

HOSTED BY



Contents lists available at ScienceDirect

International Journal of Nursing Sciences

journal homepage: <http://www.elsevier.com/journals/international-journal-of-nursing-sciences/2352-0132>

Review Article

The effect of Tai Chi exercise on motor function and sleep quality in patients with stroke: A meta-analysis



Yufeng Li, Yajing Zhang, Chuyun Cui, Yaqian Liu, Mengjie Lei, Tingting Liu, Lina Meng, Changde Jin*

Department of Nursing, School of Tianjin University of Traditional Chinese Medicine, China, No.312 Anshan West Road, Nankai District, Tianjin 300193, China

ARTICLE INFO

Article history:

Received 13 February 2017

Received in revised form

15 April 2017

Accepted 6 June 2017

Available online 5 July 2017

Keywords:

Tai Chi exercise

Rehabilitation

Stroke

Meta-analysis

ABSTRACT

Objective: The meta-analysis is to objectively evaluate the efficacy of Tai Chi exercise for motor function and sleep quality in patients with stroke.

Methods: Randomized controlled trials(RCTs) about the effects of Tai Chi versus a non-exercise or conventional rehabilitation exercise control group on motor function and sleep quality in patients with stroke were searched from multiple electronic databases(PubMed, Web of Science, the Cochrane Library, EMBASE, AMED, CBM, CNKI, Wanfang and VIP) until August 2016. Two investigators independently screened eligible studies, extracted data, and assessed the methodological quality by using the quality evaluation criteria for RCTs recommended by Cochrane Handbook. Then meta-analysis was performed by RevMan5.3 software.

Results: A total of 17 RCTs with 1209 participants were included. The meta-analysis indicated that there was a significant difference on improving the balance function($P < 0.001$) and ability of daily activity ($P = 0.0003$) of patients with stroke between Tai Chi group and control group. However, no significant effect was found on Tai Chi for walking function and sleep quality($P > 0.05$).

Conclusion: Tai Chi exercise can significantly improve the balance function and ability of daily activities of patients with stroke, and there are no significant differences in walking function and sleep quality. Therefore, lots of multicenter, large-sample, higher quality randomized controlled trials are needed to verify the effects of Tai Chi exercise in improving walking function and sleep quality for patients with stroke.

© 2017 Chinese Nursing Association. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Stroke, also known as cerebral vascular accident, is a group of acute cerebrovascular diseases which caused by different causes of acute cerebral circulation disorders (cramps, occlusion or rupture) leading to portion or diffuse brain dysfunction [1]. According to reported global estimates, approximately 15 million people suffer from a stroke each year, resulting in 5.5 million deaths, with 5 million cannot live independently because of disability [2]. In 2015, the "Chinese Stroke Prevention Report" pointed out that stroke has become the first leading cause of death among Chinese residents, and the prevalence of stroke continues to increase [3]. Disabilities

following stroke can affect daily living activities of patients and lead to great suffering to patients and heavy economic burdens to the family and society [4]. This trend has profound financial and social consequences [5].

Hence, effectively treating stroke is important. Exercise training can promote spontaneous neural functional recovery in patients with cerebrovascular disease, thereby accelerate the process of functional recovery [6]. In recent years, Tai Chi is popular in stroke patients. All the participants noted various physical, functional, and psychological benefits from participating in the Tai Chi exercise, which was perceived as a good way of integrating various skills learned during rehabilitation [7]. Tai Chi, a kind of traditional Chinese low-moderate intensity aerobic exercise, incorporate slowness, rhythmic movements, relaxation, mental concentration, movement coordination, and flow into the next one with elements of meditation, body awareness, and imagery while breathing deeply [8,9]. Tai Chi exercise mode is a more reasonable way of

* Corresponding author.

E-mail addresses: lyftulip@163.com (Y. Li), jcd1886@sina.cn, jcd1886@hotmail.com (C. Jin).

Peer review under responsibility of Chinese Nursing Association.

rehabilitation exercise, and some studies have found that practicing TaiChi exercise can improve the ability of gait and balance, increase muscle strength for motor system function, and promote good mental state, which was useful for patients with stroke, and even for healthy adults [10,11]. In addition, studies have reported [12,13], Tai Chi exercise can effectively improve the sleep quality of the elderly. Although the results of some clinical studies investigating the effects of Tai Chi exercise on people with stroke have been reported, their findings have not been widely publicized or acknowledged. The objective of this study was to examine the evidence on the effect of Tai Chi exercise for motor function and sleep quality in stroke patients by performing a systematic review and meta-analysis of relevant randomized controlled trials (RCTs).

2. Methods

2.1. Search strategy

We carried on a comprehensive search of the literature in five English databases: PubMed, Web of Science, the Cochrane Library, EMBASE and AMED, and four Chinese databases: CBM, CNKI, Wanfang and VIP databases, which have been searched from their establishment to August 2016. We used following MeSH terms and all field terms when searching. The language was restricted to Chinese and English. The references of all included articles was searched twice and in order to avoid missing literature. The search strategy for PubMed is showed in Table 1.

2.2. Eligibility and exclusion criteria

Research papers selected and analyzed in this study had to meet the following eligibility criteria:

P (population): patients meet the 1995 fourth cerebrovascular disease diagnostic criteria, duration ≤ 6 months, and by electronic computer X-ray tomography technique(CT), magnetic resonance imaging(MRI) confirmed stroke;

I (intervention): TaiChi, Taiji, Tai Ji Quan, Tai Chi Chuan with or without other treatment;

C(comparison):any type of conventional rehabilitation exercise (including general care, routine exercise therapy)

O(outcome): outcome measures followed: (1)Balance function(using the Berg Balance Scale (BBS) to assess); (2)Walking function(using the gait, the Timed Up-and-Go Test(TUG) and Holden walking grading scale to evaluate); (3)Ability of daily activities (using Activities of Daily Living(ADL), Barthel Index, Modified Barthel Index, Tunk Impairment Scale(TIS), physical function scores of Short Form Health Survey 36 (SF-36) and Generic Quality of Life Inventory-74(GQOLI-74) to evaluate); (4) Quality of sleep (using the Pittsburgh Sleep Quality Index(PSQI) to assess).

