The Effectiveness of Tai Chi Exercise in Improving Aerobic Capacity

A Meta-Analysis

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Purpose: Meta-analysis involves the integration of several studies with small sample sizes, enabling the investigator to summarize research results into useful clinical information. Tai Chi exercise has recently gained the attention of Western researchers as a potential form of aerobic exercise. A goal of this meta-analysis was to estimate the effect of Tai Chi exercise on aerobic capacity. **Methods:** A computerized search of 7 databases was done using key words and all languages. Sixteen study elements were critically appraised to determine study quality. D-STAT software was used to calculate the standardized mean differences (ES_{sm}) and the 95% confidence intervals (CI), using means and standard deviations (SD) reported on aerobic capacity expressed as peak oxygen uptake ($\dot{V}O_{2peak}$) ($mL \cdot kg^{-1} \cdot min^{-1}$). **Results:** Of 441 citations obtained, only 7 focused on aerobic capacity in response to Tai Chi exercise (4 experimental and 3 cross-sectional). Older adults including those with heart disease participated ($n = 344$ subjects); on average men were aged 55.7 years ($SD = 12.7$) and women 60.7 years ($SD = 6.2$). Study quality scores ranged from 22 to 28 (mean = 25.1, $SD = 2.0$). Average effect size for the cross-sectional studies was large and statistically significant ($ES_{sm} = 1.01$; $CI = +0.37, +1.66$), while in the experimental studies the average effect size was small and not significant ($ES_{sm} = 0.33$; $CI = -0.41, +1.07$). Effect sizes of aerobic capacity in women ($ES_{sm} = 0.83$; $CI = -0.43, +2.09$) were greater than those for men ($ES_{sm} = 0.65$; $CI = -0.04, +1.34$), though not statistically significant. Aerobic capacity was higher in subjects performing classical Yang style (108 postures) Tai Chi ($ES_{sm} = 1.10$; $CI = +0.82, +1.38$), a 52-week Tai Chi exercise intervention ($ES_{sm} = 0.94$; $CI = +0.06, +1.81$), compared with sedentary subjects ($ES_{sm} = 0.80$; $CI = +0.19, +1.41$). **Conclusions:** This meta-analysis suggests that Tai Chi may be an additional form of aerobic exercise. The greatest benefit was seen from the classical Yang style of Tai Chi exercise when performed for 1-year by sedentary adults with an initial low level of physical activity habits. Recommendations for future research are provided and the effect sizes generated provide information needed for sample size calculations. Randomized clinical trials in diverse populations, including those with chronic diseases, would expand the current knowledge about the effect of Tai Chi on aerobic capacity.

KEY WORDS: aerobic capacity, meta-analysis, oxygen consumption, Tai Chi

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Tai Chi exercise, though practiced in China for hundreds of years, has only recently gained the interest of researchers in Western countries as an alternative form of exercise.¹⁻³ Recently, improvements in cardiorespiratory function,⁴⁻⁶ balance,⁷⁻⁹ muscular strength,¹⁰⁻¹² flexibility,^{5,13,14} relaxation^{15,16} and mood state^{15,17-19} have been associated with Tai Chi. Additionally, reduction in blood pressure,^{3,20} and improvement in aerobic capacity² in patients with heart disease have been reported. Tai Chi requires no special facility or expensive equipment and can be performed either individually or in groups. Tai Chi movements are suited for persons of all ages, regardless of previous exercise experience and aerobic capacity.^{14,21} Tai Chi is a low impact, low to moderate intensity exercise incorporating elements of balance, strength, flexibility, relaxation, and body alignment. Features of Tai Chi exercise include weight-shifting between right and left legs, knee flexion, straight and extended head and trunk, rotation, and asymmetrical diagonal arm and leg movements with bent knees.^{22,23} The exercise intensity of Tai Chi is variable and can be adjusted by the height of the postures, duration of the practice session, and training style.^{22,23} Tai Chi is performed in a semisquat position. A high-squat posture and short-training session are well suited for deconditioned persons, including those with heart disease and older adults.^{22,23} The exercise intensity of Tai Chi, height of the postures, and duration are all likely to affect overall improvements in aerobic capacity. However, there is a paucity of literature on the aerobic benefits of Tai Chi exercise.

