REVIEW ARTICLE

The Effect of Tai Chi on Health Outcomes in Patients With Chronic Conditions

A Systematic Review

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Objective: To conduct a systematic review of reports on the physical and psychological effects of Tai Chi on various chronic medical conditions.

Data Sources: Search of 11 computerized English and Chinese databases.

Study Selection: Randomized controlled trials, nonrandomized controlled studies, and observational studies published in English or Chinese.

Data Extraction: Data were extracted for the study objective, population characteristics, study setting, type of Tai Chi intervention, study design, outcome assessment, duration of follow-up, and key results.

Data Synthesis: There were 9 randomized controlled trials, 23 nonrandomized controlled studies, and 15 observational studies in this review. Benefits were reported in balance and strength, cardiovascular and respiratory function, flexibility, immune system, symptoms of arthritis, muscular strength, and psychological effects.

Conclusions: Tai Chi appears to have physiological and psychosocial benefits and also appears to be safe and effective in promoting balance control, flexibility, and cardiovascular fitness in older patients with chronic conditions. However, limitations or biases exist in most studies, and it is difficult to draw firm conclusions about the benefits reported. Most indications in which Tai Chi was applied lack a theoretical foundation concerning the mechanism of benefit. Well-designed studies are needed.

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TAI CHI IS A TRADITIONAL CHINESE martial art that has been practiced in China for many centuries. It combines deep diaphragmatic breathing and relaxation with many fundamental postures that flow imperceptibly and smoothly from one to the other through slow, gentle, graceful movements.[1-5] It has been advocated for development of mind-body interaction, breathing regulation with body movement, hand-eye coordination, and tranquilization.[6-11]

Tai Chi has evolved into many different styles during its development, including Chen, Wu, Sun, and Yang style. Among these styles, Chen is the oldest, while Yang is the most popular. Despite the lack of rigorous evidence regarding its benefits, Tai Chi is widely practiced in many countries as a form of exercise for health and fitness.

Tai Chi is practiced as an exercise to promote good health, memory, concentration, digestion, balance, and flexibility and is also thought to improve psychological conditions such as anxiety, depression, and declines associated with aging and inactivity. It is also practiced to improve quality of life.[9-11] However, despite its popularity, the biological mechanism and clinical effects of Tai Chi are not well understood. The purpose of this systematic review is to summarize the studies that have examined the effect of Tai Chi on patients with a variety of chronic conditions and to identify and describe the limitations and biases of these published clinical studies.

METHODS

A total of 743 abstracts pertaining to the practice of Tai Chi were obtained from 11 sources: (1) MEDLINE search from 1966 through April 2002 (87 abstracts); (2) SPORTDiscus Database search from 1949 to December 2000 (419 abstracts); (3) Social Sciences Abstracts search from 1984 to December 2000 (19 abstracts); (4) Health Star search from 1975 to 2000 (22 abstracts); (5) PsycINFO search from 1887 to May 2001 (39 abstracts); (6) ERIC search from 1966 to May 2001 (13 abstracts); (7) AIDSLINE search from 1980 to December 2000 (4 abstracts); (8) Biological Abstracts search from 1980 to March

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Table 1. Summary of the Tai Chi Studies Reviewed*

Study Characteristic	No. of Studies
Date of publication	
Before 1990	9
After 1990	38
Group study site	
China (8 Taiwan, 2 Hong Kong)	24
United States	19
Canada	2
Australia	2
Language of study	
Chinese	16
English	31
Study design*	
Randomized controlled trials (United States)	9
Nonrandomized controlled studies (9 before-and-after trials and 14 external comparison)	23
Observational studies (3 cohort, 10 cross-sectional, 2 case-control studies)	15
Clinical domain	
Cardiovascular and respiratory function	17
Balance	11
Blood pressure	4
Musculoskeletal	4
Psychological effects	6
Endocrine and immune systems	2
Other	3

*In randomized controlled trials, the investigator manipulates use of the procedure by offering it to one group of people (the exposed group) and offering nothing, a placebo, or some other procedure(s) to another group (the control group) by random allocation. Both groups are then evaluated to determine the rates of various outcomes. In nonrandomized controlled studies, the investigator causes some subjects to be exposed to the procedure but does not use random allocation to determine the exposure; these studies include both an "internal comparison (before and after)" and an "external comparison (unexposed group)." In observational studies, the investigator does not manipulate use of the procedure but merely observes and interprets the outcomes; observational studies include 3 main types: cohort, cross-sectional, and case-control.

