Intervention effect of taijiquan exercises on the ankle joint of the elderly – meta analysis

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A Study Design
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Abstract

Background & Study Aim: Ankle sprain is the most common sports injury clinically, especially among the elderly. Once injured, it will seriously affect the patient's motor function and quality of life. As a traditional Chinese exercise, tai chi has always been favoured by the masses. The purpose of this systematically review is to know about the effects of tai chi on the ankle joints of the elderly.

Material & Methods: Computer searched PubMed, EMBASE, Web of Science, The Cochrane Library, CNKI, Wanfang database and VIP database for randomized controlled trials on the effects of taijiquan on the ankle joints of the elderly. The retrieval time was from the establishment of the database to December 2022. The software Review Manager 5.3 produced by the Cochrane Collaboration was used for statistical analysis, and continuous variables were expressed by standardized mean differences (SMD). Interval estimates are all with 95% confidence intervals (95% CI); significance level $\alpha = 0.05$.

Results: A total of 20 literatures were included, with a total of 1,080 subjects. The results of meta analysis showed that after tai chi exercise, the elderly had improved muscle strength [SMD = 1.03, 95% CI (0.73-1.34), $p<0.00001$], proprioception [SMD = 1.26, 95% CI (0.72-1.80), $p<0.00001$], balance ability [SMD = 0.68, 95% CI (0.59-0.77), $p<0.00001$], were better than the control group, with statistical significance.

Conclusion: Tai chi exercise can improve ankle muscle strength, proprioception, and balance in the elderly. In recommendations addressed to people with various diseases particular care should be taken (the review refers to the results of examinations of healthy people) and consultations with specialists in medicine and physiotherapy.

Keywords: balance ability • muscle strength • proprioception • randomized controlled trials

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Balance – *noun* **1.** the act of staying upright and in a controlled position, not stumbling or falling **2.** a state of emotional and mental stability in which somebody is calm and able to make rational decisions and judgments **3.** the proportions of substances in a mixture, e.g., in the diet [51].

Muscle strength – essential and basic physical capacity in combat sports by which the body moving status is modified [52, 53].

Proprioception – sensory information that comes primarily from sources in the muscles and joints and from bodily movements [54].

Varus – adj. describing any deformity that displaces the hand or foot towards the midline [55].

INTRODUCTION

Ankle sprain is the most common sports injury clinically, especially among the elderly. Once injured, it will seriously affect the patient's motor function and quality of life. As a traditional Chinese exercise, *tai chi* has always been favoured by the masses. *Tai chi* has a unique way of movement, most of which is performed in a half-squat position [1], requiring the body to perform a continuous shift of the centre of gravity, integrating posture control, trunk rotation, weight transfer and strength enhancement [2], all of which are conducive to balance and increased muscle strength [1]. Compared with other forms of exercise, *tai chi* practice has lower requirements on equipment, venues, and accompanying personnel, and is easy to promote [3, 4].

Clarifying the unique effect and mechanism of *tai chi* practice on enhancing ankle function in the elderly will help to further scientifically and widely promote *tai chi* exercise and reduce the risk of injury in the elderly. The conclusions from a reliable review of randomized controlled trials (RCT), can be used to further popularizing *tai chi* exercises among the elderly.

The purpose of this systematically review is to know about the effects of *tai chi* on the ankle joints of the elderly.

MATERIAL AND METHODS

Search method

PubMed, EMBASE, Web of Science, The Cochrane Library, China National Knowledge Network, Wanfang Database and VIP Database were searched, and the retrieval time limit was from the establishment of the database to December 2022. Chinese search formula: (Tai Chi OR Tai Chi) (elderly OR elderly) AND (ankle).

English search: "Tai Ji" OR "Tai Chi" OR "Tai Ji Quan" OR "Tai Chi Chuan"; "ankle" OR "Talocrural Joint" OR "Articulatio talocruralis" OR "Distal Tibiofibular Joint" OR "Tibiofibular Joint, Distal" OR "Inferior Tibiofibular Joint" OR "Tibiofibular Syndesmosis".

The search is carried out by combining subject terms with free words, and at the same time, the references included in the research are added to supplement the relevant literature.

