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Research Article

Effects of A Short-term Cardio Tai Chi Program on Cardiorespiratory Fitness and Hemodynamic Parameters in Sedentary Adults: A Pilot Study

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Abstract
This study evaluates the effects of a short-term Cardio *Tai Chi* program on the cardiorespiratory fitness and hemodynamic parameters in sedentary adults. Thirty-one sedentary participants (age: 58 ± 9 years, body mass: 63 ± 12 kg) were subjected to an exercise program during 10 sessions over a 10-day period within 2 weeks. The Cardio *Tai Chi* program consisted in a series of three to five intervals lasting 90 s each at ~70% maximal heart rate separated by 2-min of low-intensity recovery. Primary outcome measures were cardiorespiratory fitness (peak oxygen uptake, $\dot{V}O_{2peak}$) assessed by the Rockport walking test and resting hemodynamic parameters (systolic, diastolic, mean, and pulse pressures). We observed a significant difference of means on post-pre $\dot{V}O_{2peak}$ [4.5 ml/kg/min, 95% confidence interval (CI): 3.1 to 5.8, p = 0.004], systolic blood pressure (-5.5 mmHg, 95% CI:-7.3 to -3.8, p = 0.010) and pulse pressure (-3.7 mmHg, 95% CI:

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-5.2 to -2.3, p = 0.028). No significant differences were observed for diastolic pressure (−1.8 mmHg, 95% CI: -2.6 to -1.0, p = 0.226), mean blood pressure (2.5 mmHg, 95% CI: 1.4 to 3.6, p = 0.302), or resting heart rate (-0.9 beat/min, 95% CI: -2.0 to 0.1, p = 0.631). Our findings suggest that engaging in a short-term Cardio *Tai Chi* program can improve cardiorespiratory fitness and hemodynamic parameters in sedentary adults.

1. Introduction

Physical inactivity-an activity level insufficient to meet current recommendations- is considered the major public health problem of this century [1], accounting for 3.2% to 7.8% of coronary heart disease worldwide [2]. There is compelling evidence that both physical activity and exercise are associated to numerous positive health-related bio-psychosocial outcomes such as lowering blood pressure and cardiovascular disease risk factors, improving the cardiorespiratory fitness, preserving bone mass, and reducing the risk of falling, improving anxiety, quality of life, and delaying all-cause mortality [3]. A report on the pandemic of physical inactivity strongly urges the academics to provide supporting evidence for effective programs to advance global health through physical activity [4]. Because exercise can be prescribed in the treatment of many diseases, including psychiatric, neurological, metabolic, musculoskeletal, cancer, pulmonary, and cardiovascular [5], there is a need for programs that can promote the regular practice of physical activity in the general population and particularly those at a high risk of cardiovascular diseases.

Tai Chi Chuan-or *Tai Chi*-is a Chinese mind-body practice enrolling meditation, static and dynamic body postures associated with controlled breathing that is most closely related to exercise [6,7]. The practice of *Tai Chi* comprises sequences of stances, *i.e.*, coordinated upper- and lower-limb movements in predominantly slow and smooth trajectories [8-11]. A large multicenter study from 13 countries summing up 6410 participants performing either *Tai Chi* or *Qi Gong* reported health benefits related to bone density, cardiorespiratory effects, physical function, falls prevention, postural balance, and related risk factors, quality of life, self-efficacy, patient-reported outcomes, psychological symptoms, and immune- and inflammation-related responses [12]. As related to cardiovascular diseases, recent systematic reviews and meta-analyses show that *Tai Chi* practice can improve systolic blood pressure (SBP) and diastolic blood pressure (DBP) and cardiorespiratory fitness [13-15]. Although complementary and alternative medicine therapies are promising for patients with cardiac rehabilitation, it still lacks high-quality evidence in the study of the relationship between *Tai Chi* and cardiorespiratory fitness [14-17].

