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Tai Chi Research Review

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Abstract

This paper is a review of empirical studies, systematic reviews and meta-analysis publications on tai chi from the last few years. The review includes demographics/prevalence of tai chi as a practice, bibliometric analyses of the tai chi publications and the use of tai chi for physical fitness and cognitive function. Also, studies are reviewed on tai chi effects on psychiatric, medical and immune conditions as well as aging problems. Most of the recent tai chi research has focused on balance problems in the elderly. The methods and results of those studies are briefly summarized along with their limitations and suggestions for future research. Basically, tai chi has been more effective than control and waitlist control conditions, although not always more effective than treatment comparison groups such as other forms of exercise. More randomized controlled studies are needed in which tai chi styles are compared to each other and tai chi is compared to active exercise groups. Having established the physical and mental health benefits of tai chi makes it ethically questionable to assign participants to inactive control groups. Shorter sessions should be investigated for cost-effectiveness and for daily practice. Multiple physical and physiological measures need to be added to the self-report research protocols and potential underlying mechanisms need to be further explored. In the interim, the studies reviewed here highlight the therapeutic effects of tai chi.

Tai Chi Research Review

This paper is a review of empirical studies, systematic reviews and meta-analyses on tai chi that have been published over the past few years (since our last review in 2012) [1]. The term tai chi was entered into PubMed and the selection criteria were empirical studies (single arm or randomized controlled studies) in which standard treatment, waitlist and treatment comparison groups were used as controls for the different style tai chi groups. Systematic reviews, bibliometric analyses and meta-analyses are also included. Exclusion criteria were case studies, qualitative studies, small sample pilot studies and research in which the assessors were not blind.

Brief summaries of papers are given on the demographics/prevalence of tai chi as a practice as well as bibliometric analyses of tai chi. Most of the studies reviewed here involve tai chi effects on psychiatric and medical conditions. These include student stress, cognitive and physical function; psychological conditions including insomnia, anxiety, depression, obesity-related depression and schizophrenia; cardiovascular and cardio respiratory conditions including hypertension and stroke; pain syndromes including low back pain, arthritis, fibromyalgia and spinal cord injuries; autoimmune conditions including type II diabetes and multiple sclerosis; immune conditions including breast cancer and lung cancer; and aging problems including anxiety disorder, fear of falling and balance, osteoporosis, knee osteoarthritis and Parkinson's. Most of the recent tai chi research has focused on balance problems in the elderly. The methods and results of those studies are briefly summarized along with their limitations, potential underlying mechanisms and suggestions for future research.

Demographics

Tai chi is a martial art that is basically a slowed down version of karate movements and they are typically performed alone rather than in contact with a partner. Tai chi is practiced as 5 different styles with the Yang and Sun forms being the most popular in the U.S. and those that have been practiced in the studies summarized here [1,2]. The Yang style was created by Yang Luchan in the early 1800s in China and is the most widely practiced and easiest to learn, although there are 20 variations of this style with varying numbers of movements. The Sun style was created by Sun Lutang as a combination of Yang and other styles in about 1900 in China and is well-known for its smooth, flowing movements, although it is a more upright, less flowing style than the Yang style and lacks the more physically vigorous leaping and crouching movements of the other more difficult styles.

Tai chi movements typically lead to large vertical and mediolateral displacements of the body as compared to walking

[2]. During movements called, for example, repulse monkey" and "wave hand in cloud", the knees remain flexed while range of motion involves larger abduction and adduction of the knees than for walking. When tai chi practitioners and non-practitioners have viewed videotapes of tai chi sequences, the practitioners were able to discriminate the technical from the aesthetic components of the actions [3].

The exercise intensity of tai chi has been evaluated by oxygen consumption and heart rate [4]. These cardio respiratory and energy expenditure measures suggest that tai chi is a low intensity exercise. When the safety of tai chi was evaluated in a systematic review, only 33% of 153 eligible randomized controlled trials (RCTs) included the reporting of adverse events and of those, only 12% overall noted a monitoring protocol for adverse events [5]. The adverse events reported were typically minor and basically musculoskeletal aches and pains typically in the knees and back. These results are tentative and much of the reporting of adverse events has been limited and inconsistent.

Barriers as well as promoters for participation in tai chi have included physical and mental health, time of day, socialization, accessibility and availability of teachers [6]. These data came from a study in which 87 lower socioeconomic older adults from multiple ethnic backgrounds were interviewed before starting a 16-week tai chi program. Another study measured adherence to a 16-week tai chi program for multi-ethnic middle-aged and older adults living in a low socioeconomic environment [7]. In this sample of 210 participants (mean age=68) greater adherence was associated with older age, greater perceived stress, higher education and higher scores on mental and physical scales. In contrast, lower adherence was associated with higher baseline weekly physical activity.

A bibliometric analysis on 507 tai chi studies included8% systematic reviews, 50% randomized clinical trials, 18% randomized current controlled clinical studies and 23% single-arm (pre-post) studies [8]. The most frequent diseases/conditions studied were hypertension, diabetes, osteoarthritis, osteoporosis, breast cancer, heart failure, chronic obstructive pulmonary disease, coronary heart disease, schizophrenia and depression [8]. The primary reason given for practicing tai chi was for health promotion. The most common tai chi style was the Yang style, and typically tai chi was practiced 2 to 3 one-hour sessions per week for 12 weeks. Tai chi was combined with other therapies including medications, physical therapies and health education in 41 %of the studies and was practiced alone in 59% of them. At least 95% of the studies reported positive effects while 5% of the studies noted uncertain effects, and no serious adverse events were mentioned. These data are highly suggestive, although only half the studies reviewed were randomized clinical trials. This breakdown is consistent with that of the current review.

Student stress

Table 1: Students, physical fitness and cognitive functions that have been improved by tai chi: conditions, reference numbers, trial types, comparison groups and primary results (< and> signs indicate significant effects at least at p<.05).

Condition	Reference #	Trial	Comparison	Primary results
Student stress				
Middle school 9	RCT	Control	< anxiety	
University	10	RCT	Control >flexibility & balance	
	11	REVIEW	<depr, anxiety & sleep problems	
Physical fitness				
Physical performance	12	Quasi-exper	Control	>physical performance
	13	RCT	Other activ.	>walking speed
Cognitive functions				
Dual task	14	RCT	gen. interest class	> perform. dual cog. task
Cog. task & erp	15	RCT	exercise	=on P3 amplitude & cog. task
	16	RCT	aerobics	= on P3 amplitude & cog. task
Cog. task & fMRI	17	RCT	seated tai	=on fMRI & memory task
6 cog. tasks	18	tai chi experts vs. naïve	>performance 6 cog. tasks	
Several cog. tasks	19	REVIEW	exercise	>performance several cog. tasks
Several cog. tasks	20	Meta	exercise	>performance several cog. tasks

A control group comparison, a randomized controlled trial and a systematic review were found in the recent literature on tai chi for student stress (Table 1). In the non-controlled group comparison 160 middle school students were given a one-year tai chi program comprised of 60 minute sessions given five times a week [9]. The tai chi group showed improvement in behavior, intellectual and school status and popularity as well as reduced anxiety as compared to the control group. In a study on college students, 206 participants were randomly assigned to a 12-week tai chi group or to a control group that was instructed to continue their original activities [10]. The tai chi group showed significant improvements in flexibility on the site and reach test and on balance, and no adverse events were noted.

