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Tai Chi Exercise for Patients with Cardiovascular Conditions and Risk Factors: A Systematic Review

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Abstract

PURPOSE—To conduct a systematic review of the literature evaluating tai chi exercise as an intervention for patients with cardiovascular disease (CVD) or with cardiovascular risk factors (CVRF).

METHODS—We searched: 1) Medline, CAB Alt Health Watch, BIOSIS previews, Science Citation Index, EMBASE, and Social Science Citation Index from inception through October 2007; 2) Chinese Medical Database, China Hospital Knowledge, China National Knowledge Infrastructure, and China Traditional Chinese Medicine Database from inception through June 2005; and 3) performed hand searches at the medical libraries of Beijing and Nanjing Universities. Clinical studies published in English and Chinese including participants with established CVD or CVRF were included. Data were extracted in a standardized manner; 2 independent investigators assessed methodological quality, including the Jadad score for randomized controlled trials (RCT).

RESULTS—Twenty-nine studies met inclusion criteria: 9 RCT, 14 non-randomized studies (NRS), and 6 observational trials (OBS). Three studies examined subjects with coronary heart disease, 5 in heart failure, and 10 in heterogeneous populations that included those with CVD. Eleven studies examined subjects with CVRF (hypertension, dyslipidemia, impaired glucose metabolism). Study duration ranged from 8 weeks to 3 years. Most studies included <100 subjects (range 5–207). Six of nine RCTs were of adequate quality (Jadad ≥3). Most studies report improvements with tai chi, including blood pressure reductions and increases in exercise capacity. No adverse effects were reported.

CONCLUSION—Preliminary evidence suggests that tai chi exercise may be a beneficial adjunctive therapy for some patients with CVD and CVRF. Further research is needed.

Keywords

Exercise; Tai chi; Cardiovascular disease prevention

Cardiovascular disease is clearly an important public health problem, with 1 in 3 American adults affected.[1] Mortality due to underlying cardiovascular disease accounts for more than one-third of all deaths. The evidence from long-term prospective studies consistently suggests

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that the majority of cardiovascular disease is preventable with healthy lifestyles and modification of known risk factors.[2] While pharmacological therapy is often emphasized, the critical importance of non-pharmacological approaches and lifestyle modifications, including physical activity and exercise, continues to be recognized for both primary and secondary prevention of cardiovascular disease.

In recent years, with the popularity and prevalence of mind-body therapies, there has been a growing interest in tai chi exercise for patients with cardiovascular disease.[3–5] Tai chi (t'ai chi or taiji) has origins in ancient Chinese martial arts and combines gentle physical activity, with elements of meditation, body awareness, imagery, and attention to breathing. The scientific literature describing tai chi is varied, with studies reporting benefits in a number of health conditions, from balance and reduction of falls in frail adults, to improvements in quality of life and symptoms in rheumatoid arthritis, human immunodeficiency virus, cancer, and heart failure.[6,7] A substantial amount of research examines the cardiovascular effects of tai chi, including cardiorespiratory fitness and exercise capacity, although most data are available for blood pressure.[4,8–10]

To date, there have been no comprehensive systematic reviews examining the use of tai chi specifically in patients with cardiovascular conditions, and very little is known about what is published in the Chinese language. Our objective was to conduct a systematic review of the Chinese and English language literature on tai chi exercise as an intervention for patients with cardiovascular disease and cardiovascular risk factors, and to offer recommendations for future research.

METHODS

We conducted electronic literature searches of Medline (from 1966), CAB (from 1973), Alt Health Watch , BIOSIS previews (from 1969), Science Citation Index (from 1945), EMBASE (from 1991) and the Social Science Citation Index (from 1956) through October 2007 using search terms "tai chi," "tai chi chuan", "ta'i chi," "tai ji," and "taijiquan." In addition, we performed searches of the Chinese Medical Database, China Hospital Knowledge, China National Knowledge Infrastructure, and China Traditional Chinese Medicine Database from inception to June 2005, and performed hand searches at the medical libraries of Beijing and Nanjing Universities in China. We also performed hand searches of retrieved articles for additional references.