Improving cardiorespiratory fitness and reducing other cardiovascular risk factors such as blood pressure are both strongly associated to a regular engaging in physical activity with defined frequency, intensity, time, type, volume, pattern, and progression of cardiorespiratory exercise [3] All the aforementioned requirements are met by traditional *Tai Chi* practice except for the exercise intensity [18,19]. We thus speculate that *Tai Chi* practice might elicit the minimal exercise intensity level (*i.e.*, threshold), provided the traditional stances are performed under more vigorous movements thus promoting cardiorespiratory fitness [3]. As a corollary, risk factors related to cardiovascular diseases might be modified as well. Therefore, this pilot study aims to evaluate the effects of a short-term Cardio *Tai Chi* program on the cardiorespiratory fitness and hemodynamic parameters in sedentary adults. We hypothesized that the regular practice of *Tai Chi* at aerobic target intensity levels might elicit physiological responses that positively affect cardiorespiratory fitness and hemodynamic parameters, both associated with reduced cardiovascular risk.

2. Materials and Methods

2.1. Ethical approval

The Institutional Review Board at the University of East-West Medicine has approved this project before its execution in accordance with the ethical standards set in the Helsinki Declaration of 1975. Participants provided written informed consent before being admitted to this study.

2.2. Study design and sample size estimates

This pilot study is an uncontrolled, before-and-after study design (quasi-experimental) [20,21] in which a short-term program of exercises was applied in 10 sessions over a 10-day period within 2 weeks (Fig. 1). Measurements were obtained from baseline testing and after the 10 sessions were finished. Three assessors performed the measurements independently, and they were not aware of the purpose of the measurements. Participants were not informed about their testing results during their enrollment.

The sample size was estimated for the main outcome of this study, i.e., maximal oxygen uptake in metabolic equivalent (MET) corresponding to 3.5 mL/kg/min in a healthy 40-year-old 70kg man [22]. A minimal sample size of 31 participants in this single-arm, before-and-after study was obtained from $\beta = 0.20$, $\alpha_{\text{two-tailed}} = 0.05$, a small effect size = 0.2 as in a previous study [23] and $S(\Delta) = 0.4$ using an online calculator (http://www.sample-size.net/sample-size-study-paired-t-test/).

2.3. Participants

Thirty-one participants (age: 58 ± 9 years, body mass: 63 ± 12 kg) were enrolled in this study, and all participants completed the study protocol without missing sessions. Participants were contacted from posters, churches, and word of mouth. Eligibility criteria comprised ages between 30 and 80 years, no diagnosis of cardiovascular or metabolic diseases, no use of medication regularly, absence of musculoskeletal pain or condition that limit exercise practice, commitment of attending the *Tai Chi* sessions, and a

