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Original Article

Effect of Tai Chi on Cardiac and Static Pulmonary Function in Older Community-Dwelling Adults at Risk of Ischemic Stroke: A Randomized Controlled Trial*

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ABSTRACT **Objective**: To evaluate the effect of tai chi exercise on cardiac and static lung function for older community-dwelling adults at risk of ischemic stroke. **Methods**: A total of 170 older community-dwelling adults (aged 55–75 years old) at risk of ischemic stroke were allocated to either tai chi training group (85 cases, five 60-min sessions of tai chi training per week for 12 weeks) or control group (85 cases, usual pbysical activity for 12 weeks) using a computer-generated randomization. The echocardiographic parameters of cardiac structure, cardiac function and static lung function were measured at baseline, after 12 weeks of intervention and additional 12-week follow-up period by a blinded professional staff member using a color Doppler ultrasound imaging device or a cardiopulmonary function instrument. The *t* test and linear mixed model based on the intention-to-treat analysis principle was used to calculate the effect. The adverse effect was observed. **Results**: Most of echocardiographic parameters on the cardiac structure, cardiac function and static lung function between the tai chi group and control group did not have a significant difference either post 12-week intervention or additional 12-week follow-up period. Only three parameters involving in right ventricular diameter (P=0.024), main pulmonary artery diameter (P=0.002) and vital capacity maximum (P=0.036) were beneficial to be improved in the tai chi group compared to the control group by the analysis of mixed linear model. No adverse effects were found during the intervention period. **Conclusions**: The 12-week tai chi exercise did not have an obvious beneficial effect on cardiac structure, cardiac function and static lung function in older community-dwelling adults at risk of ischemic stroke. (Trial registration No. ChiCTR-TRC-13003601)

KEYWORDS tai chi, cardiac structure and function, static lung function, ischemic stroke, randomized controlled trial

The cardiopulmonary system undergoes certain structural and functional changes as age increases, such as decreases of the lung elasticity, left ventricular diastolic and systolic function, respiratory muscle function and efficiency of breathing,[1,2] loss of cardiac myocytes with reactive hypertrophy of the remaining cells,[3] decreases in end-diastolic and systolic volumes, and increases in wall thicknesses.[3,4] These changes evoke gradual stiffening of the arteries, as well as an inevitable increase in blood pressure, which are the important causes and risk factors of ischemic stroke.[5-7] Increasing studies have indicated that low levels of cardiopulmonary fitness/function were associated with a high risk of cardiovascular disease, stroke and all-cause mortality and that improvements in fitness have a protective effect on stroke and other atherosclerotic cardiovascular diseases.[8,9]

Although cardiopulmonary fitness/function is affected by congenital and ageing-related factors, physical activity and exercise are its primary determinants in adults.[10] A number of published studies have demonstrated that regular physical activity/exercise can significantly improve the cardiopulmonary

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fitness/function and attenuate or even reverse increasing arterial stiffness and hypertension.[11-13] Part of these benefits may be mediated through the positive effects of physical activity on cardiopulmonary structure, such as improving left ventricular compliance,[14,15] mild remodeling of the aorta,[16] enlarging of the right ventricular chamber[17] and dilating of the atrial,[18] and biatrial morphological and functional changes.[19] Therefore, physical activity/exercise among the middle-aged and elderly is considered to be protective against stroke, and moderate-to-vigorous intensity exercise on most days of the week has been recommended to reduce stroke risk.[20] However, the level of compliance with physical activity recommendations among older adults over 60 years remains suboptimal.[21,22]

Tai chi is a type of traditional Chinese Qigong exercise characterized by gentle physical movement and meditation, as well as breathing.[23,24] As a no-contact, moderate-impact, mind-body exercise, tai chi has been practiced for several hundred years in China to promote health in the general population and particularly in older community-dwelling adults. Our previous meta-analysis and systematic review indicated that tai chi had a positive effect on the majority of cardiac function outcomes (e.g., reducing resting heart rate and increasing stroke volume and cardiac output), lung capacity [e.g., improving forced vital capacity (FVC)] and cardiorespiratory endurance and was beneficially associated with the primary prevention of stroke among middle-aged and elderly adults.[25,26] The purpose of this trial was to evaluate the effect of tai chi exercise on cardiac structure, cardiac function and static lung function for community-dwelling older adults at risk of ischemic stroke.

