individual randomized clinical trials using the Jadad scoring criteria.[23] Since it is not possible to double blind participants in a Tai Chi intervention, appropriate single blinding was assessed in relation to study personnel and outcome assessors.[24] Any discrepancy in scoring was reviewed until a consensus was reached.

Results

Literature search

Figure 1 summarizes the literature search and study selection process. The search identified a total of 172 potential articles. After removing 46 duplicates, 126 articles were screened for inclusion based on the title and abstract. After screening, a total of 108 articles were excluded. The main reasons for exclusions were due to the study design such as qualitative, descriptive, review papers, protocols, commentaries, not using a Tai Chi intervention, inappropriate study sample such as no CVD diagnosis, or no full-text article available.

Studies selected

A total of 15 clinical trials (13 RCTs,[25–37] two quasi-experimental studies with comparison groups[38,39]) met the inclusion criteria (Table 1). The majority of these studies were conducted in Asia (53.3%, *n*=8) or North America (33.3%, *n*=5), with the other studies conducted in Europe (13.3%, *n*=2). There were a total of 1853 participants enrolled, including two studies among coronary heart disease participants (*n*=164, mean age=65 years, 37% women),[25,38] five studies among chronic heart failure participants (*n*=530, mean age=68 years, 34% women),[26–29,39] four studies among participants with hypertension (*n*=930, mean age=62 years, 55% women),[30,31,32,33] and four

Table 1. Tai Chi exercise, quality of life and psychological well-being in cardiovascular disease: review of clinical trials.

First author[reference], year Location	Study design	Participant details	*N*	Intervention and control details	Measures	Results	Challenges to scientific rigor
Coronary heart disease							
Wieczorrek,[25] 2016 Germany	RCT	Cardiac rehab. patients Mean age=63 years 30% women	47	TC plus cardiac rehab., *n*=22 Unknown style, unknown postures Unknown sessions, 52 weeks Cardiac rehab. only, n=25 Unknown sessions, 52 weeks	QOL: SF-12 Anxiety: HADS Depression: HADS	No significant differences ($p>0.05$) in QOL, anxiety or depression between groups post-intervention Attrition=47% SAE=not reported Intervention Adherence: Cardiac rehab.=76% TC+ cardiac rehab.=67%	Internal validity: Intervention: potential inadequate dose Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity: Representativeness: primarily men with CHD Replication: interventions not well described
Park,[38] 2010 Korea	QE	Adults with CHD Mean age=66 years 43% women	117	TC with E, *n*=38 Yang+Sun style, 19 postures 24 sessions, 24 weeks Plus nutrition education 6 sessions, 24 weeks And stress management 6 sessions, 24 weeks TC only, *n*=30 Yang+Sun style, 19 postures 24 session, 24 weeks UC, *n*=49	QOL: SF-36	TC+E had significantly better perceived mental health (QOL) post-intervention ($p=0.02$) compared with controls Attrition=27% SAE=not reported Intervention Adherence: TC+E=88%, TC=83%	Internal validity: Intervention: potential inadequate dose Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity: Representativeness: primarily men with CHD Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors
Chronic heart failure							
Li,[26] 2019 China	RCT	Heart failure patients Mean age=65 years 57% women	326	TC, *n*=163 Yang style, 24 postures Unknown sessions, 24 weeks Controls, *n*=163 Aerobic exercise Unknown sessions, 24 weeks	QOL: SF-36 Anxiety: SAS Depression: SDS	TC had significantly higher QOL ($p<0.01$), less anxiety ($p<0.01$) and depression ($p<0.01$) post-intervention compared with controls Attrition=TC=21%, Controls=26% SAE=not reported Intervention adherence=not reported	Internal validity:: Intervention: potential inadequate dose, unknown adherence Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times External validity: Representativeness: adults living in China Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors
Yeh,[28] 2013 USA	RCT–pilot	Heart failure patients with preserved ejection fraction Mean age=66 years 50% women	16	TC, *n*=8 Yang style, 5 postures 24 sessions, 12 weeks Aerobic exercise, *n*=8 Stretching/strength training 24 sessions, 12 weeks	QOL: MLHF Psych. distress: POMS (lower score better)	TC had less depression (POMS-depression) post-intervention ($p=0.05$) compared with aerobic exercise Attrition=0% SAE=none Intervention adherence: TC=89%, aerobic exercise=88%	Internal validity: Intervention: potential inadequate dose Small sample: underpowered External validity: Representativeness: primarily White, older adults Interaction effects: potential treatment variation due to different instructors
Redwine,[39] 2012 USA	QE	Patients with heart failure Mean EF=35% Mean age=67 years 12% women	28	TC, *n*=16 Yang style, 17 postures 24 sessions, 12 weeks UC, *n*=12	Depression: BDI	TC had significantly less depression post-intervention ($F_{4,19}=4.5$, $p<0.05$, $eta^2=0.28$) compared with UC Attrition=14% (*n*=4, TC) SAE=not reported Intervention adherence: TC=87.5%	Internal validity: Intervention: potential inadequate dose Small sample: underpowered External validity: Representativeness: primarily White men

