Journal of Cardiovascular Nursing
Vol. 00, No. 0, pp. 00–00 | Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.

Benefits of Tai Chi Exercise Among Adults With Chronic Heart Failure

A Systematic Review and Meta-Analysis

Ruth Taylor-Piliae, PhD, RN, FAHA, FAAN; Brooke A. Finley, MSN, PMHNP-BC, RN-BC

Downloaded from https://journals.lww.com/jcnjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i1H1ZzW/4XwuXLgAgArpyaZPkM2xubX9CC3pLED7g= on 07/02/2020

Background: Exercise-based cardiac rehabilitation is safe and effective for adults with chronic heart failure (CHF), yet services are greatly underutilized. However, tai chi is a popular and safe form of exercise among older adults with chronic health conditions. **Objective:** A systematic review and meta-analysis was conducted to examine the benefits of tai chi exercise among persons with CHF. **Methods:** An electronic literature search of 10 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) was conducted from January 1, 2004, to August 1, 2019. Clinical trials that examined tai chi exercise, were published in English or German languages, and conducted among participants with CHF were included. Comprehensive Meta-Analysis version 2.0 software (Biostat, Inc) was used to calculate effect sizes (ie, Hedges *g*) and 95% confidence intervals using random effects models. **Results:** A total of 6 studies met the inclusion criteria, enrolling 229 participants (mean age, 68 years; 28% women; mean ejection fraction = 37%). At least 3 studies reported outcomes for exercise capacity (n = 5 studies), quality of life (n = 5 studies), depression (n = 4 studies), and b-type natriuretic peptide (n = 4 studies), allowing for meta-analysis. Compared with controls, tai chi participants had significantly better exercise capacity ($g = 0.353$; $P = .026$, $I^2 = 32.72\%$), improved quality of life ($g = 0.617$; $P = .000$, $I^2 = 0\%$), with less depression ($g = 0.627$; $P = .000$, $I^2 = 0\%$), and decreased b-type natriuretic peptide expression ($g = 0.333$; $P = .016$, $I^2 = 0\%$). **Conclusion:** Tai chi can be easily integrated into existing cardiac rehabilitation programs. Further research is needed with rigorous study designs and larger samples before widespread recommendations can be made.

KEY WORDS: depression, exercise tolerance, heart failure, meta-analysis, quality of life

Heart failure is a global, chronic health problem affecting at least 26 million people worldwide and is increasing in prevalence, owing to advances in treatment modalities along with an aging population.[1] In the United States, an estimated 6.2 million adults have chronic heart failure (CHF). Among adults 65 years and older, the incidence of heart failure is estimated to affect 21 in 1000 older adults. By the year 2030, CHF prevalence is expected to increase to 8 million adults, with direct costs expected to reach $69.8 billion in the United States.[2] Adults with CHF frequently experience low exercise tolerance, poor quality of life (QOL), depression, and recurrent hospitalizations and are at greater risk for morbidity and mortality.[3,4]

Exercise-based cardiac rehabilitation is safe and effective for patients with CHF, with improved exercise tolerance, better QOL, and fewer CHF-related hospitalizations reported.[4,5] Among older adults with CHF, reported benefits of cardiac rehabilitation include better physical function (eg, balance and gait speed) and improved exercise capacity and QOL, with less depression and social isolation.[4] A recent systematic review and meta-analysis among adults with CHF having either reduced (<45%) ejection fraction or those with preserved (≥45%) ejection fraction found that exercise-based cardiac rehabilitation was effective in reducing overall hospitalizations (risk ratio, 0.70; 95% confidence interval [CI], 0.60–0.83) and improving QOL (standard mean difference, –0.60; 95% CI, –0.82

Ruth Taylor-Piliae, PhD, RN, FAHA, FAAN
Associate Professor, College of Nursing, University of Arizona, Tucson.
Brooke A. Finley, MSN, PMHNP-BC, RN-BC
Doctoral Student, College of Nursing, University of Arizona, Tucson; Nurse Practitioner, The Meadows Behavioral Health, Wickenburg; and FasPsych, LLC, Scottsdale, Arizona.

The authors have no funding or conflicts of interest to disclose.

Correspondence
Ruth Taylor-Piliae, PhD, RN, FAHA, FAAN, College of Nursing, University of Arizona, 1305 N Martin Ave, PO Box 210203, Tucson, AZ 85721-0203 (rtaylor@nursing.arizona.edu).

DOI: 10.1097/JCN.0000000000000703

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

to −0.39; I^2 = 87%), despite different types of exercise, doses, or delivery methods (eg, home vs clinic).[3] However, cardiac rehabilitation services are greatly underused among adults with CHF, with only 10% (heart failure with reduced ejection fraction = 12.2%, heart failure with preserved ejection fraction = 8.8%) receiving a referral to cardiac rehabilitation upon discharge from hospital.[6,7]

Tai chi is a promising adjunct to exercise-based cardiac rehabilitation for adults with CHF.[8–10] As a low-impact, low- to moderate-intensity exercise originating in China, tai chi is suitable for older adults to perform, including those with chronic health conditions or poor exercise tolerance.[11,12] According to a systematic review examining adverse events reported in tai chi intervention studies,[13] tai chi is a safe form of exercise. Reported adverse events were typically minor and primarily musculoskeletal related (eg, knee or back pain), whereas no intervention-related serious adverse events as a result of participation in tai chi were reported.[13] Reported benefits of tai chi exercise include improved physical function such as reduced blood pressure among hypertensive adults,[14,15] better balance, strength and flexibility,[16,17] fewer falls,[18,19] and improved aerobic endurance.[20,21] Other reported benefits include improved cognitive function,[22] less stress, anxiety, depression, and better QOL.[10,23] Qualitative research conducted among adults with CHF confirms these findings, relating better physical and mental health, such as walking ability, energy, social support, and empowerment, after participation in a tai chi intervention.[24,25] Given the reported benefits, there has been increasing interest in using tai chi exercise for adults with CHF.

To date, a total of 4 meta-analyses focused on CHF have been conducted, examining the effectiveness of tai chi.[12,26–28] However, these meta-analyses were limited in scope (eg, search limited to 2 or 4 databases),[12,27] included data from the same study twice (second article was a secondary analysis reporting outcome data on the same participants),[26,28] or included studies with a high risk of bias (lack of allocation concealment and blinding of outcome assessors absent).[26,28] Thus, the aim of this systematic review and meta-analysis was to address these issues, examining clinical trials published during the past 15 years, to assess the potential benefits of tai chi exercise among persons with CHF.