Eligibility criteria

Available human clinical studies published in English and Chinese which specified a target study population of subjects with a known cardiovascular condition or with cardiovascular risk factors (including hypertension, dyslipidemia, and diabetes) were included. Studies that specifically examined subjects with stroke were not included. Studies that examined cardiovascular outcomes in healthy individuals were not included (eg, blood pressure or cholesterol in subjects with normal baseline blood pressure or lipid profiles).

Data extraction and synthesis

Data were extracted in a standardized manner by 2 independent reviewers. Data were extracted from Chinese language articles with direct translation to English. To assess methodological quality of studies, we developed an A,B,C summary quality grading system adapted from methods used in Evidence Reports of the AHRQ Evidence-Based Practice Centers (www.ahrq.gov/clinic/epcindex.htm). Two independent investigators assessed methodological quality, evaluating each study according to specific criteria for each study design type (randomized controlled trial [RCT], prospective non-randomized controlled and

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non-controlled studies [NRS], and observational controlled and non-controlled studies [OBS]) and assigning an A, B, or C grade based on the potential for bias in the study. Summary quality grading criteria for each of the 3 design strata are listed in Table 1. This system evaluates and rates studies within each of the study design strata. By design, it does not attempt to assess the comparative validity of studies across different design strata. Thus, in interpreting the methodological quality of a study, one should note the quality grade *and* the study design. Grade A was given to studies where there appeared to be the least amount of bias and results were likely valid. Grade B was given to studies that appeared susceptible to some bias, but not sufficient to invalidate the results. Grade C was given to studies with evidence of significant bias that may invalidate the results. For RCTs, in addition to the summary quality grade, we also indicate a modified Jadad score. Because in most cases, double-blinding is impractical in tai chi studies, our modification gives one point for proper single blinding of the outcome assessors. Grading discrepancies between the independent reviewers occurred rarely and were resolved via discussion.

RESULTS

We screened 841 English-language and 859 Chinese-language abstracts and full text articles for potentially relevant data. A total of 31 studies (14 in English, 17 in Chinese) met the inclusion criteria. Two Chinese studies were excluded: one due to poor quality and insufficient information for data extraction, and one that reported on children with cardiac murmurs and congenital heart disease.[11,12] The remaining 29 studies were analyzed, including 9 RCTs, 14 NRS, and 6 OBS.[13–41] Studies were conducted in 1) homogeneous populations of subjects with reported coronary heart disease or heart failure (Table 2), in 2) heterogeneous populations with a proportion of subjects having a cardiovascular condition (eg, coronary disease, arrhythmia, “cardiovascular condition” not otherwise specified) (Table 3), and in 3) both homogeneous and heterogeneous populations of subjects with cardiovascular risk factors (ie, hypertension, dyslipidemia, impaired glucose metabolism or diabetes mellitus) (Table 4). Within these trials, reported outcomes included blood pressure, heart rate, exercise capacity, heart rate variability, lipids, fasting glucose, pulmonary function, cardiac hemodynamic indices, functional measures, flexibility, mood and quality-of-life. Study duration ranged from 8 weeks to 3 years. Most studies included <100 subjects (range 5–207). Study heterogeneity precluded formal meta-analysis. No adverse events associated with tai chi were reported. Of the 9 RCT’s, 5 received an A rating and 2 received a B rating. Of the 14 NRS, 10 received a B rating. Of 6 OBS, 1 received an A rating and 5 received a B rating.

Studies in Patients with Reported Cardiovascular Disease (Table 2 and Table 3)

The data are limited with only 3 studies that specifically studied patients with coronary disease.[13–15] In the only RCT, Channer et al[13] randomized patients recovering from an acute myocardial infarction to a mixed tai chi/qigong intervention or to conventional aerobic exercise or to a cardiac support group. After 8 weeks, both aerobic exercise and tai chi were associated with significant reductions in systolic blood pressure (SBP) (−4 ± 7.5 and −3 ± 3.3) mmHg, respectively, both $P<.05$). Diastolic blood pressure (DBP) was improved in the tai chi group only (−2 ± 2.7 mmHg, $P<.01$). No between-group comparisons were made. This study also reported decreases in resting heart rate and greater compliance with tai chi class.[13]

