



EFFECTS OF TAI CHI ON BALANCE AND GAIT IN STROKE SURVIVORS: A SYSTEMATIC META-ANALYSIS OF RANDOMIZED CONTROLLED TRIALS

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Objective: To investigate the effects of tai chi on balance and gait in stroke survivors.

Methods: A systematic meta-analysis of randomized controlled trials on the effects of tai chi on balance and gait in stroke survivors.

Results: Five randomized controlled trials, with a total of 346 patients, were included in the meta-analysis. All of these studies had a high bias based on the Cochrane Collaboration recommendation, and a relatively small sample size. In the pooled analysis, the tai chi group exhibited a significantly better gait ability than the control group, as evaluated with the Timed Up and Go (TUG) test and Short Physical Performance Battery (SPPB) (-0.26 [-0.50 to -0.03], $p=0.027$; $I^2=0\%$, $p=0.682$), but no significant difference in dynamic standing balance scores was found between tai chi and control groups (0.154 [-0.269 to 0.578], $p=0.475$; $I^2=26.6\%$, $p=0.256$).

Conclusion: Tai chi may be beneficial for stroke survivors with respect to gait ability in the short term, but further large, long-term randomized controlled trials with standard evaluation indicators are needed to confirm this conclusion.

Key words: tai chi; stroke; balance and gait; systematic meta-analysis.

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Poor physical functioning and significantly decreased quality of life are often reported in stroke survivors (1, 2). Poor gait and balance are correlated with an increased risk of falling, which is one of the most common complications experienced by stroke patients during rehabilitation (3). Therefore, effective interventions are needed for improving physical functioning and quality of life among survivors of stroke.

Regular physical activity improves physical functioning, reduces fall rates and improves quality of life among stroke survivors (4). Many studies suggest that tai chi leads to improved physical functioning, fewer falls, and better quality of life in healthy older adults

LAY ABSTRACT

Tai chi is beneficial in enhancing gait ability in stroke survivors. Most stroke survivors have poor balance control and walking skills, and conventional muscle or balance exercises do not achieve satisfactory physical improvement. Tai chi has been practiced for centuries and has become a popular exercise worldwide in recent years. It has been reported to improve prognosis in many conditions, including balance and gait in stroke survivors. This research systematically reviewed 5 relevant studies of the role of tai chi on balance and gait functions in stroke survivors. Tai chi was found to be beneficial with respect to gait ability in the short term in stroke survivors.

(5, 6). Tai chi comprises slow, graceful and precise movements, performed with a low centre of gravity. Tai chi has been practiced for centuries and has become a popular exercise worldwide in recent years (7). The requirement for deep breathing and relaxation of the body and mind when practicing tai chi is in line with stroke rehabilitation programmes that encourage patients to relax and stay calm in order to achieve better recovery.

Tai chi increases muscle flexibility and strength, and inhibits abnormal posture and convulsion patterns, thus improving ability to control motion and balance functions in patients with Parkinson's disease and cerebrovascular disease (8, 9). The effects of tai chi in stroke rehabilitation have been studied (10, 11) and, in some cases, it has been incorporated into stroke rehabilitation programmes. Therefore, it is of clinical significance to review systematically the published data on tai chi practice in stroke survivors. The aim of this study is to evaluate the effectiveness of tai chi on rehabilitation in stroke patients, in order to help clinicians to make evidence-based decisions on the use of tai chi in stroke patients.

METHODS

Study design

A systematic review of published randomized control trials (RCTs) on the effects of tai chi on rehabilitation in stroke survivors was performed, followed by a meta-analysis of the findings of the selected studies. Ethical approval was not required for the present study.

Search strategy

An electronic search of the PubMed, EMBASE and Cochrane databases was performed for published studies on tai chi in stroke survivors, with no limitations on language or publication year, using the following search terms: “tai chi”, or “Taiji”, and “stroke”, or “cerebral apoplexy”, or “acute cerebral accident”, or “cerebral infarction”. A Google Scholar search was also performed using these search terms.

