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ORIGINAL ARTICLE

Development of a Direction-Oriented Motion and Short-Sitting and Lying Tai Chi (DOM-SSLTC) Model for Function Recovery in Stroke Patients

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Abstract

Introduction Tai Chi has been shown to have significant benefits in improving muscle strength, balance, and quality of life. The purpose of this study was to design a sitting or lying Tai Chi model with a better playing posture that is easier to play, and with greater exercise efficiency for stroke patients.

Methods Eighteen stroke patients were recruited (> 6 months post-stroke; modified Rankin Scale: 2–4). The Direction-Oriented Motion and Short-Sitting and Lying Tai Chi (DOM-SSLTC) model was composed of nine typical Yang-style Tai Chi forms. All the subjects received 12 practice sessions (90 min per session) led by a Tai Chi master, and performed the DOM-SSLTC for 60 min per day for 3 months at home. The characteristics of the exercise patterns were quantified using a Tai Chi master's motions. National Institutes of Health Stroke Scale, Modified Ashworth Scale, Modified Rankin Scale, Barthel Index, muscle endurance, and psychological evaluations were used to evaluate the effect of the Tai Chi exercise program on the stroke patients.

Results The results showed that the rectus femoris and sternocleidomastoid muscles had larger contractions and also had larger trunk flexion in the deep breath with one leg stretched Tai Chi pattern. The 18 stroke patients had significantly decreased Depression Questionnaire scores and improvements in muscle power of knee stretching and sitting up after training.

Conclusion This newly developed Tai Chi model with one leg stretched allowed the stroke patients to practice with more intensive exercise, and resulted in improvements in muscle power and depression scale after 3 months exercise.

Keywords Stroke recovery · Exercise training · Rehabilitation · Psychology · Muscle power

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1 Introduction

Tai Chi is composed of physical motions integrated with deep chest and diaphragmatic breathing with the aim of creating harmony between the body and mind in a mind–body exercise called internal mental energy (Qi) [1]. Although the exercise intensity of Tai Chi is considered to be mild to moderate, it has been shown to have benefits in improving physical activity and muscular strength [2, 3], balance [4–6], health-related quality of life (QOL) [1, 7], cognition [8, 9], and psychological well-being [10–12]. Tai Chi has also been shown to be safe and effective in improving neurologic [4], orthopedic, and cancer-specific QOL [13], for stroke patients [14–17], and in patients with many other chronic medical diseases [1, 10]. Tai Chi Yoga has been shown to have beneficial effects on the brain, including a significantly thicker cortex in the hemisphere in neuroscience studies [18, 19] which can aid in recovery from neurological injuries such as in stroke patients. However, most of these studies have applied a Tai Chi stance that may not be safe or suitable for people with movement disabilities.

Sitting Tai Chi has been shown to have beneficial effects in the elderly and disabled, and sitting Tai Chi training for 12 weeks has been reported to improve dynamic sitting balance and handgrip strength in patients with spinal cord injuries [20]. In addition, Cheung et al. reported improvements in shoulder joint flexibility and muscle strength after a 15-week, 30-session Tai Chi training program in sedentary individuals with lower limb disabilities [21]. Furthermore, Barlew et al. reported greatly improved movements and independence in terms of humiliation, frustration, loss and humility in 10 wheelchair-bound individuals after an 8-week session of sitting Tai Chi [22]. Stroke patients have high rates of morbidity, mortality, and disability, and sitting Tai Chi or even lying Tai Chi may help them to achieve a higher QOL. Two previous studies investigated sitting Tai Chi in stroke patients and reported improvements in symptoms of depression [23], eye-hand coordination, weight shift and reaching a distance [24].

Although our previous model of stance Tai Chi was well designed, it was still limited by complications of lower limb motion and weight shift [22, 25]. We showed that it could be performed by healthy persons and stroke patients with no significant or slight disabilities (Modified Rankin Scale (MRS) 1 & 2), however it is not appropriate for patients with moderate and moderately severe disabilities (MRS 3 & 4), especially those with gait and balance disorders, wheelchair users, and bedridden patients. Two recent review articles investigated the use of Tai Chi in stroke rehabilitation programs, and found that Tai Chi appeared to be beneficial for stroke rehabilitation, but that it was important to assess the safety and effect of the Tai Chi model before such use [26]. The significant heterogeneity in previous studies may be due to the various types of Tai Chi styles [27]. Guo pushed for the introduction of wheelchair Tai Chi at the Beijing Olympics/Paralympics Cultural Festival in 2008, and since then wheelchair Tai Chi has gained considerable popularity as a fitness program in China for people with disabilities [28]. However, this model does not stretch the legs, and it may constrain trunk motion and reduce the intensity of exercise. Stretching the leg when playing standing Tai Chi provide a larger stability base [29], and this may provide more stability to allow for a larger range of motions during playing sitting Tai Chi, especially for stroke patients. A higher intensity of exercise is more efficient [30]. Moreover, the torso of a stroke patient is usually not so much affected compared to the upper and lower extremities and trunk exercises could enhance the balance performance post stroke [31]. Therefore, if the Tai Chi exercise involves more trunk movements, it will be able to train and improve the core ability of the trunk and accelerate the recovery of the patient.