(Continued)

Table 1. (Continued)

First author[reference], year Location	Study design	Participant details	*N*	Intervention and control details	Measures	Results	Challenges to scientific rigor
Caminiti,[29] 2011 Italy	RCT–pilot	Chronic heart failure patients Mean EF=33% Mean age=74 years 15% women	60	TC +ET, *n*=30 Yang style, 10 postures 30 min, 24 sessions, 12 weeks Plus aerobic exercise (cycle or walk) 30 min, 24 sessions, 12 weeks ET, *n*=30 Aerobic exercise (cycle or walk) 30 min, 48 sessions, 12 weeks	QOL: MacNew QLMI (higher score better)	TC+ET had significantly better QOL post-intervention (p=0.03) compared with ET only Attrition=0% SAE=not reported Intervention adherence=not reported	Internal validity: Intervention: potential inadequate dose, unknown adherence Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity: Representativeness: primarily men with chronic heart failure Replication: interventions not well described
Yeh,[27] 2011 USA	RCT	Heart failure patients LVEF=29% Mean age=67 years 36% women	100	TC, *n*=50 Yang style, 5 postures 24 sessions, 12 weeks HE, controls, *n*=50 24 sessions, 12 weeks	QOL: MLHF Psych. distress: POMS (lower score better)	TC had significantly better QOL (p=0.02), negative mood ($p<0.01$), and depression ($p<0.01$) post-intervention compared with controls Attrition=3% SAE=18 (not related to intervention) Intervention adherence: TC=75%, HE=67%	Internal validity: Intervention: potential inadequate dose Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times External validity: Representativeness: primarily White men Interaction effects: potential treatment variation due to different instructors
Hypertension							
Shou,[30] 2019 China	RCT	Adults with HTN SBP ⩾140 <160 mmHg or DBP ⩾90 <100 mmHg No HTN meds Mean age=52 years 50% women	208	TC, *n*=104 Simplified style, 24 postures Unknown sessions, 12 weeks UC, *n*=104 12 weeks	QOL: SF-36	TC had better QOL post-intervention ($p<0.05$). *No between group analyses conducted* Attrition=5% SAE=not reported Intervention adherence=not reported	Internal validity: Intervention: potential inadequate dose Testing: potential bias as outcomes assessed multiple times External validity: Representativeness: adults living in China Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors
Ma,[40] 2018 China	RCT	Community-dwelling older adults on HTN meds Mean age=69 years 31% women	158	TC, *n*=79 Simplified style, 24 postures 10 sessions, 5 weeks; followed by peer-led TC classes 72–120 sessions, 24 weeks UC, *n*=79	QOL: SF-36 Depression: CES-D	TC had significantly better QOL ($p<0.01$), and less depression (p=0.02) post-intervention compared with UC Attrition=28.5% SAE=not reported Intervention adherence=not reported	Internal validity:: Intervention: potential inadequate dose, unknown adherence Mortality/attrition: differential dropout rates External validity: Representativeness: older adults living in China on HTN meds Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors
Chan,[32] 2018 Hong Kong	RCT	Adults with HTN plus 2–3 CVD risk factors Mean age=64 years 55% women	264	TC, *n*=82 Yang style, 24 postures 24 sessions, 12 weeks BW, *n*=82 150 min/week, 12 weeks Controls, *n*=82 UC	QOL: SF-12 Stress: PSS-10	TC had significantly better perceived physical health (QOL) post-intervention ($p<0.01$) compared with BW and controls TC had significantly less perceived stress post-intervention (p=0.02) compared with controls Attrition=11% SAE=not reported Intervention adherence ⩾80%: TC=90%, BW=88%	Internal validity: Intervention: potential inadequate dose Testing: potential bias as outcomes assessed multiple times External validity: Representativeness: adults living in Hong Kong

