Coordination Exercise and Postural Stability in Elderly People: Effect of Tai Chi Chuan

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ABSTRACT. Wong AM, Lin Y-C, Chou S-W, Tang F-T, Wong P-Y. Coordination exercise and postural stability in elderly people: effect of Tai Chi Chuan. Arch Phys Med Rehabil 2001;82:608-12.

Objective: To evaluate the effects of coordination exercise on postural stability in older individuals by Chinese shadow boxing, Tai Chi Chuan (TCC).

Design: Cross-sectional study.

Setting: Research project in a hospital-based biomechanical laboratory.

Participants: The TCC group ($n = 25$) had been practicing TCC regularly for 2 to 35 years. The control group ($n = 14$) included healthy and active older subjects.

Intervention: Static postural stability test: progressively harder sequential tests with 6 combinations of vision (eyes open, eyes closed, sway-referenced) and support (fixed, sway-referenced); and dynamic balance test: 3 tests of weight shifting (left to right, forward-backward, multidirectional) at 3 speeds.

Main Outcome Measures: Static and dynamic balance of Sensory Organization Testing (SOT) of the Smart Balance Master System.

Results: In static postural control, the results showed no differences between the TCC or control group in the more simple conditions, but in the more complicated SOT (eyes closed with sway surface, sway vision with sway surface), the TCC group had significantly better results than the control group. The TCC group also had significantly better results in the rhythmic forward-backward weight-shifting test. Duration of practice did not seem to affect the stability of elder people.

Conclusion: The elderly people who regularly practiced TCC showed better postural stability in the more challenged conditions than those who do not (eg, the condition with simultaneous disturbance of vision and proprioception). TCC as a coordination exercise may reduce the risk of a fall through maintaining the ability of posture control.

Key Words: Balance; Elderly; Exercise; Posture; Rehabilitation; T'ai Chi.

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PREVENTIVE CARE for the elderly has received increased attention because of the rapid increase in the elderly population and their disproportionately high medical expenses.[1] Falls are a major cause of morbidity, hospitalization, and mortality among older people.[2-4] Approximately 30% of those over 65 years of age sustain a fall, with about half of them having multiple events. About 10% to 15% of falls result in serious injuries and in soft tissue injuries. Many studies show that impaired balance and decreased lower extremity strength are important risk factors in the loss of physical functioning and the occurrence of falls in older adults.[5-9]

Recent studies have shown that supervised exercise for the elderly should emphasize aerobic, strength, flexibility, and balance training.[10-12] However, vigorous exercises suited for older people are relatively few because of the significant decline in organ function with aging. Joint degeneration, poor eyesight, poor balance, and loss of stamina are universal in the older population. Therefore, coordination exercise with low velocity, low impact, and a high interest level, which also provides a good training effect, is preferred for most older persons.

Tai Chi Chuan (TCC) is a traditional Chinese conditioning exercise (fig 1) that is suitable for older people and patients with chronic disease. The basic TCC exercise is a series of graceful movements linked together in a continuous sequence so that the body is constantly shifting from foot to foot, with a lower center of gravity (COG; knee and hips held in flexion). During the performance of TCC, deep breathing and mental concentration are required to achieve harmony between body and mind.[13] Several cross-sectional studies[14-17] have suggested that TCC training may be beneficial to health. Our previous studies[18-22] have shown TCC to be beneficial to the cardiorespiratory system, flexibility, muscle strength, and body fat composition.[18-22] As for postural control and balance, the Atlanta Fragility and Injuries: Cooperative Studies of Intervention Techniques (FICSIT)[12] and Tse and Bailey[23] both reported that older TCC practitioners had significantly better postural control and a reduced risk of falls.[12,18-20] However, some further evaluative studies of the balance system did not support their findings.[21,22]

In this study, we proposed that those subjects who practiced coordination exercises such as TCC would have better postural control and stability than active nonpractitioners. We also tried to prove that for older persons, it is never too late to begin an exercise regimen, and that a better outcome can be achieved with this regimen than without.