Lan and colleagues²² reported the exercise intensity during performance of the classical Yang style among experienced Tai Chi practitioners to be at 55% of the subjects' peak oxygen uptake. Zhuo and colleagues²⁴ reported the estimated energy costs of performing the classical Yang style of Tai Chi to be 4.1 metabolic equivalents (METs), with work intensity not exceeding 50% of an individual's maximum oxygen uptake. Schneider and Leung²⁵ reported that the exercise intensity of performing Tai Chi was 4.6 METs. Zhuo and colleagues²⁴ have also reported that the energy cost for performing a simplified form of Tai Chi requires an average of 2.9 METs with a maximum oxygen uptake at less than 40%. Energy requirements for Tai Chi Chih, a simplified form of Tai Chi, were reported by Fontana²⁶ to range from 1.5 to 2.6 METs,²⁶ depending on whether the subject was sitting or standing. There seems to be a wide range of exercise intensities associated with Tai Chi performance, ranging from 1.5 to 4.6 METs.

Maximum oxygen consumption ($\dot{V}O_{2\max}$) is considered the best measure of aerobic capacity and provides important information about cardiorespiratory

function.^{27,28} $\dot{V}O_{2\max}$ is the greatest amount of oxygen a person can take in from inspired air while performing dynamic exercise involving a large part of total muscle mass.²⁷ $\dot{V}O_{2\max}$ is considered the gold standard for determining aerobic capacity,^{27,28} though not feasible or appropriate for some patient populations. Aerobic capacity is derived from gas exchange during exercise testing and is difficult to obtain in older populations and those with compromised cardiopulmonary functioning. In high risk or diseased populations, it may be more appropriate to obtain $\dot{V}O_{2\text{peak}}$ if symptoms such as angina, deconditioning or other factors prevent subjects from achieving maximum oxygen consumption levels.^{27,28} Oxygen consumption derived from $\dot{V}O_{2\text{peak}}$ during exercise testing is most accurate when measured directly from expired gases.^{27,28} Another term to express oxygen consumption is *metabolic equivalents*.^{27,28} One metabolic equivalent (MET) is a unit of resting oxygen uptake (~ 3.5 mL of O_2 per kilogram of body weight per minute [$\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$]).²⁹ In this meta-analysis, $\dot{V}O_{2\text{peak}}$ in $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ is used as the measure of aerobic capacity.

The effect of Tai Chi exercise on aerobic capacity is important to know if clinicians want to recommend Tai Chi as an alternative form of aerobic exercise. The majority of the published studies examining cardiorespiratory responses to Tai Chi exercise by measuring aerobic capacity have small sample sizes. A meta-analysis involves the integration of several studies with small or large sample sizes, enabling the investigator to summarize the research results into useful clinical information. Therefore, the purpose of this meta-analysis was to estimate the extent to which Tai Chi exercise affects aerobic capacity.

Methods

Literature Search and Study Selection

A computerized search of 7 databases (PubMed, CINAHL, Current Contents, Cochrane Library, Digital Dissertations, PsychINFO, and SocAbstracts) was done using key words for the various English language spellings of Tai Chi (eg, Tai Chi, Tai Chi Chuan, Tai Chi Quan, Tai Ji, and Tai Ji Quan). All languages were accepted. A total of 441 citations were obtained. Abstracts of all research studies were reviewed using a study selection form to determine whether subjects were randomly assigned to a Tai Chi exercise intervention or whether a Tai Chi exercise group was compared with another group; and if aerobic capacity was an outcome measure. The following types of articles were rejected: review, commentary, case report, research methodology paper, a

reanalysis of data, a meta-analysis, an overview, qualitative research not related to the meta-analysis topic, or if aerobic capacity was not included as an outcome variable. Several articles appeared in more than one database.