In this study, we present a Direction-Oriented Motion Short-Sitting and Lying Tai Chi (DOM-SSLTC) model which we developed for stroke patients and patients with disabilities that can be used as a standard form of Tai Chi for related research. We also aimed to confirm the superiority of the physical motion and muscle activity of the DOM-SSLTC with regards to stretching one leg when playing Tai Chi compared to a previous sitting Tai Chi model without leg activity.

2 Methods

2.1 Study Participants

A Tai Chi master with over 20 years of experience in Tai Chi and over 10 years teaching in the community designed the DOM-SSLTC model. This master also had experience teaching Tai Chi to stroke patients. He demonstrated the DOM-SSLTC model with three different exercise patterns in sitting positions. These motions were compared to evaluate mechanical differences in kinesiology and muscle activation that could help to elucidate differences in exercise intensity and benefits between the three modes. This also helped to establish a safe and easy-to-learn larger range of trunk and limb motions in the sitting Tai Chi model that could also be applied in a lying position.

This greater range of body movement and increased muscle contraction in the Tai Chi pattern demonstrated by the master was then applied to stroke patients. Between October 2014 and June 2015, 18 stroke patients, the segment spasticity ranged from MAS 2–4, (13 males and 5 females; 15 of whom had an ischemic stroke and 3 a hemorrhagic stroke; mean age: 60.0 ± 12.5 years; height: 164.3 ± 7.5 cm; weight: 68.0 ± 10.2 kg) were enrolled from the neurology and rehabilitation outpatient clinics at E-DA Hospital in Kaohsiung, Taiwan, for the patient-based DOM-SSLTC model. None of them had ever performed Tai Chi before. Their disability status was based on their MRS score, including a score of 2 (6/18), 3 (4/18), and 4 (8/18). All of the patients were aged ≥ 43 years and all had post-stroke disabilities of the limbs for longer than 6 months. In addition, all of the patients were free of major cardiac and respiratory medical diseases, and none had any contraindications for doing Tai Chi exercises. The Institutional Review Board of our hospital approved this study, and all of the participants gave written informed consent before participating in the study.

2.2 Design of the Sitting and Lying Tai Chi Model

Our newly designed DOM-SSLTC model was based on the DOM-BSSTC model [25]. The four main motion directions (forward–backward, rotational, lateral, and up–down) used the nine movements of Yang-style Tai Chi. The model was composed of two basic postures: Gong Bu (Fig. 1a–j), a bow-shaped sitting posture with one leg stretched; and Ma Bu (Fig. 1k–r), a horse riding posture with the legs flexed. The sitting Tai Chi model was intended for those with gait and balance disorders, wheelchair users, and bedridden patients. The lying Tai Chi model was intended for those who could not maintain their upper body in an erect position and those who wanted to play Tai Chi when lying in bed.

Some modifications from the previous stance model were made for playing Tai Chi in the sitting or lying position. The "Kick Upward with Foot" (Fig. 1o) movement was added instead of separating the foot [24]. The Beginning (Fig. 1b) and Closing (Fig. 1q–r) movements and the "Step Back Whirl Arms" movements were also added to the upward-downward motions (Fig. 1m–r) to facilitate playing Tai Chi in sitting and lying positions.

Technical limitations of performing Tai Chi in sitting and lying positions include restrictions in leg, waist, and trunk motion. Therefore, we designed the characteristic motions so that each movement could be completed in only two steps. First, the upper trunk motion was performed with both arms starting at the beginning movement. In the Gong Bu posture, the stretched leg and Dan Tien (lower abdomen) co-contractions were then performed (Fig. 1a–j). The lower trunk motion was started after slight Dan Tien contraction in the Ma Bu posture (Fig. 1k–r), after which the arms, leg and trunk could easily perform any motion of each movement. While playing Tai Chi, a practitioner has to control their mind to lead the motion and adjust their breathing according to the Tai Chi motion sequence.

The DOM-SSLTC model was designed based on three exercise patterns, including natural breathing with the legs flexed (M1) similar to a previous sitting Tai Chi posture [28], deep breathing with the legs flexed (M2), and deep breathing with one leg stretched (M3). For the stroke patients with hemiparesis with high spasticity, the Tai Chi model was modified so that the affected limbs were placed on and directed by the healthy arms which allowed these patients to play in the same manner as healthy practitioners (Fig. 2). The motion of the affected limbs when playing Tai Chi depended on the degree of segment spasticity (MAS 2–4) and its active movement ability. Therefore, when a handicapped forearm was placed on a healthy forearm to maintain the posture, the healthy arm could at any pronation/supination posture hold the stroke forearm depending on the patient's weakness, and the motion of the arm was mainly led by the shoulder under abdominal contraction and deep breathing to stabilize the trunk. Stretching of the handicapped lower leg also depended on the weakness and spasticity of the patient.

Only one leg stretching exercise was used in the DOM-SSLTC model (in Gong Bu movements) with almost no foot movements or weight shift, making it much easier to learn and play at any position and place. All of the movements were performed on both sides (right and left hand side), with each movement repeated several times before changing to another movement. While playing this model, the motion range, speed, and loading could be controlled freely by natural breathing or appropriate deep breathing, or a combination of natural and deep breathing patterns, depending on the physical, mental, and mood conditions. This Tai Chi model, with a combination of any exercise pattern (M1–M3), was comfortable and enjoyable for the patients in any situation. It could also prevent dizziness due to overly deep inspiration and expiration.