METHODS

This systematic review and meta-analysis is reported in accordance with the Preferred Reporting Items of Systematic Reviews and Meta-analysis guidelines[29] 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 heart failure OR cardiac failure OR chronic heart failure OR congestive heart failure. The search was limited to humans, clinical trials, full-text articles, and published in English or German languages between January 1, 2004, and August 1, 2019. The search was limited to the past 15 years, given the advances in diagnostic modalities and treatment of heart failure, as newly developed medications and devices for heart failure have been widely adopted in clinical practice, unlike in years before 2004.[30] An example of the search in PubMed can be found in Appendix A.

Eligibility Criteria

Full-text articles using a clinical trial study design (ie, randomized clinical trial [RCT] or quasi-experimental study with a comparison group), incorporating a tai chi exercise intervention, among individuals with heart failure (all types) were included. There were no limits according to age, gender/sex, outcome, the type of control/comparison groups, or the tai chi intervention frequency, intensity, time, or type.

Study Selection

After removing duplicates of articles retrieved, 2 reviewers (RTP and BF) independently screened the titles and abstracts of potentially eligible articles to determine whether the articles satisfied the eligibility criteria. After initial screening, full-text manuscripts of potential articles were retrieved and reviewed in detail according to eligibility criteria.

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, outcomes measured, and challenges to scientific rigor were recorded. Inclusion and exclusion of studies were conducted in accordance with the Preferred Reporting Items of Systematic Reviews and Meta-analysis guidelines.[29]

Data Synthesis

Comprehensive Meta-Analysis Version 2.0 software (Biostat, Inc, Englewood, New Jersey) was used to calculate effect sizes (ie, Hedges *g*) and 95% CIs using random-effects models, to estimate the mean of the distribution of effects that could have been observed (eg, different participants or intervention protocols). Hedges *g* was used to calculate the standardized mean difference and is similar to Cohen *d*, but with an adjustment to

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

correct bias inherent when using Cohen *d* with small sample sizes.[31] Using the random effects model, the individual study weights are more balanced; thus, the summary effect is more conservative. In addition, 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). Meta-analyses were conducted when at least 3 studies reported the same outcome.

Study Quality of Individual Studies

Study quality was assessed using a modified version[32] of the Downs and Black Quality Index checklist.[33] The Quality Index checklist is widely used with established psychometric properties for determining the methodological quality of both RCTs and nonrandomized studies.[34–36] The Quality Index checklist contains 27 items to evaluate reporting (10 items), external validity (3 items), bias (7 items), confounding (6 items), and power (1 item) of published studies. In 2005, the Agency for Healthcare Research and Quality used a modified version of Downs and Black Quality Index checklist for an evidence report on perinatal depression.[32] The modified Quality Index checklist simplified the 1-item power question. All of the items are scored either as a 1 (yes) or 0 (no or unable to determine), except for 1 item reporting the distribution of potential confounders (yes = 2, partial = 1, no = 0) and the single item on power, which is scored from 0 to 2 (ie, power analysis conducted: yes, ≥2 outcomes = 2; yes, 1 outcome = 1; no = 0). Possible scores range from 0 to 29, with the higher score representing a higher quality study (low quality = score ≤14, moderate quality = score 15–23, high quality = score ≥24). Two reviewers (RTP and BF) independently assessed the studies using the modified Downs and Black Quality Index checklist.[32] 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 127 potential articles. After removing 45 duplicates, 82 articles were screened for inclusion based on the title and abstract. After screening, a total of 72 articles were excluded. The main reasons for exclusions were the study design (eg, qualitative, descriptive, review papers, protocols, commentaries), not using a tai chi intervention, inappropriate study sample (ie, no heart failure diagnosis), or no full-text article available (eg, abstract only).

Studies Selected

A total of 6 clinical trials (5 RCTs[37–41] and 1 quasi-experimental study with a comparison group[42]) met the inclusion criteria (Table 1). These studies were conducted in North America (67%, n = 4) or Europe (33%, n = 2), and all were published in English. A total of 299 participants with CHF enrolled in these studies. These participants were on average 68 years old and most were men (72%). Participants had on average a New York Heart Association functional class II, although it ranged from I to IV, with left ventricular ejection fraction ranging from 23% to 63.5%.

Tai Chi Intervention

The Yang style of tai chi was most commonly practiced in these studies (n = 5, 83%), whereas 1 study used the Wu style of tai chi.[37] The study intervention length for most studies (n = 5, 83%) was 12 weeks with 2 sessions provided each week (total = 24 sessions), whereas 1 study had a 16-week intervention with 2 sessions each week (total = 32 sessions).[37] Intervention adherence was only reported by 67% of these studies (n = 4). Among the studies reporting intervention adherence rates, the average was approximately 84% (range, 75%–89%; Table 1).

Control Conditions

Usual care (n = 3 studies) was the most common control condition, followed by other aerobic exercise (n = 2 studies) or a health education-control (n = 1 study). Adherence rates to these control conditions were reported by only 33% of these studies (n = 2), with adherence rates of 67% or 88% reported (Table 1).

Outcomes Measures

These studies mainly assessed exercise capacity (n = 5 studies), QOL (n = 5 studies), depression (n = 4 studies), and B-type natriuretic peptide (n = 4 studies). Other reported outcomes were echocardiograms,[41] physical activity,[39,41] exercise self-efficacy,[39,41] fatigue,[42] lower body strength,[38] fall risk,[39] plasma norepinephrine,[40] and 24-hour electrocardiograms.[40]

Meta-analyses were conducted when there were at least 3 studies reporting the same outcome. Exercise capacity was assessed using a variety of measures including cycle ergometers, a 6-minute walk test, or an incremental shuttle walk test. The 6-minute walk test or the incremental shuttle walk test data were used to quantify exercise capacity in the meta-analysis. Quality of life was assessed using either the Minnesota Living With Heart Failure Questionnaire, a visual analog scale, or the MacNew Quality of Life After Myocardial Infarction questionnaire. The Minnesota Living With Heart Failure Questionnaire or the visual analog scale was used to quantify QOL in the meta-analysis.