Following initial selection criteria, 14 studies and 1 doctoral dissertation were examined in depth to determine whether they met the selection criteria. A total of 8 studies investigated Tai Chi and aerobic capacity and met the inclusion criteria. Four of the articles were experimental studies (2 randomized clinical trials,^{19,20} 2 quasi-experimental^{2,4}), 3 were cross-sectional studies,^{5,25,30} and 1 was a prospective cohort study.⁶ In the cross-sectional studies, 2 groups of different subjects were matched on age, gender, and body composition, allowing for adequate group comparisons. The prospective cohort study examined age-related deterioration in aerobic capacity and how Tai Chi may slow progressive decline. Subjects in the Tai Chi exercise and control groups in the prospective cohort study had statistically significant different baseline $\dot{V}O_2$ scores. Thus, group comparisons at the end of the study were not feasible,⁶ and the study was not included in the analysis. A total of 7 studies were included in this meta-analysis. Characteristics of the subjects in these studies can be found in Table 1 (experimental) and Table 2 (cross-sectional).

Development of Study Quality Scoring Tool

A study quality scoring tool was developed on the basis of previous work from Chan and Bartlett.³¹ A total of 16 study elements were critically appraised to determine a study quality score. Elements reviewed included study design, sample selection, description of the independent variable (Tai Chi), description of the outcome measure (aerobic capacity), data analyses, and results. The highest possible study quality score was 32; each item had a possible score of 0 to 2 (0 = absent, 1 = partially defined, 2 = clearly defined), with possible scores ranging from 0 to 32. The methodological quality of both experimental and cross-sectional studies could be assessed using this tool. Any study with a quality score below 67% (<21) of the total possible score³¹ was eliminated from this analysis.

Measurements of Effects of Tai Chi Exercise Assessed

In order to measure the benefits of exercise, the frequency, intensity, duration, type, and preference of exercise need consideration.^{27,28} Current recommendations by the American College of Sport Medicine^{27,28} include exercise frequency of 3 to 5 days per week, an intensity of either 65% to 90% of maximum heart rate or 50% to 85% of maximal

oxygen uptake, duration of 20 to 60 minutes per session, aerobic type activity, and participation in an enjoyable aerobic activity. In very unfit individuals, the exercise intensity based on 55% to 64% of an individual's predicted maximum heart rate may be most suitable.^{27,28} Aerobic capacity is influenced by age, weight, gender, exercise habits, genetic factors, and cardiovascular clinical status. Effects of Tai Chi exercise on aerobic capacity in this meta-analysis included study design, gender, physical activity habits, style of Tai Chi exercise, and the duration of the Tai Chi exercise intervention-training period.

Data Abstraction and Calculation of Effect Size

Using the data abstraction form developed for this meta-analysis, information from the 7 studies was abstracted (by Ruth Taylor-Piliae) to record study sample characteristics, the independent variable (Tai Chi), the outcome variable (aerobic capacity, expressed as $\dot{V}O_2$ peak in $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), results, and statistical methods. Effect sizes were calculated from the standardized mean differences using means and standard deviations reported on the outcome measure (aerobic capacity).

The standardized mean difference effect size (ES_{sm}), also called d , is a scale-free measure that can contrast results for 2 groups, with continuous underlying distributions.^{32,33} Effect sizes are important for power calculations when designing research studies and help clinicians and researchers understand the magnitude and direction of a relationship.^{33,34}

The following formula³⁴ was used:

$$ES_{sm} = \frac{\text{Mean}_{Rx} - \text{Mean}_C}{S_{pool}}$$

Where Rx denotes Tai Chi exercise group, C denotes control or comparison group, and

$$S_{pool} = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

where n = sample size and s = standard deviation.