2.3 Characteristics of the DOM-SSLTC Model

Upper trunk motion with deep breathing and chest expansion as preparation for the initial arm motion of each movement: Both arm motions started with deep breathing and chest expansion as the *"Beginning movement"* (Fig. 1b) to facilitate motion of the arms in any movement during the sitting and lying posture.

Lower trunk motion fixation with deep expiration and lower abdominal contraction as preparation for the final motion of each movement: In the Gong Bu posture, the leg was stretched to enhance the Dan Tien co-contraction and increase the forward–backward motion of the trunk. After the Dan Tien contraction, the arms and trunk could easily and smoothly be moved at the same time in the final motion of each movement (Fig. 1d–e, g, j).

Fig. 1 Sitting posture with one leg stretched exercise pattern. Starting from the beginning movement (**a**, **b**) and then going into two sitting postures, Gong Bu (**b**–**j**) and Ma Bu (**k**–**r**). The "Grasp Sparrow's Tail" is in the forward–backward direction (**c**–**e**), and "Parting Wild Horse's Mane" (**f**, **g**) and "Single Whip" (**h**–**j**) are for the rotational motion in the Gong Bu posture. The lateral motion "Cloud Hand"(**k**, **l**), and up/down motion of the leg includes "Step Back Whirl Arm" (**m**, **n**), "Golden Rooster Standing" with "Kick with Right Foot" (**o**), and finally returning to the "beginning movement" (**p**), and "Closing of Tai Chi" (**q**, **r**) in the Ma Bu posture

Complete each movement in only two steps: The first motion was the upper trunk and the second motion was the lower trunk. Each movement was easy to remember and practice (Figs. 1, 2).

Deep breathing to enhance trunk motion and coordinate limb motion: Playing Tai Chi uses an inner breathing force to drive muscle force. Proper breathing plays an important role in coordinating the breathing with physical motion and its fitness value. Chest expansion with deep nasal inhalation was performed to prepare for the starting motion, followed by natural mouth exhalation and relaxed during the motion, and the final posture of each movement was completed with slow deep mouth exhalation [32].

Nearly the same techniques in sitting and lying positions: The lying model could be practiced while sitting on a chair with the trunk and head touching a wall, just as in a relaxed lying posture on the floor.

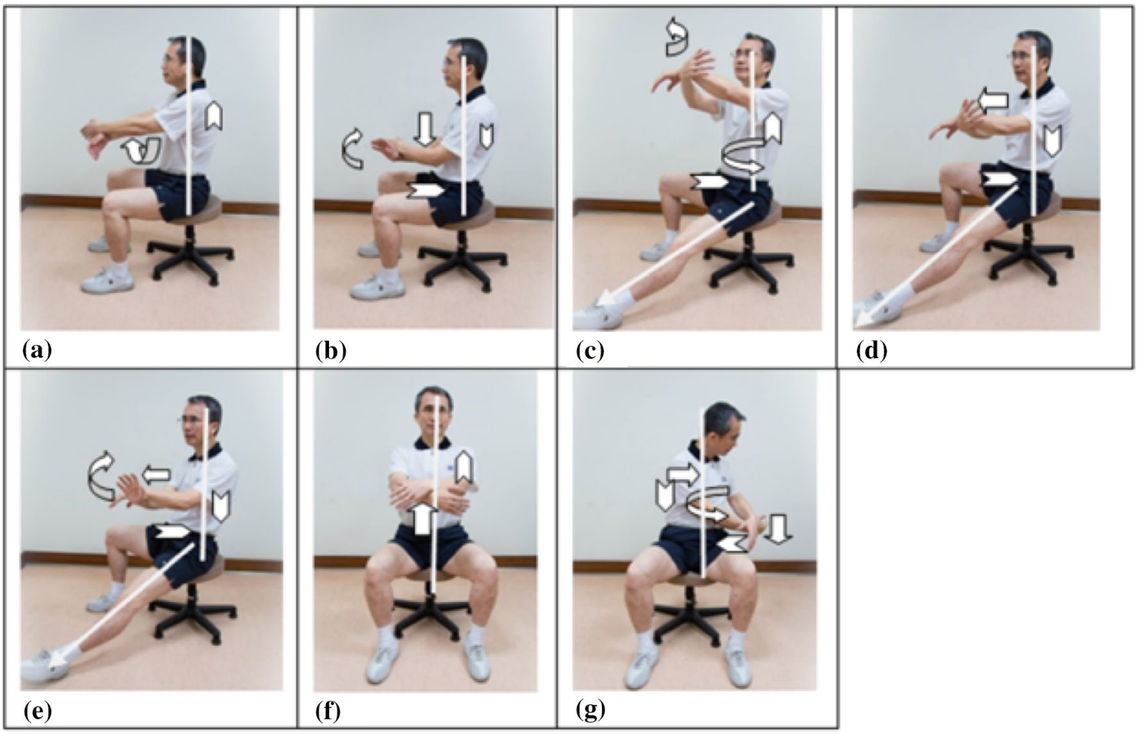


Fig. 2 Sitting Tai Chi posture for a patient with left hemiparesis. The left disabled arm is placed on the right arm, with motion led by the right healthy arm. The beginning movement (**a**, **b**), "Grasp Sparrow's Tail" (**c**–**e**), and "Cloud Hand" (**f**, **g**)

2.4 Interventions

All of the patients received a total of 12 practice sessions once a week (90 min per session) led by a Tai Chi master to ensure a uniform technique and consistent experience at our hospital. The group practice started with 5 min warm up, 20 min of Tai Chi exercise three times with 20 min rest between, and then 5 min of cooling down exercise. During the 20 min of Tai Chi exercise, the stroke patients would perform each movement three times from the "Beginning movement" to the "Closing of Tai Chi" as one set, and they performed five 5 sets in total. At home, the patients performed the DOM-SSLTC model for 60 min per day (three sessions of 20 min each) for 3 months. Family members were encouraged to practice together with the patient to assist and help them to remember the various motions of the Tai Chi movements. A diary was also recorded by the patients or family members. A research assistant called each patient twice a week to encourage them and confirm that they were actually practicing at home.