(Continued)

Table 1. (Continued)

First author[reference], year Location	Study design	Participant details	*N*	Intervention and control details	Measures	Results	Challenges to scientific rigor
Sun,[33] 2015 China	RCT	Adults with HTN 45–64 years=67% ⩾65 years=33% 82% women	300	TC, *n*=150 Unknown style, unknown postures 156 sessions, 52 weeks Controls, *n*=150 (reading/learning computers) 156 sessions, 52 weeks	QOL: SF-12	TC had significantly better perceived physical health (QOL) post-intervention (p=0.05) compared with controls Attrition=11% SAE=not reported Intervention adherence=not reported	Internal validity: Intervention: potential inadequate dose Testing: potential bias as outcomes assessed multiple times External validity: Representativeness: mainly retired women living in China Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors
Stroke survivors							
Kim,[34] 2015 Korea	RCT	Hospitalized stroke patients Mean age=54 years 41% women	22	TC, *n*=11 Unknown style, 10 postures 12 sessions, 6 weeks PT, *n*=11 General physical therapy, 6 weeks	QOL: SF-36	TC had significantly better QOL ($p<0.01$) post-intervention compared with PT Attrition=0% SAE=not reported Intervention adherence=not reported	Internal validity: Intervention: potential inadequate dose Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity: Representativeness: primarily men living in Korea Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors
Taylor-Piliae,[35] 2014 USA	RCT	Community dwelling stroke survivors Mean age=70 years 47% women	145	TC, *n*=53 Yang style, 24 postures 36 sessions, 12 weeks SilverSneakers, *n*=44 Strength and ROM 36 sessions, 12 weeks UC, *n*=48 Written PA materials plus phone call 12 sessions, 12 weeks	QOL: SF-36 Depression: CES-D	No significant between group differences post-intervention Attrition=10% SAE=1 (not related to intervention) Intervention adherence: TC=82%, SilverSneakers=81%, UC=93%	Internal validity: Intervention: potential inadequate dose Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times External validity: Representativeness: primarily White, well-educated men
Taylor-Piliae,[36] 2012 USA	RCT–pilot	Community dwelling stroke survivors Mean age=68 years 48% women	28	TC, *n*=16 Yang style, 24 postures 36 sessions, 12 weeks UC, *n*=12 Written PA materials plus phone call 12 sessions, 12 weeks	QOL: SF-36 Depression: CES-D	No significant between group differences post-intervention. Attrition=11%, TC, *n*=3 SAE=1 (not related to intervention) Intervention adherence: TC=92%, UC=99%	Internal validity: Intervention: potential inadequate dose Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity: Representativeness: primarily White, well-educated men
Wang,[37] 2010 Japan	RCT	Older stroke survivors Mean age=77 years 69% women	34	TC, *n*=17 Yang style, unknown postures 12 sessions, 12 weeks Stroke rehab. *n*=17 Aerobics/resistance training	QOL: GHQ-60 GHQ-Depression (lower score better)	TC had significantly better QOL (p=0.01) and less depression (p=0.02) post-intervention compared with stroke rehab. Attrition=15% SAE=not reported Intervention adherence=not reported	Internal validity: Intervention: potential inadequate dose Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity: Representativeness: primarily older women, living in Japan Replication: interventions not well described Interaction effects: potential treatment variation due to different instructors