D-STAT* software was used to calculate the ES_{sm} and the 95% confidence intervals. The ES_{sm} for each study was weighted by the sample size and pooled variance. The postintervention mean aerobic capacity ($\dot{V}O_2$ peak) was used to contrast the experimental and control group in the experimental studies, as there was no difference in the baseline mean scores in these studies. The ES_{sm} for 1 of the experimental studies²⁰ was calculated by D-STAT using the mean

*Johnson, BT D-STAT: Software for the Meta-Analytic Review of Research Literature. Lawrence Erlbaum Associates, Inc; 1989.

TABLE 1 Experimental Studies

Author/ Year	Study Design	Size	Gender	Mean Age in Years (SD)	Tai Chi Style	Length of Intervention	Group	Baseline Mean $\dot{V}O_2$ peak, $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (SD)	Follow-up Mean $\dot{V}O_2$ peak, $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (SD)	Effect Size	LBCI	UBCI
Brown et al 1995	RCT	11	Male	50.4 (5.7)	Not specified	16 wk	Tai Chi	31.7 (5.1)	30.8 (4.1)	-0.3580	-1.154	+0.4379
		14	Male	50.5 (7.4)			Control (sedentary)	31.9 (5.4)	32.7 (5.8)			
		7 17	Female Female	51.5 (8.3) 53.6 (9.4)		16 wk	Tai Chi Control (sedentary)	25.0 (4.4) 26.7 (6.0)	23.8 (4.7) 25.2 (4.4)	-0.3101	-1.1857	+0.5830
Lan et al 1998	Quasi-exper	9	Male	65.2 (4.2)	Yang, 108 postures	52 wk	Tai Chi	24.2 (5.2)	28.1 (5.4)	+0.8176	-0.1442	+1.779
		9	Male	66.6 (3.9)			Control (sedentary)	24.0 (4.8)	23.6 (5.0)			
		11 9	Female Female	64.9 (4.7) 65.4 (3.8)		52 wk	Tai Chi Control (sedentary)	16.0 (2.5) 15.8 (2.5)	19.4 (2.8) 15.6 (2.6)	+1.334	+0.3609	+2.307
Lan et al 1999	Quasi-exper	9	Male	55.7 (7.1)	Yang, 108 postures	52 wk	Tai Chi	26.2 (4.4)	28.9 (5.0)	+0.6572	-0.2469	+1.561
		11	Male	57.2 (7.6)			Control (walking program)	26.0 (3.9)	25.6 (4.6)			
Young et al 1999	RCT	27	Not specified	Not specified	Yang, 13 movements	12 wk	Tai Chi	Not specified	0.97* (4.1)	-0.1598	-0.7105	+0.3909
		24	Not specified	Not specified			Control (aerobic exercise)	Not specified	1.64* (4.1)			

Note: RCT denotes randomized clinical trial; Quasi-exper, quasi-experimental study; WK, week; LBCI, lower bound confidence interval; and UBCI, upper bound confidence interval. Effect size is not significant if 0 is included in the confidence interval.

*Mean change in aerobic capacity.