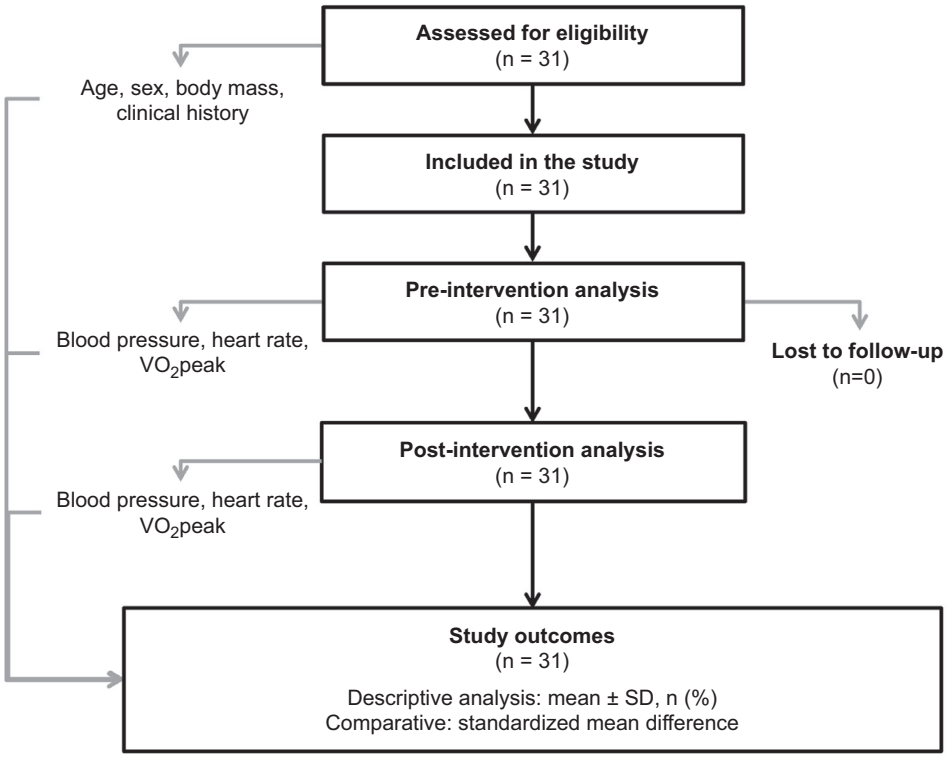

Figure 1 Study flowchart.

self-reported sedentary lifestyle (*i.e.*, not engaging in physical activity for the last 6 months).

2.4. Intervention: the Cardio *Tai Chi* exercise program

The Cardio *Tai Chi* program was designed after the integration of traditional *Tai Chi* practice [24] and features of aerobic exercise. The class of Cardio *Tai Chi* comprises selected *Tai Chi* stances performed at a fast pace for a higher intensity exercise (Fig. 2). Exercise intensity is moderated by varying the number of intervals of fast pace (two *Tai Chi* movements) that are interleaved by slow pace movements (one *Tai Chi* movement), with transitional motion (two *Tai Chi* movements). The high-intensity movement of each stance is progressively moving the body from moderate speed to higher speed within 90 s in each section.

The training program consisted in 10 sessions over a 10-day period within 2 weeks. Participants were familiarized with the *Tai Chi* stances before the first session. Sessions were performed daily from Saturday to Tuesday and Thursday (with Wednesdays and Fridays as rest days). The intensity of the sessions was distributed as follows (Table 1): three repeated sections in Level #1 (3 intervals of fast pace movements lasting 90 s); four sections in Level #2 (4 intervals of fast pace movements lasting 90 s) and five sections in Level #3 (5 intervals of fast pace movements lasting 90 s). Within each interval, the exercise intensity was increased until eliciting the ~70% maximal heart rate (HR) as measured during the assessment (section 2.5). Each interval of fast pace movements was separated by 2 minutes of low-intensity recovery. Participants had a 30-s resting period and 30 s to switch the *Tai Chi* stance into slow motion before and after the rest. There is a 30-s transition time between fast and slow pace. All sessions started and ended with a 5-minute period of warm-up and cooldown using the *Tai Chi* stances. The total time of exercise in Levels 1-3 is ~20, 24, and ~27 min, respectively.

2.5. Assessments

The primary outcome consisted of estimated $\dot{V}O_{2peak}$ as determined from a continuous submaximal exercise test on an electronically treadmill (Pro-Form 505 CST) using the Rockport walking test [25,26]. The test consisted in walking as quickly as possible for 1600 m (running or jogging was not permitted) wearing the Wireless Blood Pressure Monitor BP5 (iHealth Labs Inc., CA, USA). The time spent to complete the target distance and the HR achieved immediately after the test were both recorded and then computed in an age-specific regression equation allowing for the estimation of $\dot{V}O_{2peak}$. The $\dot{V}O_{2peak}$ was expressed in mL/kg/min and by calculating the MET [3]. Differences between values higher than 1 MET before and after the program were considered clinically relevant [27].