METHODS

Subjects

The TCC subjects were recruited from a Tai Chi club and the control subjects from the volunteer group at Chang Gung Memorial Hospital. An informed consent form was given to every subject. All the subjects were community dwellers and led an active lifestyle. None had a history of falls in the past 3 months. The TCC subjects had been regularly practicing TCC

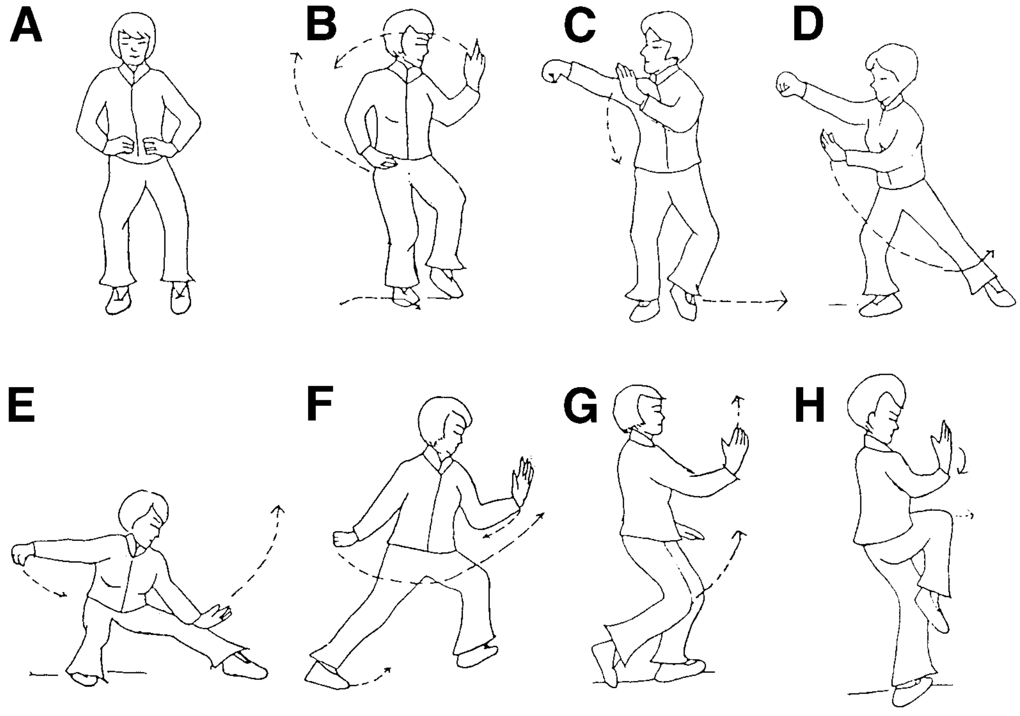

Fig 1. A typical TCC form (fundamental posture and movement): (A) preparing form with palms down; (B) starting leg posture with float up and down correlated hand work; (C) turn to left with hook hand; (D) side-load posture; (E) single-leg squat posture; (F) front-load posture; (G) single-leg bending and rising; (H) "golden pheasant" standing on 1 leg.

for 2 to 35 years (average, 15.6 ± 10.5yr) at the time of recruitment.

All the subjects are predominantly healthy and were examined by the same physician (Y-CL). The subjects who had a history of significant cardiovascular, pulmonary, metabolic, or musculoskeletal disease (eg, joint fracture, artificial joint replacement), or neurologic diseases (eg, stroke, Parkinson's disease, dementia, poor vision) were excluded.

Twenty-five TCC practitioners (8 men, 17 women; age range, 66–74yr) and 14 healthy and active nonpractitioners (4 men, 10 women; age range, 66–76yr) were recruited for this study. The TCC practitioners were divided by duration of TCC practice: more or less than 3 years (group I <3yr; group II ≥3yr). No significant difference was noted in gender, age, body weight, or body height among the 3 groups (table 1).