Similarly, there were only 5 studies examining patients with heart failure. Two of 3 RCTs were of adequate quality.[16,20] Yeh et al[16] randomized patients to a tai chi intervention or to usual care. After 12 weeks, patients who practiced tai chi showed an increase in exercise capacity (+84 ± 45 vs. −51 ±88 meters on a 6-minute walk, $P<.01$), improved B-type natriuretic peptide (−48 ± 105 vs. +89 ±210 pg/ml, $P=.03$) and improved disease-specific quality of life using the Minnesota Living with Heart Failure Questionnaire, compared with the control group.[16]

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Barrow et al[20] found similar results in quality of life using a 16-week tai chi intervention compared to usual care. No difference was seen, however, between groups in exercise tolerance using the incremental shuttle walk test. A correlation was reported between home practice time and improvement in walk distance.[20] Other small, prospective, non-randomized studies provide limited evidence for improvements in physiological parameters and functional capacity.[18,21] Of note, both Chinese language studies report improvements in left ventricular ejection fraction.[19,21]

Ten studies (5 NRS, 5 OBS) examined tai chi in heterogeneous populations that included some proportion of subjects with cardiovascular disease (eg, coronary heart disease). These studies vary in quality and report improvements in blood pressure, resting heart rate (HR) HR, HR recovery after exercise, and cardiac hemodynamics such as stroke volume and cardiac output. Two studies included patients with chronic obstructive pulmonary disease and reported improvements in pulmonary function tests (increased vital capacity, total lung capacity, and forced vital capacity) after tai chi (within group analysis) and compared with usual care.[23,25] Three observational studies with heterogeneous cardiovascular populations were designed to examine tai chi's acute physiological effects and to measure tai chi exercise intensity. These studies report conflicting results with respect to direction of change acutely in heart rate and blood pressure. No adverse effects were reported.

Studies in Patients with Cardiovascular Risk Factors (Table 4)

Hypertension—Four RCT's were available that report on blood pressure changes in patients with hypertension.[30–33] All 4 studies report a reduction in blood pressure with tai chi (usually a 12 week intervention). In the highest quality of these, Young et al compared a light intensity tai chi program that "emphasized physical movements rather that meditational aspects" to moderate intensity walking and low-impact aerobic dance.[30] They reported comparable blood pressure changes (±SD) in both groups (−7.0 ± 8.8 vs. −8.4 ± 8.8) mmHg SBP; −2.4 ±5.5 vs. −3.2 ±5.5 mmHg DBP, respectively), however, no difference between groups. Of note, they did report higher compliance with home exercise in the tai chi group.

Dyslipidemia—Two RCTs are available that examined changes in lipid profile. While Tsai et al[31] reported reductions in total cholesterol (−15.2 md/dL), LDL (−20 md/dL), TG (−23.8 mg/dL) and increases in HDL (+4.7 mg/dL) after 12 weeks of tai chi in patients with hypertension compared to usual care, Thomas et al[32] reported no change in these same parameters in a mixed population that included more than half of patients with dyslipidemia. One larger observational trial conducted in China did suggest improvements in lipid parameters.[41]

Impaired Glucose Metabolism—Two RCTs are available that examined changes in glucose metabolism, suggesting no effect with tai chi.[32,34–35] Tsang et al[34] reported no change in insulin resistance or sensitivity (0 vs. −0.1 Homeostasis Model Assessment Index 2 (HOMA2)-insulin resistance and −0.8 vs. 5 for HOMA2%-insulin sensitivity), hemoglobin A1c (HgbA1C) (−0.07% vs. 0.12%), or body composition (−0.39 vs. −0.07 kg/m2, body-mass index) after 16 weeks of tai chi compared to calisthenics and gentle stretching in patients with type 2 diabetes. There was a reduction in body fat in both groups, although no difference between groups. Thomas et al[32] compared 12 weeks of tai chi to strength and resistance training and to usual care in elder participants with cardiovascular risk factors. Fasting glucose and HgbA1C were reduced in each of the groups (−0.5 vs. −0.5 vs. −0.3 mmol/L and −0.3% vs. −0.3% vs. −0.3% in tai chi, resistance training, control groups, respectively), yet there were no differences between groups. Only 14% of this study population had impaired glucose metabolism at baseline. One NRS did suggest modest reductions in HgbA1C and reductions in fasting glucose.[40]

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DISCUSSION

The available studies suggest that tai chi exercise may have beneficial effects for patients with cardiovascular conditions and some cardiovascular risk factors, although the literature to date is limited. Very few studies specifically examine patients with coronary artery disease or heart failure, although the available studies report positive results in both functional and physiological parameters. In investigations of patients with cardiovascular risk factors, most information is available on blood pressure effects and hypertension. The data on tai chi's effect on lipids and glucose metabolism are unclear. More than half of the studies in this review were published in Chinese and offer data that have historically been excluded from other reviews.