Secondary outcomes comprised resting HR and resting blood pressure. During the supervised training intervention, HR was recorded using Deluxe Pulse Oximeter (Veridian Deluxe Pulse Oximeter #11-50D) to ensure that participants were exercising at the prescribed target intensity. SBP and DBP were also assessed using the Wireless Blood Pressure

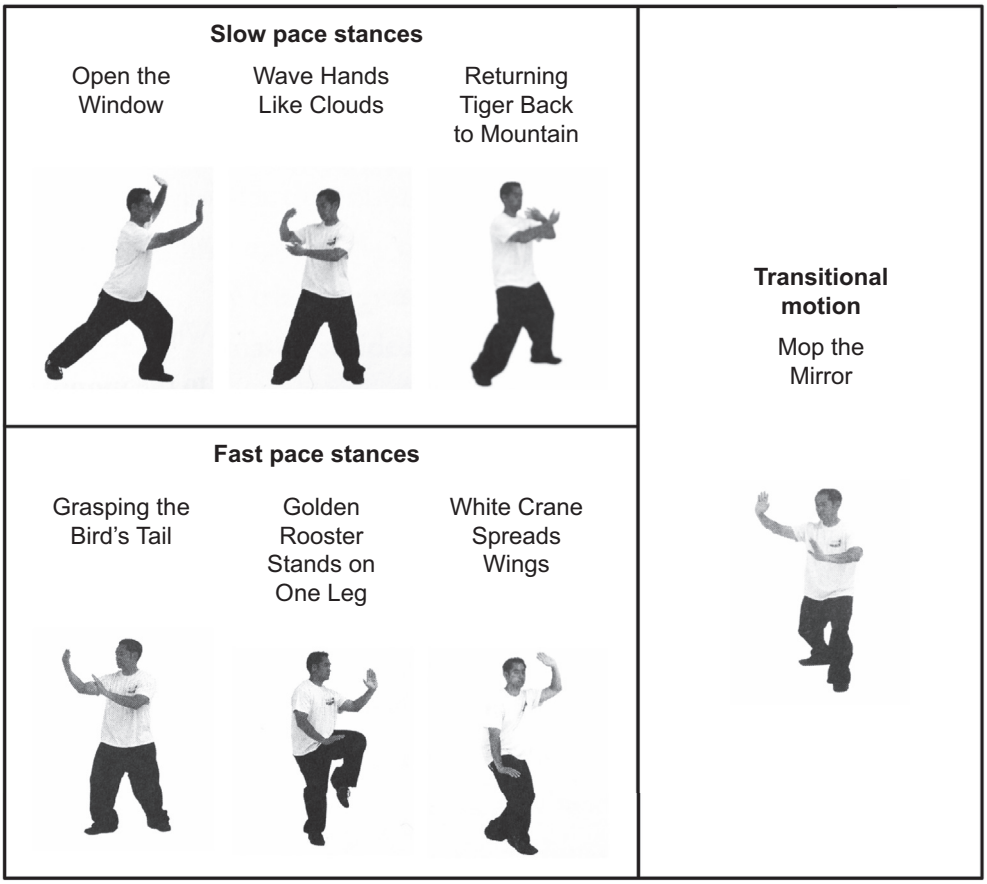

Figure 2 Slow, fast, and transitional stances used in Cardio *Tai Chi* Program. Exercise intensity is moderated by varying the number of intervals of fast pace (two *Tai Chi* movements) that are interleaved by slow pace movements (one *Tai Chi* movement), with transitional motion (two *Tai Chi* movements). The high-intensity movement of each stance is progressively moving the body from moderate speed to higher speed within 90 s in each section.

Monitor BP5 (iHealth Labs Inc., CA, USA). Pulse pressure (PP = SBP - DBP) and mean blood pressure (MBP = DBP + PP/3) were also calculated [28].

2.6. Statistical analysis

Data were typed in an electronic worksheet for statistical analysis (Excel, Microsoft Corp., USA). Data are summarized as mean ± SD or frequency (%) depending on the variable type. Difference in Means (MD) and standardized mean difference (SMD) with 95% confidence intervals (95% CI) were also calculated as effect size estimates. Before-and-after comparisons were evaluated using the *t* test for dependent samples (two-tailed analysis). Pearson's coefficient was used to quantify the correlation between values of the outcome variables before and after the program. Statistical significance was set to $p < 0.05$. Substantive evidence was assessed by effect sizes (SMD) and is interpreted as per the suggested values [23].