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In a systematic review on tai chi with university students including 68 reports on a sample of 9,263 students, four primary and eight secondary outcomes were noted [11]. These included increased flexibility, reduced depression symptoms, decreased anxiety and improved interpersonal sensitivity. The secondary outcomes were improved lung capacity, better balance, faster running time, and better quality sleep, reduced symptoms of compulsion, somatization and phobia and decreased hostility. The authors suggested that universities may provide tai chi as a means of promoting the well-being of their students.

Cognitive and physical function

Several researchers have conducted studies on cognitive and physical functions in various age groups. In a quasi-experimental design with a non-equivalent comparison group, healthy and active women were assigned to a tai chi program (twice a week for 8 weeks) or a control group [12]. By the end of the program the tai chi group was showing better physical performance. In a study with an elderly sample, tai chi was provided twice per week for six months and that group was compared to a control group who participated in "other non-athletic activities" [13]. Assessments made at three and six months suggested that the tai chi group performed better on the Mini-mental state examination, on grip strength and on walking speed. In a randomized controlled study older women were randomly assigned to a 12-form Yang style tai chi training or a general interest class control group [14]. At the end of 16 weeks the tai chi group showed superior performance on a dual task cognitive exercise and better balance during the dual task condition.

In a study with a relatively complex design and measures, four groups were recruited including older adults performing endurance exercise, older adults practicing tai chi, older adults with a sedentary lifestyle and young adults practicing tai chi [15]. The participants completed a task-switching exercise while event related potentials were recorded. Both the endurance exercise and the tai chi group had larger P3 amplitudes (indicating greater attentiveness) and equivalent performance on the cognitive task. In another event-related potential study tai chi participants were compared with aerobic exercise and sedentary control participants [16]. Both exercise groups had larger P3 amplitudes during a task switching test.

In a functional magnetic resonance imaging (fMRI) study that measures activation of different parts of the brain and functional connectivity between different parts of the brain, a tai chi group was compared to a quigong (seated tai chi) group [17]. Both groups showed significant improvement on a memory quotient test, and their fMRIs showed increased functional connectivity between the hippocampus and the medial prefrontal cortex, suggesting that both forms of exercise may prevent memory decline during the aging process. This, however, was the only study that appeared in the recent literature that compared standing tai chi with sitting tai chi (qui gong), so it is unclear whether standing or sitting tai chi is more effective. In a study comparing tai chi experts with tai chi-naïve adults, the tai chi experts showed better performance on six cognitive tasks [18]. Typically, tai chi experts or tai chi practitioners have performed better than tai chi naive adults which are not surprising.

In a systematic review of nine studies including 632 participants, the tai chi groups compared to "usual activities groups" showed better performance on several cognitive tasks [19]. The problems with this review are that only five of the nine studies were randomized controlled trials and as many as 12 different tests were used, making it difficult to measure the consistency across studies.

In a meta-analysis, a large effect size was noted on cognitive tests when tai chi participants were compared with nonintervention controls, but only a moderate effect size was found when tai chi was compared with exercise controls [20]. Again, only 11 of the 20 eligible studies were randomized controlled trials. Nonetheless, the results highlight the positive effects of tai chi on cognitive functioning, at least in older adults. Younger adults have not been assessed for tai chi effects on cognitive functioning.

Psychological conditions

Table 2: Stress and psychological conditions that have been improved by tai chi: conditions, reference numbers, trial types, comparison groups and primary results (< and > signs indicate significant effects at least at p<.05).

Condition	Reference #	Trial	Comparison	Primary results
Psychological Conditions				
Insomnia	21	correl.	Time in tai chi	no effect
	22	RCT	cog. behav ther	cog behav ther >sleep
Anxiety	23	REV		<anxiety
Depression	24	SURVEY	>tai chi	<depression
	25	META	waitlist controls	<depression
	26	META		<depression & anxiety
Obesity with depr	27	RCT	waitlist control	<depression
	28	RCT	control	no changes body comp.
	29	RCT	Circuit exercise	circuit exercise <BMI
Schizophrenia	30	RCT	exercise	=negative & depression symptoms

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Several psychological conditions have been treated by tai chi in the last few years including insomnia, anxiety, depression, obesity with depression symptoms and schizophrenia (Table 2). Significantly fewer tai chi studies have been conducted on psychological than physical conditions which is somewhat surprising given that most of the studies have featured older adult samples who would have psychological as well as physical problems.

Insomnia: For insomnia, tai chi was surprisingly ineffective. In one study, linear regression analysis suggested that the duration of practicing tai chi and the style of tai chi did not make a significant contribution to sleep quality [21]. In this null finding study, however, most of the participants were good sleepers which would reduce the likelihood of sleep being altered. In addition, it is surprising that the duration of practicing tai chi did not make a difference as longer-term practitioners typically experience greater benefits. Different styles of tai chi are rarely compared, so the finding that different styles did not have different effects needs to be replicated. Sleep effects have been noted, in contrast, in a randomized controlled trial on older adults with chronic and primary insomnia [22]. These participants were randomly assigned to a cognitive behavioral therapy group, a tai chi group or a sleep seminar education control group. Tai chi was associated with improvements in sleep quality, fatigue and depression as compared to the control group. However, the cognitive behavior therapy group performed better than both the tai chi and control groups in terms of the remission of clinical insomnia. The superior effects for cognitive behavior therapy may relate to the unusually long tai chi sessions (2 hours) held weekly for four months having been too exhausting for these older adults.

Anxiety: Surprisingly, only one paper could be found in the recent literature on tai chi for anxiety. This was a review paper on 17 articles that met inclusion criteria with eight of them being from the US, two from Australia, two from Japan, two from Taiwan and one each from Canada, Spain and China [23]. Reduced anxiety was noted in at least 12 of the studies reviewed. However, the authors noted several limitations of this body of research including that most of the studies were non- randomized controlled trials that featured small sample sizes, non-standardized tai chi interventions and many different outcome measures.

Depression: Tai chi effects on depression have recently been researched in the form of a survey and a couple meta-analyses. In the survey study, 529 Japanese tai chi practitioners were given questionnaires on their training and their depression symptoms [24]. The prevalence of depressive symptoms was 16%. The length of tai chi training was independently related to the lesser prevalence of depressive symptoms. In a meta-analysis of randomized controlled trials on tai chi and depression, four trials with 203 participants met inclusion criteria [25]. Tai chi significantly reduced depression symptoms as compared with wait-list control groups. In another systematic review and meta-analysis, 37 randomized controlled trials and five quasi-experimental studies were included to assess the effects of tai chi on depression, anxiety and psychological well-being [26]. The conclusion of the meta-analysis was that tai chi had beneficial effects on depression, anxiety, general stress management and exercise self-efficacy.

