



# Effects of 24-Form Tai Chi on Cardio-Pulmonary Functions, Exercise Performances, and Cognitive Functions of the Aged

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## Abstract

**Background:** The study aimed to discuss the influences of 24-form Tai Chi on cardio-pulmonary functions, exercise performances, and cognitive functions of the aged.

**Methods:** Forty old people in Pingdingshan of China were selected through convenient sampling method from 2020 to 2021. They were randomly divided into the observation group ( $n=20$ ) and the control group ( $n=20$ ). The observation group exercised 24-form Tai Chi for 8 weeks, three times per week, 45 min per session. The respondents were evaluated by cardiopulmonary exercise testing, sitting-standing test, 6-min walking test, and the Berg balance scale. The P300 test was performed to evaluate the cognitive functions of respondents.

**Results:** After the intervention, the observation group was significantly ( $P<0.05$ ) superior to the control group concerning maximal oxygen consumption, anaerobic threshold, vital capacity, stroke volume (SV), cardiac output (CO), left ventricular end-diastolic diameter (LVEDD), left end-diastolic velocity (EDV), sitting-standing test, 6-min walking test, and the Berg balance function scores, showing statistically significant differences ( $P<0.05$ ). The content of body fat and body mass index (BMI) of the observation group decreased significantly, whereas muscle mass and fat-free mass increased dramatically, which were however significantly lower than those of the controlled group ( $P<0.05$ ). Moreover, the P3b amplitude of the observation group increased significantly ( $P<0.05$ ) and was significantly higher than that of the control group ( $P<0.05$ ).

**Conclusion:** The 24-form Tai Chi not only improves cardio-pulmonary functions and exercise performances of the aged but also increases cognitive functions of the aged.

**Keywords:** 24-form Tai Chi; The aged; Cardio-pulmonary functions; Exercise performances; Cognitive functions

## Introduction

Since the 21<sup>st</sup> century, the health conditions of the aged have become a key social concern with the rapid progress in global population aging.

Physiological functions of the aged decrease gradually as getting older and older, which are manifested by calcification of increased pulmonary fibrosis as well as decreased elasticity, alveo-



lar atrophy and thoracic activity, thus weakening the cardio-pulmonary functions and decreasing exercise performances (1). In addition, the aged are undergoing degradation of cognitive functions, which significantly affects the living ability, and social activities with the increase in age (2). Health conditions of the aged not only bring huge burdens to families and society but also restrict social and economic development. Hence, urgency arises to adopt effective measures according to poor cardiopulmonary functions, exercise performances, and cognitive functions of the aged to improve their physiques and physical and psychological health.

Physical exercise is an important way to improve the physique of people. Increasing studies (3-4) have demonstrated that regular exercises are not only conducive to physical health of the aged but can also improve their cognitive abilities. Physical exercises have a positive effect on the physical health of the aged (5). Exercise training could improve the balance and gait functions of the aged and could improve the scope of joint movement (6). Eight-week physical exercises could improve muscle strength and delay progress in sarcopenia of the aged (7). Exercise training could improve physical activities and the living quality of the aged (8). Yoga exercise combinations could promote the improvement of cognition, emotion, and cognitive functions of the aged (9).

Some studies (10-11) also showed that physical exercises could effectively prevent executive hypofunction in the aged. The characteristic differences in the P3 incubation period of electroencephalography (EEG) exist between the aged who often attended aerobic exercises and the aged who often sit but scarcely exercise. It found that the aged who often participated in aerobic exercises had a shorter P3 incubation period, indicating stronger cognitive functions. This finding indicates that aerobic exercises are conducive to decelerate the degradation of cognitive functions of the aged. Although physical exercise is an effective method to strengthen physical health and improve cognitive functions of the aged, some studies found that physical exercises could

not improve cognitive functions of the aged. In addition, the aged are a special group, choosing an appropriate mode of exercise is critical, and ordinary exercises might be inapplicable. Therefore, it has to explore physical exercises by the characteristics of the aged.

As a traditional health maintenance method in China, Tai Chi is recommended as an attempt to recover balance abilities (12). 24-form Tai Chi requires coordination of respiration and attention during exercises, thus realizing the goal of keeping fit and prolonging life (13). Tai Chi cooperates with dynamic meditation during physical exercises (14). It might be a form of motion with dual loads of aerobic exercises and spiritual training (15). Long-term Tai Chi exercises have been proven to improve cardiopulmonary functions, neural adjustment, endocrine, and global functions of the body (16). Tai Chi can improve the peak oxygen uptake and promote myocardial oxygen supply to improve cardiac functional states (17). However, the influences of Tai Chi on cardio-pulmonary functions and cognitive functions of the aged remain unknown.