Measurement Equipment

The SMART Balance Master®[a] was selected to acquire postural stability measurement under defined conditions. This device consists of (1) Two 9 × 18-inch forceplates on which an individual stands. The 2 forceplates are supported by 4 force transducers (strain gauges) mounted symmetrically on a supporting center plate. The fifth transducer is bracketed to the center plate directly beneath the pin joint. (2) A visual enclosure, which is composed of a wall covered with gray-collar aluminum sheet and a small blue dot pattern, enclosing the subject on 3 sides, and a computer monitor located approximately 60cm in front of the subject at eye level. (3) An overhead bar with safety harness. (4) A 486 computer and software system. This system was automatically calibrated by an internal system that activated when the operating system was turned on. The forceplate data were sampled at 100Hz.

Measurement Procedure

Body height and weight were measured for each subject. A harness was secured with straps to an overhead bar to protect the subject in case of a fall. Subjects stood in bare feet on the platform with the medial malleolus at the rotation's axis, as indicated by a line on the forceplate. The lateral borders of the feet were placed 26.5cm apart and equidistant from the centerline of the force platform. The feet were pointed slightly outward to provide each subject with a comfortable foot placement.

Static postural stability test. Subjects were evaluated for postural stability sequentially as follows (table 2): (1) eyes open and fixed support (EO); (2) eyes closed and fixed support (EC); (3) sway-referenced vision and fixed support (SV); (4) eyes open and sway-referenced support (SS); (5) eyes closed and sway-referenced support (ECSS); and (6) sway-referenced vision and support (SVSS). A complete protocol included 2 single trials of EO and EC conditions and 3 consecutive trials for the remaining conditions. Each trial was 20 seconds long.

Table 1: Comparison of Characteristics Between TCC and Control Groups

	Men/Women	Duration of Practice (yr)	Age (yr)	Body Weight (kg)	Body Height (cm)
Control (*n* = 14)	4/10	0	69.1 ± 3.1	57.9 ± 10.6	158.6 ± 6.7
TCC Group I (*n* = 8)	2/6	2 ± 0.8	66.4 ± 9	66.4 ± 9	158 ± 9.5
TCC Group II (*n* = 17)	6/11	20.4 ± 7	69.9 ± 4.5	69.9 ± 4.5	155.4 ± 6.7

NOTE. Group I, duration of practice <3yr; Group II, duration of practice ≥3yr.

Table 2: The Comparison of Ankle Strategy Between TCC and Control Groups

	Groups	Mean Difference	*p*
SV	Control and Group I	3.20 ± 1.2	.035*
	Control and Group II	1.99 ± 0.96	.139
	Groups I and II	1.20 ± 1.16	.921
ECSS	Control and Group I	9.15 ± 3.91	.075
	Control and Group II	8.93 ± 3.15	.021*
	Groups I and II	0.22 ± 3.76	1.0
SVSS	Control and Group I	16.38 ± 5.11	.008*
	Control and Group II	15.96 ± 4.11	.001*
	Groups I and II	0.41 ± 4.90	1.0

* $p < .05$ by using Bonferroni adjustment.

Table 3: Comparisons of Maximal Stability and Average Velocity Between TCC and Control Groups

Stability Test	Groups	Mean Difference	*p*
Maximal stability			
ECSS	Control and Group I	16.87 ± 5.62	.0144*
	Control and Group II	12.21 ± 4.52	.0311*
	Groups I and II	4.66 ± 5.29	1.0
SVSS	Control and Group I	21.80 ± 5.15	.0004*
	Control and Group II	19.74 ± 4.14	.0001*
	Groups I and II	2.06 ± 4.94	1.0
Average velocity†			
ECSS	Control and Group I	.65 ± .18	.0027*
	Control and Group II	.68 ± .14	.0001*
	Groups I and II	.04 ± .18	1.0
SVSS	Control and Group I	.59 ± .17	.0038*
	Control and Group II	.59 ± .14	.0003*
	Groups I and II	.004 ± .16	1.0

* $p < .05$, by using Bonferroni adjustment.
† Velocity of COG.

The subject was informed of the condition (EO or EC; visual surroundings will move, floor will move) before the beginning of data collection for each trial.