Obesity with depression symptoms: In a study on obese people with elevated depression symptoms, 213 participants were randomly assigned to a 24-week tai chi intervention or a waitlist control group [27]. The tai chi group showed a significant decrease in depression and stress and an increase in leg strength. These improvements were maintained for the tai chi group over the second 12 weeks of follow-up. In another randomized controlled study, only 26 obese women (a very small sample) were assigned to a 12-week tai chi intervention or control group [28]. The tai chi exercises were combined with resistance training and a special diet, suggesting that the tai chi effects were confounded by the resistance training and diet. Although there were no significant changes in body composition, the combined intervention improved performance on the timed get up and go test. In still another study on body composition, a Yang style tai chi group was compared to an exercise group, with both groups exercising 60 minutes three times per week for 12 weeks [29]. The tai chi group showed a decrease in systolic blood pressure. However, the exercise group showed greater benefits included increases in basal metabolic rate, total body muscle mass, lean body mass and bone mineral content and decreases in body mass index, body fat and diastolic pressure. These results perhaps are not surprising in that the tai chi group practiced with the same frequency but with only 50 to 60% the intensity of that of the exercise group.

Schizophrenia: The management of schizophrenia by anti-psychotic medications often has severe side effects leading to the use of complementary treatments like tai chi. In the only recent study that could be found on schizophrenia, patients were randomized to tai chi, exercise or waitlist control groups [30]. Both exercise groups received 12 weeks of the intervention and assessments were made at 3 and 6-month follow-ups. Both exercise groups showed significant decreases in motor deficits and increases in backward digit span, and the exercise group also showed fewer negative schizophrenic symptoms (such as lethargy and apathy)as well as fewer depression symptoms.

Cardiovascular/cardio respiratory disease

Eighteen randomized controlled trials, systematic reviews and /or meta-analyses were found on tai chi with cardiovascular/ cardio respiratory conditions (Table 3). These include coronary heart disease risk factors, hypertension, cardiovascular and kidney disease, coronary artery disease, stroke and COPD. These conditions, next to balance in the elderly, were the most frequently studied conditions assessed for tai chi effects.

Table 3: Cardiovascular conditions that that have been improved by tai chi: conditions, reference numbers, trial types, comparison groups and primary results (< and > signs indicate significant effects at least at p<.05).

Condition	Reference #	Trial	Comparison	Primary results
Cardio vascular				
Coronary heart dis	31	Quasi-exper	Control	<Systolic & Diastolic BP
Hypertension	32	REV		<Syst & Diast BP <cholesterol
	33	RCT	Waitlist	<pro inflammatory cytokines
	34	RCT	Control	< blood pressure & BMI
	35	RCT	Usual care	>anti-inflammatory
Cardio & Kidney Dis	36	RCT	Control	>renal function
Myocardial infarction	37	RCT	Stretching	>peak oxygen consumption
Coronary artery dis.	38	REV	Control	<coronary heart dis. symptoms
Stroke	39	RCT	Usual care	<falls
	40	REV	Exercise	<blood pressure
Respiratory Function	41	RCT		>stroke volume
	42	RCT	Education	no differ
	43	META		>stroke volume
COPD	44	RCT	Treadmill	<respiratory rate
	45	RCT	Control	>lung function
	46	META	Control	>vital capacity
	47	META	Exercise	=6 min. walking test
	48	META	Exercise	=effects

Coronary heart disease risk: In a quasi-experimental design, a 16-week tai chi plus a weight loss program were compared to a control group who were asked to maintain their normal lifestyle [31]. The tai chi group lost weight and improved on body mass index, waist circumference, systolic blood pressure, diastolic blood pressure and sit and reach flexibility, suggesting that tai chi can ameliorate coronary heart disease risk.

Hypertension: In a systematic review on tai chi for primary prevention of cardiovascular disease, 13 small randomized trials (1520 participants) not surprisingly showed that the duration and style of tai chi differed between studies [32]. And the samples ranged from people with borderline hypertension, hypertension or hypertension combined with kidney disease. In addition, the reviewed studies featured non-treatment control groups. Despite these limitations, reductions were noted in systolic blood pressure, diastolic blood pressure, triglycerides and total cholesterol. These findings are confirmatory of randomized control trials, but the considerable heterogeneity between studies, the small samples and the risk for bias highlight the need for higher-quality, longer-term trials.

In a randomized controlled trial that included a waitlist control group, eight weeks of tai chi led to reduced cardiovascular risk in middle-age women [33]. In this study the cardiovascular-risk women who experienced tai chi had less fatigue and showed a down-regulation of pro-inflammatory cytokines including interferon gamma, tumor necrosis factor, and interleukins 4 and 8. In addition, the women showed increased mindfulness, spiritual thoughts and behaviors and self-compassion.

In a randomized controlled study on adults with hypertension, blood pressure and body mass index were reduced, but metabolic syndrome and lipid levels did not improve [34]. In an unusual design comparing hypertensive receiving tai chi, a hypertensive usual care group and a healthy non-hypertensive group, low density lipoprotein cholesterol levels decreased, high density lipoprotein cholesterol levels decreased and both systolic and diastolic blood pressure decreased by the end of the 12 week treatment period [35]. A unique finding was an increase in nitric oxide, which is significant because of its anti-inflammatory effects. Further research is needed to confirm the nitric oxide effects in a larger cohort.

Cardiovascular and kidney disease: To study the effects of tai chi on renal and cardiac function of patients with chronic kidney and cardiovascular diseases tai chi was provided for 30 minutes 3 times a week for 12 weeks and tai chi was compared to an inactive control group [36]. At the end of the study, the tai chi group had better glomerular filtration rate and left ventricular ejection (both measures of renal function) and greater high-density lipoprotein levels. In addition, the tai chi group had lower heart rate, systolic blood pressure, diastolic blood pressure and total cholesterol, triglyceride and low density lipoprotein levels. Tai chi appeared to improve these functions by the regulation of lipid levels.

Myocardial infarction: Patients with myocardial infarction typically show decreased peak oxygen consumption [37]. In a single-blind randomized controlled clinical trial, patients assigned to the tai chi group participated in three weekly sessions

of tai chi for 12 weeks while the control group participated in full-body stretching exercises [37]. At the end of the study the tai chi group showed a significant increase in peak oxygen consumption while the control group showed a non significant decline.

Coronary artery disease: In an extensive review of 201 studies on tai chi with patients experiencing coronary artery disease, only three randomized controlled trials met criteria [38]. Each of these trials had a control group that practiced exercise training or received counseling for exercise. The results suggested that tai chi was an effective form of treatment for patients with coronary artery disease. However, as the authors noted, the methodology in all of the studies was flawed and the sample sizes were small.