TABLE 2 Cross-Sectional Studies*

Author/Year	Study Design	Size	Gender	Mean Age in Years (SD)	Group	Tai Chi Style	Mean $\dot{V}O_2$ peak, mL · kg ⁻¹ · min ⁻¹ (SD)	Effect Size	LBCI	UBCI
Schneider et al 1991	Cross-sectional	10	Male	35.5 (3.9)	Tai Chi	Not specified	44.3 (6.6)	+0.1571	-0.7208	+1.035
Lai et al 1993	Cross-sectional	10	Male	30.0 (5.0)	Wing Chun	...	43.4 (4.0)	+1.3836	+0.7252	+2.0421
		21	Male	58.7 (3.9)	Tai Chi	Yang, 108 postures	33.9 (6.3)			
		23	Male	59.1 (4.0)	Sedentary	...	26.3 (4.4)			
		20	Female	58.3 (4.8)	Tai Chi	Yang, 108 postures	21.8 (2.2)			
Lan et al 1996	Cross-sectional	26	Female	57.5 (4.7)	Sedentary	...	19.0 (3.6)	+1.2289	+0.5503	+1.9076
		22	Male	70.4 (4.1)	Tai Chi	Yang, 108 postures	26.9 (4.7)			
		18	Male	69.5 (4.2)	Sedentary	...	21.8 (3.1)			
		19	Female	66.9 (2.7)	Tai Chi	Yang, 108 postures	20.1 (2.9)			
		17	Female	67.1 (2.8)	Sedentary	...	16.5 (2.0)			

Note: LBCI denotes lower bound confidence interval; UBCI denotes upper bound confidence interval. Effect size is not significant if 0 is included in the confidence interval.

*Matched on gender, age, and body composition.

change in aerobic capacity, because of incomplete descriptive data. The ES_{sm} in the cross-sectional studies were derived from group contrasts between the Tai Chi exercise and the comparison groups. All relevant data derived from the studies were coded and entered into SPSS (10.0)³⁵ for analysis.

Interpretation of Effect Sizes

Cohen³³ has previously presented guidelines for assessing effect sizes. An effect size (ES) of 0.20 is judged to be a small effect, 0.50 as a medium effect, and 0.80 as a large effect.³³ In addition, a proportion of variance (η^2) can be calculated. Analysis of variance is a *t*-test statistic for means greater than 2. The analysis of variance ES is called *f*; and $f = d/2$. Using the formula $\eta^2 = [d^2/(d^2 + 4)]$, the percentage of variance between 2 groups can be calculated.³³ Finally, interpretation of the ES can be expanded by transforming the ES into a percentile. The percentile is obtained by referring to a normal distribution table and identifying the area under the curve associated with the ES, referred to as the measure of nonoverlap, (U_3).³³ U_3 is the percentage of the control distribution exceeded by the upper 50% of the treatment population.³⁶ U_3 readily provides the clinician with information regarding the success or failure of a treatment or intervention. For example, if the ES = 0.85, then 80% of the control group is below the average person in the treatment group. Also, it is important to note that when 50% of the control group is below the average person in the treatment group, then the ES = 0 (eg, no nonoverlap).^{32,33,36}

Results

Descriptive Data From Studies in Meta-Analysis

Quality scores ranged from 22 to 28 (mean = 25.1, SD = 2.0) and no studies were excluded on the basis of their quality. The purpose of each study was clearly defined in all of the studies included in the meta-analysis. All but 1 of the studies had a complete and comprehensive description of subject characteristics. All of the studies had the dependent variable (aerobic capacity) clearly defined. However, only 1 of the 7 studies had the rater blinded to group assignment when collecting the data on aerobic capacity.

Within these studies, a total of 344 subjects participated; 166 subjects were in Tai Chi exercise groups. There were 82 males and 57 females, and no gender was specified for the remaining 27 subjects practicing Tai Chi. There were 178 subjects in either control or comparison groups. Sample sizes ranged from 7 to 27 subjects per group. Mainly, healthy older adults

participated in these studies ($n = 6$). In the Tai Chi exercise groups, on average men were 56.0 years old ($SD = 12.3$) and women were 60.4 years old ($SD = 7.0$). Control/comparison groups were similar with regard to age and health status (men = 55.5 years, $SD = 14.2$; women = 60.9 years, $SD = 6.4$).

Four of the 7 studies had subjects perform the classical Yang style of Tai Chi, which constitutes 108 postures. One study had a modified 13-movement Yang style of Tai Chi, while Tai Chi styles were unspecified in 2 of the studies. In the 2 experimental studies, the duration of the Tai Chi exercise sessions ranged from 45 to 60 minutes, 3 to 5 times per week. The length of the Tai Chi intervention-training period ranged from 12 to 52 weeks. The workload of the outcome variable, aerobic capacity, was provided either by treadmill or cycle ergometer in all of the studies.

