Effects of Tai Chi Mind-Body Movement Therapy on Functional Status and Exercise Capacity in Patients with Chronic Heart Failure: A Randomized Controlled Trial

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PURPOSE: To examine the effects of a 12-week tai chi program on quality of life and exercise capacity in patients with heart failure.

METHODS: Thirty patients with chronic stable heart failure and left ventricular ejection fraction ≤40% (mean [± SD] age, 64 ± 13 years; mean baseline ejection fraction, 23% ± 7%; median New York Heart Association class, 2 [range, 1 to 4]) were randomly assigned to receive usual care (n = 15), which included pharmacologic therapy and dietary and exercise counseling, or 12 weeks of tai chi training (n = 15) in addition to usual care. Tai chi training consisted of a 1-hour class held twice weekly. Primary outcomes included quality of life and exercise capacity. Secondary outcomes included serum B-type natriuretic peptide and plasma catecholamine levels. For 3 control patients with missing data items at 12 weeks, previous values were carried forward.

RESULTS: At 12 weeks, patients in the tai chi group showed improved quality-of-life scores (mean between-group difference in change, –25 points, $P = 0.001$), increased distance walked in 6 minutes (135 meters, $P = 0.001$), and decreased serum B-type natriuretic peptide levels (–138 pg/mL, $P = 0.03$) compared with patients in the control group. A trend towards improvement was seen in peak oxygen uptake. No differences were detected in catecholamine levels.

CONCLUSION: Tai chi may be a beneficial adjunctive treatment that enhances quality of life and functional capacity in patients with chronic heart failure who are already receiving standard medical therapy. **Am J Med. 2004;117:541–548.** ©2004 by Elsevier Inc.

The prevalence of chronic heart failure is increasing as the population ages, and the disease is the most common reason for hospitaladmission among Medicare patients. Approximately 5 million adults in the United States are affected, with 550,000 new cases diagnosed each year (1). Despite advances in pharmacologic therapy, such as the use of angiotensin-converting enzyme inhibitors and beta-blockers, patients with heart failure experience progressively deteriorating function.

Reduced physical activity in patients with heart failure leads to progressive deconditioning and exercise intolerance (2). Trials have shown exercise to be associated with improvements in exercise capacity, left ventricular hemodynamics, and quality of life (2,3); attenuation of neurohormonal activation and ventricular remodeling (4,5); and decreased risk of hospitalization and death (6). These studies, however, varied in the type of physical activity, setting, duration, and intensity. Current American Heart Association guidelines do not specify a standard exercise prescription for patients with heart failure (2).

Tai chi is a mind-body movement therapy with origins in traditional Chinese martial and healing arts. Although widely practiced in Asia, particularly among the elderly, its popularity is increasing in the United States. Reported benefits include increased balance and decreased incidence of falls (7–9), increased strength and flexibility (8,10–12), reduced pain and anxiety (13,14), improved

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Table 1. Outline of the Tai Chi Intervention

Week	Activities	Approximate Duration (min)
1	Introductory Session: Overview of Program	
	1. Tai chi principles, philosophies	15
	2. Demonstration of tai chi form	10
	3. Expectations of participants	10
	4. Description of class format	5
	5. Participation in warm-up exercises	30
2–5	Warm-up Exercises (Repeated during All Sessions)	
	1. Standing	
	a) "Drumming the body"	6
	b) "Swinging to connect kidney and lungs"	3
	c) "Washing the body with *qi*"	3
	d) Standing meditation and breathing	3
	2. Sitting	
	a) Neck/shoulder stretches	6
	b) Arm/leg stretches	3
	c) Sitting meditation and breathing	6
	Total Warm-up time	30
	Tai Chi Movements	
	1. "Raising the power"	5–10
	2. "Withdraw and push"	5 per side
	(Warm-up and Movements 1–2)	
	3. "Grasp sparrow's tail"	5 per side
	4. "Brush knee twist step"	5 per side
10–12	(Warm-up and Movements 1–4)	
	5. "Wave hands like clouds"	5–10

self-efficacy (15,16), and enhanced cardiopulmonary function (10,11,17–20). Despite the lack of randomized controlled trials, tai chi has become available in some cardiac rehabilitation programs (21).