Clinical Implications and Advantages of Tai Chi

Given the existing evidence, tai chi exercise may be a reasonable adjunct to conventional care. It may be appropriate for those unable or unwilling to engage in other forms of physical activity, or as a bridge to more rigorous exercise programs in frail or de-conditioned patients. Patients with early detection of cardiovascular risk factors (eg, borderline hypertension) may be reluctant to begin drug therapy and non-pharmacological approaches are often welcomed. These lifestyle interventions have been recognized as important and effective strategies for primary prevention.[42] In addition, patients with either pre-hypertension or established hypertension, who otherwise feel well, may be less motivated and find it difficult to engage in and maintain a regular exercise regimen. Finding an appropriate, non-threatening, easy-to-perform activity that patients will maintain is critical to therapeutic success. Clinical trials have reported excellent compliance with tai chi interventions, and suggest that tai chi may promote exercise self-efficacy.[43,44] Likewise, exercise is a well-recognized and effective strategy for secondary prevention in patients with established cardiovascular disease. Unfortunately, studies have continued to show that conventional cardiac rehabilitation programs are underutilized.[45] Therapies such as tai chi may offer patients additional options, whether as an adjunct to formal cardiac rehabilitation, as a part of maintenance therapy, or as an exercise alternative at any point along this continuum.

Safety

Collectively, these studies suggest that tai chi may be safe for patients with cardiovascular disease. The three studies with higher-risk coronary patients reported no adverse effects.[13–15] In addition, exercise intensity of tai chi can be easily modified. Many studies have reported metabolic equivalents of 1.5–4.0 (approximately low-moderate intensity aerobic exercise), which may be a reasonable exercise level for even the more deconditioned cardiac patient.[46–48]

Study Limitations

The quality of studies within this review varied significantly. Overall, quality was poorer in the Chinese language studies (6/15 vs. 0/14 earning a C rating) compared to English language studies. The majority of studies earned a B rating. Since most studies reported positive results, the possibility of publication bias exists. In addition, we were unable to perform meta-analyses due to study heterogeneity (with differences in design, selection of control, as well as intervention style, intensity, and dose/duration). There were also inherent limitations in our use of the Jadad scale, given the nature of tai chi trials and the difficulty and impracticality of double-blinding. Despite these limitations, this review provides the first comprehensive synthesis of both English and Chinese language literature describing the use of tai chi exercise in cardiovascular populations.

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Future Research

There is a clear need for more rigorous research of tai chi for cardiovascular health. However, as with many other mind-body interventions, tai chi is unlike a standardized pharmaceutical and inherently heterogeneous, posing significant challenges to the design and interpretation of studies. The current literature represents a mix of different styles, protocols, intervention dose and duration, emphases (eg, meditation vs. movement), combinations of other activities (eg, qigong warm-ups), and types or qualifications of instructors. On a further level, tai chi is heterogeneous because it integrates multiple therapeutic components (eg, musculoskeletal efficiency, breathing, mindfulness, psychosocial interaction, and rituals).[49] For future studies, we will need to better address this heterogeneity and complexity. At the least, we will need larger sample sizes, clear reporting standards so that interventions are well-described and reproducible, and carefully chosen outcome measures that measure both mechanisms of effect and clinical efficacy.

Several trials are currently ongoing, including 2 independent investigator groups studying tai chi for patients with heart failure at Beth Israel Deaconess Medical Center/Harvard Medical School in Boston and the Veterans Research Medical Foundation in San Diego. A preliminary trial of tai chi in obese patients with cardiovascular risk factors is currently ongoing at Queen's Medical Center in Honolulu. With these and future thoughtfully-designed investigations, we may better understand the benefits, mechanisms, and role of tai chi exercise in the prevention and management of cardiovascular disease.