In 6 of the studies,^{2,4,5,19,25,30} aerobic capacity was derived from $\dot{V}O_{2peak}$ through estimations obtained from subjects' expired air. One study²⁰ used predicted maximal workload using published equations by plotting heart rate and estimating workload at the predicted maximal heart rate. Thus $\dot{V}O_{2max}$ is not likely to have been achieved in these studies. Though use of $\dot{V}O_{2peak}$ and established equations for estimating oxygen consumption during exercise testing is common, aerobic capacity may have been overestimated due to wide variance inherent with multistage testing.^{27,28}

Effects of Tai Chi on Aerobic Capacity

The effect size and the 95% confidence interval were calculated for each study, weighted by the sample size

and pooled variance. Effects of Tai Chi exercise on aerobic capacity in this meta-analysis also included study design, gender, physical activity habits, style of Tai Chi exercise, and the length of the Tai Chi exercise intervention-training period. The percent of variance between groups (η^2) and the measure of nonoverlap (U_3), was only calculated for effects found to be statistically significant (Table 3).

The average effect size for the cross-sectional studies was large ($ES_{sm} = 1.01$; $CI = +0.37, +1.66$) (Fig 1), while in the experimental studies the average effect size was small ($ES_{sm} = 0.33$; $CI = -0.41, +1.07$) (Fig 2). In the cross-sectional studies, approximately 20% ($\eta^2 = 0.20$) of the variance in aerobic capacity could be explained by group. Aerobic capacity for the average subject in a Tai Chi exercise group was higher than 84% of the subjects in the comparison groups in the cross-sectional studies.

Six of the 7 studies^{2,4,5,19,25,30} reported gender-specific descriptive statistics and enabled gender-specific effects to be calculated. Effect sizes of aerobic capacity in women ($ES_{sm} = 0.83$; $CI = -0.43, +2.09$) were somewhat higher than those for men ($ES_{sm} = 0.65$; $CI = -0.04, +1.34$), though not statistically significant.

Effect sizes examining aerobic capacity based on the physical activity habits of subjects in the control and comparison groups were also calculated. Four of the studies^{4,5,19,30} had sedentary subjects as comparisons, while the other 3 studies^{2,20,25} involved subjects doing other exercise, such as walking. Approximately 14% ($\eta^2 = 0.14$) of the variance in aerobic capacity could be explained by physical activity habits. Aerobic capacity for the subjects in a Tai Chi exercise

TABLE 3 Aerobic Capacity Effects Sizes and 95% Confidence Intervals ($n = 344$)

Selected Group for Analysis	<i>n</i>	ES	LBCI	UBCI	η^2	U_3
Study Design						
Cross-sectional	186	1.01*	+0.37	+1.66	0.20	0.84
Experimental	158	0.33	-0.41	+1.07		
Gender [†]						
Women	126	0.83	-0.43	+2.09		
Men	167	0.65	-0.04	+1.34		
Physical Activity Level						
Sedentary comparisons	253	0.80*	+0.19	+1.41	0.14	0.79
Other exercise	91	0.22	-0.81	+1.24		
Style of Tai Chi						
Classical Yang style	224	1.10*	+0.82	+1.38	0.23	0.86
Modified or unspecified	120	-0.17	-0.54	+0.20		
Length of Tai Chi Intervention [‡]						
52 weeks	58	0.94*	+0.06	+1.81	0.18	0.83
12 or 16 weeks [§]	100	-0.28*	-0.53	-0.02	0.02	0.61

Note: *n* denotes sample size; ES, effect size; LBCI, lower bound confidence interval; UBCI, upper bound confidence interval; η^2 = percent of explained variance between groups (η^2) and U_3 = percentage of the treatment group above the control group mean. The effect size is not significant if 0 is included in the confidence interval; η^2 and U_3 are reported only for significant ES.