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

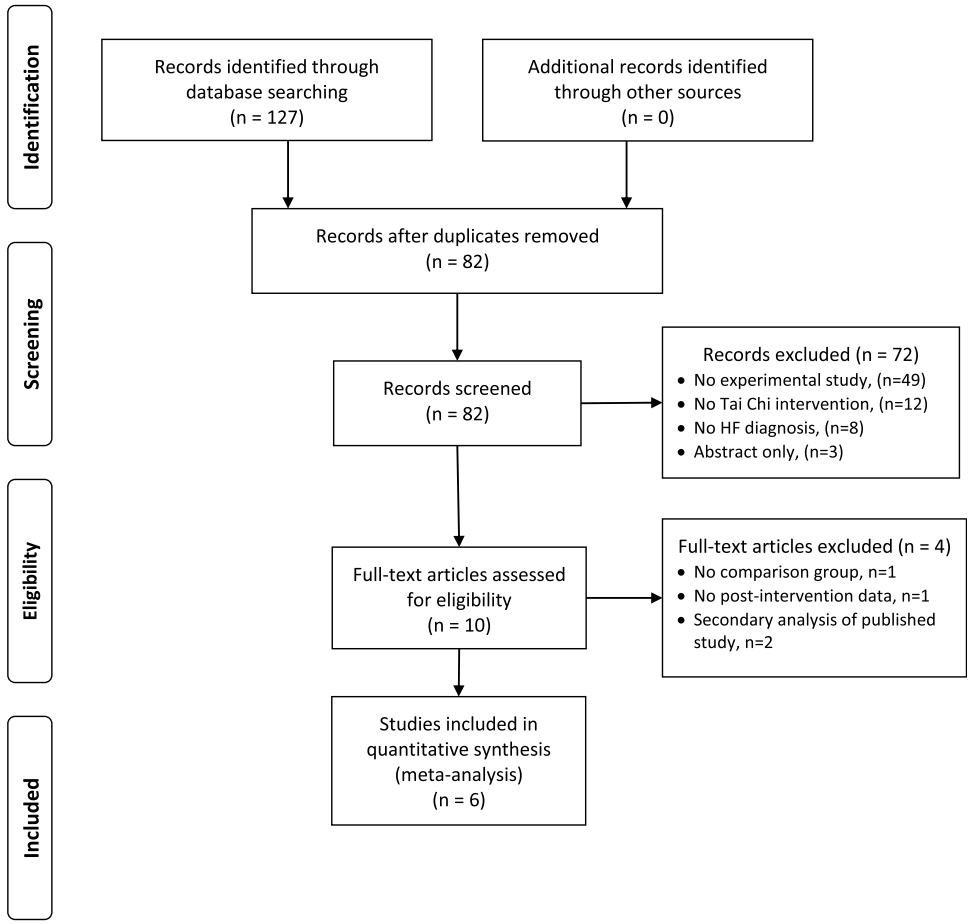

FIGURE 1. *Preferred Reporting Items of Systematic Reviews and Meta-analysis flow chart.*

Depression was assessed using the Profile of Mood States depression scale, the Beck Depression Inventory, or the Symptom Checklist-90-Revised depression scale. B-type natriuretic peptide was assessed using a commercially available fluorescence immunoassay, whereas N-terminal pro-B type natriuretic peptide was assessed using an electrochemiluminescence immunoassay (Table 1).

Methodological Quality of the Individual Studies

The average study quality of the clinical trials using the modified Downs and Black Quality Index checklist[32] was moderate (mean score, 23; range, 18–27; Table 2). Among the studies included in this meta-analysis, potential internal and external validity weaknesses identified challenges to scientific rigor. Internal validity weaknesses comprised unknown intervention adherence rates with potentially inadequate tai chi doses, differential dropout 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, study replication difficulties as some interventions were not well described, along with possible interaction effects as treatment variation was possible because of different instructors (Table 1).

Synthesis of Results

Meta-analyses were conducted for exercise capacity, QOL, depression, and B-type natriuretic peptide, as at least 3 studies assessed these outcomes. When tai chi was compared with controls, a significant small effect for better exercise capacity (Hedges g = 0.353; P = .026, I^2 = 32.72%; Figure 2A), a significant moderate effect for better QOL (g = 0.617; P = .000, I^2 = 0%; Figure 2B), a significant moderate effect for less depression (g = 0.627; P = .000, I^2 = 0%; Figure 2C), and a significant small effect for lower B-type natriuretic peptide expression (g = 0.333; P = .016, I^2 = 0%; Figure 2D) were found.

Reports of Safety and Adverse Events

A total of 3 clinical trials reported serious adverse events that occurred during the study period, although none were attributable to the tai chi intervention or

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

TABLE 1 Tai Chi Exercise and Heart Failure: Review of Clinical Trials

First Author, Year, Location	Study Design	Participant Details	N	Intervention/Control Details	Measures	Results	Challenges to Scientific Rigor
Yeh,[41] 2013, United States	RCT-pilot	Patients with heart failure with persevered ejection fraction Mean LVEF = 63.5% Mean NYHA symptom class II, range = 1–3 Mean age = 66 y 50% women	16	TC, n = 8 Yang style, 5 postures 24 sessions, 12 wk Aerobic exercise (AE), n = 8 Stretching/strength training 24 sessions, 12 wk	Exercise capacity: cycle ergometer and 6MWT QOL: MLHFQ Depression: POMS-D Biomarkers: BNP Other Echocardiography: E/A and E/e' Exercise self-efficacy Physical activity: CHAMPS	TC had significantly better 6MWT ($P = .02$), and less depression ($P = .05$) postintervention, compared with AE. There were no significant differences ($P > .05$) in QOL or BNP between groups postintervention. Attrition = 0% SAE = none Intervention adherence: TC = 89%, AE = 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,[42] 2012, United States	QE	Patients with heart failure, NYHA symptom class II Mean EF = 35% Mean age = 67 y 12.5% women	28	TC, n = 16 Yang style, 17 postures 24 sessions, 12 wk Usual care (UC), n = 12	Depression: BDI Other Fatigue: MFSI-SF	TC had significantly less depression postintervention ($F_{4,19} = 4.5$, $P < .05$, $\eta^2 = 0.28$) and less fatigue ($F_{4,19} = 4.2$, $P < .05$, $\eta^2 = 0.43$) compared with usual care. 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
Caminiti,[38] 2011, Italy	RCT-pilot	Patients with chronic heart failure Mean EF = 33% Mean age = 74 y 15% women	60	TC plus endurance training (ET), n = 30 Yang style, 10 postures 30 min, 24 sessions, 12 wk Plus aerobic exercise (cycle or walk), 30 min, 24 sessions, 12 wk ET, n = 30 Aerobic exercise (cycle or walk) 30 min, 48 sessions, 12 wk	Exercise capacity: 6MWT QOL: MacNew QLMI and VAS Biomarkers: NT-proBNP Other Strength: knee extensions	TC + ET had significantly better exercise capacity ($P = .03$), better QOL, and less BNP ($P = .02$) postintervention ($P = .03$), compared with ET only. TC + ET had significantly better peak torque of quadriceps ($P = .04$) postintervention, compared with ET. Attrition = 5% (ET only) SAE = none Adherence = not reported	Internal validity Intervention: potential inadequate dose, unknown adherence Mortality/attrition: differential dropout rates Testing: potential bias as outcomes assessed multiple times Small sample: underpowered External validity Representativeness: primarily men with CHF Replication: interventions not well described
Yeh,[39] 2011, United States	RCT	Patients with heart failure Mean LVEF = 29% NYHA symptom class 2, range = 1–3 Mean age = 67 y 36% women	100	TC, n = 50 Yang style, 5 postures 24 sessions, 12 wk Health Education (HE, controls), n = 50 24 sessions, 12 wk	Exercise Capacity: Cycle Ergometer and 6MWT QOL: MLHFQ Depression: POMS-D Biomarkers: BNP, CRP, endothelin-1, TNF	TC had significantly better QOL ($P = .02$), less negative mood ($P < .01$), and better exercise self-efficacy ($P < .01$) postintervention, compared with controls.	Internal validity Intervention: potential inadequate dose Testing: potential bias as outcomes assessed multiple times External validity