The study aimed to discuss the influences of 24-form Tai Chi on cardio-pulmonary functions, exercise performances, and cognitive functions of the aged. Conclusions provide some references to promote the physical and psychological health of the aged.

## **Methods**

### ***Data collection***

Forty aged in Pingdingshan of China were selected through the convenient sampling approach from January 2020 to July 2021. Inclusion criteria are as follows: 1) aged between 65 and 75; 2) middle school or higher; 3) no neural or physical dysfunctional diseases in self-report; 4) no other systematic intervention training in 1 year. Meanwhile, the following are the exclusion criteria: 1) patients with mental disorders; 2) patients with serious psychological illness; 3) patients unfit for exercise due to severe pains. Included subjects were divided into the control group ( $n=20$ ) and the observation group ( $n=20$ ) by using the ran-

dom digital table. Two groups have no statistically significant differences in terms of gender and age (Table 1).

This study was approved by the Ethics Committee of Pingdingshan University, and all included respondents have signed the Informed Consent.

**Table 1:** Comparison of general information of two groups ( $\bar{x} \pm s$ )

<i>Groups</i>	<i>Gender (male/female, cases)</i>	<i>Age (yr)</i>	<i>Stature (cm)</i>	<i>Weight (kg)</i>
Observation group	12/8	68.12±2.41	163.54±6.32	62.31±7.12
Control group	14/6	68.34±2.52	164.87±5.89	63.89±7.46
<i>t/x<sup>2</sup></i>	0.440	0.282	0.688	0.685
<i>P</i>	0.507	0.779	0.495	0.497

### **Exercise intervention schemes**

This experiment organized 24-form Tai Chi exercises to the observation group for 8 weeks, 3 times per week, and 45 min per session. Single 24-form Tai Chi exercise intervention was divided into three stages: preparation (5 min), main (35 min), and recovery (5 min). During the preparation and recovery stages, respondents made preparation activities and exercises, including active traction, breathing exercises, among others. In the main stage, the main intervention scheme comprising three times of the simplified Tai Chi compiled by the General Administration of Sports of China and 2.5-min intervals was formulated with references to previous studies. The entire exercise process was accomplished through the cooperation of 1 coach and 2 observers. The control group did not adopt 24-form Tai Chi intervention but only exerted general physical activities. During the entire intervention process, the tester made a call visit to respondents every week to collect information on physical exercises and physical and psychological health conditions.

### **Quality control**

In the research design stage, a one-month pre-test was carried out before the experiment to observe problems in the implementation of 24-form Tai Chi and optimize it. This stage lays the foundation for the formal experiment. In the intervention implementation stage, all intervention workers shall have experience in 24-form Tai Chi exercises. In the data collection stage, data input,

re-assessment, and analysis were all finished by two people.

### **Evaluation indexes**

Before and after the intervention, the following indexes of the two groups were evaluated.

*Cardiopulmonary exercise testing.* The cardiopulmonary function tester Quark b2 (Cosmed-Italy) was applied. The symptom self-limiting maximum exercise loading slope progressive test was applied. Physiological parameters in the exercises were recorded, including maximal oxygen consumption ( $VO_2^{\max}$ ) and anaerobic threshold (AT). Meanwhile, the vital capacity of respondents was tested using the vital capacity tester.

*Cardiac ultrasound index.* The left end-diastolic velocity (EDV), Left ventricular end-systolic volume (ESV), left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (ESD), ejection time (ET), heart rate (HR), ejection fraction (EF), cardiac output (CO), and stroke volume (SV) of patients were tested by echocardiography.

*Sitting-standing test.* Sitting-standing test was used to evaluate muscle strength and tolerance of lower limbs: a 45-cm high chair was placed against the wall, and patients sat on the chair, keeping feet flat with equal width to shoulders. Two arms cross over in front of the chest. The number of rounds for the back of patients to leave the chair and then sit on the chair again in 30s was counted. At each standing, the knee joint was stretched

completely, the hip touching the chair surface completely when the patient sat back, with the center of gravity falling on the chair.

*The 6-min walking test.* The 6-min walking test was used to evaluate the walking ability of the lower limbs: A 30-m long path was marked on the flat ground, and respondents were asked to walk along the path as far as possible in 6 min. The walking speed could be controlled by patients (18).