2.5 Outcome Measurements

2.5.1 Comparison of Kinesiology and Muscle Activation in Three Tai Chi Modes

To compare differences in the three kinds of sitting Tai Chi exercise patterns, the motions of a Tai Chi master in the four movement directions were recorded. The center of gravity (COG) transition and trunk motion (motion of the trunk relative to the pelvis) during the Tai Chi movement and muscle activation were then quantified. A chair was placed in the direction of the laboratory coordinate system, in which the x-axis represented the anterior–posterior direction of the chair, the y-axis represented the medial–lateral direction, and the z-axis represented the vertical direction. The same reflective markers as used in previous studies were attached to record body movements for analysis while playing Tai Chi [25], and were captured using a motion capture system (Qualisys™, Sweden) at a 200-Hz sampling rate.

A 4th-order low-pass Butterworth filter with 6-Hz cut-off frequency was used to smooth the raw motion data. COG analysis was performed on a 12-segment model [33] using body segment parameters as described previously [34]. An electromyography (EMG) system (Trigno, DELSYS Inc., MA, USA) was used to measure muscle activation of the rectus abdominis, pectoralis major, rectus femoris, serratus anterior and sternocleidomastoid at a sampling rate of 800 Hz. The rectus abdominis and sternocleidomastoid muscles were kept straight at the basic central column (trunk) and were mainly used for forward–backward motion. The rectus femoris muscle was also mainly used to make larger central column forward–backward motions, while the pectoralis major and serratus anterior muscles were used to keep the upper limbs in the holding a relaxed ball posture. The raw EMG data were band-pass filtered at 20–450 Hz, full wave rectified, and the root-mean-square of the signal was derived using a moving window of 125 ms. All muscle activation levels were normalized to maximal voluntary isometric contractions (MVIC).

2.5.2 Effects of Tai Chi Exercise on the Stroke Patients

To assess the effects of the sitting and lying Tai Chi model on the stroke patients in terms of physical loading, mind, mood, and QOL after 3 months of exercise, the MRS, Modified Ashworth Scale (MAS), National Institutes of Health Stroke Scale (NIHSS), Barthel Index, psychology evaluations using the Taiwanese Depression Questionnaire (TDQ; 18 Questions), and muscle power of the knee extensors (MP1) and trunk flexors and rotators (MP2) muscles were evaluated. To avoid observation bias, all examinations and evaluations were performed by the same physician. The muscle endurance of the knee extensors was evaluated by alternately extending the knee from a natural sitting position to a fully extended position when sitting on a chair with back support. Trunk muscle endurance was tested via sit-ups with the knee bent and a pillow used to keep the chin in a neutral position, with a hand alternately touching the opposite bent knee (Fig. 3). Repetitions of both motions measured for 1 min were used as the muscle endurance score.

2.6 Statistical Analysis

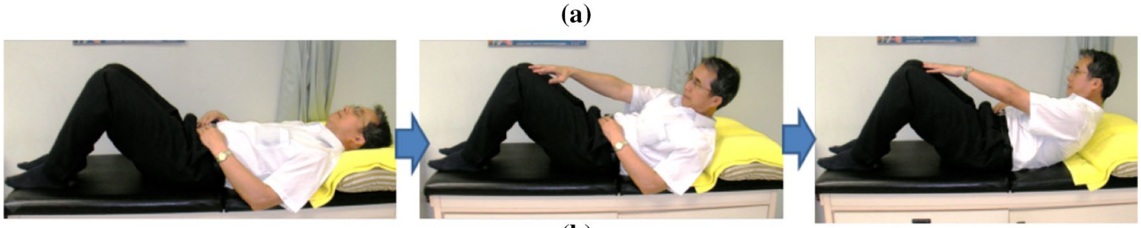
The paired *t* test was used to compare the means of the following seven scores before and after the Tai Chi training program: TDQ, MRS, MAS, Barthel index, NIHSS, MP1, and MP2.

3 Results

3.1 Data of Kinesiology for the Three Kinds of Exercise Patterns

Comparing the three kinds of exercise patterns (M1: natural breathing with one leg flexed, M2: deep breathing with one leg flexed, and M3: deep breathing with one leg stretched) to the Tai Chi master during the sitting Tai Chi forward–backward movement (Fig. 1a), larger trunk internal rotation and flexion were noted in M3 (Fig. 4). However, during rotational movement (Fig. 1b), only a larger trunk flexion was found in M3 (Fig. 4). Among the three models of exercise pattern during the forward–backward and rotational movements in sitting Tai Chi, there was almost no change in the position of the COG (Fig. 5). The three kinds of exercise patterns in lateral and up-down directions of Tai Chi movements were similar to changes in trunk rotation and COG position.