Tai chi incorporates both physical and meditative elements, which makes it distinctly different from conventional treadmill or bicycle workouts. It is relatively nonstrenuous and low impact, and is characterized by postural alignment, weight shifting, and relaxed circular movements. Tai chi has been estimated to equal about 2 to 4 metabolic equivalents, comparable with mild-moderate aerobic exercise (22,23). Exercise trials have suggested that lower intensity activity may be as beneficial as exercise of higher intensity in heart failure patients (24). Tai chi may thus be suitable for older or severely deconditioned cardiac patients. Our objective was to investigate whether tai chi is beneficial as an adjunctive treatment to usual care for patients with chronic heart failure.

METHODS

Study Design

A total of 30 patients were recruited from advanced heart failure clinics at Beth Israel Deaconess Medical Center and Brigham and Women's Hospital in Boston, Massachusetts. Clinicians approached eligible patients to discuss enrollment in a study of "tai chi, a slow-moving and meditative exercise." Patients were assigned randomly to receive either 12 weeks of tai chi training in addition to their usual care, or to usual care alone, without a formal supervised exercise protocol. Usual care included pharmacologic therapy, dietary counseling, and general exercise advice per American College of Cardiology/American Heart Association guidelines (3). Patients receiving usual care only were offered tai chi at the conclusion of the study. We used permuted block randomization with variable block size to generate treatment assignments. Assignments were sealed in sequentially numbered, opaque envelopes and opened by an unblinded investigator following the patient's baseline testing. All patients provided written informed consent. Each institution's human subjects review board approved the protocol.

Study Sample

Inclusion criteria comprised left ventricular ejection fraction ≤40% by echocardiography in the past year and maintenance on a stable medical regimen, defined as no major changes in pharmacologic therapy in the past 3 months. Exclusion criteria comprised unstable angina, myocardial infarction, or cardiac surgery within the past 3 months; uncontrolled cardiac arrhythmias; major

Table 2. Baseline Characteristics of the Study Sample

Characteristic	Tai Chi (n = 15)	Control (n = 15)	*P* Value
	Mean ± SD or Number (%)		
Age (years)	66 ± 12	61 ± 14	0.67
Male sex	10 (67)	9 (60)	0.71
Race			0.28
Black	7 (47)	4 (27)	
White	8 (53)	9 (60)	
Asian	0	2 (13)	
Baseline ejection fraction (%)	24 ± 7	22 ± 8	0.43
New York Heart Association class	2.2 ± 1.0	2.2 ± 0.6	0.19
I	4 (27)	1 (6.6)	
II	6 (40)	9 (60)	
III	3 (20)	5 (33)	
IV	2 (13)	0	
Medications			
Angiotensin-converting enzyme inhibitor	13 (87)	14 (93)	0.54
Beta-blocker	14 (93)	13 (87)	0.54
Loop diuretic	13 (87)	15 (100)	0.48
Digoxin	11 (73)	8 (53)	0.45
Spironolactone	4 (27)	4 (27)	1.00
Cholesterol-lowering agent	5 (33)	6 (40)	0.70
Heart failure etiology			0.79
Idiopathic dilated	9 (60)	8 (53)	
Ischemic	4 (27)	4 (27)	
Alcohol-related	1 (7)	1 (7)	
Hypertensive	0	1 (7)	
Peripartum	1 (7)	0	
Adriamycin-induced	0	1 (7)	
Cardiovascular-related comorbid conditions			
Coronary artery disease	4 (27)	7 (47)	0.45
Implanted cardiac device*	6 (40)	4 (27)	0.70
Arrhythmia	10 (67)	6 (40)	0.27
Valvular heart disease	7 (47)	3 (20)	0.25
Hypertension	11 (73)	9 (60)	0.70
Diabetes	3 (20)	5 (33)	0.68

* Automatic implanted cardiac defibrillator or pacemaker.

structural valvular disease; current participation in a conventional cardiac rehabilitation program; lower extremity amputation; cognitive dysfunction; and inability to speak English.