*significant ES.

[†]51 subjects not included due incomplete descriptive data.

[‡]Sample of 158 subjects.

[§]Control group better than 61% of the subjects in treatment group.

FIGURE 1. Cross-sectional studies, $n = 3$.

group was higher than 79% of the sedentary subjects (average $ES_{sm} = 0.80$; CI = +0.19, +1.41).

Dose-treatment effects of Tai Chi exercise were calculated by the style of Tai Chi exercise performed. Four of the 7 studies^{2,4,5,30} utilized the longest form of the Yang style of Tai Chi with 108 postures. The other 3 studies had subjects perform a simplified Yang style form (13 movements)²⁰ or the style of Tai Chi was not specified in 2 of the studies.^{19,25} Approximately 23% ($\eta^2 = 0.23$) of the variance in aerobic capacity could be explained by style of Tai Chi exercise. Aerobic capacity for the average subject performing the classical Yang style form of Tai Chi exercise was higher than 86% of the subjects in the control or comparison groups (average $ES_{sm} = 1.10$; CI = +0.82, +1.38).

In the 4 experimental studies,^{2,4,19,20} Tai Chi exercise session ranged from 45 to 60 minutes (mean = 56 minutes, SD = 7.5), 3 to 5 times per week (mean = 4 times per week, SD = 0.8). The length of Tai Chi intervention training period ranged from 12 to 52 weeks (mean = 33 weeks, SD = 22). Only effect sizes examining aerobic capacity based on length of the Tai Chi intervention were calculated. Approximately 18% ($\eta^2 = 0.18$) of the variance in aerobic capacity could be explained by length of the Tai Chi exercise-training period. Aerobic capacity for the average subject participating in a 52-week Tai Chi exercise group was higher than 83% of the subjects in the control group (average $ES_{sm} = 0.94$; CI = +0.06, +1.18). On the other hand, the improvement in aerobic capacity for the average subject in the 12-week or 16-week

FIGURE 2. Experimental studies, $n = 4$.

control group was better than 61% of the subjects in the Tai Chi exercise group (average $ES_{sm} = -0.28$, $CI = -0.53, -0.02$). However, this result is not likely to be clinically relevant, only 2% ($\eta^2 = 0.02$) of the variance in aerobic capacity could be explained by the number of weeks subjects remained in the control condition.

Discussion

Given the limited number of studies pertaining to the effects of Tai Chi exercise on aerobic capacity in women ($n = 126$), these results need to be interpreted with caution. However, this early review appears to indicate potential gender differences in the effectiveness of Tai Chi exercise on aerobic capacity. Effect sizes of Tai Chi exercise on aerobic capacity in women were greater than those for men, though not statistically significant. This finding suggests that it may be important to consider, and future studies could clarify if there are gender differences by designing stratified randomization (based on gender). The development of alternative exercise programs for women including Tai Chi exercise could be of value, as previous research has reported that women desired exercise options other than using the treadmill or cycle.³⁷ Further, 1 of the experimental studies²⁰ did not provide gender information for the subjects completing the study. It is unknown if an effect based on gender would have resulted in different findings.

The degree of improvement in aerobic capacity depends on the exercise intensity, duration, and frequency, as well as the subject's initial level of physical activity. Persons who were sedentary before beginning Tai Chi exercise made greater gains with a more favorable effect. This finding is consistent with the traditional western exercise literature wherein the most sedentary persons demonstrate the greatest benefit when they initiate a regular program of exercise.³⁸ However, consideration needs to be given to possible selection bias, as Tai Chi masters were compared with sedentary subjects (>5 years), matched on age and gender, in 2 of the cross-sectional studies.^{5,30} This selection of subjects with distinctly different exercise proficiencies is likely to influence the large effect sizes obtained. Further, the extent to which diet and other lifestyle practices influenced the results was not measured.