BDI: Beck Depression Inventory; BW: brisk walking; CES-D: Center for Epidemiologic Studies Depression Scale; CHD: coronary heart disease; CVD: cardiovascular disease; DBP: diastolic blood pressure; E: education; EF: ejection fraction; ET: endurance training; GHQ: General Health Questionnaire; HADS: Hospital Anxiety and Depression Scale; HE: health education; HTN: hypertension; LVEF: left ventricular ejection fraction; MacNew QLMI: Quality of Life after Myocardial Infarction questionnaire; MLHF: Minnesota Living with Heart Failure questionnaire; PA: physical activity; POMS: Profile of Mood States; PSS: Perceived Stress Scale; Psych.: psychological; PT: physical therapy; QE: quasi-experimental; QOL: quality of life; RCT: randomized clinical trial; rehab.: rehabilitation; ROM: range of motion; SAE: serious adverse event; SAS : Self-rating Anxiety Scale; SBP: systolic blood pressure; SDS: Self-rating Depression Scale; SF: Short Form; TC: Tai Chi; UC: usual care

Table 2. Risk of bias for the individual randomized clinical trials.

Jadad scoring criteria	Wieczorrek, 2016	Li, 2019	Yeh, 2013	Caminiti, 2011	Yeh, 2011	Shou, 2019	Ma, 2018	Chan, 2018	Sun, 2015	Kim, 2015	Taylor-Piliae, 2014	Taylor-Piliae, 2012	Wang, 2010
Randomization	2	2	2	2	2	1	2	2	1	1	2	2	1
Blinding[a]	0	0	2	0	2	0	1	2	2	0	2	2	2
Withdrawals/ dropouts	1	1	1	1	1	1	1	1	1	0	1	1	1
Score	**3**	**3**	**5**	**3**	**5**	**2**	**4**	**5**	**4**	**1**	**5**	**5**	**4**
Risk of bias	Low	Low	Low	Low	Low	*High*	Low	Low	Low	*High*	Low	Low	Low

Jadad scoring ⩾3=low risk of bias, <3=high risk of bias (range 0–5).[23]
[a]Appropriate single-blinding.[24]

studies among stroke survivors (*n*=229, mean age=67 years, 51% women).[34–37]

Tai Chi intervention

The Yang style of Tai Chi was most commonly practiced in these studies (*n*=9, 60%). The study intervention length varied greatly, ranging from six to 52 weeks (mean=17 weeks), with on average 36 sessions provided (range=12–156). Intervention adherence was reported by only 53.3% of these studies (*n*=8). Among the studies reporting intervention adherence rates, the average was approximately 83% though wide-ranging rates were reported (67–92%) (Table 1).

Control conditions

Usual care (*n*=8 studies) was the most common control condition, followed by some type of other exercise (*n*=6 studies), or an education-control (*n*=1 study). Adherence rates to these control conditions were reported by only 40% of these studies (*n*=6). Among these studies the average adherence rate was approximately 85%, though widespread rates were reported (67–99%) (Table 1).

Outcomes measures

These studies assessed quality of life (*n*=14 studies), psychological distress (*n*=2 studies), stress (*n*=1 study), anxiety (*n*=2 studies), and depression (*n*=7 studies). Quality of life was assessed using a variety of measures including the Minnesota Living with Heart Failure Questionnaire, the Short Form Health Survey, or the MacNew Quality Of Life after Myocardial Infarction Questionnaire. Psychological distress was assessed using the Profile of Mood States. Stress was assessed using the Perceived Stress Scale, while anxiety was assessed using either the Hospital Anxiety Scale or the Self-Rating Anxiety Scale. Depression was assessed using a variety of measures including the Beck Depression Index, Hospital Depression Scale, the Center for Epidemiologic Studies Depression Scale, General Health Questionnaire-Depression, POMS-Depression, or the Self-Rating Depression Scale (Table 1).

Methodological quality of RCTs and risk of bias

The study quality of the 13 RCTs using the Jadad scale[23] criteria was on average acceptable (mean score=3.8, range=1–5). However, two of the RCTs[30,34] did not describe the randomization method or whether blinding was used, indicating a high risk of bias (Table 2).

Synthesis of results

Meta-analyses were conducted for CVD overall and then according to type of CVD, when there was >1 study for the outcomes of interest: general quality of life (QOL) (*n*=6 studies), perceived mental health QOL (*n*=8 studies), perceived physical health QOL (*n*=8 studies), depression (*n*=9 studies), anxiety (*n*=2 studies), and psychological distress (*n*=2 studies), comparing Tai Chi with controls.