Inclusion criteria

Publications were selected for full-text review based on our review of the abstracts of articles identified by the key word searches. The inclusion criteria were:

- (i) *Types of studies.* Only randomized trials were included in this systematic review. Quasi-randomized and observational studies were excluded. No language constraints were placed on our study.
- (ii) *Types of participants.* The population of interest included all adult patients undergoing tai chi with a documented history of stroke.
- (iii) *Types of interventions.* The main intervention of interest was the use of tai chi in stroke survivors, with usual care as the control. All types of tai chi, regardless of the form, style, duration and frequency, were accepted, and the usual care in the control included conventional rehabilitative treatment, exercise or ongoing treatment.
- (iv) *Types of outcome.* The outcome indicators focused on balance and gait after stroke.

Article selection

Two reviewers (YZ and GYL) conducted the literature search independently, with the relevance of each article first being evaluated according to its title and abstract. The full-texts of the remaining articles were obtained and screened for eligibility by 2 reviewers (YZ and GYL). Disagreements during article selection were resolved by discussion and consensus opinion.

Data extraction

Two reviewers (GYL and WW) extracted the information from each included trial into pre-defined data collection forms. Data included authors, country, year of publication, sample size, inclusion and exclusion criteria, types of tai chi, types of control, duration and outcome indicators and outcomes. If necessary, the primary authors of trials were contacted via email to provide further information about what was perceived as incomplete data. Furthermore, the “data extraction” form was used to record and calculate the relevant outcome data.

Quality assessment

Two reviewers (YZ and GYL) independently evaluated the quality of the eligible RCTs according to the Cochrane Collaboration Risk of Bias Tool (12). The following study aspects were evaluated:

random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessments, incomplete outcome data, selective reporting, and other biases. A third author (WW) was consulted if any disagreement persisted.

Data analysis

Stata 12.0 software was utilized for statistical analysis. Standardized mean differences (SMDs) and 95% confidence intervals (95% CI) were used for analyses. Statistical heterogeneity was assessed by a χ^2 test and I^2 statistics. According to the Cochrane standard, heterogeneity across studies was regarded as substantial if I^2 was greater than 50%. A fixed-effect model was applied to calculate the pooled statistics in the absence of substantial heterogeneity (> 50%). Conversely, a random effects model was applied. It should be noted that the results obtained by the random-effects model should be interpreted with caution.

RESULTS

Description of included studies

Literature search. The electronic literature search from PubMed, EMBASE and Cochrane databases yielded a total of 78 citations, of which 14 potentially eligible studies were identified based on their titles and abstracts. Only 5 articles met the inclusion criteria after the contents of the 14 articles were reviewed. The other studies were excluded because they were reviews, meta-analyses, study protocols or non-randomized controlled studies. Details are shown in Fig 1.

Study characteristics. The 5 included studies (13–18) had a total of 346 stroke survivors, from China, South Korea, Israel and the USA. For tai chi, 6 weeks of practice were employed in the study by Kim et al. (15) Other studies adopted a scheme of 12 weeks of tai chi practice. One study adopted Sun style tai chi practice (13), 2 studies adopted Yang style tai chi practice (16,

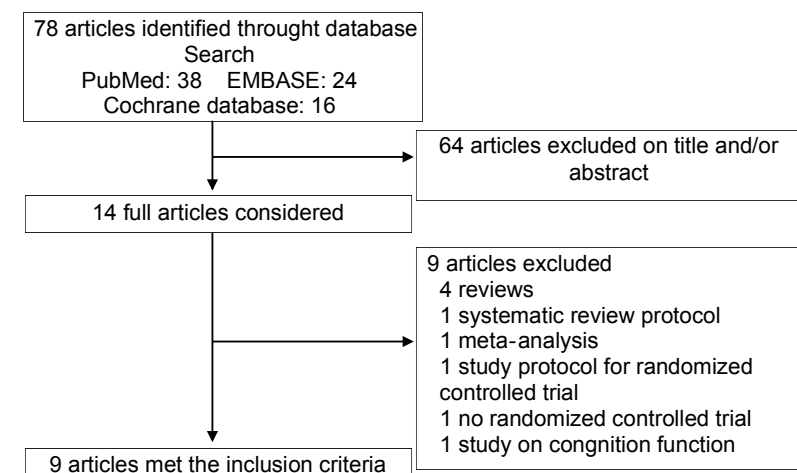


Fig. 1. Characteristics of the randomized trials included in the meta-analysis.