2001 (30 abstracts); (9) Sociological Abstracts search from 1963 to December 2000 (3 abstracts); (10) CINAHL search from 1982 to May 2001 (28 abstracts); and (11) Chinese Medical Database from 1976 to June 2000 (obtained from Nanjing Medical University Library) (79 abstracts). The search strategies used the text word "Tai Chi." This includes English and Chinese articles and all types of studies.

Original studies were included in the systemic review if they evaluated Tai Chi for treatment of a chronic condition and reported outcome data. Randomized controlled trials (RCTs), nonrandomized controlled studies (NRSs), and observational studies qualified.

The following criteria were used to evaluate study quality: (1) well-defined study question; (2) explicit and/or appropriate eligibility criteria; (3) proper allocation of intervention groups; (4) use of groups with similar baseline characteristics; (5) confounders accounted for; (6) interventions and outcomes adequately described; (7) blinded outcomes assessment; (8) valid outcome measurements and statistical methods; (9) adequate follow-up rate; dropout rate reported; and (10) conclusions supported by the findings. Two investigators extracted data.

Articles were categorized into clinical domains. For each clinical domain, we summarized information from each study. The summary tables described the interventions of Tai Chi, the outcomes measured, and the authors' main conclusions when appropriate. Included studies for each clinical domain were also assessed to determine the strengths and limitations of the most important studies following a detailed rationale for the appraisal of study characteristics related to quality. Because of the heterogeneity of outcomes, study designs, and settings, we did not perform a meta-analysis on the outcomes.

RESULTS

All abstracts were reviewed to identify the relevant studies related to the effects of Tai Chi. Of the 743 abstracts initially identified, 679 were excluded because they were review articles, case reports, letters or comments, conference proceedings, information about Tai Chi classes or training programs, theses or dissertations, newspaper articles, announcements, or duplicate publications.

After the initial screening, 64 articles were retrieved and reviewed. Seventeen studies were eliminated because they were duplicate publications, English translations of original Chinese articles, or contained major methodologic flaws such as study populations that did not meet the eligibility criteria, measurement tools that lacked rigorous validity and had not been tested with the population under consideration, and inadequately reported outcomes.

Ultimately, 47 studies (9 RCTs, 23 NRSs, and 15 observational studies) related to the clinical issues were identified for data abstraction and critical appraisal (**Table 1**). The characteristics of the original research articles were assessed for each of 7 conditions.[12-57] Our reported results correspond to the data on each condition and are summarized below.

BALANCE CONTROL AND FALLS

The evidence on balance comprised 11 studies[12-23] (**Table 2**): 2 RCTs of 24 and 200 subjects, respectively; 5 NRSs of 125 subjects in total; 3 cross-sectional studies with a total of 104 subjects; and 1 follow-up study of 110 subjects. Balance control, maximal voluntary extension, strength, flexibility, cardiovascular endurance, and postural stability were measured in these studies.

Seven clinical trials[12-19] (2 RCTs and 5 NRSs) reported that 8 to 16 weeks of Tai Chi training significantly improved balance, flexibility, and strength of knee extension and reduced the occurrence of falling in community-dwelling elders. One follow-up study[20] of 110 community-dwelling persons (mean age, 80 years) that combined strengthening and weight-training programs for 3 months, then 6 months of Tai Chi training, found a favorable impact on a variety of balance measures. Three cross-sectional studies[21-23] of individuals with 1 to 35 years of Tai Chi practice experience revealed that long-term Tai Chi practitioners had greater lower extremity flexibility than nonpracti-