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TABLE 1

ABC quality grading criteria for three study design strata*

Randomized controlled trials
• Adequate randomization, proper single blinding of assessors, and reporting of dropouts (modification of Jadad score)
• Adequate methods used to assess physical activity
• No errors or discrepancies in reporting results
• Clear inclusion/exclusion criteria
• Sample size estimates/justification
• Adequate description of tai chi intervention (eg, style, training schedule, frequency/duration of classes, instructor experience)
• Adequate description of comparison groups
Prospective, non-randomized studies (controlled and non-controlled)
• Unbiased selection of the cohort (prospective recruitment of subjects)
• Sufficiently large sample size
• Adequate description of the cohort; clear inclusion/exclusion criteria
• Adequate methods used to assess physical activity
• Adequate description of tai chi intervention (eg, style, training schedule, frequency/duration of classes, instructor experience)
• Adequate description of comparison groups
• Use of validated method for ascertaining clinical outcomes
• Adequate follow-up period
• Completeness of follow-up
• Analysis (multivariate adjustments) and reporting of results; use of appropriate statistical analyses
Observational Studies (controlled and non-controlled)
• Valid ascertainment of cases
• Unbiased selection of cases
• Appropriateness of the control population (as applicable)
• Clear inclusion/exclusion criteria
• Comparability of cases and controls with respect to potential confounders
• Adequate methods used to assess physical activity
• Adequate description of tai chi intervention (eg, style, training schedule, frequency/duration of classes, instructor experience)
• Adequate description of comparison groups
• Appropriate statistical analyses

* ABC summary quality grading system adapted from methods used in Evidence Reports of the AHRQ Evidence-Based Practice Centers (www.ahrq.gov/clinic/epcindex.htm). Grade A= Least bias; results are valid. B= Susceptible to some bias, but not sufficient to invalidate the results. C= Significant bias that may invalidate the results.

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TABLE 2

Studies examining Tai Chi in coronary heart disease and heart failure

Reference (Author, Yr, Country, Language)	Study Design	Study Population Description, Mean Age	N*	Intervention/ Control Details	Main Results**	Modified Jadad; ABC Quality Score†
Coronary Heart Disease						
Channer 1996, UK, E	RCT	• CHD, Post-acute MI • 56 yrs	126	• Wu style TC/Qigong × 8 wks • Exercise to music • Support group	• ↓ BP • ↓ Resting HR • Greater compliance with TC	+2 B
Lan 1999, Taiwan, E	NRS	• CHD, Post-CAB (Men) • 57 yrs	20	• Yang style TC × 1 yr • Walking	• ↑ Exercise capacity • Greater compliance with TC • TC exercise intensity 48–57% HR_{max} reserve	B
Zheng 2004, China, C	NRS	• CHD, Post-hospital discharge • 68 yrs	24	• Yang style TC (Simplified 24 forms) × 3 mos • No control	•↓ DBP •No change in SBP or resting HR •↑ HR max during exercise;↑ HR reserve	C
Heart Failure						
Yeh 2004, US, E	RCT	• CHF, chronic stable LVEF <=40% NYHA Class I–IV • 64 yrs	30	• Yang style TC × 12 wks • Usual care	• ↑ Exercise capacity • ↓ B-type natriuretic peptide • Improved HF-specific QOL • No change in catecholamines • Improved sleep stability • NS trend improved heart rate variability during sleep	+4 A
Wei 2003, China, C	RCT	• CHF, LVEF range not specified (CHD 40%, HTN 60%) NYHA Class II–IV • 60 yrs	70	• Yang style TC (Simplified 24 forms) × 12 wks • Usual Care	• ↑ LVEF	+1 C
Barrow 2007, UK, E	RCT	• CHF, chronic stable, systolic dysfunction LVEF range not specified NYHA Class II–III • 70 yrs	52	• Wu Chian Chuan style × 16 wks • Usual Care	• No change in exercise tolerance • Improved HF-specific QOL • NS trend improved depression scores	+3 A
Fontana 2000, US, E	NRS	• CHF, chronic stable, LVEF= 25–35% (2 unspecified) • 65 yrs	5	• Modified TC × 12 wks • No control	• ↑ Exercise capacity (6min walk) • Improved HF-specific QOL, ↓ symptoms (dyspnea) • Improved vigor and physical function • Good compliance with TC after 3 months	B