Stroke: Stroke is one of the leading causes of death in the world [39]. A couple studies on stroke survivors show the positive effects of tai chi. In a single blind randomized controlled trial survivors of stroke were randomly assigned to a Yang style 24-postures short-form tai chi, a strength and range of motion exercise group or a usual care group. The tai chi and exercise groups attended one hour classes three times a week for 2 weeks [39]. The tai chi participants had two thirds fewer falls than the exercise and care groups and both exercise groups had significantly better aerobic endurance.

In a systematic review 36 eligible studies with a total of 2393 participants were identified [40]. When the risk factors for stroke were considered, the analysis revealed that tai chi was correlated with lower body weight, body mass index, as well as lower systolic and diastolic blood pressure and lower low density lipoprotein levels even for less than a half year of intervention. However, when tai chi was compared to similar exercises, the primary effect was only lower blood pressure.

Cardio respiratory diseases

Turning to cardio respiratory diseases, positive effects of tai chi on respiratory and cardiovascular function were observed following 12 months of tai chi [41]. At the end of the study the results showed that stroke volume was increased, ejection fraction was improved as was vital capacity and heart rate was decreased. One of the potential underlying mechanisms for tai chi's positive effects on cardio respiratory functions is that tai chi focuses on the coordination between respiration and body movements [42]. In the aging process apparently respiration affects postural sway, and by tai chi improving respiratory function it can also improve postural control. This relationship was shown in a study on a 12 week tai chi intervention versus an educational control group [42]. While the tai chi training did not alter standing postural control or respiration, the coupling between respiration and postural control was reduced. For some reason as in many other tai chi studies, the sample sizes for the two groups were unequal which may reflect a self-selection bias and which may have contributed to these null findings.

In a systematic review and meta-analysis 20 studies with 1868 participants suggested that tai chi had positive effects on the majority of cardio function outcomes [43].These included systolic and diastolic blood pressure, heart rate, stroke volume, cardio output, lung capacity, cardio respiratory endurance and stair test index.

Chronic obstructive pulmonary disease (COPD)

COPD has also benefited from tai chi. In a randomized controlled study comparing tai chi with treadmill exercise, the respiratory rate during tai chi was significantly lower than during treadmill exercise even though the mean values of oxygen uptake did not differ across the two exercises [44]. In another randomized controlled study patients with COPD were assigned to either a control group or a tai chi group [45]. Lung function parameters and diaphragm strength parameters were significantly increased in participants who successfully completed the six-month tai chi program. In a systematic review and meta-analysis on the effects of tai chi on chronic obstructive pulmonary disease, 15 articles involving 1354 participants met criteria [46]. Compared to an inactive control group tai chi was more effective in improving exercise on six - minute walking test, on forced expiratory volume in the first second and on forced vital capacity. The tai chi group also scored better on the dyspnea score, fatigue score and total score of the Chronic Respiratory Disease Questionnaire. However, once again, it is not surprising that tai chi effects would be more positive than those of an inactive control group. Future studies need to compare different styles of tai chi or at least compare tai chi with active exercise groups to determine reliable treatment effects.

To address that question, a systematic review and meta-analysis study included both exercise and non-exercise comparison groups and the tai chi group once again performed better than the non-exercise group on the chronic respiratory disease questionnaire [47]. However, when compared with the physical exercise group, the tai chi group showed inferior performance on that scale, even though the groups did not differ on the 6 minute walking test. When a systematic review and meta-analysis was performed on 18 tai chi studies for cardiovascular or cardio respiratory conditions, tai chi was no more effective than other forms of exercise [48]. Given the stress underlying cardiovascular and cardio respiratory conditions, it is somewhat surprising that tai chi was not more effective than other forms of exercise because its meditative component and the need to be totally concentrated on the tai chi form (called focused mindfulness) would be a distract or from stress.

Pain syndromes

Just as for other forms of complementary therapy such as yoga and massage, pain syndromes have been frequently studied for tai chi effects. Briefly reviewed here are tai chi studies on low back pain, arthritis, osteoarthritis and rheumatoid arthritis, fibromyalgia and spinal cord injury pain (Table 4).

Table 4: Pain syndromes that have been improved by tai chi: conditions, reference numbers, trial types, comparison groups and primary results (< or > signs indicate significant effects at least at p<.05).

Condition Reference #Trial Comparison Primary Results				
Pain Syndromes				
Low back pain	49	RCT	Stretching	<pain & muscle activity
Arthritis	50	RCT	waitlist control	< pain & stiffness
Knee osteo	51	RCT	<pain	
Hip osteo	52	RCT	>6 minute walk	
Rheumatoid arth	53	RCT	general info	<cholesterol
	54	single	arm	<inflammatory cytokines
Fibromyalgia	55	single arm	<pain	
Spinal injuries	56	single arm	<pain	
	57	RCT	control	>sitting balance

Low back pain: In a study on low back pain 40 males with low back pain were randomly assigned to a tai chi group or a stretching group [49]. The exercises were performed for one hour three times per week for four weeks. Wireless surface electromyography was used to measure muscle activity and a visual analog scale was used to measure pain. The decrease in both muscle activity and in pain was greater for the tai chi group than the stretching group.

Arthritis: In an assessment of the Arthritis Foundation tai chi program, those with arthritis were randomly to the tai chi group or a waitlist control group [50]. Following this eight week program balance was improved. At one year improvements in pain, fatigue and stiffness were noted, suggesting long-term effects in at least 30% of those who continued tai chi practice following the end of the program.

Knee osteoarthritis: A systematic review of studies on tai chi for knee osteoarthritis used the following selection criteria: 1) randomized controlled clinical trial; 2) patients with knee osteoarthritis; 3) tai chi exercise; and 4) studies published in English or Chinese [51]. Tai chi was an effective way of relieving pain and improving physical function for those with knee osteoarthritis. However, the randomized controlled trials did not include exercise comparison groups.

Hip osteoarthritis: Individuals with hip osteoarthritis were randomly assigned to a tai chi or a control group [52]. After six weeks of the program the tai chi group walked farther in the 6-minute walk test and they were faster in the get up and go test.

Rheumatoid arthritis: Given that rheumatoid arthritis is a risk factor for cardiovascular disease, several measures of that risk were taken in a tai chi study on rheumatoid arthritis [53]. Patients were randomly assigned to either a tai chi group receiving once a week sessions for 3 months or a control group who received general information about the benefits of exercise. Endothelial function increased and arterial stiffness and cholesterol decreased in the tai chi group. Surprisingly, pain was not assessed in this study. Arthritis-associated pain is generally associated with inflammatory mediators such as cytokines [54]. Following only one hour of practice by tai chi practitioners, plasma levels of IL-1a and IL-12 were decreased. This single arm, small sample pilot study needs to be replicated.