Table 2. Effects of Tai Chi on Balance

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Wolf et al,[12,13] 1996, 1997	United States	200	76	RCT	15 wk (1 h, 2 times/wk) 108 forms of Yang	Balance, strength, flexibility, cardiovascular fitness, stability	Reduced the risk of multiple falls and lowered blood pressure
Jacobson et al,[14] 1997	United States	24	20-45	RCT	12 wk (3 times/wk) 108 forms of Yang	Balance, strength, stability	Improved balance function, kinesthetic sense, and strength
Hain et al,[15] 1999	United States	22	20-76	NRS (before-after trial)	8 wk (1 h/wk) Selected from Yang, Pa-Kua, and Wu	Balance, stability, quality of life and others	Improved balance
Forrest,[16] 1997	United States	8	37	NRS (before-after trial)	16 wk (1 h, 2 times/wk) Simplified form	Balance, stability	Improved the ability to use the elasticity of the peripheral tissues for postural stabilization
Shih,[17] 1997	United States	11	31	NRS (before-after trial)	16 wk (50 min, 3 times/wk) Beijing 24 forms	Balance, stability	Increased postural stability
Schaller,[18] 1996	United States	46	70	NRS	10 wk (1 h/wk) Simplified 24 forms	Balance, flexibility, quality of life and others	Improved balance in community-dwelling elders
Yan,[19] 1998	United States	38	79	NRS	8 wk (45 min, 3 times/wk) Simplified 24 forms	Balance, stability	Improved dynamic balance control and smoothness in rapid-aiming arm movements
Wolfson et al,[20] 1996	United States	110	80	Cohort study	6 mo (1 h/wk) No data for style	Balance, strength, stability	Improved balance and strength
Lin et al,[21] 2000	Taiwan, China	28	71	Cross-sectional	2-35 y No data for style	Balance, stability	Improved postural stability
Tse and Bailey,[22] 1992	United States	18	65-86	Cross-sectional	1-20 y No data for style	Balance, stability	Improved postural control
Hong et al,[23] 2000	United States	58	68	Cross-sectional	13.2 y Classical Yang	Balance, flexibility, cardiovascular fitness	Long-term regular practice has favorable effects on the promotion of balance control, flexibility, and cardiovascular fitness in older adults

Abbreviations: NRS, nonrandomized controlled study; RCT, randomized controlled trial.
*Includes control group.

tioners and that Tai Chi was effective in improving normal gait velocity and producing a trend toward improved maximal gait velocity in elders. Overall, these studies reported that long-term Tai Chi practice had favorable effects on the promotion of balance control, flexibility, and cardiovascular fitness and reduced the risk of falls in elders.

However, most studies were NRSs,[15-19] had no comparison group,[15-17]or had relatively small sample sizes.[14-17,21-22] Other studies lacked detailed information on health status and eligibility criteria,[15-17] and blinding assessment of outcomes were not well reported in some studies.[17,19,20,23] In others, potential selection bias[15-17] and uncontrolled confounding factors such as age, body mass index, sex, exercise time, and a large discrepancy in Tai Chi practitioner experience might also have existed.[14,20-23] Furthermore, the cross-sectional studies were too limited to explain the cause-effect relationships.[21-23] The differences between styles of Tai Chi exercise, especially between the traditional Chinese styles (Chen, Yang, and Wu) and self-modified as well as westernized Tai Chi forms, were not made clear. The personalities of participants and the abilities of different Tai Chi instructors may vary. Several studies reported a wide range of Tai Chi exercise experience, spanning from 1 year to 35 years, making it difficult to relate the amount of benefit to the duration of exercises.[21-23]

MUSCULOSKELETAL CONDITIONS

Four studies[24-27] evaluated Tai Chi effects on musculoskeletal conditions (**Table 3**). One RCT[24] of 33 patients with osteoarthritis reported that 12 weeks of Tai Chi practice significantly improved arthritis symptoms, self-efficacy, level of tension, and satisfaction with general health status. Functional capacity (1-leg standing balance, 50-foot (15-m) walking speed, and time to rise from a chair), arthritis self-efficacy, and quality of life (Arthritis Impact Measurement Scale) were measured.

One publication[25] reported 2 NRSs of 47 and 28 patients with rheumatoid arthritis, respectively, who underwent 10 weeks of Tai Chi training. Disease activity (joint tenderness and number of swollen joints) and exacerbation of joint symptoms were measured; 50-foot (15-m) walk and handgrip strength were measured; and a written functional assessment was performed. The study showed no significant differences between the Tai Chi and control groups in disease activity. The authors suggested that Tai Chi appeared to be safe for patients with rheumatoid arthritis and might serve as a weight-bearing exercise with additional potential advantages

Table 3. Effects of Tai Chi on Musculoskeletal Condition

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Hartman et al,[24] 2000, osteoarthritis	United States	33	68	RCT	12 wk (1 h, 2 times/wk) 9 forms from Yang	Arthritis scale, clinical symptom, quality of life, functional, balance and flexibility	Enhanced arthritis self-efficacy, quality of life, and functional mobility among older adults with osteoarthritis
Kirsteins et al,[25] 1991, rheumatoid arthritis	United States	Study 1, 47; Study 2, 28	37-70 38-72	NRS	10 wk (90 min, 1 time/wk in study 1) (90 min, 2 times/wk in study 2) A series of 15 movements extracted from the Yang style Tai Chi short form	Clinical symptom,† strength and endurance, functional	No significant exacerbation of joint symptoms
Lan et al,[26] 2000, community-dwelling subjects	Taiwan, China	41	62	NRS (before-after trial)	6 mo (54 min/d) 108 forms of Yang style	Strength and endurance	Enhanced muscular strength and endurance of knee extensors in elderly individuals
Husted et al,[27] 1999, multiple sclerosis	United States	19	NR	NRS	8 wk (1 h, 2 times/wk) No data	Quality of life, functional, balance and flexibility	Maximized independence and improved quality of life for people with chronic disabling conditions