*Berg balance evaluation.* A total of 14 items were used to evaluate the patients. Each item was evaluated by score 0 to 4 (19). The lower total score indicates the poor balance ability of patients. *Body component index.* The body component analyzer (Biospace) made in Korea was applied to test the content of body fat, muscle mass, fat-free mass, body mass index (BMI), and waist-hip ratio (WHR). Patients were prohibited to drink and exert rigorous exercises for 24h before the test. Normal saline was applied onto feet and hands of patients in advance to strengthen conductivity of skin.

*P300 test.* P300 was induced by Three-stimulus Oddball stimuli (20). The standard stimulus was the image of number "8" with black background and white letter. The target stimulus was the image of number "2" with black background and white letter. The non-target stimulus was the image of letter "A" with black background and white letter. These stimuli occurred randomly at the proportions of 76%, 12%, and 12%, respectively. A total of 300 stimuli were given at an interval of 2.75s. All three images were displayed on the screen, which was 1.5 m away from the respondents, with light gray background. Respondents were asked to press the mouse with their index fingers when a target stimulus occurs, but they should not make any responses to other stimuli. Before the formal experiment, respondents practiced 15 times to familiarize themselves with the task. P3b is stimulus-induced by the low-frequency target, and P3a is stimulus-induced by the low-frequency non-target. Electroencephalography (EEG) signals of respondents were collected synchronously by using the Neuroscan 64 electroencephalograph. Respondents washed

their hair with alkaline shampoo and put on the EEG hat after drying. The grounding electrodes were between the electrode points Fz and AFz in the forehead, while the reference electrode was on the connecting line of bilateral temporal bone mastoid processes. Conductive pastes (GT5, Wuhan Greentech) were injected into each electrode. The dosage of conductive pastes was adjusted to lower impedance of each electrode lower than 5 k $\Omega$ . Vertical and horizontal electrooculograms (EOG) were monitored by a bipolar recording method. The sampling frequency of all electrodes was 1,000 Hz, and the band-pass filtering was 0.1-100 Hz. The artifact of data was eliminated, and EEG section with great disturbances or drifts was eliminated manually. EOG interference was eliminated by a correlation method. The Butterworth filter was applied for 1 Hz high-pass filtering and 30 Hz low-pass filtering of data. Data were segmented according to target stimuli and disturbance stimuli. The period of 900 ms, including 100 ms before the event stimuli and 800 ms after the event was chosen to extract P300. The period of 100 ms before the stimuli was chosen to calibrate the baseline. Artifact of the segmented data was further eliminated by the threshold value method at the standard of  $\pm 80$   $\mu$ V. The period exceeding  $\pm 80$   $\mu$ V was eliminated. Next, superposition average processing was implemented. According to the characteristics of respondents, the time window of P3b component was 300-500 ms, in which the amplitude and incubation period were calculated. According to previous studies, amplitude was defined as the peak value after occurrence of stimuli, and incubation period was defined as the time from occurrence of stimuli to the occurrence of peak. The time of displaying image stimuli and the time of respondents pressing the mouse were recorded automatically by the system. The response time was outputted automatically by E-prime software.

### *Statistical method*

Data analysis was carried out by using SPSS 22.0 (IBM Corp., Armonk, NY, USA). Measurement data that was observed to normal distribution was expressed in ( $\bar{x} \pm s$ ) and adopted pairwise *t*-

test (intragroup comparison) or grouped *t*-test (inter-group comparison). The enumeration data adopted  $\chi^2$ -test.  $P < 0.05$  indicates statistically significant differences.

## Results

### Comparison of cardio-pulmonary functions of two groups before and after intervention

Before intervention, two groups had no statistically significant differences in terms of various indexes. After intervention,  $VO_2^{\max}$ , AT, vital capacity, SV, CO, EDD, and EDV of the observation group were superior to those of the control group ( $P < 0.05$ ) (Table 2).

**Table 2:** Comparison of cardio-pulmonary functions of two groups before and after intervention ( $\bar{x} \pm s$ )

Variable	Observation group (n=20)		Control group (n=20)	
	Before	After	Before	After
$VO_2^{\max}$ (L/min)	3.45±0.16	3.51±0.23	3.49±0.18	4.12±0.21 <sup>ab</sup>
AT ( L/min )	1.83±0.21	2.64±0.15	1.85±0.19	2.48±0.16 <sup>ab</sup>
vital capacity ( ml )	2105.36±305.61	2698.69±345.88	2100.89±301.56	2365.82±331.09 <sup>ab</sup>
SV(ml)	65.41±5.46	72.33±6.08	65.38±5.39	68.41±5.96 <sup>ab</sup>
CO (L/min)	4.02±0.69	4.86±0.69	4.16±0.62	4.35±0.87 <sup>ab</sup>
EF (%)	0.65±0.08	0.43±0.05	0.66±0.05	0.62±0.08
HR (bpm)	74.36±5.89	72.66±5.58	74.25±5.93	71.98±5.46
ET (s)	0.34±0.03	0.29±0.05	0.33±0.02	0.30±0.04
ESD (cm)	3.52±0.25	3.79±0.29	3.56±0.21	3.68±0.26
EDD (cm)	4.39±0.16	4.71±0.21	4.38±0.13	5.06±0.23 <sup>ab</sup>
ESV (ml)	35.26±2.59	36.33±2.51	35.31±2.62	36.21±2.49
EDV (ml)	102.36±11.69	126.54±15.66	102.41±11.74	115.49±12.75 <sup>ab</sup>