Table 1
Search strategies.

#1	Stroke[Mesh]
#2	"Apoplexy" OR "Cerebrovascular Accident" OR "Cerebrovascular" OR "Apoplexy Cerebrovascular Stroke"OR"Brain Vascular Accident" OR"Cerebral Stroke" OR "Acute Stroke" OR "Acute Cerebrovascular Accident" [All fields]
#3	#1 OR#2
#4	Tai Chi[Mesh]
#5	"Taiji" OR"Tai Ji Quan"OR "Tai Chi Chuan"[All fields]
#6	#4 OR#5
#7	"randomized controlled trial" OR "random*" OR "RCT"
#8	#3 AND#6 AND#7

MeSH: Medical Subject Heading.

S(study design): RCT, English and Chinese studies were selected.

Studies were excluded if they met any of the following: (1)case reports or reviews or systematic reviews; (2) duplicate record literature; (3) multiple intervention measures, making it difficult to evaluate the effects of a single measure; (4)can not to obtain effective data. After conducting search, two reviewers perused independently the title and abstract of the studies resulting from the search criteria we had set for qualified studies. Furthermore, we thoroughly read the contents of these research papers and considering select those papers that met the criteria of this study.

2.3. Data extraction

Two reviewers screened independently according to the inclusion and exclusion criteria. Each included study is extracted data independently by two reviewers using a pre-designed data extraction form. The following information was extracted:study characteristics (eg, author and year), subjects characteristics (eg, age and number of sample), study design, place of study, description of interventions, duration of trial period and indexes of assessed outcomes. During the processes above, disagreements between the two reviewers were resolved through consulting, if the consensus could not be reached, the third reviewer was consulted for a final decision.

2.4. Risk of bias assessment

The risk of bias was assessed by two reviewers using the Cochrane Handbook for Systematic Reviews of Interventions [14]. Two reviewers assessed independently for risk of bias in each included study. Six components associated with the risk of bias were assessed: randomization sequence generation, allocation concealment, blinding of outcome assessors, incomplete outcome data, selective reporting, and other biases. Each item would be rated as "low risk of bias", "unclear risk of bias", or "high risk of bias" in the light of Cochrane Handbook [14]. In our study, it is impossible to blind researchers and subjects in the non-pharmacological clinical trials. However, it is feasible to blind the outcome assessors (blinding to the study objectives and outcomes). So, for the purposes of this review, blinding of outcome assessors was considered as adequate. The independent evaluation is completed, the two researchers on the evaluation results were discussed and reached a consensus. If there was disagreement, the third researcher was consulted.

2.5. Statistical analysis

The meta-analysis was performed by using the RevMan 5.3 software. When meta-analysis was conducted for continuous variables, if all studies assessed the same outcome by the same scale, the weighted mean difference(WMD) was used as a summary statistic in meta-analysis; if all studies evaluated the same outcome by different scales, the standardized mean difference(SMD) was used as a summary statistic in meta-analysis, and all analysis were calculated 95% confidence interval (95%CI).In meta-analysis, statistical heterogeneity be measured by Chi-square test, I^2 and P value. When $P > 0.1$ and $I^2 < 50\%$, a fixed-effects model would be applied and $P < 0.1$ and $I^2 \geq 50\%$, a random-effects model would be applied if articles were considered clinically similar enough. We only use descriptive analysis if the heterogeneity is too obvious which can not determine the source. Corresponding 95% CI and P value as pooled effect would present the result of meta-analysis. A $P < 0.05$ was considered to be statistically significant. Publication bias was assessed by means of funnel plot and Egger's test of asymmetry [15].

3. Results

3.1. Study selection

The result of search process is presented in Fig. 1. Our search initially obtained 261 relevant articles. 87 studies were duplicates and excluded, 174 remained. Screening of titles and abstracts of the remaining publications, 39 were screened for proper studies, of which 135 were excluded owing to the following reasons: (1) not RCT(12 studies); (2) duplicate paper (29 studies); (3) reviews and case (30 studies); and (4) not related to topic (64 studies). After reading the 39 full-text literature, 22 studies were excluded due to not meet the inclusion criteria or no empirical data. Finally, a total of eligible 17 studies were included in the meta-analysis.

3.2. Study characteristics

This study included 17 RCTs, including 1209 cases, 613 cases in the intervention group and 596 cases in the control group. The study duration ranged from 4 weeks to 48 weeks. Table 2 shows the basic characteristics of the included studies.

3.3. Risk of bias assessment

The risk of bias of the included studies which is presented in the risk of bias graph and risk of bias summary(Figs. 2 and 3). Of 17 included studies, eight studies described the methods of randomization, by computer-generated or random numbers. Five studies revealed that the allocation concealment was adequate. Most of them have problems about blinding, only eight described assessor blinding. Low-level articles were resulted from incomplete outcome data. Even though reported the dropouts, there was no intention-to-treat (ITT) analyses. All seventeen trials reported important outcomes. Consequently, the seventeen studies can be regarded as at low risk in selective outcome reporting bias.

3.4. Meta-analysis results

3.4.1. Comparison of balance function between Tai Chi exercise group and the control group

A total of nine studies [21–28,31] were included in the study, involving 670 cases and the balance function of the stroke patients was evaluated by the Berg Balance Scale. The result of meta-analysis showed a significant heterogeneity($I^2 = 97\%$).