Abbreviations: NR, not reported; NRS, nonrandomized controlled study; RCT, randomized controlled trial.
*Includes control group.
†Outcomes not well defined in the original article.

of stimulating bone growth and strengthening connective tissue.

Another NRS[26] described 41 community-dwelling subjects (mean age, 62 years) who participated in a 6-month Tai Chi training course. The researchers found that concentric knee extensor peak torque increased by 15% to 20%, and eccentric peak torque increased by 15% to 24% in men. The women also showed increases, ranging from 14% to 22% in concentric peak torque and 18% to 24% in eccentric peak torque. In addition, the knee extensor endurance ratio increased by 10% to 19% in men and 10% to 15% in women. Therefore, the study concluded that Tai Chi training may enhance muscular strength and endurance of knee extensors in elderly individuals.

An NRS study[27] of 19 patients with multiple sclerosis involved an 8-week Tai Chi training course that measured walking speed, hamstring flexibility, and psychosocial well-being using the Medical Outcomes Study 36-Item Short-Form General Health Survey. The results revealed that Tai Chi increased walking speed and hamstring flexibility. Patients experienced improvements in vitality, social functioning, mental health, and ability to carry out physical activities and emotional roles. The study concluded that Tai Chi maximized independence and improved quality of life for people with chronic disabling conditions.

The limitations of these studies included small sample size,[24-27] lack of randomization,[25-27] loss to follow-up,[25,26] potential selection bias, uncontrolled confounding factors,[25-27] unclear statistical analysis,[25-27] lack of standardized outcome measures,[25-27] and lack of blinded assessment of outcome.[25-27]

HYPERTENSION

We found 2 RCTs,[28-29] and 2 NRSs[30-31] with a total of 401 patients with hypertension (**Table 4**). The duration of Tai Chi training for the studies was 8 to 12 weeks[28-29,31] and 3 years.[30] Blood pressure, maximal oxygen uptake, and heart rate (HR) were recorded before and after each session. A reduction of mean blood pressure was found for regular Tai Chi practice in all the studies. Young et al[28] found adjusted mean (SE) changes in systolic blood pressure during the 12-week intervention period of –8.4 (1.6) mm Hg and –7.0 (1.6) mm Hg in the aerobic exercise and Tai Chi groups, respectively (within-group $P<.001$; between-group $P=.56$). Corresponding changes for diastolic blood pressure were –3.2 (1.0) mm Hg in the aerobic exercise group and –2.4 (1.0) mm Hg in the Tai Chi group (within-group $P<.001$; between-group $P=.54$). Channer et al[29] reported that over 11 sessions of exercise, both aerobic and Tai Chi exercise were associated with reduction in systolic blood pressure ($P<.05$), and Tai Chi was also associated with a reduction in diastolic blood pressure ($P<.01$) in patients recovering from acute myocardial infarction. Similar findings were also reported in 2 NRSs[30,31] conducted in China.

These studies included biases due to volunteer effect, confounding factors, and loss to follow-up.[28,30,31] The eligibility criteria were not clearly specified,[29-31] and several studies lacked standardized outcome measurements and appropriate statistical analysis.[30-31]

CARDIOVASCULAR AND RESPIRATORY SYSTEM

Numerous studies have evaluated the effects of Tai Chi on cardiovascular and respiratory function.[32-48] Since 1993, three observational studies and 2 NRSs[32-36] were conducted by Tai-