(continues)

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

TABLE 1 Tai Chi Exercise and Heart Failure: Review of Clinical Trials, Continued

First Author, Year, Location	Study Design	Participant Details	N	Intervention/Control Details	Measures	Results	Challenges to Scientific Rigor
					Other TUG Exercise self-efficacy Physical activity: CHAMPS	There were no significant differences ($P > .05$) in exercise capacity, TUG, or any biomarkers between groups postintervention. Attrition = 3% SAE = 9 (not related to intervention/study protocol) Nonserious AE = 9 Intervention adherence: TC = 75%, HE = 67%	Representativeness: primarily white men Interaction effects: potential treatment variation due to different instructors
Barrow,[37] 2007, UK	RCT	Patients with chronic heart failure LVEF = not reported NYHA symptom class range = 2–3 Mean age = 68 y 18% women	65	TC, n = 32 Wu style, unknown postures 32 sessions, 16 wk Controls (usual care), n = 33	Exercise Capacity: ISWT QOL: MLHFQ Depression: SCL-90-R	TC had significantly better QOL ($P < .01$) postintervention, compared with controls. There were no significant differences ($P > .05$) in exercise capacity or negative mood between groups postintervention. Attrition = 20% (TC = 22%, C = 18%) SAE = 3 (not related to intervention/study protocol) Nonserious AE = 4 Intervention adherence: not reported	Internal validity Intervention: potential inadequate dose, unknown adherence Mortality/attrition: differential dropout rates Small sample: underpowered External validity Representativeness: primarily men with CHF Replication: interventions not well described
Yeh,[40] 2004, United States	RCT	Patients with chronic heart failure Mean LVEF = 23% NYHA symptom class 2, range = 1–4 Mean age = 64 y 37% women	30	TC, n = 15 Yang style, 5 postures 24 sessions, 12 wk Usual care (controls), n = 15 (pharmacologic therapy, dietary counseling, and general exercise advice per guidelines)	Exercise capacity: cycle ergometer and 6MWT QOL: MLHFQ Biomarkers: BNP and plasma norepinephrine Other 24-h ECG Holter monitor	TC had significantly better 6MWT ($P < .01$) and QOL ($P < .01$), with a decrease in BNP ($P = .03$), postintervention, compared with controls. There were no other significant differences ($P > .05$) between groups postintervention. Attrition = 0% SAE = 5 (not related to intervention/study protocol) Intervention adherence: TC = 83%	Internal validity Intervention: potential inadequate dose External validity Representativeness: primarily white men

Abbreviations: 6MWT, 6-minute walk test; BDI, Beck Depression Inventory; BNP, B-type natriuretic peptide; CHAMPS, Community Healthy Activities Model Program for Seniors Questionnaire; CRP, C-reactive protein; E/A, ratio of mitral peak velocity of early filling to mitral peak velocity of late filling; ECG, electrocardiogram; E/e', ratio of mitral peak velocity of early filling to early diastolic mitral annular velocity; EF, ejection fraction; ISWT, incremental shuttle walk test; LVEF, left ventricular ejection fraction; MacNew QLMI, Quality of Life After Myocardial Infarction Questionnaire; MFSI-SF, Multidimensional Fatigue Symptom Inventory–short form; MLHFQ, Minnesota Living With Heart Failure Questionnaire; NT-proBNP, N-terminal pro-B type natriuretic peptide; NYHA, New York Heart Association; POMS, Profile of Mood States; QOL, quality of life; SAE, serious adverse event; SCL-90-R, Symptom Checklist-90-Revised; TC, tai chi; TNF, tumor necrosis factor; TUG, timed up-and-go test; VAS, visual analog scale.