(a)



(b)

Fig. 3 The test procedure of muscle power: **a** knee extensor **b** trunk flexor

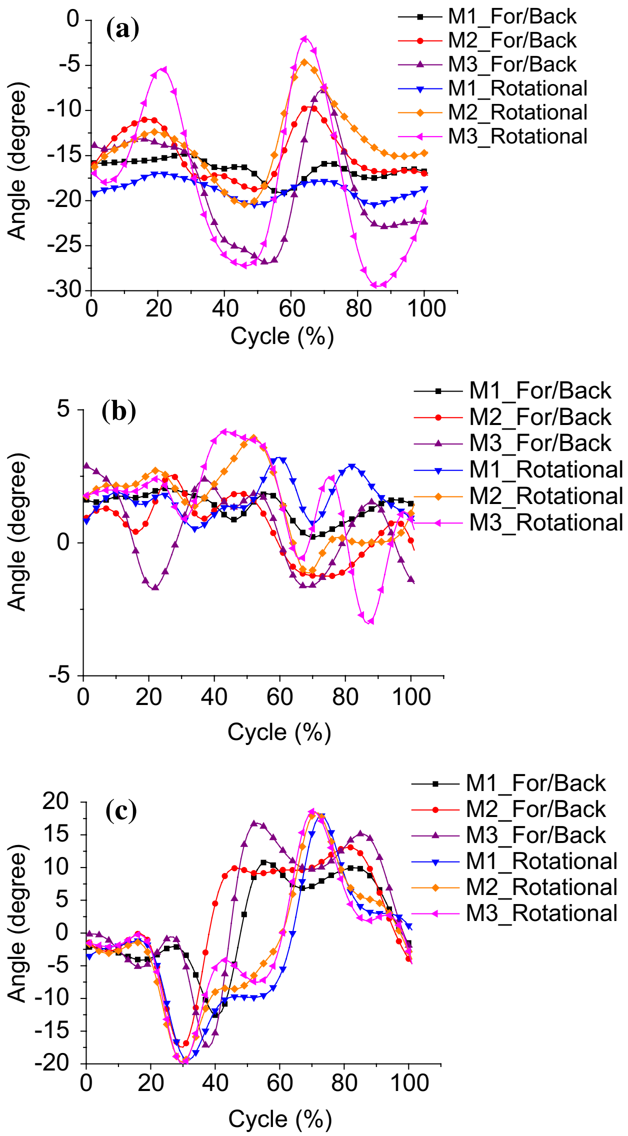


Fig. 4 Three trunk rotations: **a** extension(+)/flexion(−), **b** left(+)/right(−) bending and **c** left(+)/right(−) rotation during forward–backward and rotational sitting Tai Chi movement with the three kinds of exercise patterns (*M1* natural breathing with the leg flexed; *M2* deep breathing with the leg flexed; and *M3* deep breathing with the leg stretched; For/Back: forward/backward). Every cycle is starting from the "beginning movement" (0%) and end at "Closing of Tai Chi" (100%)

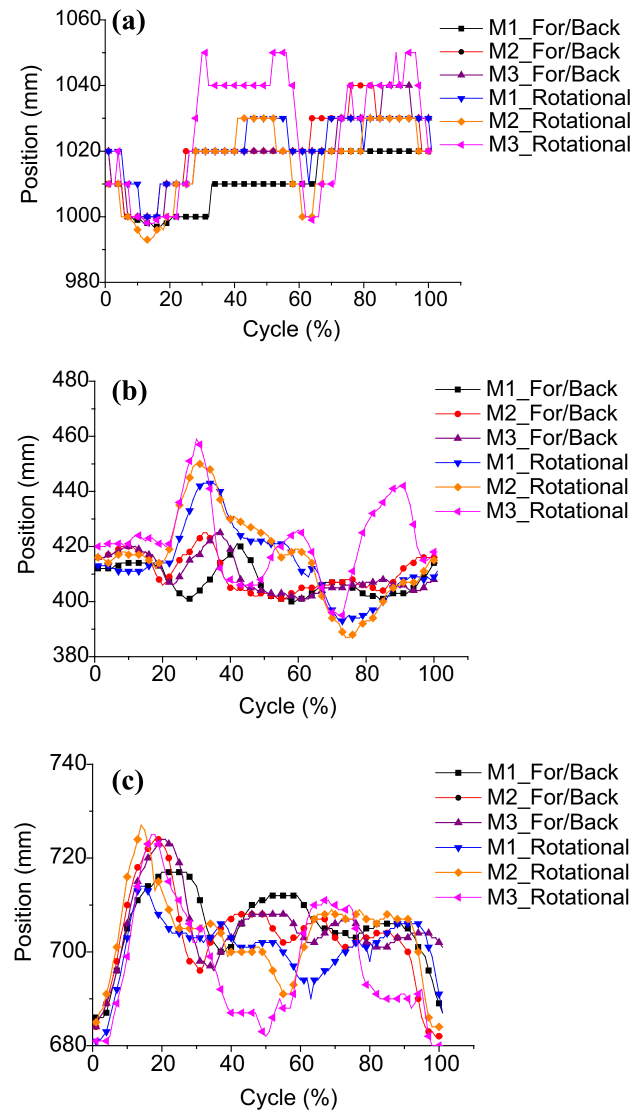


Fig. 5 The center of gravity (COG) movement in **a** posterior(+)/interior(−), **b** right(+)/left(−) and **c** superior(+)/inferior(−) rotation during forward–backward and rotational sitting Tai Chi movements with three kinds of exercise patterns (*M1* natural breathing with the leg flexed; *M2* deep breathing with the leg flexed; and *M3* deep breathing with the leg stretched; For/Back: forward/backward). Every cycle is starting from the "beginning movement" (0%) and end at "Closing of Tai Chi" (100%)