Table 4. Effects of Tai Chi on Hypertension

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Young et al,[28] 1999	United States	62	69-80	RCT	12 wk (1 h, 2 times/wk) Yang style	Blood pressure, maximal oxygen uptake, physical activity, cardiorespiratory fitness	Decreased blood pressure in both Tai Chi and aerobic groups
Channer et al,[29] 1996	United States	126	56	RCT	8 wk (1 h, 2 times/wk for 3 wk and 1 time/wk for 5 wk) Wu style short form	Blood pressure,† cardiorespiratory fitness†	Decreased blood pressure in both Tai Chi and aerobic groups in patients recovering from acute myocardial infarction
Chou and Li,[30] 1994	China	143	54	NRS	3 y (every morning) No data for style	Blood pressure,† cardiorespiratory fitness†	Decreased blood pressure
Fang and Wang,[31] 1985	China	70	40-70	NRS	12 wk (40 min, 2 times/wk) Simplified 24 forms	Blood pressure†	Decreased blood pressure

Abbreviations: NRS, nonrandomized controlled study; RCT, randomized controlled trial.
*Includes control group.
†Outcomes were not well defined in the original article.

wan groups to evaluate the cardiovascular effect of regular Tai Chi practice (**Table 5**). Two cohort studies[32,33] of 90 and 84 subjects with 6.3 and 6.7 years' experience of Tai Chi, respectively, were reported. Cardiopulmonary exercise testing using incremental cycle ergometry and HR measurements were performed in these studies. The researchers found that the oxygen uptake ($\dot{V}O_2$ and work rate in the Tai Chi group were significantly higher than in the control group. Tai Chi practitioners had a smaller decline in the maximum oxygen uptake than their sedentary counterparts.

One case control study[34] of 76 subjects with 11.8 years of Tai Chi practice (mean age, 69 years) evaluated cardiovascular function, flexibility, and body composition. The researchers found that the long-term Tai Chi practitioners showed higher $\dot{V}O_2$ scores in the stand-and-reach test and a lower percentage of body fat than their sedentary counterparts. Two NRSs[35,36] evaluated the training effect of Tai Chi for 38 community-dwelling subjects (aged 58-70 years) and 20 low-risk patients who underwent coronary artery bypass surgery (mean age, 57 years). After 1 year of 4-times-weekly Tai Chi training, the Tai Chi group showed significantly enhanced cardiorespiratory function, strength and flexibility, and increased $\dot{V}O_2$ and work rate compared with the control group who performed self-adjusted exercises.

One NRS[37] with 20 subjects (aged 30-35 years) examined the metabolic and cardiorespiratory responses to continuous performance of Tai Chi and Wing Chun (rapid forceful striking and kicking movements with forced expirations timed with punching and kicking in an attempt to achieve maximum power). The exercise values corresponded to 52.4% of maximum oxygen uptake values ($\dot{V}O_{2max}$) and 70.5% of maximum HR (HR_{max}) for Wing Chun and only 36.4% of $\dot{V}O_{2max}$ and 59.8% of HR_{max} for Tai Chi. The ventilatory equivalent for $\dot{V}O_2$ obtained during Tai Chi (21.7) was significantly lower than for Wing Chun exercise (24.2). The authors concluded that Tai Chi practitioners use efficient breathing patterns during exercise. However, because Tai Chi is a low- to moderate-intensity form of exercise, it might not be suitable for improving cardiorespiratory fitness.

Results related to the effect of Tai Chi on cardiovascular and pulmonary function have been reported in 11 publications by Chinese researchers since 1979.[38-48] Although 1 study[40] reported that the metabolic intensity of the activity seemed insufficient to generate improvements of cardiorespiratory fitness in healthy young adults, all other studies suggested that regularly practiced Tai Chi might delay the decline of cardiorespiratory function in older individuals and might be prescribed as a suitable exercise for older adults.

No RCTs were identified in this area, and the overall study quality was very poor, especially among the studies conducted in China. Many limitations were found in the Chinese studies, such as unclear study designs,[32,34,36-48] small sample sizes,[36-38,40-41,43-45,47] poorly reported baseline health status and eligibility criteria of the subjects,[38-48] lack of comparison groups,[41,45-47] lack of detailed information about the types of Tai Chi exercise and duration of the trial,[37,39-40,42-43,46-48] lack of accounting of subjects lost to follow-up,[38-48] and no blinding of outcome assessors.[38-48] In addition, study limitations included potential selection bias,[32-33,37-48] confounding factors,[32-33,37-48] inconsistent measurement intervals,[33-35,39-42,44-48] and large differences in Tai Chi practitioner experience.[33-35,39-42,44-48]

PSYCHOLOGICAL RESPONSES

The effect of Tai Chi on psychological responses were evaluated in 3 RCTs[49-51] and 3 NRSs[52-54] (**Table 6**). Results from 2 RCTs indicated that 283 low-activity older adults participating in either a 16-week or a 6-month Tai Chi exercise program showed improvement compared with the control groups in several