Notes: Compared with the results of the same group before intervention, <sup>a</sup> $P < 0.05$ . Compared with the control group, <sup>b</sup> $P < 0.05$

### Comparison of exercise performances of the two groups before and after intervention

Before intervention, two groups had no statistically significant differences in terms of the sit-

ting-standing test, 6-min walking test, and the Breg balance function scores. After intervention, the observation group was superior to the control group in these indexes ( $P < 0.05$ ) (Table 3).

**Table 3:** Comparison of exercise performances of the two groups before and after intervention ( $\bar{x} \pm s$ )

Groups	Timepoint	Sitting-standing test (round)	6-min walking test (m)	Breg balance (scores)
Observation group (n=20)	Before intervention	8.21±1.17	158.74±31.36	47.26±4.70
	After intervention	8.36±1.25	162.54±45.74	48.11±4.75
Control group (n=20)	Before intervention	8.24±1.21	155.87±33.17	47.65±4.68
	After intervention	9.21±1.32 <sup>ab</sup>	189.24±31.54 <sup>ab</sup>	52.41±5.12 <sup>ab</sup>

Notes: Compared with the results of the same group before intervention, <sup>a</sup> $P < 0.05$ . Compared with the control group, <sup>b</sup> $P < 0.05$



**Changes in the body component indexes of the two groups before and after intervention**

Before intervention, two groups had no statistically significant differences in terms of body component indexes. After intervention, content

of body fat and BMI of the observation group declined significantly, whereas muscle mass and fat-free mass increased dramatically compared with those of the control group ( $P < 0.05$ ) (Table 4).

**Table 4:** Changes in the body component indexes of the two groups before and after intervention ( $\bar{x} \pm s$ )

Variable	Observation group (n=20)		Control group (n=20)	
	Before	After	Before	After
Content of body fat (kg)	22.89±4.15	20.45±4.02	22.92±4.19	21.32±3.98 <sup>ab</sup>
Muscle mass (kg)	36.58±3.98	39.98±4.15	36.62±4.03	38.05±3.96 <sup>ab</sup>
Fat-free mass (kg)	39.85±3.26	45.03±3.86	39.75±3.36	42.16±3.29 <sup>ab</sup>
BMI	24.36±0.65	23.05±0.59	24.31±0.59	22.01±0.46 <sup>ab</sup>
WHR	0.95±0.03	0.92±0.08	0.96±0.04	0.93±0.05

Notes: Compared with the results of the same group before intervention, <sup>a</sup> $P < 0.05$ . Compared with the control group, <sup>b</sup> $P < 0.05$

**Comparison of the P300 test results of the two groups before and after intervention**

Before intervention, two groups had no statistically significant differences in terms of P300 test results. After intervention, the P3b amplitude of observation group increased significantly

( $P < 0.05$ ) compared with that of the control group ( $P < 0.05$ ). The response period of the observation group was shorter than that of the control group, but no statistically significant differences existed (Table 5).

**Table 5:** Comparison of P300 test results of two groups before and after intervention ( $\bar{x} \pm s$ )

Groups	Timepoint	P3b amplitude ( $\mu V$ )	P3b incubation period (ms)	Response time (ms)
Observation group (n = 20)	Before intervention	2.91±0.74	438.36±87.54	632.36±97.54
	After intervention	3.95±1.02 <sup>ab</sup>	443.54±78.41	602.58±84.51
Control group (n = 20)	Before intervention	2.96±0.81	440.11±72.36	637.51±89.49
	After intervention	2.99±0.79	462.14±81.24	651.25±91.23

Notes: Compared with the results of the same group before intervention, <sup>a</sup> $P < 0.05$ . Compared with the control group, <sup>b</sup> $P < 0.05$

**Discussions**

As seen from Tables 2 and 3 after intervention,  $VO_2\text{max}$ , AT, vital capacity, SV, CO, EDD, EDV, sitting-standing test, 6-min walking test, and the Breg balance function scores of the observation group are superior to those of the control group. This finding reflects that 24-form Tai Chi can improve cardio-pulmonary functions of

the aged, which is similar to the conclusions of Liu et al (21). This finding might be because 24-form Tai Chi is a set of general exercises that integrates consciousness, breathing, and action training. Moreover, long-term Tai Chi can promote blood flow better, while middle and high-strength breathing exercises can also strengthen the negative pressure in the chest, expand the thoracic cavity, and increase EDV and EDD.