Tai Chi exercise styles varied among the studies reviewed. The classical Yang style comprises 108 postures and is more difficult to learn.^{5,30} Simpler forms have fewer postures and exclude some of the more strenuous movements, such as deep squatting or vigorous kicking. While the simplified forms of Tai Chi are shorter and easier to learn, they may

have a reduced training benefit. The 4 studies^{2,4,5,30} that utilized the classical Yang style of Tai Chi had larger effect sizes. The findings are likely due to the inclusion of more strenuous movements and the longer time needed to complete the entire set of postures.

In the 4 experimental studies, the Tai Chi exercise intervention ranged from 45 to 60 minutes, 3 to 5 times per week, and is consistent with the current recommendations for western-style exercise.^{27,28} However, the length of the Tai Chi intervention training period varied, ranging from 12 to 52 weeks. Subjects in 2 of the 4 experimental studies^{2,4} had longer intervention times (52 weeks) than the other 2 experimental studies (12 or 16 weeks).^{19,20} The largest effect was seen in the studies with the 52-week intervention time. However, the improvement in aerobic capacity for the average subject in the 12-week or 16-week control group was significantly better than subjects in the Tai Chi exercise groups. This finding may partially be attributed to a threshold effect when performing Tai Chi exercise or a dropout effect.

Subjects in the 12-week or 16-week Tai Chi exercise groups participated in either a simplified or unspecified form of Tai Chi and may have had a reduced training benefit. In the study by Young and colleagues,²⁰ moderate-intensity aerobic exercise, instead of sedentary controls, may partially explain why the improvement in aerobic capacity for the average 12-week control subject was greater than the average subject in the Tai Chi exercise group. Further, the mean change in aerobic capacity within and between the 12-week or 16-week control and Tai Chi exercise groups was small in these 2 studies.

Finally, the dropout rate for subjects participating in a 52-week intervention was approximately 26.5%, while the 12-week and 16-week intervention studies reported dropout rates of 17% and 8% respectively. Future research could help explain these findings by examining dose-response effects of Tai Chi exercise.

Conclusion

The findings of this meta-analysis fill a gap in the literature and highlight a potential benefit in aerobic capacity when performing Tai Chi. This meta-analysis included a total of 7 studies, only 4 of which used an experimental design. It is likely that the small samples in these studies had insufficient power for the researchers to detect significant differences between groups, assuming that $\alpha = .05$ and power = 0.80 were utilized.

Tai Chi may be an additional form of aerobic exercise, suitable for sedentary older adults and those with heart disease.^{2,3,20} The slow and graceful

movements of Tai Chi have several advantages over other forms of exercise, as Tai Chi does not require any special clothing or equipment, making Tai Chi a cost-effective and affordable form of exercise. Tai Chi may also foster adherence due to its practical utility (may be performed any time and at any place). Moreover, Tai Chi might be an enjoyable and preferred form of exercise for some.¹

Future research studies examining the effect the Tai Chi on aerobic capacity should consider using the same frequency, duration, and intensity of Tai Chi exercise as that recommended by the American College of Sports Medicine.^{27,28} This is necessary in order to have valid comparisons of the effect of Tai Chi exercise to traditional forms of exercise, such as walking. Further, it is recommended that an established style of Tai Chi be used, such as the classical Yang style, rather than unspecified or modified forms, so as to provide a comparison to published findings. Research among diverse populations, including persons with chronic diseases, would help to expand current knowledge about the effect of Tai Chi on aerobic capacity. However, aerobic capacity is only 1 potential outcome, and improvements in balance,⁷⁻⁹ muscular strength,¹⁰⁻¹² flexibility,^{5,13,14} relaxation^{15,16} and mood state^{15,17-19} may be additional benefits of doing Tai Chi.

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