In the SV condition, the visual enclosure was rotated simultaneously and proportionally with the spontaneous sway of the subject, thereby minimizing the sway-related visual feedback. In this circumstance, visual feedback conflicted with somatosensory and vestibular feedback. In the SS condition, the support surface was tilted around the ankle joint–related somatosensory feedback from the ankle and foot, and the somatosensory input conflicted with the visual and vestibular inputs. In addition, the visual enclosure and the support surface simultaneously tilted synchronously with the subject's spontaneous body sway during the SVSS condition. The sensory conditions were sequentially administered. Thus, the subjects were gradually challenged to stand in a progressively more difficult sensory environment.

Dynamic balance test. All subjects accomplished the following 3 dynamic balance tests. (1) Rhythmic lateral weight shifting from left to right (L/R). There were 3 movement speeds to trace the target of the screen: (1) slow, moving from 1 line to the other every 3 seconds; (2) moderate, moving from 1 line to another every 2 seconds; and (3) fast, moving from 1 line to another every 1 second. (2) Rhythmic forward-backward weight shifting in 3 movement speeds from slow to moderate to fast. (3) Multidirectional weight shifting from forward to backward, L/R, left forward, left backward, right forward, and right backward, in 8 directions in 75% of limit of stability. The test was typically completed within 15 minutes for each subject.

Data Reduction

Two important outcome measures of postural stability are offered in this dynamic posturographic system. The equilibrium score is a measure of maximal stability (100% indicating little swing, 0% lost balance or falling down). The postural sway, measured from the hips (0%) relative to the ankle joint (100%), represents the ankle strategy for maintaining maximum balance.

The measure of center of pressure was converted into the COG sway ankle (θ), based on the assumption that the height of COG was at .5527 body height,[24] an inverted pendulum model, and an initial forward lean of 2.3°.[25]

The functional limits of stability, ie, the angular distance from the center of the body that can deviate without loss of balance, are 6.25° anteriorly, 4.45° posteriorly, and 8° laterally for the average adult subject. The sway angle (theta peak) was then normalized into a percentage of normal limit (12.5° anteroposteriorly), expressed as percentage of limits of stability.[26]

The software program automatically assigned all the data into the dynamic posturography.

Data Analysis

Baseline characteristics were compared between the 2 groups of TCC practitioners and control group by using Student's *t* test. Data, which were repeatedly gathered from the dynamic posturography of the 3 trails of 6 sensory test conditions in each subject, were calculated in averaged responses. The analysis of variance test with Bonferroni adjustment was used to analyze the significance of difference across groups. The post hoc Tukey test was used for between-group comparisons and $p \leq .05$ was considered statistically significant.

RESULTS

The results showed no differences between the TCC and control groups in the more simple conditions of static balance, such as EO, EC, and SS. The TCC group had significantly better results in the ankle strategy at more complicated conditions, such as SV, ECSS, and SVSS (table 2). For maximal stability, the TCC group had significantly better results at ECSS and SVSS (table 3). However, there were no significant differences between the 2 groups of TCC practitioners (tables 2, 3). For the COG, average velocity results in both groups of TCC practitioners were better in the ECSS and SVSS conditions than in the control group (table 3). The difference of dynamic stability in rhythmic forward-backward weight shift was more significant than that of lateral weight shift in the TCC and control groups. The comparison of composition of forward-backward axial velocity was shown in table 4.

Table 4: The Comparison of Dynamic Stability of Forward-Backward Axial Velocity Using Bonferroni Adjustment Between TCC and Control Groups

	Groups	Mean Difference	*p*
Composition	Control and Group I	.86 ± .33	.043*
	Control and Group II	.81 ± .27	.014*
	Groups I and II	.05 ± .32	1.0

* $p < .05$.

DISCUSSION

Shadow boxing (TCC), a popular traditional Chinese exercise, is said to have been founded by a legendary Taoist priest, Chang San-Feng, in the 13th century, after observing a fight between a crane and a snake. The basic exercise is a series of individual graceful movements in a slow, continuous, circular pattern. During exercise, all movements link together in a continuous sequence that flows smoothly and slowly. The body is constantly shifted from foot to foot in a semisquatting posture. Different parts of the body take turns playing the role of stabilizer and mover, allowing smooth movements to be executed without compromising balance and stability. It is low-impact and low-velocity exercise. During the performance of TCC, mind concentration and breathing control is slow, and abdominal type is integrated with the patterns of movements.[13] A series of grading exercises that are composed of different numbers and manners of posture make TCC suitable for younger and older adults of various physical condition.