QOL. A significant large effect for better general QOL was observed overall (Hedges' *g*=0.96; *p*=0.02, I^2=94.99%) when Tai Chi was compared with controls (Figure 2(a)). When examining general QOL according to type of CVD, better general QOL was not significant (Hedges' *g*=1.00; *p*=0.14, I^2=96.75%) among chronic heart failure participants (*n*=4 studies). There was only one study examining general QOL among hypertensive participants (Hedges' *g*=0.94; *p*=0.00) and only one study among stroke survivors (Hedges' *g*=0.75; *p*=0.03), thus additional meta-analyses were not conducted. When examining better mental health QOL, only a small significant effect was observed overall (Hedges' *g*=0.20; *p*=0.01, I^2=15.93%) when Tai Chi was compared with controls (Figure 2(b)). When examining mental health QOL according to type of CVD, a significant moderate effect for better mental health QOL was observed (Hedges' *g*=0.46; *p*=0.03, I^2=0%) among coronary heart disease participants (*n*=2 studies), yet this was not significant among hypertensive (*n*=3 studies, Hedges' *g*=0.13; *p*=0.13, I^2=0%) or stroke participants

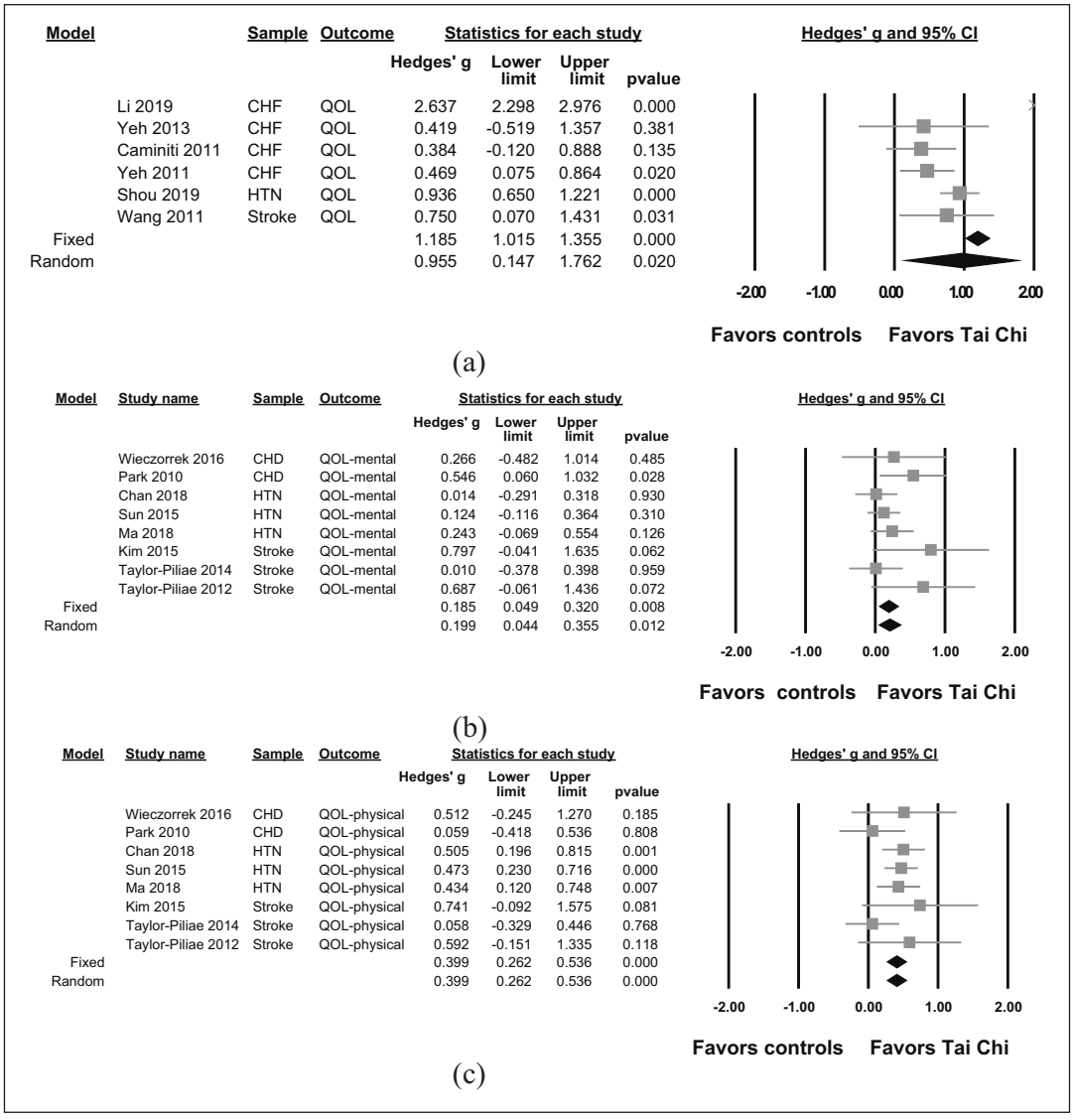

Figure 2. Quality of life meta-analysis. (a): General quality of life, (b) mental health quality of life, (c) physical health quality of life.
CHD: coronary heart disease; CHF: chronic heart failure; CI: confidence interval; HTN: hypertension; QOL: quality of life