Fibromyalgia A low to moderate intensity tai chi program with 3 sessions per week for 12 weeks was offered to 36 patients (29 women) [55]. Immediate post-session reductions in pain were noted. However, pain was assessed by a visual analogue scale in this single arm study. And, surprisingly, no other recent tai chi for fibromyalgia studies could be found.

Spinal cord injury pain: Seated tai chi has been used with those who have spinal cord injuries. In a single arm study, 26 participants were enrolled for a 12 week seated tai chi course consisting of weekly sessions [56]. After each session the patients reported less pain, better sense of emotional well-being, mental distraction, physical well-being and a sense of spiritual connection. However, attrition was high with only nine participants completing half of the 12 sessions and once again this was not a randomized controlled study with a comparison group to validate the effects of tai chi on spinal cord injury pain. However, this is a rare example of the use of seated tai chi.

In another seated tai chi study, patients with spinal cord injuries were given 90 minute sessions two times a week for 12 weeks or assigned to a control group [57]. At the end of the intervention, the seated tai chi group showed improved dynamic sitting balance and greater hand grip strength. However, the groups did not differ on quality of life measures. Once again, this is a small sample and the groups were not randomly assigned. Further, seated tai chi is rarely practiced, although it would clearly be the tai chi of choice for patients who are immobilized with spinal cord injuries.

Autoimmune conditions

Diabetes and multiple sclerosis were the only autoimmune conditions in the recent tai chi literature (Table 5). These included a randomized controlled trial and a systematic review on diabetes and two randomized controlled trials on multiple sclerosis.

Table 5: Auto-immune and immune conditions that have been improved by tai chi: conditions, reference numbers, trial types, comparison groups and primary reasons (< and > signs indicate significant effects at least at p<.05).

Condition	Reference #	Trial	Comparison	Primary Results
Auto-immune				
Type ll Diabetes	58	RCT	walking	=walking and glucose
	59	REV	<glucose	
Multiple Sclerosis	60	RCT	Usual care	>balance & walking speed
	61	RCT	control	>balance
Immune				
Immune markers	62	single arm	>DNA repairing	
	63	RCT	Usual care	>antioxidants & anti-inflammatory
	64	RCT	cog. behav. ther.	= reduced pro-inflammatory cytokines
	65	RCT	cog. behav. ther.	>reduced pro-inflammatory cytokines
Breast cancer	66	META	control	> upper limb mobility
Lung cancer	67	RCT	exercise	<physical & general fatigue
	68	RCT	usual care	>immune cell number & activity
Cancer in general	69	RCT	health edu.	<syst. Blood pressure & cortisol
	70	META	>CD 34 rejuvenating cells	

Diabetes: In a study on Hong Kong Chinese adults 374 middle-age diabetes patients were randomly assigned to a 12 week training 45 minutes per day, five days per week of tai chi or self -paced walking or a control group [58]. Both exercise groups experienced moderate weight loss and significantly improved their waist circumference and fasting blood glucose. A systematic review revealed mixed findings with four RCTs that compared various types of exercise and tai chi [59]. That meta-analysis failed to show group differences on fasting blood glucose which was not surprising in that tai chi and exercise frequently have similar effects. However, surprisingly, the meta-analysis of the five RCTs that compared tai chi with antidiabetic medication showed more favorable effects of tai chi than medication on fasting blood glucose. The authors concluded that these tai chi effects on fasting blood glucose in diabetes clearly need replication studies.

Multiple sclerosis: Individuals suffering from multiple sclerosis have experienced many problems including balance, mobility, fatigue and depression [60]. A sample of 32 multiple sclerosis patients randomly assigned to a tai chi group participated in two weekly sessions of 90 minutes duration for six months while the comparison group received treatment as usual [60]. Following the intervention, the tai chi group showed greater balance and coordination, less depression, and their quality of life improved. In another randomized controlled study, 36 women with multiple sclerosis were randomly assigned to a tai chi or a control group [61]. After 12 weeks of twice a week Yang style tai chi sessions, the tai chi group had better balance scores on the Berg balance scale. Unfortunately this was assessed by self-report rather than objectively observed.

Immune conditions

Several recent studies were found on tai chi effects on immune markers and conditions (Table 5). The marker studies assessed antioxidants, anti-inflammatory cells, cytokines and cancer cells. Of the immune conditions, breast cancer has received the most attention, although a couple studies were found on lung cancer as well as cancer survivors in general.

Immune markers: In a single arm study, the 24-form simplified tai chi was practiced five times weekly for 12 weeks to determine the effects of tai chi on antioxidant capacity and DNA repairing [62]. The young Chinese females in this study showed an improved oxidative stress response and increased DNA repairing. These results are promising although limited because of the small sample size and the single arm design. In a randomized controlled study, 71 sedentary volunteers with periodontal disease were randomly assigned to a tai chi or treatment as usual group [63]. Tai chi was practiced five days a week for a period of six months. Antioxidants and anti-inflammatory cytokines increased and were linked to improvement of periodontal disease in the tai chi group. It is not clear that these tai chi effects would have resulted from a comparison between tai chi and an active exercise group.

In another randomized controlled trial on tai chi and immune markers, 123 older adults with insomnia were randomly assigned to cognitive behavioral therapy (CBT), tai chi or asleep seminar control group for two hour sessions weekly over a four-month period [64]. Given that sleep disturbances are associated with inflammation; several pro-inflammatory cytokines were measured. Both the CBT and tai chi groups experienced reduced levels of C-reactive protein, pro-inflammatory cytokines and pro-inflammatory gene expression. These results were surprising inasmuch as CBT is a physically inactive therapy. However, a potential underlying mechanism common to CBT and tai chi may be the facilitation of sleep which would in turn improve immune function in both groups.

Breast cancer: The same group of researchers who studied an insomnia group also assessed a group of 90 breast cancer survivors with insomnia using similar measures [65]. In this

randomized controlled trial the breast cancer survivors with insomnia were randomly assigned to a tai chi or a CBT for insomnia group. In this study the C-reactive protein levels did not change, but the levels of interleukin -6 (IL -6) and tumor necrosis factor (TNF) were reduced following tai chi but not following CBT for insomnia. The genes encoding pro-inflammatory mediators were also reduced in the tai chi versus the CBT for insomnia group. It is not clear why this research group was able to document immune changes following CBT for insomnia in the group that had late - life insomnia but no changes for the breast cancer survivors with insomnia. This inconsistency may relate to the intervention being longer in the insomnia - alone study, i.e. one month longer for the CBT for insomnia treatment to take effect, or it may simply be that the immune system was more compromised in the breast cancer survivors and thereby less reactive to the CBT treatment and more reactive to the greater activity of tai chi. The underlying mechanism for the CBT and tai chi effects in the insomnia alone study may be sleep mediated while the tai chi effects on the breast cancer victims may have been mediated by activity increasing stimulation of pressure receptors in turn enhancing vagal activity resulting in lower levels of cortisol and pro-inflammatory cells.