Table 5. Effects of Tai Chi on Cardiorespiratory Condition

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Lai et al,[32] 1993	Taiwan, China	90	58	Cohort study	6.3 y (54 min, 4 times/wk) 108 forms of Yang	Incremental cycle ergometry, cardiopulmonary function, oxygen uptake, heart rate and electrocardiography	Tai Chi practitioners had superior cardiorespiratory function compared with their sedentary counterparts
Lai et al,[33] 1995	Taiwan, China	84	65	Cohort study	6.7 y (54 min, 5 times/wk) 108 forms of Yang	Cardiopulmonary function, oxygen uptake, heart rate and electrocardiography	May delay the decline of cardiorespiratory function in older individuals
Lan et al,[34] 1996	Taiwan, China	76	69	Case-control†	11.8 y (4.3 times/wk) 108 forms of Yang	Cardiopulmonary function, oxygen uptake, heart rate and electrocardiography	Long-term practice may benefit cardiorespiratory function, flexibility, and body composition in the elderly
Lan et al,[35] 1998	Taiwan, China	38	58-70	NRS	12 mo (54 min, 4.6 times/wk) 108 forms of Yang	Cardiopulmonary function, oxygen uptake, heart rate and electrocardiography	Improved health fitness of the elderly
Lan et al,[36] 1999	Taiwan, China	20	57	NRS	1 y (54 min, 3.8 times/wk) 108 forms of Yang	Incremental cycle ergometry, cardiopulmonary function, oxygen uptake, heart rate and electrocardiography	Enhanced cardiorespiratory function for low-risk patients with coronary artery bypass surgery
Schneider and Leung,[37] 1991	United States	20	30-35	NRS	81.6 mo No data for style	Cardiopulmonary function, oxygen uptake, heart rate and electrocardiography	Tai Chi is of low to moderate intensity and may not be suitable for improving cardiorespiratory fitness
Brown et al,[38] 1989	China	6	34	Cross-sectional	8.3 y Long form of Yang	Incremental cycle ergometry, cardiopulmonary function, oxygen uptake	Tai Chi leads to a more efficient use of the ventilatory volume than cycle ergometry
Gong et al,[39] 1981	China	100	41-80	Cross-sectional	1-30 y No data for style	Heart rate and electrocardiography	Tai Chi represents a lighter load than other forms of physical training
Zhuo et al,[40] 1984	China	11	24-35	Cross-sectional	5 y No data for style	Heart rate and electrocardiography‡	The metabolic intensity of the activity seems insufficient to generate improvements in cardiorespiratory fitness in healthy young adults
Zhang et al,[41] 1979	China	22	7-12	NRS (before-after trial)	18 mo (30 min, 6 times/wk) Simplified 24 forms	Cardiopulmonary function,‡ clinical symptom, heart rate and electrocardiography	Improved clinical symptoms and cardiorespiratory function
Chang and Gao,[42] 1998	China	110	61	Cross-sectional	6-24 mo No detailed data	Cardiopulmonary function,† clinical symptom, heart rate and electrocardiography	Enhanced cardiorespiratory function
Cun and Lansimies,[43] 1998	China	14	21	Cross-sectional	No detailed data	Heart rate and electrocardiography	Changing heart rate variability and improved function of vegetative nervous system, especially increased parasympathetic nervous system
Wu and Ho,[44] 1996	China	20	54	NRS	90 d (40 min, 2 times/d) Simplified 24 forms	Cardiopulmonary function,‡ oxygen uptake, heart rate and electrocardiography	Enhanced cardiorespiratory function
Kui et al,[45] 1990	China	28	50-75	NRS (before-after trial)	90 d (3 times/wk) Simplified 24 forms	Cardiopulmonary function, oxygen uptake	Improved cardiorespiratory function compared with sedentary counterparts
Liu et al,[46] 1993	China	55	58	NRS (before-after trial)	3 mo (60 min, 2 times/d) No data for style	Cardiopulmonary function, heart rate and electrocardiography	Improved cardiorespiratory function
Cun et al,[47] 1998	China	14	64	NRS (before-after trial)	18 mo No data for style	Cardiopulmonary function, oxygen uptake	Improved cardiorespiratory function
Gao and Tan,[48] 1997	China	60	60-70	Cross-sectional	3 y No detailed data for style	Cardiopulmonary function, heart rate and electrocardiography	Improved cardiorespiratory function compared with sedentary counterparts in the elderly

Abbreviations: NRS, nonrandomized controlled study; RCT, randomized controlled trial.
*Includes the control group.
†The case-control study design was defined by the authors.
‡Outcomes were not well defined in the original article.