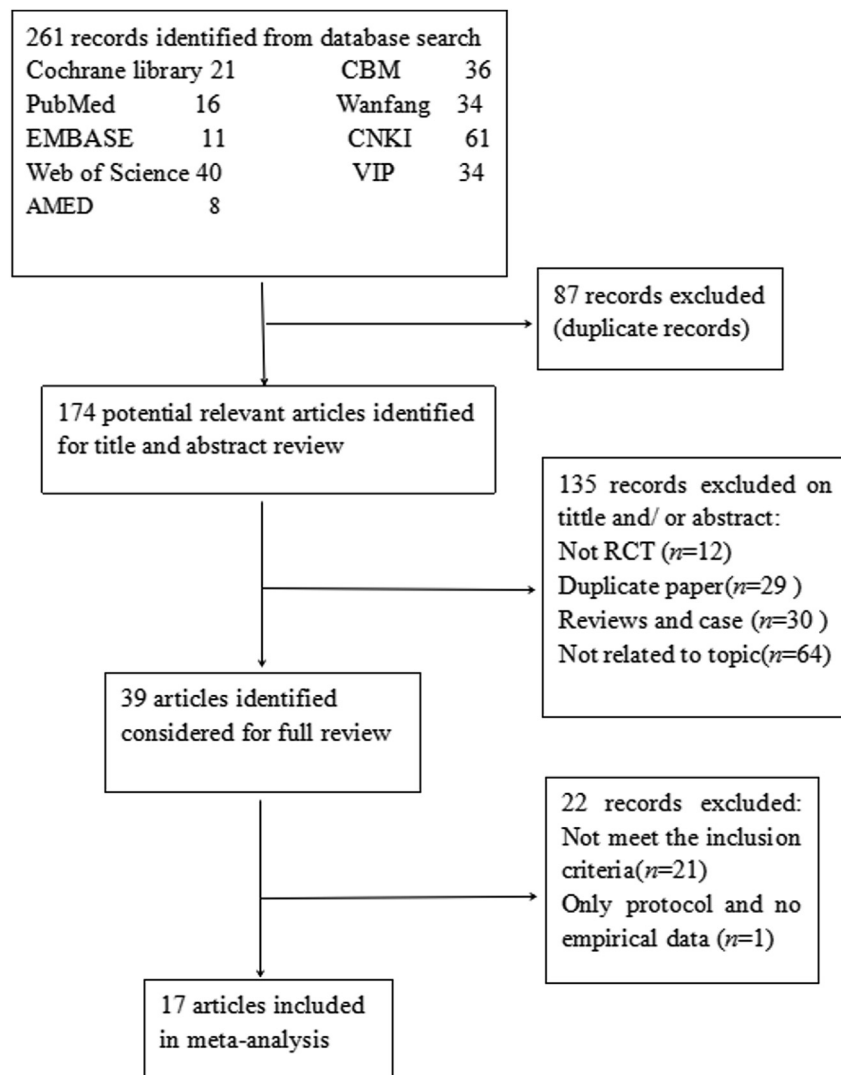


Fig. 1. Flow chart of the study selection procedure. Abbreviations: CBM:China Biology Medicine; CNKI:China National Knowledge Infrastructure; VIP:Chinese Scientific Journal Database; RCT: randomized controlled trial.

Table 2
Characteristics of the included studies.

Author(year)	Study design	Place of study	No.of Participants (T/C)	Age (year) T/C	Intervention		Frequency and duration of Tai Chiexercise	Outcomes
					T	C		
Taylor-Piliae et al. (2012) [16]	RCT	USA	28(16/12)	72.8 ± 10.1/ 64.5 ± 10.9	Yang's 24-posture short-form TaiChi	GC	12 weeks,3 times/week, 60 min/time	SPPB(gait), SF-36 (physical score), PSQI
Taylor-Piliae et al. (2014) [17]	RCT	USA	101(53/48)	71.5 ± 10.3/ 68.2 ± 10.3	Yang's24-posture short-form TaiChi	GC	12 weeks,3 times/week, 60 min/time	SPPB(gait), SF-36 (physical score), PSQI
Au-Yeung et al.(2009) [18]	RCT	Hong Kong, China	136(74/62)	61.7 ± 10.5/ 65.9 ± 10.7	Sun's12-posture short-form TaiChi	GRE	12 weeks,4 h/week	TUG
Kim et al.(2015) [19]	RCT	Korea	22(11/11)	53.45 ± 11.54/ 55.18 ± 10.20	Tai Chi exercise	GRE	6 weeks, twice/week, 60min/time	TUG, SF-36 (physical score)
Wang et al.(2010) [20]	RCT	Japan	29(16/13)	Over 50	Yang's TaiChi Chuan	GRE	12 weeks, once a week, 50min/time	PSQI
Fu et al.(2016) [21]	RCT	Jiangsu China	60(30/30)	59.7 ± 7.6/ 60.3 ± 8.4	24-posture short-form Tai Chi	GRE	8 weeks,6 times/week, 40min/time	BBS, TIS, Holden walking grading scale
Liu et al.(2009) [22]	RCT	Hubei, China	48(24/24)	52.13 ± 14.13/ 53.51 ± 12.63	24-posture short-form Tai Chi	GRE	12 weeks, 30 min/time	BBS
Zhou et al.(2010) [23]	RCT	Henan, China	68(34/34)	52.5 ± 10.8/ 50.4 ± 8.8	Yang's 24-posture short-form Tai Chi	GRE	4 weeks,2 times/week	BBS, GQOLI-74 (physical score)
Zhou(2013) [24]	RCT	Sichuan, China	68(34/34)	62.6 ± 5.7/ 63.3 ± 6.0	Tai Chi exercise	GRE	6 weeks, 10 times/week, 20–30min/time	Gait, BBS, MBI
Zhou(2015) [25]	RCT	Beijing, China	40(21/19)	55.30 ± 9.47/ 54.74 ± 7.02	Tai Chi exercise	Modern rehabilitation technology	4 weeks,5 times/week 60 min/time	BBS, BI
Yang et al.(2013) [26]	RCT	Jilin,China	100(50/50)	54.3 ± 13.8/ 55.2 ± 14.6	Tai Chi balance method	GRE	4 weeks	BBS, BI
Xu et al.(2014) [27]	RCT	Hebei, China	80(40/40)	60.14 ± 10.25/ 48.23 ± 12.32	Tai Chi exercise	GRE	12 weeks,20min/time, 2 times everyday	BBS
Xie(2008) [28]	RCT	Jilin,China	48(24/24)	35–66/ 38–62	Tai Chi exercise	GRE	10 weeks	BBS, MBI
Miu et al.(2014) [29]	RCT	Shandong, China	57(29/28)	Unclear	Yang's 24-posture short-form Tai Chi	GRE	8 weeks,2 times everyday, 30min/time	Gait
Yang et al.(2016) [30]	RCT	Jilin,China	60(30/30)	58.00 ± 11.27/ 60.07 ± 7.87	Tai Chi balance method	GRE	4 weeks, once a day, 15min/time	Holden walking grading scale, BI
Gao et al.(2012) [31]	RCT	Guangdong,China	158(76/82)	65.3 ± 12.2/ 63.5 ± 11.3	Seat type 10-posture Tai Chi	GRE	4 weeks,2 times/day, 60 min/time	BBS, BI
Zheng et al.(2015) [32]	RCT	Guangdong,China	106(51/55)	59 ± 13/ 60 ± 12	Tai Chi exercise	GRE	48 weeks,2 times everyday, 30 min/time	ADL