3. Results

Table 2 summarizes the descriptive and comparative analyses of cardiorespiratory fitness and hemodynamic parameters. A significant MD was observed on post−pre $\dot{V}O_{2peak}$ (MD 4.5 ml/kg/min, 95% CI: 3.1 to 5.8, $p = 0.004$), with a MD higher than the 1-MET minimum clinically important difference (MD: 1.3 MET, 95% CI: -0.1 to 2.6, $p = 0.004$).

Significant differences were also observed for SBP (MD: -5.5 mmHg, 95% CI: -7.3 to -3.8, $p = 0.010$) and pulse pressure (MD: -3.7 mmHg, 95% CI: -5.2 to -2.3, $p = 0.028$), all with large effect sizes (SMD: 0.94 to 1.27). No significant differences were observed for diastolic pressure (MD: -1.8 mmHg, 95% CI: -2.6 to -1.0, $p = 0.226$) and mean blood pressure (MD: 2.5 mmHg, 95% CI: 1.4 to 3.6, $p = 0.302$), both showing a medium effect size (SMD: 0.60 to 0.73). Resting HR was also not statistically different on post-pre analysis (MD: 0.9 beat/min, 95% CI: -2.0 to 0.1, $p = 0.631$), with a small effect size (SMD: 0.27).

Correlation analysis between values before and after the program showed moderate to strong correlation coefficients for $\dot{V}O_{2peak}$ ($r = 0.857$), SBP ($r = 0.830$), pulse pressure ($r = 0.839$), HR ($r = 0.600$), DBP ($r = 0.599$), and mean blood pressure ($r = 0.352$).

4. Discussion

This pilot study evaluated the effects of a short-term Cardio *Tai Chi* program on the cardiorespiratory fitness and

hemodynamic parameters in sedentary adults. We found both statistical and clinical evidence favoring the hypotheses that the short-term practice of *Tai Chi* at minimum aerobic target intensity levels elicits physiological responses that positively affects cardiorespiratory fitness and hemodynamic parameters. To the best of our knowledge, this is the first study to propose the *Tai Chi* practice under aerobic target intensity levels and to evaluate its effect on cardiorespiratory fitness and hemodynamic parameters, both associated to cardiovascular risk. This study fills an important gap in literature [13,14] regarding whether the already acknowledged biopsychosocial benefits of practicing traditional *Tai Chi* are observed in other circumstances of practice.

We observed a substantive increase in estimated $\dot{V}O_{2peak}$ that was also larger than the minimum clinically important difference of 1 MET (each 1-MET increase in exercise capacity is related to a 10 to 20% improvement in survival from cardiovascular diseases) [27]. This finding is slightly better than those reported after 16-week high-intensity interval training program or continuous moderate-intensity exercise training in adults with hypertension [29]. This suggests that the Cardio *Tai Chi* program using several selected stances from the simplified form of *Tai Chi* at aerobic target intensity levels was capable of promoting cardiorespiratory fitness. In the traditional practice of *Tai Chi*, the upper and lower extremities perform movements, whereas the body moves resembling walking at a speed that is relatively slower compared with activities of daily living [8-11]. Because walking speed is strongly correlated to both aerobic capacity and mitochondrial activity [30], we speculate that movement speed in the Cardio *Tai Chi* played a major role in the observed cardiorespiratory effects. Interestingly, studies comparing the effects of traditional *Tai Chi* practice versus brisk walking on cardiorespiratory fitness found no difference in elderlies [31,32].

The observed reduction in systolic and pulse pressures was also substantive and similar to those reported by systematic reviews and meta-analyses [13-15] on the traditional *Tai Chi* practice. Systolic and pulse pressures are well known, strong, independent predictors of cardiovascular morbidity [33]. The finding that Cardio *Tai Chi* contributes to lowering blood pressure values strongly suggest this program as an option for controlling cardiac risk factors by engaging in a regular physical activity. Nonetheless, diastolic and mean blood pressures did not improve after this 2-week Cardio *Tai Chi* program, as well as resting heart rate. The traditional practice of *Tai Chi* for 5 min acute and temporarily increases the heart rate variability (HRV) in young and older adults [34], which is in agreement that larger HRV during exercise is associated with better physical fitness [35]. We thus speculate whether a longer trial could elicit stronger substantive effects on those cardiac risk factors if any.