Table 6. Effects of Tai Chi on Psychological Measures

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Li et al,[49] 2001	United States	148	73	RCT	6 mo (1 h, 2 times/wk) Classical Yang	Depression score; anxiety, mood, stress scales, storytelling; well-being scale; satisfaction scale; general health scale	Higher levels of health perceptions, life satisfaction, positive affect, and well-being; lower levels of depression, negative affect, and psychological distress
Brown et al,[50] 1995	United States	135	51	RCT	16 wk (45 min, 3 times/wk) No data for style	Anxiety, mood, stress scales, storytelling; satisfaction scale; self-competence	No significant difference among 5 training groups on measures of mood, self-esteem, personality, or life satisfaction
Baron,[51] 1998	Canada	90	Children (grades 4-6)	RCT	12 wk (1 h, 2 times/wk) Yang style	Anxiety, mood, stress scales, storytelling; self-competence; visual-motor integration	Improved perceived self-competence and visual-motor integration
Jin,[52] 1992	Australia	96	36	NRS	46.4 and 36.4 mo (1-h meditation) Either the long form or Yang style or Wu style	Anxiety, mood, stress scales, storytelling†	Stress-reduction effect
Fu et al,[53] 1995	China	90	18-68	NRS	1 mo (30 min, 6 times/wk) No data for style	Anxiety, mood, stress scales, storytelling†	Improved symptoms and reduced stress and anxiety
Gibb et al,[54] 1997	Australia	9	79 (66-90)	NRS (before-after trial)	7 wk (2 times/wk) No data for style	Anxiety mood, stress scales, story telling†	Structured reminiscence with Tai Chi facilitated thinking that was focused and insightful beyond the level normally manifested for this group of participants

Abbreviations: NRS, nonrandomized controlled study; RCT, randomized controlled trial.
*Includes control group.
†Outcomes were not well defined in the original article.

indices of psychological well-being that evaluated depression, psychological distress, positive well-being, life satisfaction, and perceptions of health.[49,50]

Another RCT[51] examined the psychological effect of a 12-week Tai Chi program on 90 schoolchildren, grades 4 to 6 (52 boys, 38 girls), who were pretested on measures of perceived self-competence, visual-motor integration, and anxiety. The Tai Chi group significantly improved their scores on the perceived self-competence and visual-motor integration tests.

Two NRSs[52,53] with a total of 186 patients reported that 1 to 46 months of Tai Chi practice improved mood and reduced stress and anxiety. Nine elderly patients diagnosed with multiple-infarct dementia or Alzheimer disease participated twice weekly over 7 weeks in a before-and-after Tai Chi trial.[54] The authors concluded that "structured reminiscence with Tai Chi facilitated thinking that was focused and insightful, beyond the level normally manifested for this group of participants."

Although these 6 studies (including 3 RCTs) were conducted in 4 countries (United States, Canada, China, and Australia), the study populations were poorly defined. The Tai Chi interventions were not adequately described, and there was no blinding of outcome assessors to intervention in any of these studies.

ENDOCRINE AND IMMUNE SYSTEMS

Two studies[55,56] evaluated the effects of Tai Chi practice on the endocrine or immune systems (**Table 7**). A cross-sectional Chinese study[55] of 98 elderly men reported that 10 years of Tai Chi practice might widely affect endocrine function, including the pituitary-thyroid system and the pituitary-gonad system, and may strengthen pituitary metabolic reaction among elderly men. The conclusion of this study is questionable because cross-sectional studies are not designed to evaluate causality.

An NRS of 60 elderly subjects[56] found that the total number of circulating T cells, including active T lymphocytes, were significantly higher in the Tai Chi group (30 healthy subjects, aged ≥60 years, who regularly practiced Tai Chi for 4 or more years) than in the untrained group (30 age-matched subjects).

Both studies lacked explicit and appropriate eligibility criteria. In both studies, the Tai Chi intervention was not well described, and the follow-up rate and statistical analysis were not adequately reported.

OTHER CONDITIONS

Several studies evaluated the beneficial effects of Tai Chi in other areas (**Table 8**).[57-59] A recent RCT[57] found that a 60-minute Tai Chi practice session twice a week for 6 months using a classical Yang style could significantly enhance self-efficacy in older adults. Two aspects of self-efficacy were measured: barriers and performance. The study also suggested that changes in self-efficacy cognitions were significantly related to class attendance.