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

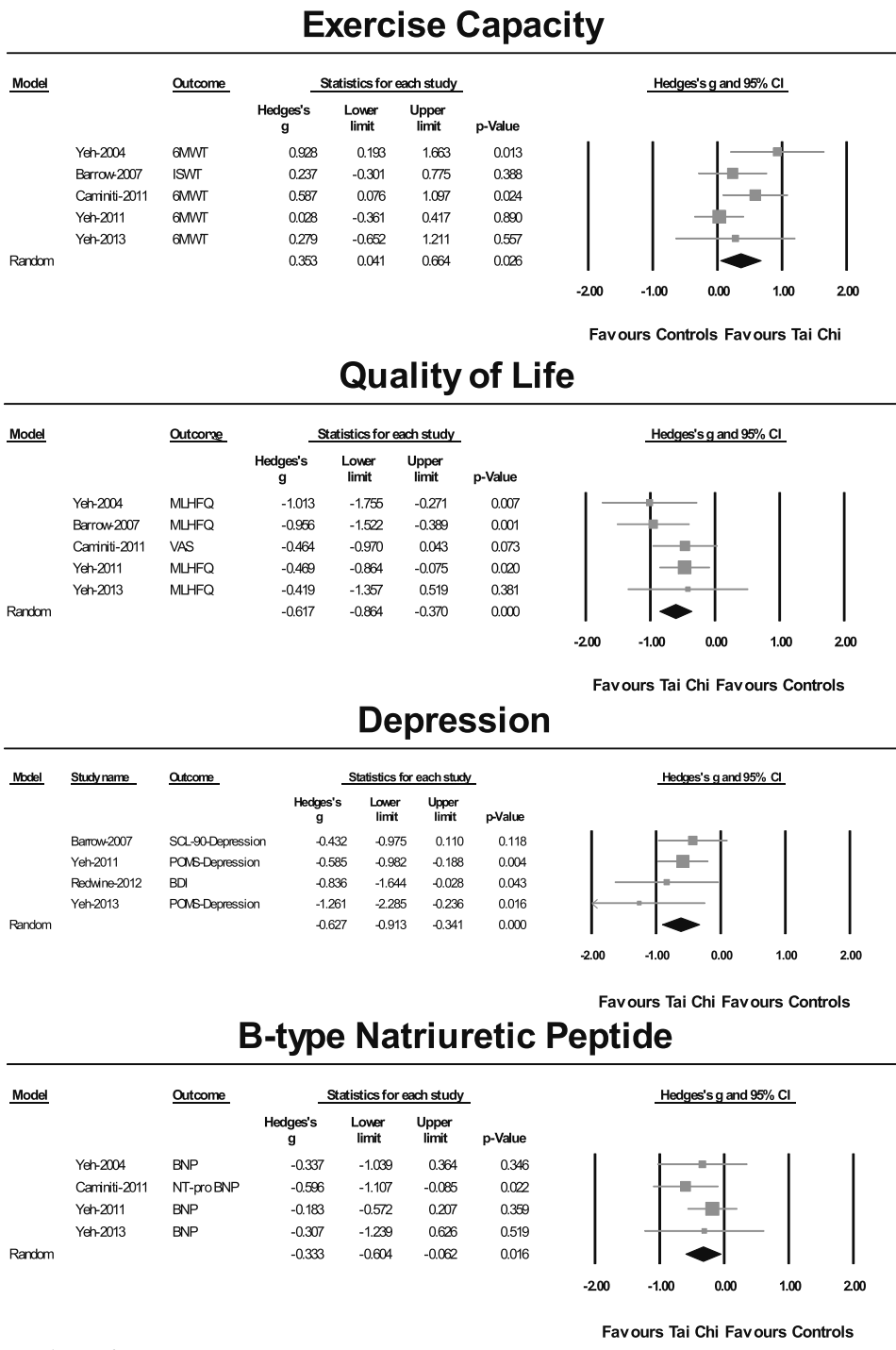

FIGURE 2. *Meta-analysis of outcomes.*

study protocol. Two studies reported that no serious adverse events occurred during the study, whereas 1 study failed to report if there were any adverse events (Table 1).

DISCUSSION

This systematic review and meta-analysis of clinical trials published during the past 15 years was conducted to assess the benefits of tai chi exercise interventions among adults with CHF. Overall, the meta-analysis results indicate that tai chi led to significantly better exercise capacity, improved QOL, less depression, and lower B-type natriuretic peptide level, compared with controls. Our findings extend previously published systematic reviews and meta-analyses[12,26–28] by using a comprehensive search of relevant articles from 10 electronic databases and only including studies with

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

TABLE 2 Downs and Black Modified Checklist[32] for Clinical Trial Quality Assessment

	Checklist Item	Yeh 2013	Redwine 2012	Caminiti 2011	Yeh 2011	Barrow 2007	Yeh 2004
Reporting							
1	Is the hypothesis/aim/objective of the study clearly described?	1	1	1	1	1	1
2	Are the main outcomes to be measured clearly described in the introduction or method section?	1	1	1	1	1	1
3	Are the characteristics of the patients included in the study clearly described?	1	1	1	1	1	1
4	Are the interventions of interest clearly described?	1	1	1	1	1	1
5	Are the distributions of principal confounders in each group of subjects to be compared clearly described? (2 = yes, 1 = partially, 0 = no)	2	2	2	2	2	2
6	Are the main findings of the study clearly described?	1	1	1	1	1	1
7	Does the study provide estimates of the random variability in the data for the main outcomes?	1	0	1	1	0	1
8	Have all important adverse events that may be a consequence of the intervention been reported?	1	0	0	1	1	1
9	Have the characteristics of patients lost to follow-up been described?	1	1	0	1	1	1
10	Have the actual probability values been reported (eg, 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1	0	1	1	1	1
	Reporting subtotal (score range, 0–11)	11	8	9	11	10	11
External validity							
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	1	1	1	1	1	1
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	1	0	1	1	1	1
13	Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?	1	1	1	1	1	1
	External validity subtotal (score range, 0–3)	3	2	3	3	3	3
Internal validity—bias							
14	Was an attempt made to blind study subjects to the intervention they have received?	0	0	0	0	0	0
15	Was an attempt made to blind those measuring the main outcomes of the intervention?	1	0	0	1	0	0
16	If any of the results of the study were based on "data dredging," was this made clear?	1	1	1	1	1	1
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?	1	1	1	1	1	1
18	Were the statistical tests used to assess the main outcomes appropriate?	1	1	1	1	1	1
19	Was compliance with the intervention(s) reliable?	1	1	0	1	0	1
20	Were the main outcome measures used accurate (valid and reliable)?	1	1	1	1	1	1
	Internal validity-bias subtotal (score range, 0–7)	6	5	4	6	4	5
Internal validity—confounding							
21	Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?	1	1	1	1	1	1
22	Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same time period?	1	1	1	1	1	1
23	Were the study subjects randomized to intervention groups?	1	0	1	1	1	1
24	Was the randomized intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?	1	0	0	0	0	1
25	Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?	1	0	0	1	1	1
26	Were losses of patients to follow-up taken into account?	1	1	1	1	1	1
	Internal validity—confounding subtotal (score range, 0–6)	6	3	4	5	5	6
Power							

(continues)

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

TABLE 2 Downs and Black Modified Checklist[32] for Clinical Trial Quality Assessment, Continued