METHODS

Trial Design

This was a two-arm, randomized controlled trial (RCT) in which participants were randomly allocated into either a tai chi training group or control group (usual physical activity) with an equal allocation ratio. The design of this study was described in further detail in the published study protocol.[27]

Ethical Approval and Registration

Ethics approval was obtained from a local ethics committee in the Affiliated People's Hospital of Fujian University of Traditional Chinese Medicine (No. 2013-020-02). The study was performed according to the Declaration of Helsinki. The study was registered at the Chinese Clinical Trial Registry (No. ChiCTR-TRC-13003601).

Participants

From October 2014 to March 2015, participants were recruited from 3 community centers (Huada, Qingting and North of Wushi Communities) in the Gulou District of Fuzhou in China through advertisements, posters, leaflets and a free clinic.

Participants were included if they were aged 55–75 years, at high risk of ischemic stroke[28] and did not take regular exercise in the last year. Regular exercise was defined as session of 30 min or more at a frequency of 3 times or more per week for more than 3 months. Those with a history of stroke; with a communication disorder; or who suffered from severe cerebrovascular diseases, musculoskeletal system diseases, or other athletic contraindications were excluded. Written informed consents were obtained from all participants prior to participation.

Randomization and Masking

The randomization sequence was computer-generated by an independent statistician working at the Center for Evidence-Based Chinese Medicine of Fujian University of Traditional Chinese Medicine through the PLAN procedure in SAS 9.1 statistical software. The allocation sequence was concealed from research staff who were engaged in recruitment, outcome assessment or statistical analysis. An independent research assistant was responsible for concealing the allocation sequence and informing participants and statistical analysts of the group allocation after baseline assessment and data analysis were completed, respectively.

Intervention

Participants in the tai chi training group were gathered in their community centers and practiced 24 forms of simplified tai chi chuan recommended by the General Administration of Sport of China.[29] The tai chi training consisted of five 60-min sessions per week for 12 weeks. Each session comprised 45 min of tai chi training, a 10-min warm-up and a 5-min cool-down. Two certified instructors were engaged to provide instruction and supervise the participants' training. Participants' attendance was documented by 2 research assistants through an attendance record form.

In addition, participants were required to keep a daily diary of their physical activity, including the type and intensity of physical activity, as well as sedentary time.

The control group was not assigned to any specific exercise intervention and was instructed to maintain their usual physical activity during the 12-week intervention period. Participants in this group were also required to record a daily diary of physical activity.

Follow-Up

Following the 12-week intervention period, all participants entered an additional 12-week unsupervised follow-up period in which no exercise intervention was administered but the daily activity record was still required.

Outcome Measurement

Demographic characteristics were obtained from an interviewer-administered questionnaire at the time of recruitment. The cardiac structure and function were characterized by the following echocardiographic parameters: aortic diameter (AD), left atrial diameter (LAD), right ventricular diameter (RVD), right atrial diameter (RAD), left ventricular diastolic diameter (LVDD), main pulmonary artery diameter (MPAD), left ventricular posterior wall thickness (LVPWT), left ventricular anterior wall thickness (LVAWT), interventricular septum thickness (IST), left ventricular ejection fraction (LVEF), mitral valve diastole blood flow peak E (E_{max}) and the ratio of E_{max}/A_{max} (E/A). Parameters of static lung function comprised vital capacity maximum (VC_{max}), FVC, forced expiratory volume in 1 second (FEV1), the rate of FEV1 to FVC, maximal voluntary ventilation (MVV), minute ventilation volume (MVE), respiratory rate (RR), inspiratory capacity (IC), expiratory reserve volume (ERV), and tidal volume (TV). These parameters were measured by a blinded professional operator at the Health Check Center of the Second People's Hospital of Fujian Province using a color Doppler ultrasound imaging device (SIEMENS Acuson X300, Germany) or a cardiopulmonary function instrument (Oxycon Pro PC, Jaeger, Germany) at baseline, 12-week post-intervention and additional 12-week follow-up period.