17), and 2 studies did not document the practice style (14, 15). All of the studies aimed to examine the effectiveness of tai chi on standing balance and gait ability of stroke survivors. Specifically, these studies evaluated dynamic and static standing balance, gait ability and quality of life with different outcome indicators, thus standardized mean difference (SMD) was employed for the pooled analysis. However, in the study by Au-Yeung et al. (13), centre of gravity (COG) was employed for dynamic standing balance evaluation, with the authors reporting detailed results in many different conditions, such as leaning forwards or backwards. We considered that it would be too difficult and not sufficiently robust to put all of these results into the pooled analysis data for dynamic standing balance. Standing balance and gait ability were also evaluated in the study by Hart et al. (14), but detailed data could not be obtained after email communication with the authors; thus, we note this study in our systematic review for reference only. The detailed results are listed in Table I.

Quality of included studies

The Cochrane Collaboration Risk of Bias Tool indicated that every article had a high risk of bias. A high holistic risk of bias was related to the evidence for this

systematic review. Randomization was used in each article, and 5 articles were unclear as to whether the authors adopted the method of allocation concealment, blinding of participants, and outcome assessments. All studies reported patients who withdrew from the investigations. The incomplete outcome in all the included articles resulted in a low risk of bias. However, all included studies were considered to have a high risk of bias.

Data analysis

Based on this systematic review, it was found that nearly all of the studies focused mainly on physical health, including static and dynamic balance, and gait ability, except for the study by Taylor-Piliae et al. (17), which was concerned mainly with the safety and feasibility of tai chi. However, their results regarding standing balance, were evaluated with the Short Physical Performance Battery (SPPB), were very detailed, hence we included their results in our pooled analysis. The majority of studies reported better balance and gait ability through tai chi, except for the study by Hart et al. (14), which did not show any improvement in balance and walking after 12 weeks of tai chi. In addition, the raw data in this study were

Table I. Basic characteristics of included studies

Author	Country	Patient characteristic, sample size	Study content	Intervention	Outcome indicator
Kim et al. 2015 (15)	South Korea	22 inpatients diagnosed with stroke (G1: 11; G2: 11); Mean age (SD), years: G1=55.18 (10.20) G2 =53.45 (11.54)	Effects of tai chi on balance, gait, and quality of life in chronic stroke patients.	G1: general physical therapy twice per day, 10 times/week, for 6 weeks; G2:G1+tai chi 60 min/session, twice per week, for 6 weeks.	Standing balance Static balance: gait view AFA-50. Dynamic balance: FRT and DGI. Gait ability: 10MWT and TUG. Quality of life: SF-36.
Au-Yeung et al. 2009 (13)	Hong Kong	136 patients with stroke >6 months (G1: 62; G2: 74); Mean age (SD), years: G1=65.9 (10.7) G2=61.7 (10.5)	Effects of tai chi on standing balance in stroke patients.	G1: breathing and stretching exercises; active mobilization of muscles and joints of the limbs and trunk in sitting and walking; and memory and reasoning exercises; G2: 12 weeks of Sun style tai chi.	Standing balance: Static balance: SOT Dynamic balance: COG excursion. Gait ability: TUG
Hart et al. 2004 (14)	Israel	18 community-dwelling first-stroke survivors (G1: 9; G2: 9);	Effect of tai chi intervention on physical function and quality of life.	G1: 12 weeks of group exercises focusing on improvement of balance for 1 h twice weekly; G2: 12 weeks of tai chi practice for 1 h twice weekly.	Standing balance: RTB, standing on the unaffected leg, BBT. Gait ability: EFAP, TUG Health status: DHP
Taylor-Piliae USA & Coull 2012 (16)	USA	25 community residents with stroke ≥3 months (G1: 12; G2: 13) Mean age (SD), years: G1=64.5 (10.9) G2=72.8 (10.1)	Safety and feasibility of tai chi intervention among stroke survivors.	G1: community-based physical activity suitable for older adults, e.g. SilverSneakers; G2: 60-min Yang style tai chi class 3 times a week for 12 weeks.	Dynamic balance: SPPB; Gait ability: SPPB; a 2-min step-in place test; Quality of life: Short Form-36; PSQI; ESDS;
Taylor-Piliae USA et al. 2014 (17)	USA	145 community residents with stroke ≥3 months (G1: 48; G2:53; G3: 44) Mean age (SD), years: G1=68.2 (10.3) G2=71.5 (10.3) G3=69.6 (9.4)	Effect of tai chi intervention on physical function and quality of life.	G1: community-based physical activity suitable for older adults; G2: 60-min Yang Style tai chi class 3 times a week for 12 weeks; G3: 1-h SilverSneakers class 3 times a week for 12 weeks.	Dynamic balance: SPPB; Gait ability: SPPB; a 2-min step-in place test; Quality of life: Short Form-36; PSQI; ESDS.