Abbreviations: RCT:randomized controlled trial; T:Tai Chi group; C:control group; GC:general care; GRE:general rehabilitation exercise; BI:Barthel Index; MBI: modified Barthel Index; BBS:the Berg Balance Scale; TUG:Timed Up-and-Go Test; ADL:Activities of daily living; SF-36:the Short Form Health Survey 36; GQOLI-74: Generic Quality of Life Inventory-74; SPPB:Short Physical Performance Battery; TIS:Tunk Impairment Scale; PSQI:the Pittsburgh Sleep Quality Index.

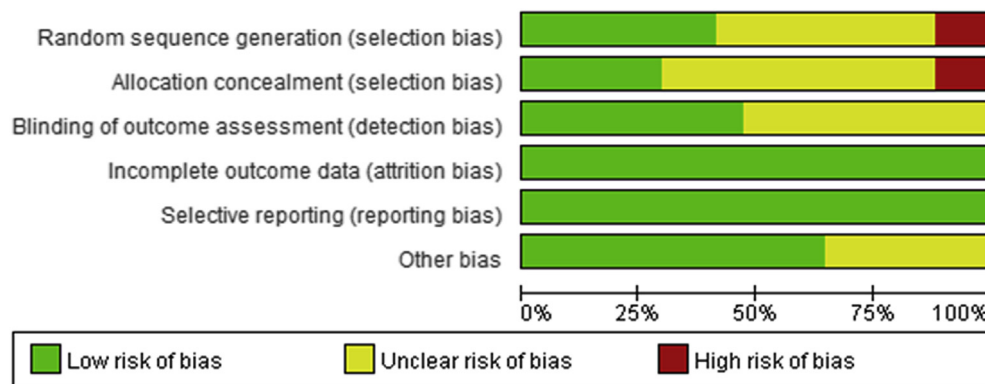


Fig. 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

Considering that the effects of different intervention times, therefore subgroup analyses were conducted. The results of subgroup analysis showed Tai Chi exercise can significantly improve the balance function of stroke patients, less than or equal to 1 month ($MD = 6.13, 95\% CI [5.37, 6.89], P < 0.001$), more than 1 month ($MD = 12.38, 95\% CI [6.67, 18.09], P < 0.001$) (Fig. 4). Therefore, the results of subgroup analysis suggested that different intervention

time is the source of heterogeneity.

3.4.2. Comparison of walking function between Tai Chi exercise group and the control group

Eight studies involving 507 cases [16–19,21,24,29,30]. Four studies [16,17,24,29] of which reported the effects of Tai Chi on the gait of stroke patients. Two studies [18,19] used the Timed Up-and-

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Au-Yeung2009	+	+	+	+	+	?
Fu 2016	+	+	+	+	+	?
Gao2012	+	+	+	+	+	?
Kim2015	+	+	+	+	+	?
Liu 2009	+	+	+	+	+	?
Miu2014	+	+	+	+	+	?
Taylor-Phillips2012	+	+	+	+	+	?
Taylor-Phillips2014	+	+	+	+	+	?
Wang 2010	+	+	+	+	+	?
Xie2008	+	+	+	+	+	?
Xu2014	+	+	+	+	+	?
Yang2013	+	+	+	+	+	?
Yang2016	+	+	+	+	+	?
Zheng2015	+	+	+	+	+	?
Zhou 2010	+	+	+	+	+	?
Zhou 2013	+	+	+	+	+	?
Zhou 2015	+	+	+	+	+	?