Intervention

The intervention consisted of 1-hour group tai chi classes held twice weekly for 12 weeks. A standard protocol of meditative warm-up exercises followed by five simplified tai chi movements (25) was developed by an experienced tai chi instructor (PMW) (Table 1). Program development was guided by similar interventions used in prior tai chi trials involving elderly patients and those with limited mobility (26). The five core movements, adapted from Master Cheng Man-Ch'ing's Yang-style short form, were chosen for ease of comprehension and their ability to be performed in cyclic repetition. Traditional warm-up exercises included weight shifting, arm swinging, visualization techniques, and gentle stretches of the neck, shoulders, spine, arms, and legs. These exercises focus on releasing tension in the physical body, incorporating mindfulness and imagery into movement, increasing awareness of breathing, and promoting overall relaxation of body and mind. Chairs were provided for resting at any time, and patients were allowed to progress at their own pace. Each class was supervised by a physician (GYY, MJW). In addition, there was a 35-minute instructional videotape outlining the warm-up exercises and tai chi movements presented in class. Patients were encouraged to practice at home at least three times per week.

Main Outcome Measures

Quality of life. Quality of life was measured using the Minnesota Living with Heart Failure Questionnaire (27).

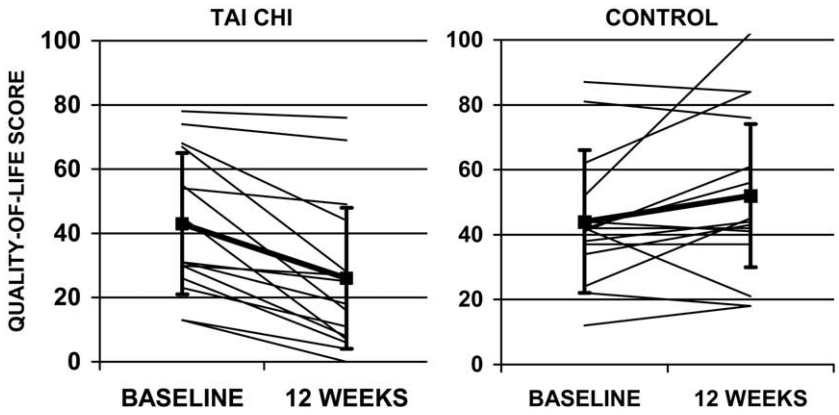

Figure 1. Change in Minnesota Living with Heart Failure quality-of-life scores from baseline to 12 weeks. Means (± SD) are shown in bold. At 12 weeks, patients in the tai chi group reported significantly better quality-of-life (lower scores) as compared with those in the usual care group ($P = 0.001$).

This self-assessment instrument consists of 21 items covering physical, psychological, and socioeconomic dimensions of illness, and quantitates the disability related to each item on a 6-point response scale. Scores range from 0 to 105, with a lower score denoting a more favorable functional status. Prior studies have reported that a score of 7 indicates some degree of impaired quality of life and that an improvement of 5 points represents a clinically meaningful change (2).

Exercise capacity. Patients performed a standardized walk test that measures the distance walked at a comfortable pace in 6 minutes. This test correlates with peak oxygen uptake, and has been used to assess functional capacity and predict survival in heart failure drug trials (28). Although the assessor was not blinded to the intervention group, the person administering the test read standard scripted instructions to each patient, stood at the same place along the corridor, and remained otherwise silent for the 6-minute duration.

In addition, patients performed a symptom-limited exercise test using a bicycle ramp protocol to determine peak oxygen uptake. Testing was performed on an electronically calibrated bicycle, with expired gas analysis under continuous electrocardiographic monitoring. Blood pressure was taken at 3-minute intervals. Respiratory gas analysis was performed on a breath-by-breath basis using a Sensormedic metabolic cart (Yorba Linda, California). Peak values were averaged from the final 20 seconds of the test. Tests were performed by blinded assessors. Peak oxygen uptake has a strong linear correlation with cardiac output and skeletal muscle blood flow, and has been used as a criterion to predict when patients with chronic heart failure should undergo cardiac transplantation (29).