G: group; G1: control group; G2: tai chi group; G3: SilverSneakers (SS) group; COG: centre of gravity; FRT: Functional Reach Test; DGI: Dynamic Gait Index; SOT: Sensory Organization Test; 10MWT: 10-m walking test; TUG: Timed Up and Go test; RTB: Romberg Test of Balance; BBT: Berg Balance Test; DHP: Duke Health Profile; SPPB: Short Physical Performance Battery; PSQI: Pittsburgh Sleep Quality Index; ESDS: Epidemiological Studies Depression Scale.

not detailed, and the corresponding author could not be contacted; however, we included this study in our systematic review.

Gait ability

A significant improvement in gait ability was seen with tai chi in stroke survivors, as evaluated with the Timed Up and Go (TUG) test and SPPB. This was proven in the pooled analysis (-0.26 [-0.50~-0.03], $p=0.027$; $I^2=0\%$, $p=0.682$). Due to the different types of continuous outcomes involved, the SMD was employed. In addition, $I^2=0\%$ suggested that heterogeneity across studies was low. Details are given in Fig. 2.

Standing balance

Although the studies by Kim et al. (15) and Au-Yeung et al. (13) reported data on static standing balance, they used different outcome indicators and reported the results according to various test conditions; thus

it was difficult and not robust to pool all of the data. Similarly, the study by Au-Yeung et al. (13) was not included in the pooled analysis for dynamic standing balance. However, there was no significant difference in dynamic standing balance between the tai chi and control groups (0.154 [-0.269~0.578], $p=0.475$; $I^2=26.6\%$, $p=0.256$). The SMD was also used due to different types of continuous outcomes. In addition, $I^2=26.6\%$ suggested that heterogeneity across studies was low (Fig. 3).

Falls or adverse events. In the 2 studies conducted separately in 2012 and 2014 by Taylor-Piliae et al. (16, 17), the main outcome indicators included physical functions (SPPB, fall rates, and the 2-minute step test) and quality of life (Medical Outcomes Study 36-Item Short-Form Health Survey, Center for Epidemiologic Studies Depression Scale, and Pittsburgh Sleep Quality Index). The results indicated that the rate of falls, which have disastrous consequences for the elderly population, was two-thirds lower in the tai chi group