Calculation of Sample Size

The sample calculation was presented in the published protocol;[27] a sample size of 170 participants was needed to achieve 80% statistical power.

Statistical Analyses

All data were analyzed by a blinded statistician using SPSS 21.0 software (IBM Inc., Chicago, IL, USA) with significance set at an alpha level of 0.05. The results were presented as mean ± standard deviation ($\bar{x} \pm s$) or median with inter-quartile range for continuous variables and as percentages for categorical variables. Student's *t* test or Mann-Whitney *U* test for continuous variables and the Pearson chi-square or Fisher exact test for categorical variables were applied to assess between-group differences. The parameters of cardiac structure, cardiac function and static lung function were analyzed based on the intention-to-treat principle, and missing data were imputed by a multiple imputation method based on the fully conditional specification algorithm. The main effect between comparison groups and interaction of group by time were analyzed using a linear mixed model with fixed effects, and then the results were summarized using Rubin's rules.[30]

RESULTS

Baseline Characteristics

Of the 170 participants originally randomized, 68 completed the tai chi training, 65 completed the control group requirements and 128 participants completed the 12-week follow-up (Figure 1). The dropout rates between the two groups showed no significant difference (20.0% *vs*. 23.5%, P=0.577). Table 1 summarizes the baseline characteristics of the 170 participants. There were no significant differences between groups in the demographic characteristics, baseline risk factors for ischemic stroke and average daily time of usual physical activity (P>0.05).

Changes of Cardiac Structure and Function

For parameters of cardiac structure, the tai chi training group showed mild decreases in RVD and MPAD compared with the control group, and the main effects between groups in RVD and MPAD were significantly different (P=0.024 and P=0.002, respectively). No significant difference was observed in other parameters of cardiac structure at each time-point, while no interaction effects of intervention by time were found. For the parameters of cardiac function, no significant difference between the two groups was found at 12-week post-intervention or additional 12-week follow-up, as well, significant differences on main effect between groups and interaction effects of intervention by time were not found (Table 2).

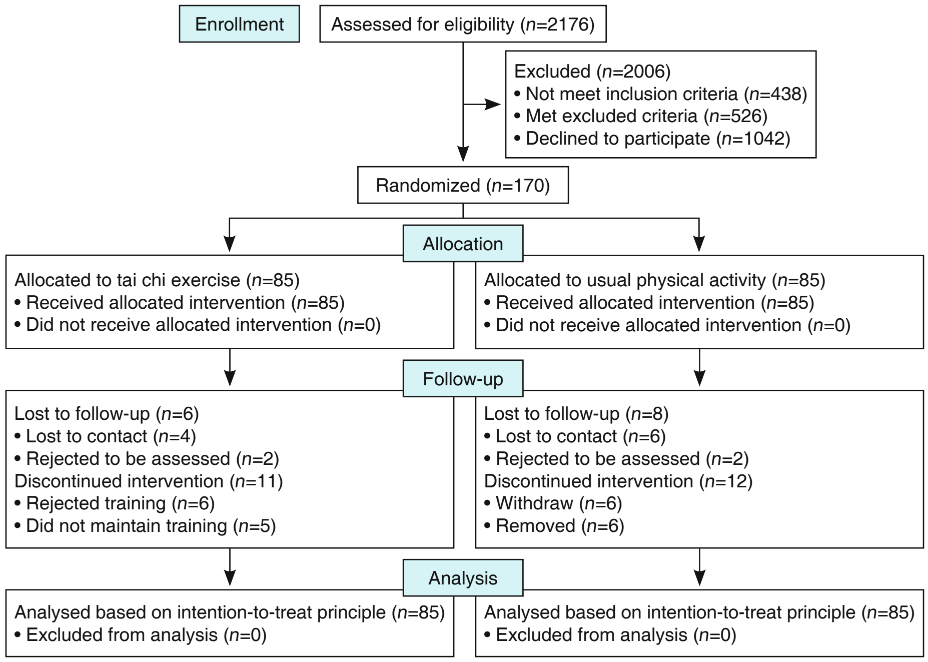

Figure 1. Flow Diagram of the Study of Tai Chi on Older Community-Dwelling Adults at Risk of Ischemic Stroke