Fig. 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

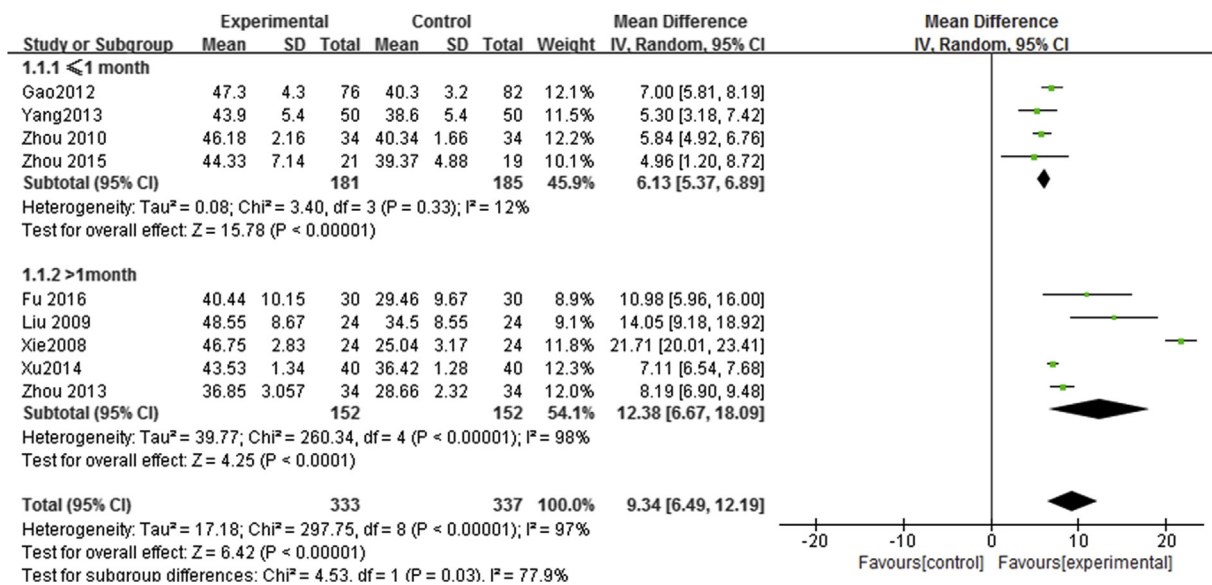


Fig. 4. Comparison of the balance function between Tai Chi exercise group and the control group.

Go Test (TUG) and two studies [21,30] used Holden walking grading scale to assess the effect of Tai Chi exercise on walking ability in stroke patients. Heterogeneity was identified across the included studies ($I^2 = 95\%$). Therefore, meta-analysis was based on random-effects model. The results showed that compared with the control group, Tai Chi did not show effective improvements on gait [$SMD = 1.71, 95\%CI(-0.27,3.70), P = 0.09$] or walking ability [$SMD = 0.12, 95\%CI(-0.31, 0.55), P = 0.59$](Fig. 5).

3.4.3. Comparison of daily activities ability between Tai Chi exercise group and the control group

Twelve studies [16,17,19,21,23–26,28,30–32] involving 856 cases, seven studies used ADL, Barthel index and Modified Barthel index, and five studies used the SF-36, GQOLZ-74 and TIS, that reported the influence of Tai Chi exercise on daily activities ability in patients with stroke. Homogeneity was detected in the incorporated studies ($I^2 = 94\%$), and then a random-effects model was performed. The results showed that, compared with the control group, Tai Chi exercise can improve significantly daily activity ability, the difference was statistically significant [$SMD = 1.21, 95\%CI(0.56, 1.85), P = 0.0003$] (Fig. 6).

Furthermore, we performed a subgroup analysis to eliminate

the heterogeneity caused by the different types of Tai Chi: four studies [16,17,21,23] used 24-posture short-form, the results showed that there was no beneficial performance in the daily activity ability compared with control group [$SMD = 0.39, 95\%CI(-0.02, 0.79), P = 0.06$]; one study used seat type 10-posture [31], the results showed that Tai Chi group showed better improvements on daily activity ability than the control group [$SMD = 4.54, 95\%CI(3.94,5.14), P < 0.001$]; two studies [26,30] used Tai Chi balance method, the results suggested that Tai Chi group showed better improvements on daily activity ability than the control group [$SMD = 1.17, 95\%CI(0.82,1.52), P < 0.001$]; five studies [19,24,25,28,32] used Tai Chi exercise, the results indicated that Tai Chi group showed better improvements on daily activity ability than the control group [$SMD = 1.21, 95\%CI(0.66,1.75), P < 0.001$] (Fig. 6). The results of subgroup analysis suggested that different type of Tai Chi exercise is the source of heterogeneity.

3.4.4. Comparison of sleep quality between Tai Chi exercise group and the control group

Three studies [16,17,20] involving 155 cases reported the sleep quality of patients with stroke by PSQI. Heterogeneity was checked in eligible studies ($P = 0.90, I^2 = 0\%$), hence, we choose a fixed-

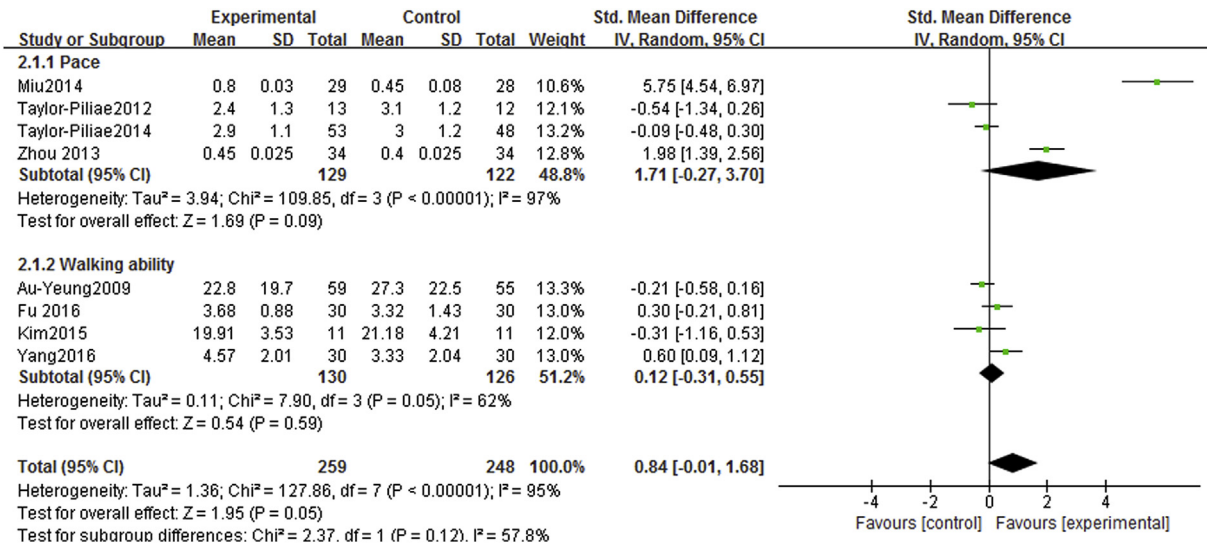


Fig. 5. Comparison of walking function between Tai Chi exercise group and the control group.

effects model. The results of meta-analysis showed that there was no significant difference in sleep quality between Tai Chi exercise and the control groups [WMD = -0.58,95%CI(-1.78,0.61), Z = 0.96,P = 0.34] (Fig. 7).