In this study, the inclusion criteria (being a healthy and active older adult) excluded those older adults with subclinical neurologic signs who were more likely to have balance impairment. The control subjects participated in some physical exercises such as jogging. The balance tests using relatively simple conditions, including EO, EC, or SS, could not show any difference between the healthy and active subjects and the TCC practitioners. However, when the conditions were more complicated for maintaining balance, including ECSS (the vestibular function under somatosensory disturbance without visual compensation) and SVSS (in the condition that visual, vestibular, and somatosensory function were disturbed), the TCC practitioners had a remarkably better balance than the active healthy subjects.

Wolf et al[27] reported that analyses of data for the 72 inactive older subjects selected from the Atlanta FICSIT randomized trial suggest that the 15-week computerized balance training using a computerized posturographic system improved postural stability, whereas the 15-week TCC practice did not. This could be because the more complicated tests for postural stability (including ECSS and SVSS) were not included in that study. Besides, in that study, the TCC group practiced at a very low intensity of training. They only attended weekly (1hr) group training sessions and were asked to practice only 10 forms from the 108 TCC forms, twice per week (5–15min/session). In contrast, the balance training group attended a higher intensity training program consisting of 3 45-minute sessions per week, and took the test using the same modality as in the training.[27] However, when survival analyses were performed with adjustments for baseline covariates, the TCC group was associated with less risk for 1 or more falls in the presence of identified risk factors. At the same time, the balance training group showed no reduction in the rate of falls.[28] This could be because of familiarization with the instrumentation in the balance training group, enhancing the results of the test for postural stability. In our study, all the TCC practitioners performed at a higher intensity of exercise, every day, for 30 to 60 minutes daily, and for more than 2 years.

Dynamic equilibrium is an essential component of successful locomotion and fall prevention. Proactive and reactive balance are the 2 balance control strategies. The proactive balance strategy involves the activation of postural adjustments before the occurrence of destabilizing forces directly associated with walking. The reactive balance strategy, on the other hand, involves activation of postural adjustments after an external disturbance is encountered, thus, assuring balance recovery.[27] In human subjects, postural reaction, including both voluntary (automatic) adjustment, are dependent on afferent impulses from proprioception, vision, labyrinthine function, and contact. Postural control involves multiple parallel commands for regulating the position of each individual component, depending on the task and on environmental constraints. The postural instability of older people may be caused by deterioration in these central afferent systems or peripheral efferent organs, including muscle weakness and decrease of flexibility. If the purpose of training is to evoke improvements in dynamic balance and coordination, then the training program may be associated with the emergent properties of the total body system, including the muscle strength, muscle endurance, and joint flexibility, as well as the somatosensory feedback system.[6-9]

Evidence is accumulating from both cross-sectional and longitudinal studies that increasing physical activity and exercise play major roles in reducing morbidity and improving quality of life for the elderly.[21] Our previous studies[18,22] have proved that TCC can be beneficial to the flexibility and muscle strength, which contribute to the prevention of falls. Therefore, TCC may be among the recommended exercise programs for the elderly. Though no well-accepted means were available for comprehensive evaluation of the physical activity level, subjects of all groups in this study led active lifestyles. As a result, a basic ability of postural control had been assumed in this study. Further studies including increasing the sample size and evaluating the level of physical intensity by questionnaire are needed. Other studies, including the comparison of motor control and reaction time in these groups, are currently being conducted in our laboratory.

CONCLUSION

Our data suggest that elderly people who regularly practice TCC show better postural stability in the more challenging conditions than those who do not (eg, conditions with simultaneous disturbance of vision and proprioception). TCC as a coordination exercise may reduce the risk of falling by maintaining the ability of posture control. TCC is strongly recommended as a regimen of coordination exercise to prevent the elderly from falling.

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