The findings presented herein should be interpreted in light of the factors jeopardizing the internal validity of uncontrolled before-and-after study design [21]. Therefore, we cannot rule out *history*, *maturation*, and *instrument decay* as rival hypotheses, but owing to the relative short-term between assessments all were considered implausible. Similarly, bias due to *testing* and *reactivity* were both also considered unlikely owing to the blinding of the participants to their own results. However, *statistical regression (toward the mean)* is weakly plausible because of the strong correlation between values of all studied variables before and after the program, mainly mean blood pressure. Nonetheless, our results strongly encourage conducting experimental trials with larger samples, direct methods for $\dot{V}O_{2peak}$ measurement, longer follow-up periods (*e.g.*, 4, 8 or 12 weeks) and control group to further explore the effects of Cardio *Tai Chi* on cardiorespiratory fitness and other cardiovascular risk factors and to observe whether the observed effects are transient or long lasting. The integration of the aerobic exercise and the traditional *Tai Chi* is a promising contribution to sport and rehabilitation fields.

In summary, the short-term practice of *Tai Chi* at minimum aerobic target intensity levels elicits physiological responses that positively affects cardiorespiratory fitness and hemodynamic parameters, all associated with reduced cardiovascular risk in sedentary adults.

Table 1 Cardio *Tai Chi* program schedule. All sessions started and ended with a 5-minute period of warm-up and cooldown using the *Tai Chi* stances. The intensity of the sessions was distributed as follows: three repeated sections in Level #1 (3 intervals of fast pace movements lasting 90 s), four sections in Level #2 (4 intervals of fast pace movements lasting 90 s), and five sections in Level #3 (5 intervals of fast pace movements lasting 90 s).

Task duration (mm:ss)	Intensity	*Tai Chi* stances		
		Level 1 (Classes 1 to 3)	Level 2 (Classes 4 to 6)	Level 3 (Classes 7 to 10)
05:00	Warm-up	Stretching exercises	Stretching exercises	Stretching exercises
00:30	Moderate	Cross hand	Cross hand	Cross hand
00:30	High intensity	Jumping rooster	Playing fiddle	Catching bird
00:30	Moderate	Jumping rooster	Side kicking	White crane
00:30	Slow down	Jumping rooster/ mapping mirror	Playing fiddle/ mapping mirror	Catching bird/ mapping mirror
00:30	Slow motion	Cloud hand	Open window	Embrace tiger
00:30	Break	Rest	Rest	Rest
00:30	Slow motion	Cloud hand	Open window	Embrace tiger
Repetitions	-	3 repetitions	3 repetitions, Level 1	3 repetitions, Level 1 and 2
05:00	Cool down	Deep breathing exercise	Deep breathing exercise	Deep breathing exercise
Total time	-	20:30	24:00	27:30

Table 2 Descriptive and comparative analysis.

Variable	Study phase		P-value	Standardized mean difference (SMD)	Effect size estimate
	Before	After			
Cardiorespiratory fitness					
$\dot{V}O_{2peak}$, ml/kg/min	37 ± 14	41 ± 15	0.004*	1.16	Large
$\dot{V}O_{2peak}$, MET	10.4 ± 4.1	11.7 ± 4.3	0.004*	0.33	Small
Hemodynamic parameters at rest					
Systolic blood pressure, mmHg	133 ± 19	127 ± 19	0.010*	−1.27	Large
Diastolic blood pressure, mmHg	77 ± 9	75 ± 9	0.226	−0.60	Medium
Pulse pressure, mmHg	56 ± 16	52 ± 15	0.028*	−0.94	Large
Mean blood pressure, mmHg	91 ± 12	93 ± 11	0.302	0.73	Medium
Heart rate, beat/min	77 ± 13	76 ± 10	0.631	−0.27	Small

Data are presented as mean ± SD.
* Statistical significance at $p < 0.05$.
MET, metabolic equivalent.

Conflict of interest

We declare that we have no conflicts of interest regarding this study.

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