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Reference (Author, Yr, Country, Language)	Study Design	Study Population Description, Mean Age	N*	Intervention/ Control Details	Main Results**	Modified Jadad; ABC Quality Score†
Zhang 1988, China, C	NRS	• "Mal LV function" NOS 6–24 mos TC experience • 61 yrs	13	• TC/Qigong (15 style) × 6–12 mos • No control	• ↓PEPI, ↓ PEP/LVET, ↑LVEF	C

Study Type Key: NRS- prospective non-randomized intervention studies, controlled and non-controlled; OBS- observational, cross-sectional studies, controlled and non-controlled; RCT- randomized controlled clinical trials

Abbreviations: C=published in Chinese; CAB, coronary artery bypass; CHD, coronary heart disease; CHF, chronic heart failure; DBP, Diastolic blood pressure; E, published in English; HR, Heart rate; LVEF, left ventricular ejection fraction; LVET, left ventricular ejection time; MI, myocardial infarction; NOS, not otherwise specified; NS, non-significant; NYHA, New York Heart Association; PEP, pre-ejection phase (PEPI, corrected for heart rate); QOL, quality of life; SBP, systolic blood pressure; TC= tai chi

*Number of study participants included in analyses

**All within-group (TC) pre-post changes are significant with $P \leq .05$ unless otherwise noted. All results in controlled trials are reported in comparison to the control group(s) and are significant with $P \leq .05$ unless otherwise noted.

†Modified Jadad for RCTs (which gives 1 point for proper single-blinding of outcome assessors); ABC Quality Score A, studies where there appeared to be the least amount of bias and results were likely valid. ABC Quality Score B, studies that appeared susceptible to some bias, but not sufficient to invalidate the results. ABC Quality Score C, studies with evidence of significant bias that may invalidate the results

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TABLE 3

Studies examining Tai Chi in heterogeneous populations including cardiovascular conditions

Reference (Author, Yr, Country, Language)	Study Design	Study Population Description, Mean Age	N*	Intervention/ Control Details	Main Results**	ABC Quality Score†
Jones 2005, Hong Kong, E	NRS	• Community dwellers •Heart condition NOS 6%, HTN 16%, Stroke 8% • 53.5 yrs	51	• Cheng 119 style TC × 12 wks • No control	•↑ Peak expiratory flow rate, •↑ Spinal flexion, ↑ stability, ↑ left shoulder flexion	B
Kui 1990, China, C	NRS	• Hospital rehabilitation clinic patients •CHD 32%, COPD/chronic bronchitis 79%, Healthy 25% • 50–75 yrs	28	• Yang Style TC (Simplified 24 forms) × 18 mos • Usual Care	• NS trend improved pulmonary function (↑VC, ↑ TLC)*** •↑FVC (P<0.001)*** • No change in control	B
Liu 1993, China, C	NRS	• Community dwellers •CHD 27%, HTN 13%, Healthy 60% • 58 yrs	55	• TC (unspecified style)×3 mos • No control	•↑ SV, ↑CO, ↑CI, ↑SWI, ↑CWI, ↑CW, ↑contractility	C
Sun 1988, China, C	NRS	• Hospital rehabilitation clinic patients •CHD 43% COPD/chronic bronchitis 64% Healthy 14% • 64 yrs	14	• Yang Style TC (Simplified 24 forms) × 18 mos • No control	• Improved pulmonary function (↑VC, ↑ FVC, ↑ FEV1, ↑ TLC)	B
Zhang 1988, China, C	NRS	• Community dwellers with CVD NOS • 61 yrs	34	• TC/Qigong (15 style) unspecified duration No prior TC experience • No control	• Improved “cardiac symptoms,” sleep quality, appetite, mood, fatigue	C
Jones 2005, Hong Kong, E	OBS controlled	• Community dwellers •Heart condition NOS 7%, HTN 14%, Stroke 4% Diabetes 1% • 53.4 yrs	149	• Cheng 119 style TC At least 6 mos experience • No TC experience	• ↑ Spinal flexion • ↓ Resting HR, ↓ lower DBP	B
Yao 1996, China, C	OBS cont	•Retired elders with and without TC experience •Arrhythmia 50% • 69 yrs	60	•TC (Simplified 24, 40, and 48 forms) 2–20yrs TC experience • No TC experience	•↓ Arrhythmias • Improved HR recovery on stand-up test • Improved HR reserve	B