3.2 Muscle Contraction in the Three Kinds of Exercise Patterns

During the forward–backward and rotational movements in sitting Tai Chi, only the serratus anterior muscle had a large contraction in all three kinds of exercise patterns. Comparing the three kinds of exercise patterns in the Tai Chi model, there were greater contractions in the rectus femoris, rectus abdominis and sternocleidomastoid muscles in the M3 pattern during the forward–backward movement. Moreover, the rectus femoris and sternocleidomastoid muscles had larger activation in the M3 pattern during rotational movement (Table 1).

3.3 Effect of Tai Chi Exercise in the 18 Stroke Patients

All 18 patients (100%) completed the DOM-SSLTC exercise program for 60 min every day for 3 months, which was confirmed by intensive phone contact with caregiver, patient,

Table 1 Peak muscle activation in different types of sitting forward–backward and rotational Tai Chi movements (% MVC)

	Rectus abdominis	Pectoralis major	Rectus femoris	Serratus anterior	Sterno-cleidomastoid
Forward–backward					
M1	8.02	7.93	9.08	24.65	7.00
M2	2.79	7.57	6.51	43.24	34.23
M3	16.69	7.57	42.33	66.76	11.79
Rotational					
M1	15.32	7.46	16.57	58.55	12.74
M2	17.51	7.67	17.20	53.13	16.88
M3	5.54	8.27	37.6	51.75	28.18

Table 2 Effect of sitting and lying Tai Chi in the stroke patients in terms of physical loading, mind, mood, and quality of life after 3 months of exercise (n = 18)

Evaluated item	Before training (mean [SD])	After training (mean [SD])	*p*-value
TDQ	11.61 (10.30)	6.06 (8.07)	< 0.001*
MRS	2.61 (0.50)	2.44 (0.78)	0.187
MAS	1.83 (1.20)	1.83 (1.04)	> 0.999
Barthel index	93.06 (10.45)	93.89 (10.51)	0.381
NIHSS	3.28 (1.97)	3.56 (1.76)	0.414
MP1 (reps/min)	38.22 (12.24)	56.50 (15.09)	< 0.001*
MP2 (reps/min)	51.22 (16.24)	70.94 (15.43)	< 0.001*

*Indicates a significant difference

family members and diary records. The TDQ scores were significantly decreased after 3 months of Tai Chi exercise. In addition, the MP1 and MP2 scores showed significant improvements, however there were no significant changes in MRS, MAS, Barthel's index, or NIHSS scores (Table 2).

4 Discussion

Several sitting Tai Chi models have been developed and studied [23, 24, 28]. Although most of these sitting Tai Chi models were derived from Yang's style, we used certain different forms in this newly developed Tai Chi model. The principle of the design of this model was based on four main motion directions and used nine forms of Yang-style Tai Chi. Moreover, the deep breathing and leg stretched motion while playing sitting Tai Chi that are particularly emphasized in this model are not found in other models.

4.1 Differences in Kinesiology and Muscle Contractions Between the Three Tai Chi Mode

The results revealed almost no differences in positional changes in COG in the three kinds of sitting Tai Chi exercise patterns in the forward–backward and rotational movements. EMG revealed milder muscle hyperactivity in the serratus anterior and sternocleidomastoid muscles in the deep breathing (M2) pattern than in the natural breathing exercise pattern (M1) (Table 1). Moreover, the DOM-SSLTC model with the deep breathing and one leg stretched exercise pattern (M3) resulted in greater trunk movement and muscle activation (Fig. 4 and Table 1). Both M2 and M3 resulted in greater physical activation of the legs and trunk compared to the previous sitting Tai Chi model with natural breathing (M1). The deep breathing exercise pattern (M2 & M3) has also been shown to be more beneficial for mind–body control [1, 10–12, 32]. As such, the M3 pattern in the DOM-SSLTC model had larger generalized physical motion and increased exercise intensity in the various exercise patterns of Tai Chi. In addition, breathing control may have been easier with the larger movement.

There were also fewer weight shift movements in all three of the exercise patterns of the DOM-SSLTC model, thereby making the DOM-SSLTC model easier to learn. This may mean that the DOM-SSLTC model is easy and safe to play for hemiparesis stroke patients as there is no weight shift, thereby avoiding losing balance and falling due to the stance mainly being on the rear healthy leg (Supplement Fig. 4). If the patient had a better physical condition, the two steps of trunk motion could also easily be applied to the stance posture without weight shift. We found that without weight shift, the COG had less movement in the anterior–posterior direction than with weight shift in tradition stance Tai Chi [25], but with greater trunk rotation. After repeated practice, the practitioners could then add weight shift but without feet movement as in regular stance Tai Chi when performing the DOM-BSSTC stance model (Supplement Fig. 4).