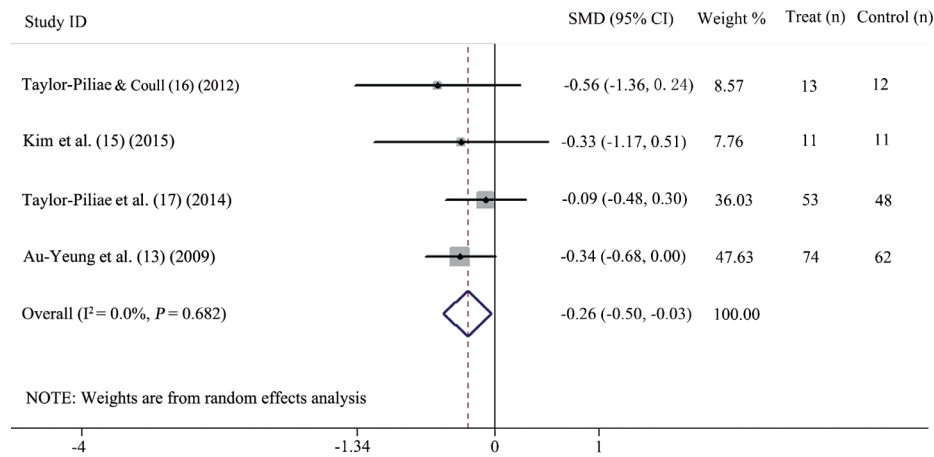


Fig. 2. Pooled results for gait ability between tai chi and control groups. 95% CI: 95% confidence interval; SMD: standardized mean differences.

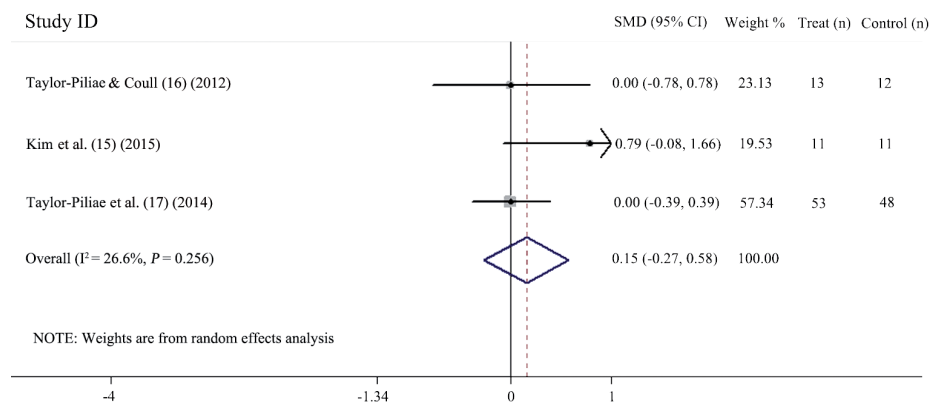


Fig. 3. Pooled results for dynamic standing balance between tai chi and control groups. 95% CI: 95% confidence interval; SMD: standardized mean differences.

(5 falls) than in the movement exercise (14 falls) and usual care (15 falls) groups (Table I).

DISCUSSION

This review found that gait ability was significantly better in the tai chi group compared with the control group according to the pooled TUG and SPPB scores ($-0.26 [-0.50\sim-0.03]$, $p=0.027$; $I^2=0\%$, $p=0.682$), and the heterogeneity across these studies was low. Gait ability is important for stroke patients to prevent falls and worse consequences. Physical activity has a positive impact on quality of life and mental health. Tai chi, as a characteristic physical therapy with a long history, should have similar benefits, and this was proven by the pooled results in the present study. This improvement may be attributed to enhanced neuromuscular responses, better control of the ankle joint of a perturbed leg and balance responses, which were also reported in studies by Gatts & Woollacott (19, 20). Recently, a meta-analysis evaluated the effect of traditional Chinese exercises on gait and balance for stroke patients. These traditional Chinese exercises also included tai chi, but they did not perform a pooled analysis on gait ability due to disunity outcome indicators, although most of these included studies reported better gait ability in the traditional Chinese exercise group (20). In the present study, TUG and SPPB were used to evaluate the effect of tai chi exercise on gait in stroke survivors, thus SMD was employed to calculate the pooled results, and statistically better results were obtained, which are in favour of tai chi. This result was also in accordance with the findings of these original studies.

A short period of tai chi was reported to improve standing balance significantly in studies by Kim et al. (15) and Au-Yeung et al. (13). When practicing tai chi patients have to continuously shift their weight and change the base of support between their 2 feet, while simultaneously performing arm movements. This approach may explain the improvement in standing balance, and these movements and shifting of the centre of gravity are specific to tai chi. In addition, proprioception of the trunk and lower limbs, and the ability to subtly control muscles and joints, may be improved by tai chi training, which may also contribute to better balance control (15). Balance is also important for stroke patients to prevent falls and worse consequences, and this positive effect on falls is also in accordance with the lower fall rate found in studies by Taylor-Piliae et al. in 2014 (17) and 2012 (16); it should be noted that this significant improvement was achieved only after several weeks of tai chi. To some degree, standing balance and gait ability are related;