3.5. Funnel plot of publication bias

When the number of studies incorporated was more than 10, we would use funnel plot analysis publication bias. In this meta-

analysis, we also used a funnel plot to determine the publication bias of daily activity ability, the results of the funnel plot analyses were symmetry, thereby indicating that no publication bias possibly exists in the included trials. (Fig. 8).

4. Discussion

The objective of this meta-analysis was to examine whether Tai Chi exercise is effective in improving stroke patients' motor

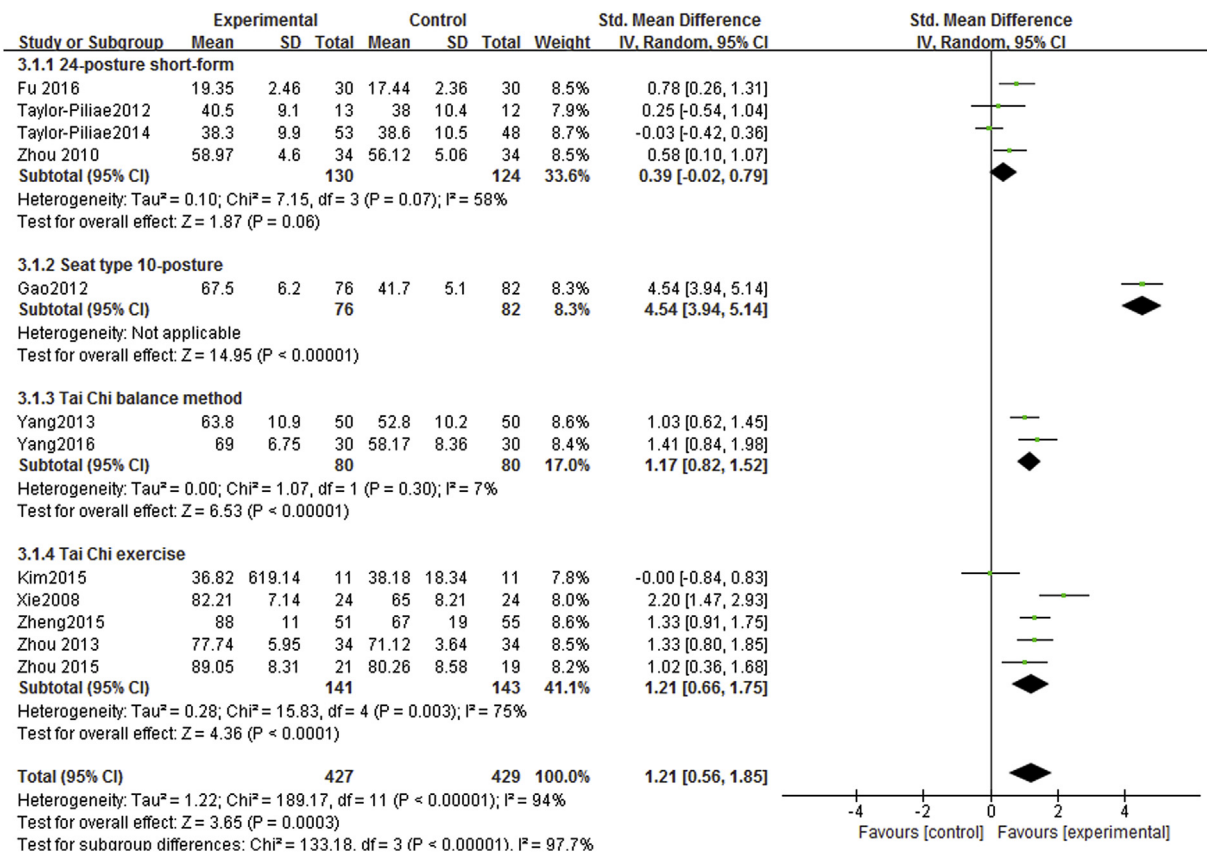


Fig. 6. Comparison of daily activities ability between Tai Chi exercise group and the control group.

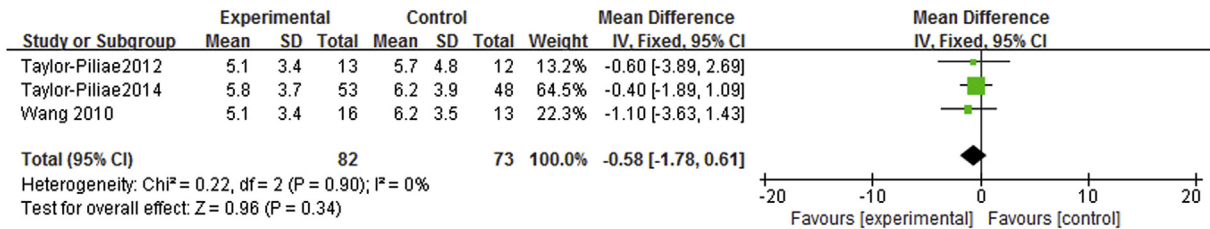


Fig. 7. Comparison of sleep quality between Tai Chi exercise group and the control group.

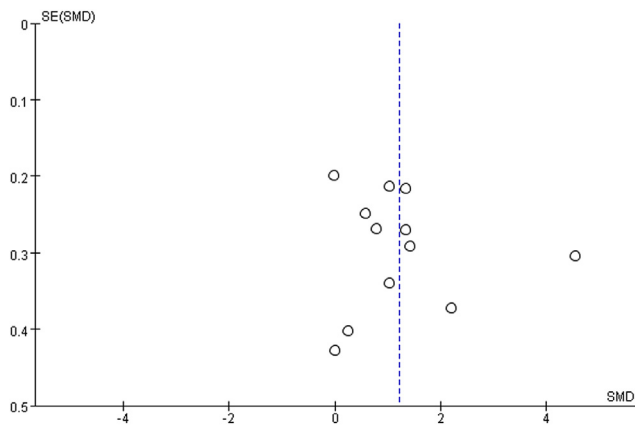


Fig. 8. Funnel plot for publication bias.

function and sleep quality. Our meta-analysis suggests that Tai Chi exercise significantly improves the balance function and ability of daily activity in patients with stroke. This meta-analysis indicated that Tai Chi has benefits in the rehabilitation of physical motor function and should be available in rehabilitation programs as an alternative approach for patients with stroke. For sleep quality, our study found that Tai Chi exercise cannot improve sleep significantly, just with a promising trend ($P = 0.34$).