In a systematic review/meta-analysis study, nine randomized controlled trials including 322 breast cancer patients met criteria [66]. In these trials, comparisons between tai chi and control therapies yielded only changes in upper limb functional mobility. These included increased handgrip dynamometer strength and limb elbow flexion. No differences were noted for pain, IL - 6, physical, social or emotional well-being. It is surprising that IL -6 was the only immune measure common across the studies that met criteria.

Lung cancer: In a randomized controlled trial on tai chi effects on patients with lung cancer undergoing chemotherapy, tai chi was compared with low impact exercise [67]. The groups practiced every other day for one hour for 12 weeks. At six and at 12 weeks the tai chi group had lower physical fatigue and general fatigue scores, although no differences were noted on the emotional subscale. In another randomized controlled study on tai chi effects on cell functions in lung cancer patients, tai chi was simply compared with a treatment as usual control group [68]. In this study, Tai chi 24 - form was practiced for 60 minutes three times a week for 16 weeks. Immune cell number and immune cell activity increased in the tai chi group as compared to the control group. Again this finding may result from comparing an active group (tai chi) with an inactive group (treatment as usual), highlighting the importance of comparing active treatment groups to determine the efficacy of tai chi.

Cancer in general In another randomized controlled trial of tai chi effects on cancer, specifically senior female cancer survivors, tai chi was compared to a health education class [69]. Tai chi was practiced and the health education classes were held for 60 minutes three times a week for 12 weeks. The tai chi group had significantly lower systolic blood pressure and cortisol levels at the end of the study. There were, however, no changes in inflammatory cytokines.

In a systematic review/meta-- analysis study on tai chi effects on cancer patients in general, 13 randomized controlled trials with 592 participants were included [70]. This study not only confirmed the decrease in cortisol levels noted in the previous study, but also showed improved quality of life measures, less fatigue and improved immune function. These authors cautiously noted an increase in CD 34 rejuvenating cells in the tai chi group. They suggested that their data were limited by the number of studies they identified and the by the high risk for bias in the studies included in their meta-analysis.

Aging problems

Most of the recent tai chi studies involve aging problems. Those include empirical studies, systematic reviews and meta-analyses on antiaging cells, anxiety, fear of falling and balance problems, physical fitness, osteoporosis, pain; Parkinson's and seated tai chi (Table 6).

Table 6: Aging conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results (< and > signs indicate significant effects at least at p<.05).

Condition	Reference #	Trial	Comparison	Primary results
Aging				
Antiaging cells	71	RCT	brisk walking	=rejuvenating cells (CD 34)
Anxiety disorder	72	RCT	drug therapy	<depr in drug ther & tai chi grpe
Fear of falling	73	RCT	tai chi & CBT	<fear of falling
	74	RCT	leg training	<falls
Balance	75	RCT	Control	>movement
	76	RCT	Control	<walking time
	77	RCT	Control	<sway paths
	78	Control	>balance	
	79	RCT	Dancing	>balance
	80	RCT	Exercise	=balance
	81	RCT	Yoga	=balance
	82	RCT	Yoga	=balance
	83	META	Miscel. Interven	>balance
Physical Fitness	84	inexperienced	>physical fitness	
	85	RCT	dancing, walking	>physical fitness
Muscle strength	86	RCT	Control	>muscle strength
	87	RCT	Control	>muscle strength

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	88	RCT	Control	>muscle strength
Osteoporosis	89	RCT	Control	<bone loss
	90	RCT	Control	>balance & strength
Knee osteoarth	91	RCT	educ. Program	< pain
	92	REV	< pain	
Parkinson's	93	RCT	control	>balance
	94	RCT	stretching	<symptoms
	95	RCT	exercise =symptoms	
	96	META	exercise	> balance
	97	META		> balance
	98	META	>balance	

Antiaging cells: In a retrospective cross-sectional study, rejuvenating and anti-aging cells were studied in a tai chi versus a brisk walking versus a no exercise habit group [71]. The CD 34 rejuvenating cells were greater in the tai chi group than in the no exercise group, but there were no differences between the tai chi and the brisk walking groups. The lack of difference between the tai chi and exercise group was not surprising given that there are often no differential effects when tai chi is compared to other forms of exercise. These data, while consistent with the previous meta-analysis [70], need to be replicated in a larger sample in a prospective random assignment design as many potential baseline differences including motivational factors could account for these effects.

Anxiety Disorder: In a randomized controlled study, 32 elderly patients with anxiety disorder were randomly assigned to a tai chi plus drug therapy group versus a drug therapy alone group [72]. After 45 days of tai chi, that group had improved significantly on depression scores and had a recurrence rate of 9% versus 43% in the control group. These data are not surprising given that the exercise of tai chi would be expected to lower anxiety and underlying anxiety hormones such as cortisol. In addition the exercise of tai chi would be expected to increase serotonin levels which have anti-anxiety affects. This study might be replicated in a larger sample and with the addition of other more objective measures of depression such as cortisol and serotonin levels.

Fear of falling: Fear of falling and balance are the most commonly studied problems for the aging in the recent tai chi literature. In a randomized controlled study 122 elderly people were randomly assigned to either a tai chi or tai chi plus CBT group [73]. Only the tai chi group experienced less fear of falling. For fear of falling the authors concluded that tai chi may be sufficient and more cost-effective. In another randomized controlled trial, home - based tai chi training was compared to lower extremity training in elderly who had fall - related emergency room visits at least six months before being recruited for the study [74]. After a six month intervention, the tai chi group was less likely to experience any falls, had a longer time to the first fall and a lower number of "fallers "as compared to the lower extremity training group.

Balance: Several dual-task studies have been conducted to assess the ability to maintain balance while performing a cognitive task, i.e. assessing balance while paying attention to something else. This is being assessed because many falls have been related to elderly individuals concentrating on something else, getting distracted and losing their balance. In one study on 10 elderly tai chi practitioners and 10 age matched non-practitioners, the participants were asked to shift their weight to reach a target with and without performing the cognitive task of counting backwards [75]. The Tai chi practitioners had shorter reaction times and faster movements than the non-tai chi practitioners. In a similar dual-task study, tai chi experts and non-experts were compared on their walking time while they performed serial subtractions [76]. Walking or stride time variability was lower in the tai chi expert group. Walking time variability has been considered a potential mediator of the risk for falling. Although comparisons of tai chi practitioners versus non-practitioners would be expected to reveal greater effects for the practitioners given their greater activity levels, but the two groups may also differ on baseline motivation, physical fitness and other variables, making their comparison tenuous at best.