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Reference (Author, Yr, Country, Language)	Study Design	Study Population Description, Mean Age	N*	Intervention/ Control Details	Main Results**	ABC Quality Score†
Liu 1996, China, C	OBS	• TC practitioners •CHD 17%, HTN 25%, Stroke 8%, COPD 17% • 63 yrs	12	• Yang style TC (Simplified 24 forms) Mean 10.6 years TC experience • No control	• Acute ↓ SBP and DBP after TC • No change in acute HR	B
Gong 1981, China, E	OBS	•TC practitioners •CHD 35%, HTN 15%, Other chronic disease 15%, "healthy" 35% • 46–80 yrs	100	• TC (Simplified form) 6–30 yrs TC experience • No control	• Acute ↑ HR during 20 min TC, returning to rest 6–8 min after exercise, similar changes by age and TC experience • No changes in pre-post BP	B
Chao 2002, Taiwan, E	OBS	• TC practitioners •CHD 6%, Arrhythmia 4%, HTN 32% • 60.7 yrs	47	• TC/Qigong (54 movements) Mean 3.6 yrs TC experience • No control	• Acute ↑HR, ↑RR, ↑BP, ↑Ve during 1hr TC • Exercise intensity 50–60% VO2max • Exercise intensity 10.8 ml/kg/min; 2.6–3.5 METs	A

Study Type Key: NRS - prospective non-randomized intervention studies, controlled and non-controlled; OBS - observational, cross-sectional studies, controlled and non-controlled

Abbreviations: ABC Quality Score A, studies where there appeared to be the least amount of bias and results were likely valid. ABC Quality Score B, studies that appeared susceptible to some bias, but not sufficient to invalidate the results. ABC Quality Score C, studies with evidence of significant bias that may invalidate the results; C, published in Chinese; CHD, coronary heart disease; CI, cardiac index; CO, cardiac output; cont, controlled; COPD, chronic obstructive pulmonary disease; CW, cardiac work; CWI, cardiac work index; DBP, diastolic blood pressure; E, published in English; FVC, forced vital capacity; HR, heart rate; HTN, hypertension; METs metabolic equivalents; NOS, not otherwise specified; NS, non-significant; RR, respiratory rate; SBP, systolic blood pressure; TC, tai chi; TLC, total lung capacity; SV, stroke volume; SWI, stroke work index; VC, vital capacity; Ve, expired ventilation; VO2max, maximal oxygen uptake

* Number of study participants included in analyses

** All within-group (TC) pre-post changes are significant with $P \leq .05$ unless otherwise noted. All results in controlled trials are reported in comparison to the control group(s) and are significant with $P \leq .05$ unless otherwise noted.

*** Within-group analysis (no between-group analysis available)

† ABC Quality Score A, studies where there appeared to be the least amount of bias and results were likely valid. ABC Quality Score B, studies that appeared susceptible to some bias, but not sufficient to invalidate the results. ABC Quality Score C, studies with evidence of significant bias that may invalidate the results

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TABLE 4

Studies examining Tai Chi in subjects with hypertension, dyslipidemia, and impaired glucose metabolism