Table 1. Baseline Demographic Characteristics of Participants in Two Groups

Variable	Tai chi group (85 cases)	Control group (85 cases)
Age (Year, $\bar{x} \pm s$)	61.01±5.20	60.73±6.05
SBP (mm Hg, $\bar{x} \pm s$)	133.81±16.74	129.04±15.94
DBP (mm Hg, $\bar{x} \pm s$)	77.74±9.28	76.35±10.48
Height (cm, $\bar{x} \pm s$)	160.41±7.42	159.70±7.46
Body weight (kg, $\bar{x} \pm s$)	65.31±9.53	64.14±10.90
Daily activity time [h, median (25%–75%)]	4.429 (2.071–6.964)	4.857 (2.857–6.892)
Gender [Case (%)]		
Male	28 (32.9)	24 (28.2)
Female	57 (67.1)	61 (71.8)
History of heart disease [Case (%)]	9 (10.6)	14 (16.5)
History of diabetes [Case (%)]	8 (9.4)	11 (12.9)
History of hypertension [Case (%)]	39 (45.9)	38 (44.7)
History of dyslipidemia [Case (%)]	50 (58.8)	53 (62.4)
Family history of stroke [Case (%)]	16 (18.8)	15 (17.7)
Smoking [Case (%)]	11 (12.9)	15 (17.7)
Drinking [Case (%)]	23 (27.1)	28 (32.9)

Notes: SBP: systolic blood pressure; DBP: diastolic blood pressure

Changes of Static Lung Function

The tai chi group showed mild increases in FVC, VC_{max}, MVV and IC compared to the control group at 12-week post-intervention or additional 12-week follow-up. However, no significant difference was found except for the main effect of VC_{max} between groups (P=0.036). No significant difference of either main effect between groups or interaction effect of intervention by time in other parameters of static lung function including MVE, EFV1, EFV1/FVC, PEF, ERV and RR was found (Table 3).

Adverse Event

There were no adverse events in this trial.

DISCUSSION

Cardiorespiratory capacity is typically associated with cerebrovascular diseases, and low cardiorespiratory capacity is an independent risk factor of ischemic stroke.(31) However, regular physical activity, especially aerobic exercise, can substantially improve the cardiorespiratory fitness among not only healthy older adults but also patients with chronic diseases by improving cardiac structure, cardiac and lung function.(14-19) As a traditional Chinese mind-body aerobic exercise with characteristics of active breathing and neuromuscular relaxation as well as slow and gentle movement,(32) tai chi has been confirmed to improve cardiopulmonary function among a healthy older population(33) and lung function among chronic obstructive pulmonary disease patients.(34) Studies also found that tai chi training was associated with improved oxygen uptake,(35) ventilatory efficiency,(36) and LVEF(37) among healthy adults or patients with chronic diseases, as well as improved tidal volume among young male volunteers.(38)

In the present RCT, we compared the effects of

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Table 2. Cardiac Structure and Function at the Baseline, Post-Intervention and Follow-Up ($\bar{x} \pm s$)