	Checklist Item	Yeh 2013	Redwine 2012	Caminiti 2011	Yeh 2011	Barrow 2007	Yeh 2004
27	Did the study mention having conducted a power analysis to determine the sample size needed to detect a significant difference in effect size for one or more outcome measure? (2 = yes, ≥2 outcomes, 1 = yes, 1 outcome, 0 = no)	0	0	0	2	0	0
	Power subtotal (score range, 0–2)	0	0	0	2	0	0
Total quality index score (range, 0–29 points)		26	18	20	27	22	25

moderate or higher study quality. Consistent with previous meta-analyses, we found statistically significant improvements in exercise capacity[12,26–28] and QOL,[26–28] although previous meta-analyses included data from the same study twice,[26,28] which may have overestimated the effects reported. In previous meta-analyses, depression was not assessed,[26–28] and B-type natriuretic peptide expression was either not assessed,[12] had nonsignificant findings,[27] or included data from the same study twice.[26,28] Furthermore, our findings support recommendations from the European Society of Cardiology that adults with heart failure participate in regular exercise to improve aerobic capacity and QOL.[43] However, the most recent heart failure guidelines from the American College of Cardiology/American Heart Association Task Force focus on management of patients with heart failure, specifically pharmacological treatment for heart failure with reduced ejection fraction or heart failure with preserved ejection fraction, and management of important comorbidities.[44] While these heart failure guidelines recommend assessment of B-type natriuretic peptide or N-terminal pro-B type natriuretic peptide to establish severity of heart failure, exercise recommendations or guidelines for heart failure were not included,[44] with the most recent heart failure exercise guidelines published in 2003.[45]

Tai chi exercise is considered a low- to moderate-intensity exercise, similar to other types of exercise used among adults with CHF, with the 6-minute walk test frequently used as an indicator of exercise capacity. Our results are similar to findings of other meta-analyses, that exercise capacity among adults with CHF significantly improved after combined aerobic and resistance training,[46] resistance training only,[47] or exercise-based cardiac rehabilitation,[48] when compared with usual care. Two recent studies support these findings with significant improvements in exercise capacity (6-minute walk test, $P < .001$) among adults with CHF (eg, heart failure with reduced ejection fraction or heart failure with preserved ejection fraction) reported after either a 12-week walking program[49] or supervised exercise training (cycle ergometer at 60%–70% max effort),[50] compared with usual care controls.

Quality of life is another important indicator of health and well-being, with the Minnesota Living With Heart Failure Questionnaire commonly used among adults with HF. Our results examining the effect of tai chi on QOL are similar to other meta-analyses reporting significantly better QOL after combined aerobic and resistance training,[46] resistance training only,[47] or exercise-based cardiac rehabilitation,[48] compared with usual care. Moreover, the meta-analysis conducted by Palmer and colleagues[48] reported that exercise-based cardiac rehabilitation led to a clinically significant improvement in QOL (−8.5 points on the Minnesota Living With Heart Failure Questionnaire). Two recent RCTs support these findings, with significantly better QOL among persons with CHF participating in either a low-intensity (walking, $P = .02$)[49] or moderate-intensity (cycle ergometer, $P < .001$) exercise.[50] As a low- to moderate-intensity exercise, tai chi is a viable exercise option among persons with CHF to foster improved QOL. However, our findings are in contrast to an RCT among persons with heart failure with preserved ejection fraction in a supervised endurance plus resistance training program, reporting no significant difference in QOL postintervention ($P = .07$), compared with usual care.[51]

In this meta-analysis, tai chi led to significantly less depression postintervention, compared with controls. Our results are similar to a recent study among persons with CHF reporting mild to moderate depression, participating in 12 weeks of supervised moderate-intensity exercise (treadmill at 60%–70% max effort) and reporting less depression ($P = .001$) postintervention, compared with usual care.[52] However, these findings are in contrast to reported results from a combined aerobic and resistance training meta-analysis ($P > .05$),[46] a 12-week walking program ($P = .06$),[49] and a 12-week supervised endurance plus resistance training program ($P = .735$) among adults with CHF,[51] that no improvements in depression were found when compared with usual care. Nevertheless, tai chi is considered a mind-body exercise and less depression is frequently reported among persons with chronic health conditions[10,53]; thus, tai chi likely offers mental health benefits beyond traditional western exercise.

The assessment of cardiac dysfunction in patients with CHF typically includes either B-type natriuretic peptide or N-terminal pro-B type natriuretic peptide blood tests, as an increase in these peptides reflects a

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

What's New and Important

- Tai chi is suitable for older adults to perform, including those with chronic health conditions (eg, CHF) or poor exercise tolerance.
- Meta-analytic evidence indicates tai chi improves exercise capacity and QOL, decreases depression, and lowers B-type natriuretic peptide levels among adults with CHF, when compared with usual care controls.

diminished capacity of the heart to deliver oxygenated blood to the body. According to the European Society of Cardiology heart failure guidelines, blood test values for B-type natriuretic peptide levels greater than 100 pg/mL or N-terminal pro-B type natriuretic peptide levels greater than 300 pg/mL indicate symptomatic heart failure, warranting further diagnostic investigation.[43] In this meta-analysis, we found that tai chi led to significantly less B-type natriuretic peptide expression postintervention, compared with controls. Our results are similar to a recent RCT among adults with CHF (average left ventricular ejection fraction, 48%), reporting significantly lower ($P < .001$) B-type natriuretic peptide, after 12 weeks of supervised exercise training (cycle ergometer at 60%–70% max effort), compared with usual care.[50] The decrease in B-type natriuretic peptide levels suggests a more stable heart failure condition after the exercise intervention.

Limitations

There are several limitations to this study. First, both RCTs and quasi-experimental studies with a comparison group were included. However, comprehensive quality assessments of all included studies were conducted using an established checklist[32,33] and were found to be either moderate[37,38,42] or high[39–41] quality. Second, moderate (32.72%) heterogeneity was observed for the exercise capacity meta-analytic outcome; however, no (0%) heterogeneity was observed for the other meta-analytic outcomes: QOL, depression, and B-type natriuretic peptide expression. Finally, our analyses were limited to full-text articles written in English, which may have omitted relevant literature published in other languages. However, this systematic review and meta-analysis was reported following established Preferred Reporting Items of Systematic Reviews and Meta-analysis guidelines, with 2 independent reviewers conducting the literature search, extracting the data, and assessing study quality.

Suggestions for Future Research

Considering the paucity of studies conducted to date, it is imperative that further research using tai chi among persons with CHF be conducted. Future research is suggested to examine biological, psychological, and social factors underpinning tai chi that may lead to improved health and well-being among adults with CHF. Further investigation of tai chi as a nonpharmacological intervention for reducing depressive symptoms among patients with CHF is warranted. Going forward, it is important that future studies report tai chi instructor training, tai chi style, number of postures, and intervention adherence rates.