Secondary Outcome Measures

Serum biomarkers. B-type natriuretic peptide samples were analyzed on whole blood collected in ethylenediaminetetraacetic acid using a fluorescence immunoassay (Biosite Triage BNP Test; San Diego, California). Levels

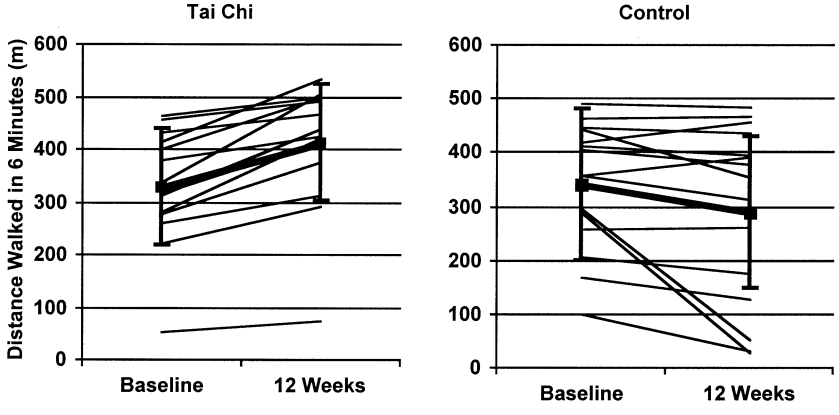

Figure 2. Change in 6-minute walk distance from baseline to 12 weeks. Means (± SD) are shown in bold. At 12 weeks, patients in the tai chi group performed significantly better as compared with those in the usual care group ($P = 0.001$). Imputation methods (last value carried forward) were used for missing 12-week data, affecting 1 patient in the control group.

Table 3. Comparison of the Effects of Tai Chi versus Usual Care Only on Changes in Outcomes during the 12-Week Trial

Outcome Measure	Tai Chi (n = 15)		Control (n = 15)*		Between-Group Difference in Change	*P* Value
	Baseline	12-Week	Baseline	12-Week		
	Mean ± SD				Mean (95% Confidence Interval)	
Minnesota Living with Heart Failure score†	43 ± 21	26 ± 23	44 ± 20	52 ± 25	−25 (−36 to −14)	0.001
6-minute walk (m)	327 ± 106	412 ± 116	340 ± 117	289 ± 165	+135 (85 to 185)	0.001
Peak oxygen uptake (mL/kg/min)	10.5 ± 3	11.4 ± 3	11.1 ± 6	10.4 ± 6	+1.6 (0.2 to 3)	0.08
Serum B-type natriuretic peptide† (pg/mL)	329 ± 377	281 ± 365	285 ± 340	375 ± 429	−138 (−257 to −19)	0.03
Plasma norepinephrine (ng/mL)	1.3 ± 0.7	1.9 ± 2.3	1.2 ± 0.8	1.4 ± 0.7	+0.35 (−0.84 to 1.54)	0.77

* Imputation methods (last value carried forward) were used for missing 12-week data, affecting 1 patient in the control group for quality-of-life score and serum B-type natriuretic peptide level, and 3 patients in the control group for peak oxygen uptake.
† Lower values indicate improvement. Thus, a negative between-group difference in change for quality-of-life score and B-type natriuretic peptide level suggests improvement, while a positive value for the 6-minute walk test suggests improvement.

correlate positively with the degree of left ventricular dysfunction; serum levels >100 pg/mL support a diagnosis of symptomatic heart failure (30).

Catecholamine samples were drawn on ice in heparinized tubes after 20 minutes of rest with an intravenous catheter in place. After centrifugation, plasma was separated and stored at –70°C. Analyses for norepinephrine were performed using high-performance liquid chromatography/electrochemical detection.

Continuous ambulatory electrocardiographic recording. Patients underwent 24-hour ambulatory electrocardiographic monitoring to assess the prevalence and frequency of cardiac arrhythmias. Recordings were performed using a Marquette Electronics series 8500 Holter monitor (Milwaukee, Wisconsin), digitized at 128 Hz, and annotated using a Marquette Electronics MARS 8000 Holter scanner. Annotations were verified manually and edited by an experienced technician who was blinded to treatment assignment.

Timing of Measurements

All measures were obtained at baseline and 12 weeks. Measurements for the quality-of-life assessment, 6-minute walk test, and peptide levels were also obtained at 6 weeks in the event that data at 12 weeks were unavailable.