Inclusion and exclusion criteria

The literature was screened according to the PICO principle [5, 6]. The inclusion criteria are as follows. Research objects: elderly people over 55 years old. Intervention measures: *tai chi*. Control group: other exercise interventions other than *tai chi*, such as stretching, brisk walking, etc. Results: Ankle joint function indicators, including muscle strength, proprioception, and balance ability. Research design: RCT; Chinese and English literature.

Exclusion criteria: Participants were hospitalized, frail, or had any overt disease related to the decline of balance, mobility and motor function, including neurological dysfunction (such as stroke, Parkinson's), cardiovascular disease (such as hypertension, Heart failure, etc.), visual impairment, hearing impairment, active arthritis, arthroplasty or fusion, any limb amputation or surgery, psychological problems, etc.; no control group; duplicate publication; abstracts, reviews, conference articles, Case reports; Non-Chinese and English literature.

Study selection

According to the inclusion and exclusion criteria, 2 researchers searched the full text of the included literature and extracted relevant data independently. The specific extraction content is as follows. Basic information of included studies: first author, year of publication, country/region. Basic information of participants: gender, age, sample size. Basic information of intervention measures: intervention measures, intervention time, and intervention frequency. Basic information of the control group: intervention measures, intervention time, and intervention frequency. Outcome measurement: Ankle joint function evaluation index. If there is a disagreement between the 2 investigators, a third investigator will be consulted until a consensus is reached. If the data in the research report is incomplete, further contact the author of the study to obtain it. If the relevant data is not obtained in the end, the study will be excluded.

Quality assessment and risk of bias

The risk of bias of the included literature was evaluated using the RCT risk of bias tool recommended in Cochrane Handbook 5.1.0. Evaluation indicators include: random sequence generation, allocation concealment, blinding of researchers and subjects, blinded evaluation of study outcomes, completeness of outcome data, reporting bias and other biases. For each evaluation index, make evaluation judgments of high risk, low risk and unclear risk. Two researchers independently evaluated the risk of bias of the included studies, and in case of disagreement, they negotiated with the third researcher until a consensus was reached [7].

Data analysis

The software Review Manager 5.3 produced by the Cochrane Collaboration was used for statistical analysis, and continuous variables were expressed by standardized mean differences (SMD). Interval estimates are all with 95% confidence intervals (95% CI). Significance level $\alpha = 0.05$. Use I^2 and p to test whether there is heterogeneity among the studies. When $p \geq 0.1$ and $I^2 \leq 50\%$, the heterogeneity among the studies is small; if $p < 0.1$ and $I^2 > 50\%$, the heterogeneity among the studies If the heterogeneity is large, analyse the source of heterogeneity, reduce the heterogeneity through subgroup analysis or sensitivity analysis, and then use the fixed effect model for meta analysis. If there is no obvious clinical heterogeneity, use random effects meta analysis was performed on the model; if the heterogeneity was too large, only descriptive analysis was performed.

Literature screening results and process

Finally, 20 articles [8-27] were included, the literature screening process is shown in (Figure 1).

RESULTS

Basic characteristics of included studies

Total 20 articles were published between 2005 and 2022, from the China, Japan South Korea, United Kingdom, United States, and other countries, with a total of 1,080 participants. There are 20-120 subjects in a single study. Regardless of two or three parallel experiments, the experimental group was *tai chi* (without distinguishing the types of *tai chi*), and the control group mostly had no intervention, or the intervention