Another way of testing balance is the sway paths both to each side and from the front to the back. In a sway path balance study, a tai chi group was compared to a no regular exercise group [77]. The tai chi group showed shorter sway paths both forward and back and to each side after 24 weeks of tai chi. Some of the sway path balance can be explained by ankle proprioception and lower extremity muscle strength [78]. In one study, a tai chi group who had practiced for 10 years on average showed better balance, ankle proprioception and muscle strength of the lower extremities than a group who did not practice tai chi [78].

In several balance studies, tai chi has been compared to other forms of exercise. In one study tai chi was compared to ballroom dancing [79]. In this randomized controlled trial, the tai chi group had a lower sway velocity both with open and with closed eyes on a firm surface as well as a foam surface. The tai chi group also had faster walking speed and shorter times moving from a sitting to a standing position with less sway in the final standing position. In another study, tai chi was compared to regular exercise that was performed three times a week for 12 weeks [80]. Both exercise groups showed better results on dynamic balance assessments. However, the tai chi group showed better performance on the single leg stance eyes open task and on a survey of activities and fear of falling scale.

In a tai chi versus yoga versus standard balance training, the three different groups practiced for 12 weeks, and on the

gold standard measures including postural sway and postural stability, all three groups showed similar improvement [81]. In another study comparing tai chi and yoga, following a 14 week program, no significant differences were noted between the groups in the incidence of falls [82]. In a meta-analysis of seven randomized controlled trials including 1088 participants, tai chi was compared with other interventions and was shown to have significantly shorter time on get up and go, prolonged time on single leg stand and improved balance [83]. Other meta-analyses on a greater number of randomized controlled trials need to be conducted to confirm these data.

Physical Fitness: Although not as frequently studied as balance in elderly people, there are at least a few studies on physical fitness and muscle strength following tai chi. For example, in a 16 week tai chi program, physical fitness was assessed in older adults with and without previous tai chi experience [84]. The tai chi group was comprised of participants who had practiced for more than a year. When this group was compared to an inexperienced group, experienced practitioners had higher ratings on physical fitness tests, as would be expected. However, when the inexperienced group was given two one -hour sessions per week of Yang style tai chi for 16 weeks, they showed significant improvements on all measures of physical fitness. In another study, physical fitness included measures of lower limb muscle strength, bone mineral density and balance [85]. In this study elderly women were randomly assigned to a tai chi group, a dance group and a walking group, and they were asked to do the exercise once a day for 40 minutes for 12 months. Physical fitness was assessed at four, eight and 12 months. After four months the dance group and walking group were showing better physical fitness than the tai chi group. At eight months all three groups were equivalent, but at 12 months the tai chi group showed a greater improvement than the dance and walking groups, suggesting that longer-term tai chi programs have longer term effects on physical fitness than the comparison dance and walking groups. It is not clear, however, the degree to which these groups were matched on exercise intensity.

Muscle strength: In a study on muscle strength of the lower extremities in the elderly, long-term tai chi practitioners were compared to those who did not practice tai chi [86]. The strength of several muscle groups including the quadriceps and hamstrings was greater in the tai chi practitioner than the non-practitioner group. Further, muscle strength and the duration of tai chi practice were significantly correlated. Although muscle strength is typically measured in the lower extremities following tai chi, at least two studies have assessed upper limb strength. In one of these studies, elderly participants were randomly assigned to a tai chi group that practiced for six months as compared to a control group who participated in other non-athletic activities [87]. After 3 months there was no difference between the groups on one leg standing time with eyes open. However, grip strength was greater and both the five minute fast walking speed and 10 minute normal walking speed were significantly greater in the tai chi group. In another study, the researchers used resistance training with the upper extremities in conjunction with tai chi as compared to a group that did not receive tai chi or resistance exercise [88]. Therabands (wide rubber strips) were used for the resistance training which was held for 60 minutes twice weekly for a period of 16 weeks. After this training, the intervention group showed a significant increase in muscle strength in both upper and lower extremities. These effects are not surprising inasmuch as the tai chi exercise would be expected to strengthen the lower limbs while the theraband resistance training is focused on increasing upper limb strength.

Osteoporosis: Osteoporosis (bone loss) is common among the elderly. In this literature search at least one randomized controlled trial and one systematic review on osteoporosis were located. In the randomized controlled trial, 119 postmenopausal women were randomly assigned to a Yang style tai chi resistance training, a traditional tai chi or a routine activity group [89]. Although the routine activity group had lower L2 - L4 bone density, neither the tai chi nor the resistance training groups experienced bone loss. In a recent systematic review on osteoporosis, only four valid studies could be found that either used a randomized clinical trial or controlled clinical trial [90]. The only positive effects were for balance, muscle strength and quality of life, highlighting the need for more research on tai chi effects on bone loss itself.

Knee osteoarthritis pain: For knee osteoarthritis the only recent tai chi papers featured a randomized controlled trial and a review. In the randomized controlled trial, older adults were recruited from eight study sites and then the sites were randomly assigned to participate in either a 20 week Sun - style tai chi or an education program [91]. Not surprisingly, the active tai chi groups experienced a greater reduction in pain than the inactive education group. In our recent review of Tai chi for knee osteoarthritis, pain was assessed by the WOMAC scale in most of the studies reviewed [92]. Range of motion and range of motion pain are highly affected by knee osteoarthritis, but those measures were not assessed in most of the studies. This was surprising given that tai chi predominantly exercises the hamstrings and quadriceps which are both involved in flexion and extension of the knee. Range of motion and range of motion pain would need to be measured to determine the primary effects of tai chi on knee osteoarthritis.

Parkinson's: Since elderly people are frequently affected by Parkinson's, it is not surprising that as many as three randomized controlled trials and three meta-analyses were found in the recent literature. In one of the randomized controlled trials, the tai chi group received 24 - form Yang style tai chi exercise for 60 minutes three times a week for 12 weeks [93]. This tai chi group improved their balance and decreased their falling, but no change occurred on the Parkinson's disease Rating Scale,

suggesting that their Parkinson's symptoms were not decreased. However when tai chi was compared to resistance training and stretching in another randomized controlled trial, the tai chi participants reported significantly better improvement on the Parkinson's disease Questionnaire and their scores on that scale were significantly correlated with their scores on the Parkinson's disease Rating Scale [94]. The authors also noted that the patient-reported outcomes were associated with a greater probability of continued exercise behavior in the tai chi group versus the other groups, suggesting that there was greater adherence by the tai chi group. In still another randomized controlled trial, tai chi was compared to multimodal exercise training and the groups were assessed after 12 weeks of the program [95]. In this study, both groups improved on movements, balance and on Parkinson's Disease Rating Scale-motor examination scores.