better gait ability would improve balance control. However, pooled analysis of dynamic standing balance did not show a significant improvement in the tai chi group ($0.154 [-0.269\sim0.578]$, $p=0.475$; $I^2=26.6\%$, $p=0.256$). The evaluation indexes of the curative effects selected in the 6 RCT studies can easily be disturbed by confounding factors (such as the course of the disease, the degree of education, the situation of the combined use of drugs and the level of home care). In a small sample size and parallel-controlled trial it is difficult to reflect the differences between the groups in the therapeutic evaluation index related to rehabilitation. This might be one of the reasons for the similar outcome results between the treatment and control groups in the present literature. We propose that if the experimental purpose is to verify whether the tai chi intervention is an effective rehabilitation therapy, a superiority test should be carried out on the basis of an add-on trial, and the boundary value of superiority should be determined according to the clinical situation. If achievement of positive results is expected with an executable and small cohort of patients, more attention should be paid to a highly sensitive evaluation index and the control of related confounding factors in a future RCT trial design. This would include, for example, the avoidance of an observation index, which is difficult to monitor in short-term interventions, and a reduction in patients' subjective rating scale for functional assessment. In addition, the degree of dysfunction in the patients enrolled should be clearly defined. It is easy to produce "ceiling effects" in patients with mild dyskinesia, which leads to no obvious changes in the condition after treatment. In general, the course of the disease affects the rehabilitation effect (21). Once the patient has the ability to learn tai chi, the earlier the treatment starts the better should be the effect (22). In addition, age was significantly correlated with rehabilitation effects, with increasing age leading to a worse prognosis for recovery (23). However, in the studies by Taylor-Piliae & Coull and Wang et al. (18), the inclusion criteria included age greater than 50 years without upper limits. Thus, it might also be important to determine the age of patients enrolled in a study. There is currently no universal or standard recommendation, however, and previous studies have set different inclusion criteria for the stroke survivors, such as at least 3 months (16) or 6 months (13) after stroke, or the ability to walk 10 m (15) or 6 m (13) independently, or a Mini Mental State Examination score ≥ 24 (13, 15) or ≥ 18 (16).

Furthermore, a low frequency and low intensity of treatments affected the outcomes (24). Increasing the frequency of treatment in the tai chi and control groups may be helpful in order to detect clearer differences

in rehabilitation outcomes between the 2 groups. Due to limited exercise opportunities, hemiplegic patients are often unable to complete the full set of 24-type or 8-type tai chi exercises. Therefore, in subsequent RCT research, several representative actions, such as “move hands like clouds”, “grasp the bird’s tail”, “push stroke squeeze and press”, which can be performed independently or with assistance as means of intervention should be selected (25–27). In future studies, the estimation of cohort size in RCTs should be based on comprehensive factors, such as the evaluation index of curative effects, the statistical analysis method, the baseline values, and the test design.

Study limitations

This systematic review has some limitations. First, no high-quality research reports were included in the review. According to the Cochrane Collaboration Risk of Bias Tool, the included studies have a high risk of bias and, although we did not set language constraints, only English-language articles were found in the search engines and some publications in their native language may not have been included, since they did not appear in the PubMed, EMBASE and Cochrane databases, thus publication bias cannot be excluded. Secondly, most of the previous studies involved small numbers of patients, and only 346 patients were included in our systematic review. The duration of tai chi practice was shorter and its true effect on rehabilitation in stroke survivors may not have been fully manifested. It should also be noted that the included studies were equivalence instead of effectiveness trials, which was not the optimum for the clarification of the effects of tai chi on balance and gait. Thus, these results must be interpreted with caution due to the equivalence trial designs, few involved studies and small cohort sizes.

Conclusion

The results of this study suggest that tai chi has beneficial effects on gait ability in the short term for stroke survivors. However, additional rigorous RCTs with a large cohort of patients and long-term follow-up are needed to determine unequivocally the beneficial effects of tai chi with respect to standing balance and gait ability.

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The authors have no conflicts of interest to declare.

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