Variables	Time	Tai chi group (85 cases)	Control group (85 cases)	Comparison between groups		Linear mixed model	
				Mean difference (95% CI)	*P* value	*P* value (between groups)	*P* value (time × group)
Cardiac structure (mm)							
AD	Baseline	27.35 ± 3.18	27.72 ± 3.42	0.37 (–1.38–0.62)	0.456		
	12-week	28.19 ± 3.22	28.59 ± 3.65	0.40 (–1.44–0.64)	0.450	0.126	0.763
	24-week	28.67 ± 2.91	28.65 ± 2.92	0.02 (–0.87–0.89)	0.971		
MPAD	Baseline	20.46 ± 1.97	20.85 ± 2.61	–0.39 (–1.09–0.31)	0.270		
	12-week	20.57 ± 2.06	20.80 ± 2.22	–0.23 (–0.87–0.42)	0.492	0.002	0.304
	24-week	20.57 ± 2.15	21.48 ± 2.17	–0.91 (–1.56–0.26)	0.007		
RVD	Baseline	29.57 ± 3.48	29.73 ± 3.46	–0.16 (–1.21–0.88)	0.759		
	12-week	28.20 ± 3.73	29.32 ± 4.23	–1.12 (–2.33–0.09)	0.068	0.024	0.468
	24-week	28.01 ± 3.35	28.61 ± 3.77	–0.60 (–1.68–0.48)	0.272		
RAD	Baseline	31.66 ± 3.46	31.25 ± 4.25	0.41 (–0.76–1.58)	0.492		
	12-week	31.16 ± 3.27	31.50 ± 3.83	–0.34 (–1.41–0.74)	0.533	0.410	0.465
	24-week	30.77 ± 3.98	31.33 ± 4.47	–0.55 (–1.83–0.73)	0.396		
LVDD	Baseline	43.79 ± 5.11	43.75 ± 3.97	0.04 (–1.35–1.42)	0.960		
	12-week	44.04 ± 4.21	43.99 ± 4.48	0.05 (–1.27–1.37)	0.940	0.735	0.995
	24-week	44.19 ± 4.22	44.22 ± 4.39	–0.03 (–1.34–1.27)	0.961		
LAD	Baseline	31.70 ± 4.58	31.82 ± 5.18	–0.12 (–1.59–1.36)	0.874		
	12-week	32.06 ± 3.75	32.63 ± 4.48	–0.57 (–1.82–0.68)	0.367	0.076	0.673
	24-week	31.69 ± 4.70	32.67 ± 5.31	0.98 (–2.50–0.53)	0.202		
LVPWT	Baseline	9.39 ± 1.10	9.27 ± 1.07	0.12 (–0.21–0.45)	0.480		
	12-week	9.33 ± 0.98	9.48 ± 0.90	–0.15 (–0.46–0.14)	0.300	0.607	0.426
	24-week	9.09 ± 0.93	9.09 ± 0.97	0.01 (–0.25–0.38)	0.677		
LVAWT	Baseline	10.27 ± 1.17	10.30 ± 1.28	–0.03 (–0.40–0.34)	0.861		
	12-week	9.94 ± 1.05	9.86 ± 0.95	0.08 (–0.25–0.38)	0.685	0.610	0.738
	24-week	9.72 ± 1.14	9.81 ± 1.18	–0.09 (–0.42–0.28)	0.683		
IST	Baseline	10.29 ± 1.42	10.19 ± 1.47	0.10 (–0.33–0.54)	0.634		
	12-week	9.91 ± 1.29	9.95 ± 1.07	–0.04 (–0.39–0.32)	0.826	0.219	0.266
	24-week	9.62 ± 1.00	9.93 ± 1.33	–0.31 (–0.67–0.05)	0.09		
Cardiac function							
LVEF (%)	Baseline	62.35 ± 4.92	62.74 ± 4.27	–0.39 (–1.78–1.01)	0.583		
	12-week	62.91 ± 3.72	62.86 ± 3.80	0.05 (–1.09–1.19)	0.926	0.899	0.818
	24-week	61.59 ± 3.29	61.50 ± 3.53	0.09 (–0.94–1.12)	0.862		
E_{max} (cm/s)	Baseline	61.27 ± 14.6	62.62 ± 15.3	–1.35 (–5.88–3.17)	0.556		
	12-week	64.77 ± 14.9	65.06 ± 16.9	–0.29 (–5.12–4.53)	0.903	0.858	0.914
	24-week	64.59 ± 15.5	64.63 ± 15.2	–0.04 (–4.69–4.61)	0.987		
E/A (%)	Baseline	0.84 ± 0.25	0.88 ± 0.29	–0.04 (–0.12–0.05)	0.402		
	12-week	0.89 ± 0.24	0.93 ± 0.29	–0.05 (–0.13–0.04)	0.265	0.137	0.978
	24-week	0.86 ± 0.27	0.90 ± 0.32	–0.04 (–0.13–0.05)	0.395		