In a meta-analysis on tai chi with Parkinson's disease, seven randomized controlled trials that were eligible showed that tai chi had beneficial effects on motor function, balance and functional mobility but not on gate velocity, step length or gate endurance [96]. However, when tai chi was compared with other active therapies, better effects of tai chi were only noted for balance. In another meta-analysis, the aggregated results of 9 studies favored tai chi on improving motor function and balance [97]. Once again, gate velocity, stride length and quality of life were not affected. However, the authors interpreted these findings cautiously because of the small treatment effects, the methodological flaws of the eligible studies and the insufficient follow-up. In still another meta-analysis, 10 trials on tai chi plus medications for Parkinson's showed improvements on the Parkinson's Disease Rating Scale, on the Berg balance scale, functional reach tests, timed get up and go test, stride length and health-related quality of life [98]. The tai chi alone group, however, was only more effective for balance and mobility outcomes.

Seated tai chi: Seated tai chi has been used to improve sitting balance and for individuals in wheelchairs. In a randomized controlled study on seated tai chi, sitting balance and eye hand coordination were assessed [99]. In this study, the tai chi group was compared to an exercise group who underwent three months of training for a total of 36 sessions including one hour sessions three times per week. The tai chi group improved on weight shifting while sitting and on maximum reaching distance from the seated position. In another seated tai chi randomized controlled study, older people in wheelchairs were randomly assigned to a group receiving seated tai chi versus a group engaging in their usual activity [100]. The tai chi group had 40 minutes of seated tai chi three times a week for 26 weeks. The seated tai chi group had lower depression scores and higher quality of life scores including general health, physical health, psychological health, and social relations. Unfortunately, once again, only self-report measures were taken.

Potential underlying mechanisms for tai chi effects

Studies have been conducted to determine the underlying physiological mechanisms for tai chi effects. Recently these have included research on fMRI's and on vagal activity.

FMRI studies: In an fMRI study for older individuals including 22 experienced practitioners and 18 tai chi naïve controls, fMRI and attention behavior tests were conducted [101]. The tai chi practitioners as compared to the inexperienced group had greater functional homogeneity in the right posterior-central gyrus and less functional homogeneity in the left anterior cingulate cortex gyrus both of which predicted better performance on attention behavior tests. As the authors noted, these findings can inform our understanding of the effects of tai chi on cognition.

Vagal activity studies: At least three recent vagal activity studies suggest increased vagal activity as a potential underlying mechanism for the effects of tai chi. In one study, 25 tai chi practitioners were compared with 25 sedentary control participants on heart rate variability (vagal activity) [102]. The tai chi practitioners had greater high frequency power and lower low-frequency power than the controls, suggesting greater vagal modulation in the practitioners. Another similar comparison between tai chi practitioners with approximately 20 years' experience and controls matched by age, sex and education also suggested increased vagal activity for the tai chi group and greater balance between parasympathetic and sympathetic activity during tai chi [103]. Vagal activity has been noted to increase even after only five minutes of tai chi exercise by inexperienced individuals [104]. In this study, during the fourth and fifth minutes of tai chi exercise increased high-frequency power and decreased low-frequency power were noted. It is not clear, however, whether these effects were transient or maintained as the monitoring of vagal activity was too short. It would also be important to compare the effects of tai chi and other forms of exercise on vagal activity. For example, vagal activity has been notably greater in yoga practitioners and also increases following yoga sessions [105]. This would not be surprising given that on many other measures tai chi and other forms of exercise have similar effects. Just as we have noted that increased vagal activity is dependent on the stimulation of pressure receptors, tai chi would involve the stimulation of pressure receptors, at least in the feet [106].

Limitations of studies and future directions

Many of the limitations and confounds we reviewed in our 2012 review paper are still problems for the tai chi literature [1]. One of the problems is that tai chi is a combination of foot and arm movements, breathing and deep concentration. Although the foot movements predominate most tai chi sessions, making tai chi a physical exercise, it is difficult to separate the effects of the foot and arm movements, the breathing and the meditation. It is a low intensity exercise in part because it involves concentration

and a slowing of nervous system activity which may be the reason that it often has lesser effects than an active exercise group. The increased vagal activity noted for the foot and the arm movements and the meditation combined suggests that those different components may have additive effects, although they have not been studied for their separate effects. More detailed descriptions of these components are needed in order for these studies to be replicated.

Another problem is that many different tai chi styles, e.g. Sun style and Yang style tai chi, have been tried with different conditions. It is possible that a specific type of tai chi may be more beneficial for a specific condition, suggesting the use of different tai chi styles as treatment comparison groups rather than using other types of exercise as treatment comparison groups. Although the two most popular styles, Yang and Sun styles have not been compared in one study, they would appear to have similar effects even though the Yang style is reputedly easier to learn.

The sessions are also highly variable including individual versus group practice, the length of the practice (20-90 minutes), the frequency of classes (daily, weekly) and the duration of intervention (weeks, months). The samples are also variable, with some studies grouping beginners with long-term practitioners even though these participants likely differ at baseline. Long-term practitioners may be in better condition at baseline and more motivated to routinely practice. Although randomized controlled designs are increasingly being used, many of the recent studies reviewed here are single - arm, pre-post studies or comparisons between tai chi and inactive control groups. Those comparisons have typically yielded positive effects for the tai chi group, but when tai chi was compared to an exercise group, the groups typically did not differ and sometimes the exercise group experienced more positive effects. Nonetheless, tai chi may remain the exercise of choice for more fragile people like pregnant women and older adults because it is a less intense form of exercise. Notably absent from the literature are tai chi effects on different cultures, different age groups and any gender effects. Although it appears to be practiced more frequently by the elderly in China, the practice has been rapidly growing in different cultures and different age groups, so those comparisons would be possible.

Many of the studies also used self - report measures which are not considered as reliable as the more objective observation measures. Physical and physiological measures that are more objective than self-report measures have rarely been used, e.g. body mass index, blood pressure and cortisol.

Conclusion

In conclusion, future research should use randomized controlled trials in which different tai chi styles are compared, and shorter sessions might help the participants more readily learn the forms. Multiple physical and physiological measures need to be added to the self - report protocols, and potential underlying mechanisms need to be further explored. Despite these methodological problems, the studies reviewed here highlight the therapeutic effects of tai chi, an old practice that has fortunately come to us from Asia and one that will hopefully become as popular as yoga in our country. For many practitioners like pregnant women and elderly people, it may be the preferred form of exercise for both its important low intensity and balancing features.

Summary

Most of the studies reviewed here involved tai chi effects on psychiatric, medical and immune conditions and aging problems. Most of the recent research has been on the elderly with a focus on balance problems. The methods and results of those studies were briefly summarized along with their limitations and suggestions for future research. Basically tai chi has been more effective than control and waitlist control conditions, although not always more effective than treatment comparison groups such as other forms of exercise. More randomized controlled studies are needed in which tai chi is compared to other forms of tai chi or at least to active exercise groups. Having established the physical and mental health benefits of tai chi makes it ethically questionable to assign participants to inactive control groups. Shorter sessions should be investigated for cost-effectiveness and for daily practice. Multiple physical and physiological measures need to be added to the self-report research protocols, and potential underlying mechanisms need to be further explored. In the interim, the studies reviewed here highlight the therapeutic effects of tai chi.

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