Additional Data Collection

At baseline, we asked patients to rate their expectations of the helpfulness of tai chi on a 10-point visual analog scale, where 10 indicated the highest expectation. At each follow-up visit, we collected data on current medications, regular activity level, recent emergency department visits, and recent hospitalizations. For patients in the intervention group, we also monitored attendance at classes and compliance with home tai chi practice. At two separate sessions (at approximately 6 and 12 weeks), heart rate and blood pressure were taken immediately before and after the class, each after 2 minutes of restful sitting.

Statistical Analysis

All statistical analyses were performed on an intention-to-treat basis. Baseline characteristics of patients were compared using *t* tests for continuous variables and the Fisher exact test for nominal variables. Two-sample Wilcoxon rank sum tests that adjusted for baseline scores were used to compare the distribution of changes after 12 weeks between treatment and control groups. Data on blood pressure and heart rate before and after tai chi sessions were analyzed using paired *t* tests. Metabolic stress test and Holter data for 3 patients in the control group were unavailable at 12 weeks: 1 patient was too debilitated to perform the tests, another refused, and the third was only available for telephone-follow-up. For this last patient, we were also unable to gather 6-minute walk, natriuretic peptide, and catecholamine measurements at 12 weeks. The last value was carried forward for analyses missing these items. Analyses were performed using SAS statistical software, version 8 (Cary, North Carolina). *P* values <0.05 were considered significant.

RESULTS

Thirty patients were recruited and followed between January 2002 and March 2003 (Table 2). The mean (± SD) age was 64 ± 13 years; the mean baseline ejection fraction was 23% ± 7%; and the median New York Heart Association class was 2 (range, 1 to 4). There were no significant differences between groups in demographic characteris-

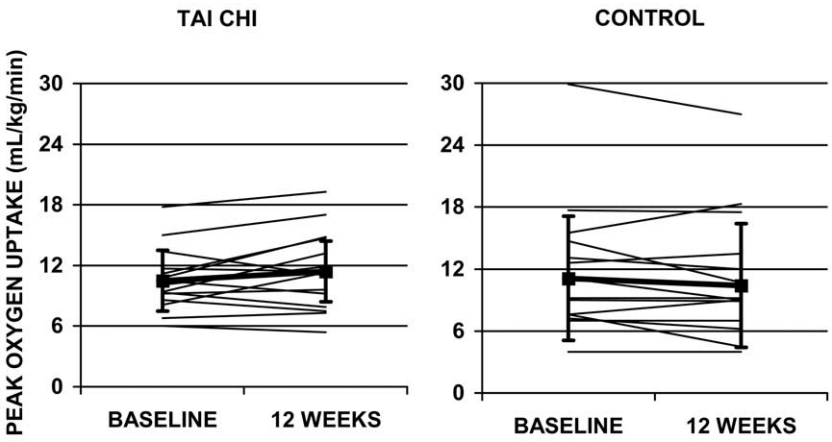

Figure 3. Change in peak oxygen uptake from baseline to 12 weeks. Means (± SD) are shown in bold. At 12 weeks, there was no significant difference between the two groups ($P = 0.08$). Imputation methods (last value carried forward) were used for missing 12-week data, affecting 3 patients in the control group.

tics, clinical factors, and rates of cardiovascular-related disease.

More than three quarters (77%) of patients reported some regular physical activity at home, such as walking. Similar proportions of patients in each group reported exercising (intervention: 14/15; control: 12/14). The duration of exercise ranged from 5 to 65 minutes, and the frequency ranged from once a week to daily.

Both groups had similar expectations of the helpfulness of tai chi at the beginning of the study (intervention: 6.5; control: 7.1; $P = 0.4$).

Changes in Outcome Measures from Baseline to 12 Weeks

Compared with controls, patients in the tai chi group showed statistically significant improvement in quality-of-life scores (Figure 1), 6-minute walk distances (Figure 2), and serum B-type natriuretic peptide levels (Table 3). Changes in peak oxygen uptake were not significant, although the intervention group showed an improvement of almost 1 mL/kg/min, while the control group showed deterioration of 0.7 mL/kg/min (Figure 3). There were no significant trends seen in resting catecholamine levels.

Twenty-four–hour Holter monitoring revealed no clinically important intraindividual differences in the incidence of arrhythmia at baseline and 12 weeks. One patient in the control group with a known history of intermittent atrial fibrillation was in normal sinus rhythm at baseline but in atrial fibrillation at 12 weeks.