Notes: AD: aortic diameter; LAD: left atrial diameter; RVD: right ventricular diameter; RAD: right atrial diameter; LVDD: left ventricular diastolic diameter; MPAD: main pulmonary artery diameter; LVPWT: left ventricular posterior wall thickness; LVAWT: left ventricular anterior wall thickness; IST: interventricular septum thickness; LVEF: left ventricular ejection fraction; E_{max}: mitral valve diastole blood flow peak E; E/A: the ratio of E_{max} and A_{max} (mitral valve diastole blood flow peak A); CI: confidence interval

tai chi training with no exercise intervention on cardiac structure, cardiac function and static lung function among older adults at risk of ischemic stroke. Only MPAD, RVD and VC_{max} parameters showed significant difference. Study has found that an increase in MPAD was associated with lower pulmonary artery compliance, higher right ventricular systolic pressure and worse right ventricular function;[39] the overall VC decreases

Table 3. Static Lung Function Parameters at Baseline, Post-Intervention and Follow-Up ($\bar{x}\pm s$)

Variables	Time	Tai chi group (85 cases)	Control group (85 cases)	Comparison between groups: Mean difference (95% CI)	Comparison between groups: *P* value	Linear mixed model: *P* value (between groups)	Linear mixed model: *P* value (time × group)
MVE (L/min)	Baseline	12.5 ± 5.8	11.5 ± 4.3	0.96 (–0.60–2.51)	0.227	0.135	0.985
	12-week	13.8 ± 8.8	13.1 ± 6.2	0.74 (–1.46–2.95)	0.503		
	24-week	15.4 ± 8.7	14.4 ± 7.9	0.99 (–1.53–3.52)	0.439		
VC_{max} (mL)	Baseline	3008 ± 750	2855 ± 758	153 (–76.4–382)	0.190	0.036	0.670
	12-week	3010 ± 696	2824 ± 732	187 (–30.2–404)	0.091		
	24-week	2987 ± 684	2906 ± 682	81 (–126–288)	0.441		
FVC (mL)	Baseline	2781 ± 658	2649 ± 675	132 (–73.4–337)	0.206	0.083	0.634
	12-week	2893 ± 663	2749 ± 695	144 (–62.5–351)	0.170		
	24-week	2820 ± 607	2769 ± 635	51 (–137–240)	0.593		
FEV1 (mL)	Baseline	2410 ± 562	2307 ± 588	103 (–72–278)	0.248	0.090	0.910
	12-week	2391 ± 525	2300 ± 580	91 (–77–259)	0.286		
	24-week	2351 ± 496	2286 ± 551	65 (–94–224)	0.422		
FEV1/FVC (%)	Baseline	87.2 ± 6.9	87.4 ± 7.7	–0.23 (–2.45–1.99)	0.838	0.448	0.286
	12-week	83.2 ± 8.8	83.8 ± 8.4	–0.60 (–3.22–2.02)	0.650		
	24-week	83.8 ± 8.1	81.8 ± 8.8	1.95 (–0.62–4.53)	0.136		
PEF (L/s)	Baseline	6.2 ± 1.6	5.9 ± 1.8	0.25 (–0.31–0.75)	0.403	0.505	0.667
	12-week	6.3 ± 1.8	6.0 ± 1.8	0.26 (–0.28–0.81)	0.344		
	24-week	6.1 ± 1.5	6.0 ± 1.8	0.10 (–0.49–0.51)	0.969		
MVV (L/min)	Baseline	84.2 ± 27.8	86.2 ± 27.3	–1.96 (–10.3–6.41)	0.645	0.835	0.452
	12-week	85.9 ± 25.2	82.8 ± 28.6	3.10 (–5.10–11.29)	0.457		
	24-week	89.9 ± 24.8	86.9 ± 25.1	2.92 (–4.66–10.48)	0.449		
IC (mL)	Baseline	2355 ± 607	2318 ± 620	37 (–150–223)	0.697	0.156	0.403
	12-week	2456 ± 739	2263 ± 662	193 (–21–406)	0.076		
	24-week	2414 ± 649	2352 ± 580	62 (–125–249)	0.513		
ERV (mL)	Baseline	653 ± 429	537 ± 372	116 (–6.5–237)	0.063	0.370	0.333
	12-week	555 ± 456	560 ± 444	–5.0 (–142–132)	0.938		
	24-week	572 ± 419	554 ± 422	18.1 (–109–146)	0.779		
RR (b/min)	Baseline	20.9 ± 10.2	19.8 ± 8.7	1.09 (–1.79–3.97)	0.455	0.442	0.910
	12-week	21.0 ± 12.4	20.9 ± 11.0	0.01 (–3.50–3.61)	0.975		
	24-week	22.3 ± 12.2	21.8 ± 12.1	0.47 (–3.21–4.16)	0.800		