Moreover, blood circulation increases during 24-form Tai Chi exercises, which will also increase the volume loading of the heart, decrease peripheral arterial resistance, and accelerate blood re-flows, thus increasing systole amplitude of the respondents, accordingly. After long-term Tai Chi exercises, cardiac functions of the aged are improved as manifested by decelerated HR and increased SV. Diastole and systole are finished by the myocardium. Tai Chi can improve myocardial oxygen consumption of bodies and strengthen myocardial contraction (22).

In this study, SV was influenced by myocardial contraction and systole. If both myocardial contraction and systole are improved, SV will surely be improved. As a type of aerobic exercise, Tai Chi makes slow movements that drive upper and lower limbs to stretch and rotate by centering at the waist. During exercises, muscles of all bodies participate in contraction. HR of Tai Chi trainers can reach 120-140 beats/s during exercises. Tai Chi is a type of moderate-strength aerobic exercise. Additionally, Tai Chi can increase muscle strength and improve flexibility, sensitivity, and balance of lower limbs. With the increase in motion control levels, the walking ability and motor functions are improved accordingly. Williamson et al (23) also pointed out that long-term Tai Chi exercises can increase  $VO_2$ max and aerobic exercise performances of trainers. To sum up, Tai Chi has positive influences on cardio-pulmonary functions and exercise performances.

Results in Table 4 show that after intervention, the content of body fat and BMI of the observation group decrease significantly, whereas muscle mass and fat-free mass increase significantly, which are however significantly lower than those of the control group ( $P < 0.05$ ). This result reflects that the 24-form Tai Chi can somewhat improve body components of the aged. This finding conforms to the research results of Liu et al (24). The reasons are analyzed as follows. Considering that fat is the major energy supply for long-term Tai Chi exercises, it is a type of middle and low-strength exercise for the aged. Slow-switch fibers are a major component participating in exercises, which contain relatively more mitochondria and

relatively higher oxidase activity. They provide energy through free fatty acids in the blood, thereby enhancing motivation of fats. Moreover, long-term Tai Chi can induce synthesis and secretion of enzymes and hormones related with fat metabolism.

Table 5 shows no statistically significant difference between two groups in terms of P3b incubation period after intervention. The P3b amplitude of the observation group increased significantly and was higher than that of the control group. P3b reflects the working memory during the processing of stimuli. Different paradigm structures can influence P3b amplitude. The more complicated paradigm structure leads to the smaller P3b amplitude and the long incubation period. Shortening the P3b incubation period indicates higher efficiency of neural processing. At present, many studies are conducted concerning the influences of exercises on P300. Old people engaging in aerobic exercises for a long period presented higher P3b amplitude than those who sat for a long time and scarcely exercised (25). The findings of this study further verify the existing studies. Furthermore, in this study, although the observation group showed shorter P3b incubation period, no statistically significant difference has been observed, which might be related to task paradigms. Therefore, the observation group showed significantly higher P3b amplitude than the control group.

Different forms of aerobic exercises have different influences on P300. The essence of Tai Chi lies in the cooperation between physical movement and dynamic meditation. Trainers regulate breathing during exercises and concentrate on each action detail. Trainers assume some spiritual loads, which might be conducive to improving their working memory and cognitive ability. Therefore, Tai Chi trainers in this study present relatively high P3b amplitude. Moreover, the response time of the observation group is shorter than that of the control group after intervention, but no statistically significant difference exists. Such differences might be either attributed to individual differences or related to small sample size.

## Conclusion

Effects of 24-form Tai Chi on cardio-pulmonary functions, exercise performances, and cognitive functions of the aged were analyzed in this study. The results indicate that 24-form Tai Chi is suitable for the aged. The training of 24-form Tai Chi can improve the cardio-pulmonary functions and the physical functions of the aged, and it is conducive to improve further the cognitive functions of the aged. Considering that the 24-form Tai Chi moves are simple and slow, easy to learn, and highly accepted by the public. Therefore, 24-form Tai Chi can be used as a routine means for the aged to exercise and keep fit in the community.

## Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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## Conflict of interest

The authors declare that there is no conflict of interests.

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