The results also revealed significant improvements in leg and abdomen muscle activity and TDQ. These findings support the conclusions of a previous randomized controlled clinical trial of the QOL and mind–body therapy in stance and sitting Tai Chi [14, 16].

4.2 Main Outcomes of the Stroke Patients After Practicing Sitting Tai Chi

After 3 months of sitting and lying Tai Chi exercises, the stroke patients had significantly lower TDQ scores. In addition, the muscle power of the knee extensor and trunk strength significantly improved after the training [1, 35]. Previous studies have also shown that Tai Chi exercise can reduce the rate of falls, improve balance ability and QOL of stroke patients [15, 17, 35]. However, there were no significant changes in MRS, MAS, Barthel Index, or NIHSS score (Table 2). In addition, the baseline physical data of the patients with disabilities due to neurological sequelae did not significantly change, although the functional ability of muscle endurance and general mind–body condition significantly improved [23]. When the stroke patients played the DOM-SSLTC model, they usually reached the intensity of "could talk but could not sing", indicating that the exercise intensity was mild to moderate. Our muscle endurance data demonstrated that the DOM-SSLTC model was sufficient to strengthen the muscles of patients with disabilities. In addition, the TDQ results revealed that the DOM-SSLTC model was a good exercise tool for mind–body control and therapy [13–16].

4.3 The Key Points in Applying the Model in Stroke Patients

Three concerns with regards to this study should be clarified. First, the stroke patients were physically affected by improper muscle tone and motor control ability, and they could not play the DOM-SSLTC model as well as the master. Even though each movement could be completed in only two steps, Tai Chi is a generalized physical exercise with harmonious balance between the body and mind under the guidance of internal mental energy (Qi) [1] for each movement, and it still requires a Tai Chi master to complete and correctly perform. Second, the limbs of the stroke patients were weak and spastic [21], with a MAS score of 3–4. As such, they needed help to learn the formal symmetric movements of the Tai Chi model. They also needed a Tai Chi master to modify some individualized motions according to their disability (Fig. 2). Finally, for the elderly and those with organic brain lesions and poor memory and mental responses, learning the generalized and variations of Tai Chi movements would be difficult. Hence, a master may also be needed to lead and do the exercises together with a caregiver.

4.4 Limitations of This Study

Since it is difficult to follow stroke patients after 6 months, a lack of control group for the randomized control trials and relatively small sample size of the participants are the apparent limitations of this study. Based on the guidelines for adult stroke rehabilitation and recovery from the American Heart Association/American Stroke Association, stroke patients may have little improvement in limb function with traditional treatment after 6 months [36]. Therefore, we believe that most of the improvements in the stroke patients were due to the Tai Chi exercise. In addition, comparisons of three different Tai Chi modes with a Tai Chi master may not be generalizable to stroke patients. In addition, assessments of the outcomes only focused on the patients' condition, muscle spasticity, overall severity, psychology condition, and daily activity ability, but did not evaluate cognitive ability or perceptive functions.

5 Conclusions

The DOM-SSTC model is performed mainly with one leg stretched with deep breathing for larger trunk motion to elicit greater muscle contraction. After 3 months of the Tai Chi exercise, the stroke patients had improvements in their psychological and physical conditions and muscle function that may have improved their quality of life.

The DOM-SSTC model is easy to learn and perform, and can be played with any or all of the three kinds of Tai Chi exercise patterns depending on the practitioner's condition. The exercise intensity of this model can be applied to those with disabilities and healthy people, and can be performed safely and enjoyed at any time and place. It can also be used as a patient-based exercise model and as a mind–body therapy model for healthy people when led by a Tai Chi master to improve the mind–body condition, QOL, and for studies on short courses of Tai Chi with sitting and lying positions in both disabled and healthy subjects.

References

1. Lan, C., et al. (2013). Tai chi chuan in medicine and health promotion. *Evidence Based Complementary and Alternative Medicine, 2013,* 502131.
2. Lan, C., et al. (2000). Tai Chi Chuan to improve muscular strength and endurance in elderly individuals: A pilot study. *Archives of Physical Medicine and Rehabilitation, 81*(5), 604–607.
3. Wu, G. (2008). Age-related differences in Tai Chi gait kinematics and leg muscle electromyography: A pilot study. *Archives of Physical Medicine and Rehabilitation, 89*(2), 351–357.
4. Hackney, M. E., & Earhart, G. M. (2008). Tai Chi improves balance and mobility in people with Parkinson disease. *Gait Posture, 28*(3), 456–460.
5. Nnodim, J. O., et al. (2006). Dynamic balance and stepping versus tai chi training to improve balance and stepping in at-risk older adults. *Journal of the American Geriatrics Society, 54*(12), 1825–1831.
6. Wang, L. H., Lo, K. C., & Su, F. C. (2012). Posture control and balance during tai chi chuan push hands movements in a fixed