Notes: MVE: minute ventilation volume; VC_{max}: vital capacity maximum; FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second; FEV1/FVC: the rate of FEV1 and FVC; PEF: peak expiratory flow; MVV: maximal voluntary ventilation; IC: inspiratory capacity; ERV: expiratory reserve volume; RR: respiratory rate; CI: confidence interval

remarkable as age increases in elderly people, and this age-related VC change is caused by changes in the thoracic structure and breathing muscle weakness in elderly people. However, if exercise programs for elderly can be developed in accordance with age, they will help to prevent VC decreases in the elderly.[40] In our study, MPAD and RVD were significantly lower, while VC_{max} was significantly higher in the tai chi group than the control group. These results indicated that a 12-week tai chi training may have a positive effect on cardiopulmonary function. Nevertheless, the majority of those measured parameters exhibited beneficial tendencies after the 12 weeks of tai chi training. A possible explanation is that the 12-week tai chi exercise intervention period may not have been sufficiently long to identify significant differences in those parameters among older community-dwelling adults at risk of ischemic stroke. This is in line with a recent RCT in which the 12-week tai chi training was not reported to have significant effects on LVDD, left ventriculor end-systole diameter and LVEF, but these parameters showed an approximate 10% increase among the tai chi group compared with the controls.[37] Second, all participants, who were older community-dwelling adults with risk factors of ischemic stroke, had relatively healthy cardiac structure, cardiac and lung function. All measured parameters in this study were in the normal reference range. Few significant parameters between comparable groups may not indicate that the 12-week tai chi training has positive benefit on cardiac structure, cardiac function and lung function.

Although we implemented this RCT earnestly and rigorously, there are inherent limitations that should be taken into consideration due to the unexpected results. A limitation of this study was the loss to follow-up, which was higher than previously estimated for this sample size (a total of 37 participants with a 21.8% total sample dropout), which resulted in high rates of incomplete outcome data and potential attrition bias. Perhaps factors such as a lack of energy, emotional state or moving away of participants led to the high loss of follow-up. However, the missing data from this high loss of follow-up likely influenced the study outcome values and led to bias, meaning that the magnitude and trend of the influence are difficult to estimate even though we imputed those missing data using appropriate methods. Another potential limitation was the short training duration (12 week), which may impede the evolvement of evident functional change and structural modification.

An additional limitation was the controlled method in which we compared the tai chi training with usual physical activity (no any specific exercise intervention) but neglected to include an active control. However, the active control, as an existing standard, is necessary to evaluate the efficacy of an intervention. In addition, we should have conducted a cardiopulmonary exercise test in this trial to evaluate the cardiopulmonary function of participants because left ventricular dimensions and volumes are strongly dependent on oxygen transport capacity in normal subjects.(41) However, we rejected this approach out of concern for the tolerance and safety of our participants and instead measured cardiac structure and static lung function. Last but not least, blinding of the participants is an important safeguard against bias in RCTs but was not implementable in this case. It is quite likely to lead to a placebo effect, although the outcome evaluators were blinded in our trial.

In conclusion, our data revealed that 12 weeks of tai chi training could only significantly improve VC_{max}, RAD and MPAD parameter for older community-dwelling adults at risk of ischemic stroke. The findings suggested that 12-week regular tai chi exercise might not have a favorable impact on cardiac structure, cardiac function and static lung function in older community-dwelling adults at risk of ischemic stroke. Further study with a substantially longer duration of intervention is necessary to better characterize these findings. No adverse events related to tai chi exercise were reported during the intervention period, which suggested that this form of exercise was safe.

Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

Zheng GH, Chen LD and Tao J conceived and designed the study. Zheng GH wrote the manuscript. Zheng GH and Tao J revised the manuscript. Zheng X and Li JZ took charge of the management of training and follow-up. Duan TJ instructed participants during tai chi training. All authors have read and approved the final version of the manuscript.

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