(n=3 studies, Hedges' g=0.40; p=0.15, I^2=54.76%). Finally, when examining better physical health QOL, a significant moderate effect was observed overall (Hedges' g=0.40; p=0.00, I^2=0%) when Tai Chi was compared with controls (Figure 2(c)). When examining physical health QOL according to type of CVD, a significant moderate effect for better physical health QOL was observed (Hedges' g=0.47; p=0.00, I^2=0%) among hypertensive participants (n=3 studies), though this was not significant among coronary heart disease (n=2 studies, Hedges' g=0.19; p=0.36, I^2=0%) or stroke participants (n=3 studies, Hedges' g=0.34; p=0.13, I^2=35.23%).

Psychological distress. A significant moderate effect for less depression was observed overall (Hedges' g=0.69; p=0.00, I^2=86.64%) when Tai Chi was compared with controls (Figure 3(a)). When examining depression according to type of CVD, a significantly large effect was observed for less depression among chronic heart failure participants (n=4 studies, Hedges' g=1.07; p=0.00, I^2=86.99%), though less depression was not observed among stroke participants (n=3 studies, Hedges' g=0.45; p=0.07, I^2=50.20%). There was only one study examining depression among coronary heart disease participants (n=1 study, Hedges' g=0.10; p=0.79) and only one study among hypertensive participants (Hedges' g=0.39; p=0.02), thus additional meta-analyses were not conducted. When examining anxiety (n=2 studies), a large but non-significant effect was observed (Hedges' g=1.36; p=0.22, I^2=96.43%) when Tai Chi was compared with controls (Figure 3(b)). When examining anxiety according to type of CVD, there was only one study examining anxiety among coronary heart disease participants (Hedges' g=0.23; p=0.55) and one study