Adverse Effects

No adverse events occurred during the tai chi sessions. One patient in the intervention group and 4 in the control group were hospitalized during the study period for exacerbation of symptoms of heart failure. There were no deaths during the 3-month study period in either group. We did not detect any significant changes in mean blood pressure (119/72 mm Hg vs. 117/72 mm Hg, $P = 0.4$) or heart rate (75 beats per minute vs. 73 beats per minute, $P = 0.3$) immediately before and after a tai chi session.

Patients in the intervention group attended 83% (20/24) of class sessions, and 93% of patients (n = 14) reported home tai chi practice for a mean duration of 86 minutes per week. All patients rated the tai chi sessions highly (4 on a 0 to 4 visual analog scale for enjoyment) and expressed interest in additional instruction. Fourteen planned to continue with tai chi on their own after the study.

DISCUSSION

We found that tai chi enhanced the quality of life and functional capacity in patients with chronic heart failure who were already undergoing standard cardiac care. These patients demonstrated improvements in 6-minute walk distances and quality-of-life scores compared with patients who did not practice tai chi. In addition, patients who practiced tai chi had reduced B-type natriuretic peptide levels, suggesting an improvement in cardiac filling pressures.

In patients with comparable disease severity, similar changes in exercise tolerance have been seen with conventional training. Trials involving step aerobics, treadmill or bicycle exercise, or arm or rowing ergometers have reported increases of 10% to 20% in the 6-minute walk test and of 12% to 31% in peak oxygen uptake (4,6,31–34). We found a comparable increase of about 25% in the 6-minute walk test among patients in the tai chi group. Results of quality-of-life measures in conventional exercise trials have been mixed (6,32,35–37). We, however, observed a large difference in Minnesota Living with Heart Failure scores between the intervention and control groups. Similar to our findings, conventional exercise

trials have failed to show consistent changes in resting norepinephrine and epinephrine levels (32,38). To our knowledge, longitudinal effects of conventional exercise on serum B-type natriuretic peptide levels have not been studied previously (39).

Our findings support prior research on tai chi and cardiovascular disease. One prospective, noncontrolled trial of 5 patients reported improvements in quality of life, 6-minute walk test distance, and symptoms after a 12-week intervention (21). Other controlled trials reported improvements in blood pressure in patients after myocardial infarction (19) and increases in peak oxygen uptake and work rate following coronary bypass surgery (18). Observational studies have suggested increased exercise endurance and cardiac output, and decreased peripheral vascular resistance and adrenergic tone (10,11,17,40–42).

Tai chi appears to be a safe alternative to conventional exercise training. No adverse events have been reported previously, and we observed none in this study. Overall, the adverse event rate in conventional exercise trials is low. However, cases of worsened heart failure, arrhythmias, and hypotension have been reported, and minor musculoskeletal injuries are common (2). In contrast, tai chi encourages patients to move fluidly with less strain, and may be beneficial for patients with musculoskeletal conditions, such as osteoarthritis or rheumatoid arthritis (13,43).

It is unclear what component of tai chi is responsible for the observed benefits. Physical activity can have important effects, yet tai chi is a lower intensity activity than those previously studied. Some studies have reported benefits of meditation and relaxation techniques in patients with heart failure (44-46). Further understanding of these components, individually and in combination, may help to define the mechanisms of tai chi.

Our study has several limitations. First, the inability to blind patients to treatment assignment and unblinded assessment of the 6-minute walk test may have influenced results. In addition, with only 30 patients, the study had limited power to detect differences in peak oxygen uptake. Although we were unable to adjust for social interaction, any effects on mood or perceived quality of life would have been unlikely to account for the magnitude of change reported in exercise capacity.

In conclusion, this study provides information on meditative exercise among patients with heart failure. Given the benefits we observed, large-scale investigations are warranted and should include blinded assessments and a comparison group that adjusts for group social effect. Other endpoints might include left ventricular hemodynamics, autonomic tone, serum biomarkers of cardiac and immune function, and survival. Further studies might also define the population most likely to benefit from this type of intervention and assess whether the observed benefits can be sustained or increased. Finally, comparisons with conventional treadmill or bicycle ergometer exercise should help define the role of tai chi in the management of patients with heart failure.

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