Reference (Author, Yr, Country, Language)	Study Design	Study Population Description, Mean Age	N*	Intervention/ Control Details	Main Results**	Modified Jadad; ABC Quality Score
Young 1999, US, E	RCT	• "High Normal or Stage I HTN" • 67 yrs	60	• Yang style TC (13 movements) × 12 wks • Walking/aerobic dance	• ↓SBP and DBP both groups (between-group p=NS) • No change in exercise capacity • Greater compliance with TC	+4† A
Tsai 2003, Taiwan, E	RCT	• "High Normal or Stage I HTN" • 51 yrs	76	• Yang style TC (108 postures) × 12 wks • Usual care	• ↓ SBP and DBP •↓ Total chol, ↓LDL, ↓TG, ↑HDL • ↓ Anxiety	+3† B
Thomas 2005, Hong Kong, E	RCT	• Elderly •HTN 61%, Dyslipidemia 59%, Impaired glucose tolerance/DM 14% • 69 yrs	207	• Yang style TC (Simplified 24 forms)× 12 wks • Strength/resistance training with Theraband • Usual activity	• ↓ DBP with TC, ↓ SBP with Theraband (between-group p=NS) • No change in total chol, TG, LDL, HDL • ↓ Fasting glucose, ↓ HgbA1C all groups (between-group p=NS)	+3 A
Shen 2000, China, C	RCT	• "Essential HTN" • 64 yrs	60	• TC/Qigong (18 postures; unspecified duration) • Medication†† • No treatment	• ↓ SBP and DBP (compared to medication and to no treatment)	+2 C
Tsang 2007 Orr 2006, Australia, E	RCT	• Type 2 DM • Metabolic syndrome 81%, HTN 76%, Dyslipidemia 65%, CHD 34% • 65 yrs	38	•Yang and Sun style TC (12 movements) Paul Lam's Tai Chi for Diabetes Program × 16 wks • Calisthenics/gentle stretching	• No change in insulin resistance or HgbA1C • ↓ Body fat in both groups (between-group p=NS) • No change in body weight, waist circumference, fat-free mass •No change in mobility or gait speed	+4 A
Wang 2000, China, C	NRS	• "Essential HTN or High Normal " (Men) • 66 yrs	54	• Yang style TC × 3 yrs • No control	• ↓ SBP and DBP	B
Fang 1985, China, C	NRS	• "Stage I/II HTN" • Range 40–70 yrs	70	• Yang style TC (Simplified 24 forms) × 12 wks • Qigong breathing • Medication (Tab Hypotensor= Captopril)†† • No treatment	• ↓ SBP and DBP all groups compared to no treatment (between group p=NS for active interventions)	B
Lu 1987, China, C	NRS	• "HTN" • 66 yrs	14	• TC (unspecified style)/ Qigong/Relaxed slow running × 6 mos • No control	• ↓ SBP and DBP •↓ Pulse pressure, ↓ PEP, ↑ LVET •No change in resting HR, SV, CO, CI	B

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Reference (Author, Yr, Country, Language)	Study Design	Study Population Description, Mean Age	N*	Intervention/ Control Details	Main Results**	Modified Jadad; ABC Quality Score
Taylor-Piliae 2006, US, E	NRS	• At least one CV risk factor •HTN 92%, Dyslipidemia 49%, DM 21% • 66 yrs	38	• Yang style TC (24 posture short form) × 12 wks • No control	• ↓ SBP and DBP at rest and after step-test • Improved balance, strength, flexibility • Improved mood, ↓ perceived stress, ↑self-efficacy, ↑ perceived social support	B
Yeh 2007, Taiwan, E	NRS	• Type 2 DM	32	Cheng TC 37 forms × 12 wks • No control	• ↓ Hgb A1C • NS trend ↓ fasting glucose	B
Liu 2004, China, C	OBS cont	• “Chronic HTN” • 66 yrs	113	• TC (unspecified style; unspecified duration) • No TC	• ↓SBP • ↓ Total chol, ↓ TG, ↑HDL • ↓ Resting HR, ↓ CI	B

Study Type Key: NRS- prospective non-randomized intervention studies, controlled and non-controlled; OBS- observational, cross-sectional studies, controlled and non-controlled; RCT- randomized controlled clinical trials

Abbreviations: C, published in Chinese; CHD, coronary heart disease; Chol, cholesterol; CI, cardiac index; CO, cardiac output; cont, controlled; DBP, diastolic blood pressure; DM, diabetes mellitus; E, published in English; HDL, high-density lipoprotein; HgbA1C, hemoglobin A1C; HR, heart rate; HTN, hypertension; LDL, low-density lipoprotein; LVET, left ventricular ejection time; NS, non-significant; PEP, pre-ejection phase; SBP, systolic blood pressure; SV, stroke volume; SWI, stroke work index; TC, tai chi; TG, triglycerides

*Number of study participants included in analyses

**All within-group (TC) pre-post changes are significant with $P \leq .05$ unless otherwise noted. All results in controlled trials are reported in comparison to the control group(s) and are significant with $P \leq .05$ unless otherwise noted.

†Modified Jadad for RCTs (which gives 1 point for proper single-blinding of outcome assessors); ABC Quality Score A, studies where there appeared to be the least amount of bias and results were likely valid. ABC Quality Score B, studies that appeared susceptible to some bias, but not sufficient to invalidate the results. ABC Quality Score C, studies with evidence of significant bias that may invalidate the results

††No further details reported