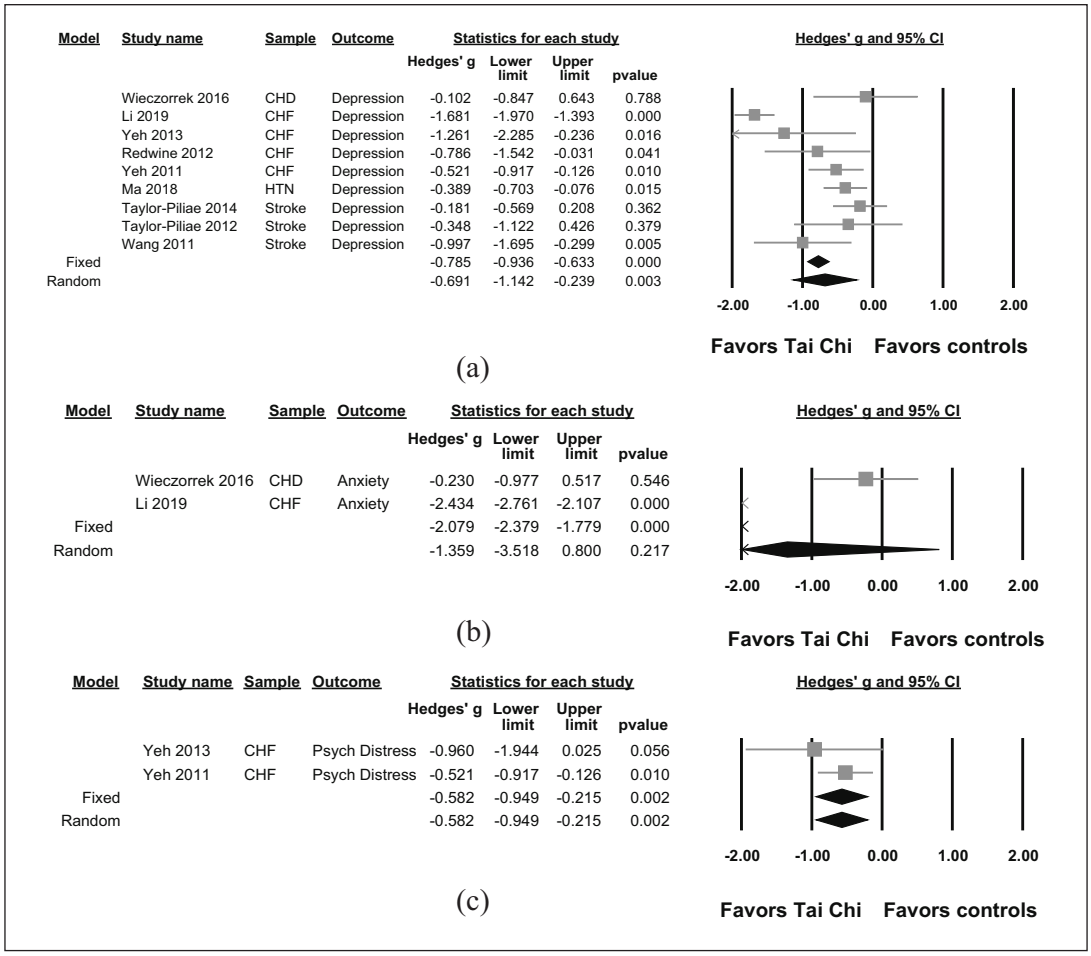

Figure 3. Psychological distress meta-analysis. (a) Depression, (b) anxiety, (c) psychological distress.
CHD: coronary heart disease; CHF: chronic heart failure; CI: confidence interval; HTN: hypertension

among chronic heart failure participants (Hedges' g=2.43; p=0.00), thus additional meta-analyses were not conducted. When examining psychological distress, only studies conducted among chronic heart failure participants were found (n=2 studies), with a moderately significant effect observed for less psychological distress (Hedges' g=0.58; p=0.00, I^2=0%) when Tai Chi was compared with controls (Figure 3(c)).

Reports of safety and adverse events

A total of three of these clinical trials reported adverse events that occurred during the study, though none was attributable to the Tai Chi intervention.[27,35,36] One study reported no adverse events,[28] while the majority of these studies (n=11, 69%) failed to report whether there were any adverse events.

Discussion

This is the first systematic review and meta-analysis of clinical trials written in English and German languages published during the past decade to assess the efficacy of Tai Chi exercise interventions for improving psychological well-being among adults with CVD. Overall, the meta-analysis results indicate that Tai Chi interventions among older adults (60 years of age and older) with CVD led to significantly better quality of life, along with less depression and psychological distress, compared with controls. Our findings are similar to another systematic review and meta-analysis examining psychological benefits of Traditional Chinese Exercise (i.e. Tai Chi, Qigong or Baduanjin), which reported better QOL and less depression among adults with CVD.[40] Further, our results are similar to other mind–body exercise intervention studies which have examined the effect of Yoga on quality of life, depression and anxiety among adults with chronic heart failure, hypertension or stroke.[41–44] While Yoga is a safe, mind–body exercise, relatively few studies have assessed psychological well-being among adults with CVD.