Tai Chi is the traditional fitness project in our country, which pay attention to inside and outside, can adjust the Yin-Yang, focusing on static and dynamic combination of the overall movement. In our study, Tai Chi exercise on the functional rehabilitation of patients with stroke were related to a comprehensive evaluation, the results of meta-analysis showed that Tai Chi exercise has a significant effect on improving balance function and daily activity ability of stroke patients, which is consistent with that of Hart et al. [33,34]. But for improving the walking function of stroke patients, this study has not found the advantages of Tai Chi exercise. The reasons may be related to disease severity condition of stroke patients, intervention duration, exercise intensity, different measurement methods of researchers and other factors.

Sleep is an important physiological phenomenon and good quality of sleep plays an important role in maintenance of normal physiological activity, physical and mental health. Some studies [35] indicated that about 95% of stroke patients with insomnia and sleep structure disorders. Study [36] has shown that, aerobic exercise can make nerve system of body to produce micro-electrical stimulation which can relieve muscle tension and mental stress, make the cerebral cortex relax, relieve psychological stress. Thereby, which contributes to improve sleep quality of stroke patients. And Tai Chi as a kind of low-moderate intensity aerobic exercise, whose fitness effect has been recognized. A narrative review [37] demonstrated Tai Chi exercise had beneficial effects on outcomes of sleep quality including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep

disturbances, and daytime dysfunction in older adults. However, these results are difficult to confirm the effect of Tai Chi exercise for stroke owing to the unclear controls for evaluating the comparisons and unknown methodological quality in included studies.

However, the results of this meta-analysis showed that, compared with control group, the effect of Tai Chi exercise on sleep quality of patients with stroke had no statistically significant. Analysis of the reasons: sleep quality which may be related with stroke patients own disease level, mental status and other factors. In addition, the number of RCTs included in this study is limited, therefore, the results of this meta-analysis still not determine the superiority of Tai Chi exercise in improving sleep quality of stroke patients.

5. Limitations

The review also presents several limitations. First, due to the characteristics of the sample, the Tai Chi intervention time, impact strength and different methods of evaluation may lead to the results heterogeneity increased; Second, most studies with short duration lacked long-term outcomes; thereby, current results are limited to the immediate effects of Tai Chi, and long-term effect on sleep lacks statistical significance possibly because of the limited number of studies and small sample size; Third, the studies included in the rating scale of outcomes is still no unified standard, and subjective evaluation high, which may influence the reliability of the results of this study.

6. Implications for further research

Tai Chi is clearly an appropriate option for the motor function rehabilitation of patients with stroke because it has significant advantages in terms of enhance balance function and ability of daily activities. However, due to the restriction of small number of papers and the lack of long-term follow-up evaluation of intervention effects, it is impossible to evaluate accurately the advantages of Tai Chi exercise in improving walking function and sleep quality of stroke patients. Further studies are needed to improve the validity and reliability of the study and provide more reliable evidence for clinical practice, we should consider improving research designs of RCTs, following as: (1) blinding to randomization and implementation; (2) more RCTs with rigorous design, multi-center and large sample; and (3) a longer study period to assess the long-term effects of Tai Chi exercise on walking function and sleep quality in stroke patients.

7. Conclusion

In summary, this systematic review showed that the effect of Tai Chi exercise on the rehabilitation of patients with stroke has certain help, mainly in the balance function and ability of daily activities. Because of the restriction of sample, it may not evaluate accurately the advantages of improving walking function and sleep quality.

Therefore, future research results from RCTs with more rigorous standards must be obtained to overcome the limitations of our existing data, and reach more reliable conclusions.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.ijnss.2017.06.001>.