CONCLUSIONS

Among adults with CHF, tai chi was effective in improving exercise capacity and QOL, with less depression and B-type natriuretic peptide levels observed, when compared with controls. Tai chi is a safe form of exercise and can be easily integrated into existing cardiac rehabilitation programs using either classes in person or remotely via online video instruction at home. Across the studies reviewed, small to moderate improvements within physical health (ie, exercise capacity, B-type natriuretic peptide levels) and mental health (ie, QOL and depression) domains were detected. However, few studies in the past 15 years have examined the benefits of tai chi among adults with CHF. Further research is needed with rigorous study designs, diverse samples inclusive of women, and adequate descriptions of important tai chi exercise intervention features.

REFERENCES

1. Savarese G, Lund LH. Global public health burden of heart failure. *Card Fail Rev*. 2017;3(1):7–11.
2. Benjamin EJ, Muntner P, Alonso A, et al. Heart disease and stroke Statistics-2019 update: a report from the American Heart Association. *Circulation*. 2019;139(10):e56–e528.
3. Long L, Mordi IR, Bridges C, et al. Exercise-based cardiac rehabilitation for adults with heart failure. *Cochrane Database Syst Rev*. 2019;1:CD003331.
4. Schopfer DW, Forman DE. Growing relevance of cardiac rehabilitation for an older population with heart failure. *J Card Fail*. 2016;22(12):1015–1022.
5. Haykowsky MJ, Daniel KM, Bhella PS, Sarma S, Kitzman DW. Heart failure: exercise-based cardiac rehabilitation: who, when, and how intense?*Can J Cardiol*. 2016;32(10 Suppl 2): S382–S387.
6. Golwala H, Pandey A, Ju C, et al. Temporal trends and factors associated with cardiac rehabilitation referral among patients hospitalized with heart failure: findings from Get With the Guidelines-Heart Failure Registry. *J Am Coll Cardiol*. 2015;66(8):917–926.
7. Forman DE, Sanderson BK, Josephson RA, Raikhelkar J, Bittner V, American College of Cardiology's prevention of cardiovascular disease Section. Heart failure as a newly approved diagnosis for cardiac rehabilitation: challenges and opportunities. *J Am Coll Cardiol*. 2015;65(24):2652–2659.
8. Taylor-Piliae RE, Silva E, Sheremeta SP. Tai chi as an adjunct physical activity for adults aged 45 years and older enrolled in phase III cardiac rehabilitation. *Eur J Cardiovasc Nurs*. 2012;11(1):34–43.
9. Salmoirago-Blotcher E, Wayne PM, Dunsiger S, et al. Tai chi is a promising exercise option for patients with coronary

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

heart disease declining cardiac rehabilitation. *J Am Heart Assoc*. 2017;6(10).
10. Liu T, Chan AW, Liu YH, Taylor-Piliae RE. Effects of tai chi–based cardiac rehabilitation on aerobic endurance, psychosocial well-being, and cardiovascular risk reduction among patients with coronary heart disease: a systematic review and meta-analysis. *Eur J Cardiovasc Nurs*. 2018;17(4):368–383.
11. Lan C, Chen SY, Lai JS, Wong AM. Tai chi chuan in medicine and health promotion. *Evid Based Complement Alternat Med*. 2013;2013:502131.
12. Chen YW, Hunt MA, Campbell KL, Peill K, Reid WD. The effect of tai chi on four chronic conditions—cancer, osteoarthritis, heart failure and chronic obstructive pulmonary disease: a systematic review and meta-analyses. *Br J Sports Med*. 2016;50(7):397–407.
13. Wayne PM, Berkowitz DL, Litrownik DE, Buring JE, Yeh GY. What do we really know about the safety of tai chi?: a systematic review of adverse event reports in randomized trials. *Arch Phys Med Rehabil*. 2014;95(12):2470–2483.
14. Chan AWK, Chair SY, Lee DTF, et al. Tai chi exercise is more effective than brisk walking in reducing cardiovascular disease risk factors among adults with hypertension: a randomised controlled trial. *Int J Nurs Stud*. 2018;88:44–52.
15. Sun J, Buys N. Community-based mind-body meditative tai chi program and its effects on improvement of blood pressure, weight, renal function, serum lipoprotein, and quality of life in Chinese adults with hypertension. *Am J Cardiol*. 2015;116(7):1076–1081.
16. Taylor-Piliae RE, Haskell WL, Stotts NA, Froelicher ES. Improvement in balance, strength, and flexibility after 12 weeks of tai chi exercise in ethnic Chinese adults with cardiovascular disease risk factors. *Altern Ther Health Med*. 2006;12(2):50–58.
17. Huang Y, Liu X. Improvement of balance control ability and flexibility in the elderly tai chi chuan (TCC) practitioners: a systematic review and meta-analysis. *Arch Gerontol Geriatr*. 2015;60(2):233–238.
18. Li F, Harmer P, Fitzgerald K, et al. Tai chi and postural stability in patients with Parkinson's disease. *N Engl J Med*. 2012;366(6):511–519.
19. Hwang HF, Chen SJ, Lee-Hsieh J, Chien DK, Chen CY, Lin MR. Effects of home-based tai chi and lower extremity training and self-practice on falls and functional outcomes in older fallers from the emergency department-a randomized controlled trial. *J Am Geriatr Soc*. 2016;64(3):518–525.
20. Zheng G, Li S, Huang M, Liu F, Tao J, Chen L. The effect of tai chi training on cardiorespiratory fitness in healthy adults: a systematic review and meta-analysis. *PloS One*. 2015;10(2):e0117360.
21. Wu W, Liu X, Wang L, Wang Z, Hu J, Yan J. Effects of tai chi on exercise capacity and health-related quality of life in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Int J Chron Obstruct Pulmon Dis*. 2014;9:1253–1263.
22. Wayne PM, Walsh JN, Taylor-Piliae RE, et al. Effect of tai chi on cognitive performance in older adults: systematic review and meta-analysis. *J Am Geriatr Soc*. 2014;62(1):25–39.
23. Wang C, Bannuru R, Ramel J, Kupelnick B, Scott T, Schmid CH. Tai chi on psychological well-being: systematic review and meta-analysis. *BMC Complement Altern Med*. 2010;10:23.
24. Yeh GY, Chan CW, Wayne PM, Conboy L. The impact of tai chi exercise on self-efficacy, social support, and empowerment in heart failure: insights from a qualitative sub-study from a randomized controlled trial. *PloS One*. 2016;11(5):e0154678.
25. Hagglund L, Boman K, Brannstrom M. A mixed methods study of tai chi exercise for patients with chronic heart failure aged 70 years and older. *Nurs Open*. 2018;5(2):176–185.
26. Gu Q, Wu SJ, Zheng Y, et al. Tai chi exercise for patients with chronic heart failure: a meta-analysis of randomized controlled trials. *Am J Phys Med Rehabil*. 2017;96(10):706–716.
27. Pan L, Yan J, Guo Y, Yan J. Effects of tai chi training on exercise capacity and quality of life in patients with chronic heart failure: a meta-analysis. *Eur J Heart Fail*. 2013;15(3):316–323.
28. Ren X, Li Y, Yang X, et al. The effects of tai chi training in patients with heart failure: a systematic review and meta-analysis. *Front Physiol*. 2017;8:989.
29. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med*. 2009;6(7):e1000100.
30. Choi HM, Park MS, Youn JC. Update on heart failure management and future directions. *Korean J Intern Med*. 2019;34(1):11–43.
31. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. *Introduction to Meta-analysis*. United Kingdom: John Wiley and Sons; 2009.
32. Gaynes BN, Gavin N, Meltzer-Brody S, et al. *Perinatal Depression: Prevalence, Screening Accuracy, and Screening Outcomes: Evidence Report/Technology Assessment No. 119*. Rockville, MD: Agency for Healthcare Research and Quality; 2005.
33. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52(6):377–384.
34. Pescatello LS, Corso LML, MacDonald HV, et al. Small sample sizes confound understanding of cardiometabolic responses to exercise. *Exerc Sport Sci Rev*. 2017;45(3):173–180.
35. MacDonald HV, Johnson BT, Huedo-Medina TB, et al. Dynamic resistance training as stand-alone antihypertensive lifestyle therapy: a meta-analysis. *J Am Heart Assoc*. 2016;5(10).
36. Viswanathan M, Ansari MT, Berkman ND, et al. Assessing the risk of bias of individual studies in systematic reviews of health care interventions. In: *Methods Guide for Effectiveness and Comparative Effectiveness Reviews*. Rockville, MD: Agency for Healthcare Research and Quality (US); 2008.
37. Barrow DE, Bedford A, Ives G, O'Toole L, Channer KS. An evaluation of the effects of tai chi chuan and chi kung training in patients with symptomatic heart failure: a randomised controlled pilot study. *Postgrad Med J*. 2007;83(985):717–721.
38. Caminiti G, Volterrani M, Marazzi G, et al. Tai chi enhances the effects of endurance training in the rehabilitation of elderly patients with chronic heart failure. *Rehabil Res Pract*. 2011;2011:1–6.
39. Yeh GY, McCarthy EP, Wayne PM, et al. Tai chi exercise in patients with chronic heart failure: a randomized clinical trial. *Arch Intern Med*. 2011;171(8):750–757.
40. Yeh GY, Wood MJ, Lorell BH, et al. Effects of tai chi mind-body movement therapy on functional status and exercise capacity in patients with chronic heart failure: a randomized controlled trial. *Am J Med*. 2004;117(8):541–548.
41. Yeh GY, Wood MJ, Wayne PM, et al. Tai chi in patients with heart failure with preserved ejection fraction. *Congest Heart Fail*. 2013;19(2):77–84.
42. Redwine LS, Tsuang M, Rusiewicz A, et al. A pilot study exploring the effects of a 12-week t'ai chi intervention on somatic symptoms of depression in patients with heart failure. *J Altern Complement Med*. 2012;18(8):744–748.
43. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure of the European Society of Cardiology (ESC). Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur J Heart Fail*. 2016;18(8):891–975.