In this study, we observed distinctive benefits from Tai Chi practice, according to CVD diagnosis. In our study, coronary heart disease participants in the Tai Chi

groups had significantly better mental health QOL compared with controls. This finding is consistent with a recent meta-analysis reporting better QOL among persons with coronary heart disease following Tai Chi-based cardiac rehabilitation.[45] However, in our study, chronic heart failure participants in the Tai Chi groups did not have a significant improvement in QOL, but had significantly less depression and psychological distress, compared with controls. These results are similar to findings in a prior meta-analysis examining the benefits of Tai Chi among adults with chronic heart failure,[46] though are in contrast to other meta-analyses reporting significantly better QOL in Tai Chi participants among adults with chronic heart failure.[47,48] In our study, we found hypertensive participants in Tai Chi groups had significantly better physical health QOL compared with controls. To our knowledge this is a novel finding among adults with hypertension. Among stroke survivors in the Tai Chi groups in our study, a non-significant moderate effect for less depression was observed compared with controls. Prior meta-analyses examining the benefits of Tai Chi among stroke survivors have primarily focused on physical function, such as balance and gait.[49,50] Absent from the literature are prior meta-analyses examining the effect of Tai Chi on psychological well-being among stroke survivors.

Tai Chi is an affordable, non-pharmacological approach to facilitate psychological well-being among individuals with CVD,[5] although not all studies have reported benefits and study quality remains inconsistent. Among the studies included in this meta-analysis, challenges to scientific rigor identified potential internal and external validity weaknesses. Internal validity weaknesses comprised unknown intervention adherence rates with potentially inadequate Tai Chi doses, differential drop-out rates among groups, potential testing bias as outcomes were assessed multiple times, and small samples with insufficient power to detect significant differences between groups. External validity weakness encompassed the limited representativeness of the study samples to the general population, study replication difficulties as the interventions were not well described, and possible interaction effects as treatment variation was possible due to different instructors. Going forward, it is important that the methodological standards of future studies be improved, better reporting of key design features such as randomization methods, blinding, or adverse events.[40] Further, future studies should report features specifically relevant to Tai Chi studies, including type of Tai Chi style, number of postures, intervention dose, and adherence rates.

Limitations

There are a number of limitations to this study. First, our analyses were limited to published studies in English and German languages, which may have omitted other important research evidence. Second, high heterogeneity was observed for several of these outcomes, indicating inconsistent findings across studies. Third, women were underrepresented in the coronary heart disease and chronic heart failure studies, limiting generalizability. Finally, some studies with poorer methodological quality were included in this review. However, this systematic review and meta-analysis was conducted following established PRISMA guidelines, with two independent reviewers conducting the literature search, abstracting the data, and assessing the risk of bias for the RCTs.

Suggestions for future research

Future research is needed to help establish behavioral, biological, and environmental mechanisms through which psychological factors influence CVD and to identify effective treatments, such as Tai Chi, to reduce their impact on morbidity and mortality. In addition, further research is needed to explore potential mechanisms of how Tai Chi improves psychological well-being, especially among adults with CVD.[4,9]

Conclusions

Among older adults with CVD, Tai Chi was effective in improving psychological well-being, with significantly better quality of life, along with less depression and psychological distress found, when compared with controls. However, these improvements were different according to CVD diagnosis. Tai Chi participants with coronary heart disease had better mental health QOL, chronic heart failure participants had less depression and psychological distress, while those with hypertension had better physical health QOL; compared with controls. Further research is needed with more rigorous study designs, adequate descriptions of important Tai Chi exercise intervention features, and carefully chosen outcome measures that assess the mechanisms, as well as the effects, of Tai Chi for improving psychological well-being.

Implications for practice

- Tai Chi is a safe, low-cost mind-body exercise that facilitates better psychological well-being.
- Meta-analytic evidence indicates that Tai Chi interventions among adults with coronary heart disease or hypertension lead to better quality of life with less depression and psychological distress among adults with chronic heart failure when compared with controls.
- Meta-analytic evidence indicates that Tai Chi did not significantly improve quality of life or reduce depression among stroke survivors when compared with controls.

Declaration of conflicting interests

The authors have no conflicts of interest to declare.

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