References

- [1] Sarti C, Rastenyte D, Cepaitis Z, Tuomilehto J. International trends in mortality from stroke, 1968–1994. *Stroke* 2000;31(7):1588–601.
- [2] Taylor-Piliae RE, Haskell WL. Tai Chi exercise and stroke rehabilitation. *Top Stroke Rehabil* 2007;14(4):9–22.
- [3] Wang LD. China stroke prevention report [M]. Beijing: Peking Union Medical College press; 2015.
- [4] Lalu RE. Changes in the quality of life of cerebral stroke patients in the first year after rehabilitation. *Z Gerontol Geriatr* 2003;36(6):484–91.
- [5] He Q, Wu C, Luo H, Wang ZY, Ma XQ, Zhao YF, et al. Trends in in-hospital mortality among patients with stroke in China. *PLoS One* 2014;9(3):e92763.
- [6] Krakauer JW. Motor learning: its relevance to stroke recovery and neuro rehabilitation. *Curr Opin Neurol* 2006;19(1):84–90.
- [7] Desrochers P, Kairy D, Pan S, Corriveau H, Tousignant M. Tai chi for upper limb rehabilitation in stroke patients: the patient's perspective. *Disabil Rehabil* 2016;27:1–7.
- [8] Wang XQ, Huang LY, Liu Y, Li JX, Wu X, Li HP, et al. Effects of tai chi program on neuromuscular function for patients with knee osteoarthritis: study protocol for a randomized controlled trial. *Trials* 2013;14:375.
- [9] Zheng G, Huang M, Liu F, Li S, Tao J, Chen L. Tai Chi Chuan for the primary prevention of stroke in middle-aged and elderly adults: a systematic review. *Evid Based Complement Altern Med* 2015;742152.
- [10] Zheng G, Li S, Huang M, Liu F, Tao J, Chen L. The effect of tai chi training on cardiorespiratory fitness in healthy adults: a systematic review and meta-analysis. *PLoS One* 2015;10(2):e0117360.
- [11] Li F, Harmer P, Fitzgerald K, Eckstrom E, Stock R, Galver J, et al. Tai chi and postural stability in patients with Parkinson's disease. *N. Engl J Med* 2012;366(6):511–9.
- [12] Nguyen MH, Kruse A. A randomized controlled trial of Tai Chi for balance, sleep quality and cognitive performance in elderly vietnamese. *Clin Interventions Aging* 2012;7(3):185–90.
- [13] Hosseini H, Esfirizi MF, Marandi SM, Rezaei A. The effect of Tai Chi exercise on the sleep quality of the elderly residents in Isfahan, Sadeghieh elderly home. *Iran Nurs Midwifery Res* 2011;16(1):55–60.
- [14] Higgins JPT, Green S. *Cochrane handbook for systematic reviews of interventions* version 5.1.0 [M]. London: The Cochrane Collaboration; 2011.
- [15] Egger M, Davey SG, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *Br Med J* 1997;315(7109):629–34.
- [16] Taylor-Piliae RE, Coull BM. Community-based Yang-style Tai Chi is safe and feasible in chronic stroke: a pilot study. *Clin Rehabil* 2012;26(2):121–31.
- [17] Taylor-Piliae RE, Hoke TM, Hepworth JT, Latt D, Najafi B, Coull BM. Effect of Tai Chi on physical function, fall rates and quality of life among older stroke survivors. *Arch Phys Med Rehabil* 2014;95(5):816–24.
- [18] Au-Yeung SS, Hui-Chan CW, Tang JC. Short-form Tai Chi improves standing balance of people with chronic stroke. *Neurorehabil Neural Repair* 2009;23(5):515–22.
- [19] Kim H, Kim YL, Lee SM. Effects of therapeutic Tai Chi on balance, gait, and quality of life in chronic stroke patients. *Int J Rehabil Res* 2015;38(2):156–61.
- [20] Wang W, Sawada M, Noriyama Y, Arita K, Ota T, Sadamatsu M, et al. Tai Chi exercise versus rehabilitation for the elderly with cerebral vascular disorder: a single-blinded randomized controlled trial. *Psychogeriatrics* 2010;10(3):160–6.
- [21] Fu CX, Zhang QY. Effects of Tai Chi Chuan on balance function and walking ability of stroke patients with hemiplegia. *J Sci* 2016;31(05):536–9.
- [22] Liu TJ, Qin P, Chen XZ. The effect of Taijiquan on improving the balance function of stroke patients. *Chin J Phys Med J Rehabilitation* 2009;31(11):781–2.
- [23] Zhou QA, Xu JY, Hu AP. The influence of Tai Chi Chuan on the rehabilitation of patients with cerebral infarction. *China Pract nerve Dis* 2010;13(22):20–2.
- [24] Zhou ZG. The effect of intensive Tai Chi gait training on gait parameters and walking ability in stroke patients with hemiplegia in Chengdu. *Medical University*; 2013.
- [25] Zhou L. The clinical curative effect of the improved Tai Chi Chuan applied to the rehabilitation of patients with ischemic stroke. *Beijing traditional Chinese Medicine Learn*; 2015.
- [26] Yang ZB, Liu D, Sun P, Zhao GD, Jia L. Clinical Tai Chi balance method in treatment of post-stroke hemiplegia balance disorders research. *Contemp Med* 2013;19(24):5–7.
- [27] Xu XD, Bai J, Zhang HL, Wang LC. Tai Chi on hemiplegia after stroke balance dysfunction in patients with stroke. *J Hebei Chin Med* 2014;08:1149–50. +1198.
- [28] Xie F. *Rehabilitation of stroke patients with balance disorders by Tai Chi rehabilitation*. Jilin University; 2008.
- [29] Miu T, Dai XN, Yan WJ, Liu J. Effect of Taijiquan training on gait parameters in patients with hemiplegic stroke. *China Sanat Med* 2014;11(13):987–8.
- [30] Yang ZB, Liu D, Chang YS, Jia L, Qiao H. Clinical analysis of Tai Chi balance method in treatment of stroke hemiplegia after walking dysfunction. *Mod distance Educ traditional Chin Med China* 2016;14(15):81–3.
- [31] Gao BJ, Feng YZ, Li QN, Li MP, Yang HF, Yin XM. The therapeutic effect of Taiji ten exercise on stroke patients with hemiplegia. *Massage Rehabilitation Med Study* 2012;03(7):71–2.
- [32] Zheng WC, Zhang YH, Jiang XQ, Chen RY, Xiao WM. Continuous Taijiquan curative effect on ischemic stroke patients before rehabilitation A prospective randomized, controlled. *J Cardiovasc* 2015;13(3):304–7.
- [33] Hart J, Kanner H, Gilboa-Mayo R, Haroeh-Peer O, Rozenthul-Sorokin N, Eldar R. Tai chi chuan practice in community-dwelling persons after stroke. *Int J Rehabil Res* 2004;27(4):303–4.
- [34] Rabadi MH. Review of the randomized clinical stroke rehabilitation trails in 2009. *Med Sci Monit* 2011;17(2):460–7.
- [35] Zhou J. Characteristics and influencing factors of sleep disorders in patients with stroke: journal of the Chinese. *J Cerebrovasc Dis* 2005;2(4):173–4.
- [36] Wei MZ, Li WZ, Lin L. The effect of aerobic exercise on the quality of sleep in the recovery period of stroke patients. *China Pract Med* 2011;6(16):24–5.
- [37] Du SZ, Dong JS, Zhang H, Jin SJ, Xu GH, Liu ZX, et al. Taichi exercise for self-rated sleep quality in older people: A systematic review and meta-analysis. *Int J Nurs Stud* 2015;52(1):368–79.