stance. *Journal of Mechanics in Medicine and Biology, 12*(05), 1250030.
7. Kin, S., Toba, K., & Orimo, H. (2007). Health-related quality of life (HRQOL) in older people practicing Tai Chi–comparison of the HRQOL with the national standards for age-matched controls. *Nippon Ronen Igakkai Zasshi, 44*(3), 339–344.
8. Miller, S. M., & Taylor-Piliae, R. E. (2014). Effects of Tai Chi on cognitive function in community-dwelling older adults: A review. *Geriatric Nursing, 35*(1), 9–19.
9. Wayne, P. M., et al. (2014). Effect of tai chi on cognitive performance in older adults: Systematic review and meta-analysis. *Journal of the American Geriatrics Society, 62*(1), 25–39.
10. Yeh, G. Y., et al. (2004). Effects of tai chi mind-body movement therapy on functional status and exercise capacity in patients with chronic heart failure: A randomized controlled trial. *American Journal of Medicine, 117*(8), 541–548.
11. Yu, R., et al. (2014). A Chinese Chan-based mind-body intervention improves psychological well-being and physical health of community-dwelling elderly: A pilot study. *Clinical Interventions in Aging, 9,* 727–736.
12. Zheng, G., et al. (2014). The effectiveness of Tai Chi on the physical and psychological well-being of college students: A study protocol for a randomized controlled trial. *Trials, 15,* 129.
13. Zeng, Y., et al. (2014). Health benefits of qigong or tai chi for cancer patients: A systematic review and meta-analyses. *Complementary Therapies in Medicine, 22*(1), 173–186.
14. Ding, M. (2012). Tai Chi for stroke rehabilitation: A focused review. *American Journal of Physical Medicine and Rehabilitation, 91*(12), 1091–1096.
15. Kim, H., Kim, Y. L., & Lee, S. M. (2015). Effects of therapeutic Tai Chi on balance, gait, and quality of life in chronic stroke patients. *International Journal of Rehabilitation Research, 38*(2), 156–161.
16. Taylor-Piliae, R. E., & Haskell, W. L. (2007). Tai Chi exercise and stroke rehabilitation. *Top Stroke Rehabil, 14*(4), 9–22.
17. Taylor-Piliae, R. E., et al. (2014). Effect of Tai Chi on physical function, fall rates and quality of life among older stroke survivors. *Archives of Physical Medicine and Rehabilitation, 95*(5), 816–824.
18. Boccia, M., Piccardi, L., & Guariglia, P. (2015). The meditative mind: A comprehensive meta-analysis of MRI studies. *BioMed Research International, 2015,* 419808.
19. Wei, G. X., et al. (2013). Can Taichi reshape the brain? A brain morphometry study. *PLoS ONE, 8*(4), e61038.
20. Tsang, W. W., et al. (2015). Sitting tai chi improves the balance control and muscle strength of community-dwelling persons with spinal cord injuries: A pilot study. *Evidence-Based Complementary and Alternative Medicine, 2015,* 523852.
21. Cheung, S. Y., et al. (2007). Physical benefits of Tai Chi Chuan for individuals with lower-limb disabilities. *Occupational Therapy International, 14*(1), 1–10.
22. Barlew, L., et al. (2013). The experience of being grounded: A phenomenological study of living with a wheelchair. *Rehabilitation Nursing, 38*(4), 193–201.
23. Li, Y. L., Hu, X. J., & Cui, L. N. (2012). Sitting tai chi for post-stroke depression: Observation of 30 cases. *Chinese Nursing Research, 26,* 2254–2256.
24. Lee, K. Y., Hui-Chan, C. W., & Tsang, W. W. (2015). The effects of practicing sitting Tai Chi on balance control and eye-hand coordination in the older adults: A randomized controlled trial. *Disability and Rehabilitation, 37*(9), 790–794.
25. Lee, L. H., et al. (2015). "Direction-oriented motion and balanced short-stance tai chi" model: Biomechanical characteristics and practicability. *Journal of Mechanics in Medicine and Biology, 15*(01), 1550013.
26. Zhang, Y., et al. (2016). Tai Chi for stroke rehabilitation: Protocol for a systematic review. *British Medical Journal Open, 6*(6), e010866.
27. Zhang, Y. Z., et al. (2015). Current trends in tai chi for stroke rehabilitation. *Journal of Traditional Chinese Medical Sciences, 2*(3), 135–139.
28. Guo, Z. (2012). Thirteen postures of wheelchair TaiJiQuan (Tai Chi): Wheelchair use as an instrument of empowerment. *Technology and Innovation, 13,* 267–279.
29. Chau, K. W., & Mao, D. W. (2006). The characteristics of foot movements in Tai Chi Chuan. *Res Sports Med, 14*(1), 19–28.
30. Pin-Barre, C., et al. (2017). Effects of high- versus moderate-intensity training on neuroplasticity and functional recovery after focal ischemia. *Stroke, 48*(10), 2855–2864.
31. Karthikbabu, S., et al. (2012). A review on assessment and treatment of the trunk in stroke: A need or luxury. *Neural Regeneration Research, 7*(25), 1974–1977.
32. Morgan, N., et al. (2014). The effects of mind-body therapies on the immune system: Meta-analysis. *PLoS ONE, 9*(7), e100903.
33. Huang, S. C., et al. (2008). Age and height effects on the center of mass and center of pressure inclination angles during obstacle-crossing. *Medical Engineering & Physics, 30*(8), 968–975.
34. Winter, D. A. (2005). *Biomechanics and motor control of human movement* (3rd ed.). New Jersey: Wiley.
35. Au-Yeung, S. S., Hui-Chan, C. W., & Tang, J. C. (2009). Short-form Tai Chi improves standing balance of people with chronic stroke. *Neurorehabilitation and Neural Repair, 23*(5), 515–522.
36. Winstein, C. J., et al. (2016). Guidelines for adult stroke rehabilitation and recovery: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke, 47*(6), e98–e169.