Table 7. Effects of Tai Chi on Endocrine and Immune Systems

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Wang,[55] 1986	China	98	60-90	Cross-sectional	10-70 y (40 min/d) No data for style	T_3, T_4, testosterone; estradiol and cortisone; TSH and FSH; LH	Increased the blood level of T_3, T_4, testosterone, estradiol, cortisone, TSH, FSH, and LH compared with control groups
Sun,[56] 1989	China	60	60	NRS	≥4 y No data for style	T cells (total and active T lymphocytes)	Increased total number of circulating T cells

Abbreviations: FSH, follicle-stimulating hormone; LH, luteinizing hormone; NRS, nonrandomized controlled study; T_3, triiodothyronine (liothyronine); T_4, thyroxine; TSH, thyrotropin.
*Includes control group.
†Outcomes were not well defined in the original article.

Table 8. Effects of Tai Chi on Other Areas

Source	Country	No. of Subjects*	Mean Age or Range, y	Study Design	Practice Duration and Style	Outcome Measured	Main Conclusions
Li et al,[57] 2001	United States	94	73	RCT	6 mo (1 h, 2 times/wk) Classical Yang	Physical functioning (SF-20), self-efficacy	Enhanced the self-efficacy and functional status in healthy, physically inactive older adults
Wang et al,[58] 2001	China	20	69	Case-control	11.2 y (54 min, 5 times/wk) Classical Yang	Bicycle ergometer; skin blood flow, cutaneous vascular conductance, and skin temperature	Higher cutaneous microcirculatory function during Tai Chi exercise than in sedentary counterparts in older adults
Slater and Hunt,[59] 1997	Canada	22	21	NRS	20 d (5 min/d before bed) No data for style	Dream diary†	Significant decrease in nightmares

Abbreviations: NRS, nonrandomized controlled study; RCT, randomized controlled trial; SF-20, Medical Outcomes Study Short-Form General Health Survey.
*Includes control group.
†Outcomes were not well defined in the original article.

A recent case-control study[58] of 20 elderly men revealed that 10 elderly men who practiced Tai Chi for 11.2 years had a 34% higher $\dot{V}O_2$ peak and higher skin blood flow, cutaneous vascular conductance, and skin temperature than the 10 sedentary men at rest and during exercise. Another NRS[59] of 22 young people (mean age, 21 years) found that 20 days of Tai Chi practice significantly decreased nightmares.

CONCLUSIONS

Most of the studies evaluated in this systematic review have been performed in China and the United States to examine the physiological and psychosocial benefits of Tai Chi for all age groups. Benefits were reported by the authors of these studies in cardiovascular and respiratory function in healthy subjects and in patients who had undergone coronary artery bypass surgery as well as in patients with heart failure, hypertension, acute myocardial infarction, arthritis, and multiple sclerosis. Benefit was also found for balance, strength, and flexibility in older subjects; falls in frail elderly subjects; and pain, stress, and anxiety in healthy subjects. Overall, Tai Chi appears to have physiologic and psychosocial benefits and appears to be safe and effective in promoting balance control, flexibility, and cardiovascular fitness for older adults with chronic conditions.

Unfortunately, many studies of Tai Chi lack rigorous scientific methods, and most investigations have been retrospective and have not used randomized control groups. It is also difficult to obtain overall quantitative estimates of treatment effects owing to the heterogeneity of inclusion criteria, patients, and outcome definitions and inadequate information on design, details of the intervention, and outcomes. It should also be noted that none of the studies from Asia were RCTs. In contrast to those published in the United States and other Western countries, almost all the studies published in mainland China, Hong Kong, and Taiwan reported positive results. Studies may have been conducted with different levels of methodologic rigor, and publication bias may be greater in some countries than in others.[60]

In addition, the mechanisms of the benefits from practicing Tai Chi for any of the conditions studied are not well understood. There are only 9 RCTs in this review, and they examined only short-duration practice of Tai Chi (8-16 weeks). Therefore, long-term effects of Tai Chi practice are still unknown, and there is insufficient information to recommend Tai Chi to patients with chronic conditions. Well-defined study questions, adequate selection criteria, groups similar at baseline, valid statistical methods, accounted-for confounders, appropriate outcome, and adequate follow-up are needed for proper evaluation of the effects of Tai

Chi. Patients and physicians who use Tai Chi intervention will be better informed by high-quality RCTs that report short- and long-term risks and benefits.

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