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

44. Yancy CW, Jessup M, Bozkurt B, et al. 2017 ACC/AHA/HFSA focused update of the 2013 ACCF/AHA guideline for the Management of Heart Failure: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines and the Heart Failure Society of America. *Circulation*. 2017;136(6):e137–e161.
45. Pina IL, Apstein CS, Balady GJ, et al. Exercise and heart failure: a statement from the American Heart Association Committee on exercise, rehabilitation, and prevention. *Circulation*. 2003;107(8):1210–1225.
46. Wang Z, Peng X, Li K, Wu CJ. Effects of combined aerobic and resistance training in patients with heart failure: a meta-analysis of randomized, controlled trials. *Nurs Health Sci*. 2019;21(2):148–156.
47. Giuliano C, Karahalios A, Neil C, Allen J, Levinger I. The effects of resistance training on muscle strength, quality of life and aerobic capacity in patients with chronic heart failure—a meta-analysis. *Int J Cardiol*. 2017;227:413–423.
48. Palmer K, Bowles KA, Paton M, Jepson M, Lane R. Chronic heart failure and exercise rehabilitation: a systematic review and meta-analysis. *Arch Phys Med Rehabil*. 2018;99(12):2570–2582.
49. Teng HC, Yeh ML, Wang MH. Walking with controlled breathing improves exercise tolerance, anxiety, and quality of life in heart failure patients: a randomized controlled trial. *Eur J Cardiovasc Nurs*. 2018;17(8):717–727.
50. Antonicelli R, Spazzafumo L, Scalvini S, et al. Exercise: a "new drug" for elderly patients with chronic heart failure. *Aging (Albany NY)*. 2016;8(5):860–872.
51. Nolte K, Herrmann-Lingen C, Wachter R, et al. Effects of exercise training on different quality of life dimensions in heart failure with preserved ejection fraction: the ex-DHF-P trial. *Eur J Prev Cardiol*. 2015;22(5):582–593.
52. Abdelbasset WK, Alqahtani BA. A randomized controlled trial on the impact of moderate-intensity continuous aerobic exercise on the depression status of middle-aged patients with congestive heart failure. *Medicine (Baltimore)*. 2019;98(17):e15344.
53. Wang F, Lee EK, Wu T, et al. The effects of tai chi on depression, anxiety, and psychological well-being: a systematic review and meta-analysis. *Int J Behav Med*. 2014;21(4):605–617.

Appendix A: Example of Literature Search in PubMed

Search Number	Query	Items Found
1	Search "Tai Ji"[Mesh]	989
2	Search "Heart Failure"[Mesh] OR "Heart Failure, Diastolic"[Mesh] OR "Heart Failure, Systolic"[Mesh]	114 592
3	"Tai Ji"[Mesh] AND ("Heart Failure"[Mesh] OR "Heart Failure, Diastolic"[Mesh] OR "Heart Failure, Systolic"[Mesh])	22
4	#3 AND (Clinical Trial[ptyp] AND "humans"[MeSH Terms] AND (English[lang] OR German[lang])	9

Copyright © 2020 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.