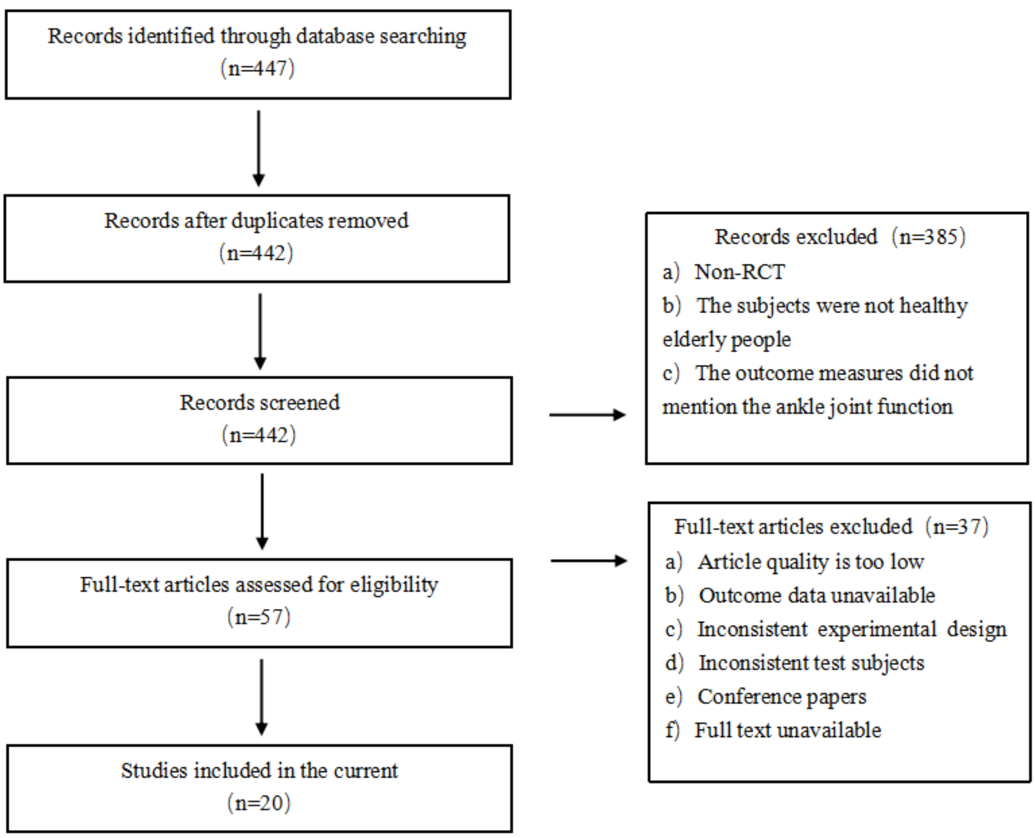

Figure 1. Literature screening process (the literature screening process).

measures were other sports such as brisk walking. The subjects are basically over 55 years old; the intervention time ranges from 3 to 24 weeks (Table 1).

Quality of included studies

The 20 included RCTs [8-27] all reported the baseline conditions of the participants, and all mentioned "random"; the data of the 20 RCTs were all reported completely (Figure 2 and 3).

Table 1. Basic characteristics of included studies.

The first author	Country or region	Sample size	Age	Means of intervention		Intervention does			Outcomes
				TG	CG	weeks	weekly frequency	minutes	
2005 Choi et al. [8]	Korea	T=29	76.96±7.7	Sun-style tai chi	maintained their routine activities	12	3	35	SLO SLC; Muscle strength; Functional Reaching Test
		C=30	78.73±6.9						
2006 Gatts et al. [9]	America	T=11	68-92	TC	Health education	3	5	90	TUGT; FR; single right/left leg stance, tandem stance right/left leg behind; EMG
		C=8	68-92						
2007 Li et al. [10]	China	T=11	71.8±7.1	TC	bingo, card playing, knitting or similar activities	24	1	60	A timed single-foot stance without vision, The Heel-Rise test
		C=9	71.8±7.1						
2008 Li et al. [11]	England	T=22	65.2±2.9	TC	No intervention	16	4	60	SLO; SLC; TSC; ankle motion sense between plantar flexion and dorsiflexion
		C=18	64.5±2.2						
2009 Li et al. [12]	China	T=25	64.9±3.2	24-form TC	No intervention	16	4	60	Muscle strength; EMG
		C=25	65.6±3.5						
2009 Yang et al. [13]	Japan	T=41	77.4±4.0	8-form TC	Aerobic exercise	12	1	70	TUGT; FR
		C=39	77.2±3.9						
2012 Liu et al. [14]	China	T=20	70.5±2.1	TC	No intervention	16	2	45	Muscle Strength Test; Ankle Joint Position Passive Matching Test
		C=20	68.6±1.6						
2013 Wang et al. [15]	China	T=40	65-75	24-form TC	No intervention	24	3	60	Balance ability test
		C=40	65-75						
2016 Chang et al. [16]	China	T=22	60.63±2.65	TC	No intervention	24	4	60	Ankle kinaesthesia
		C=21	60.80±2.91						
2016 Wang et al. [17]	China	T=20	57.3±6.5	TC	No intervention	16	1~2	45-60	Single leg stance
		C=20	55.2±6.2						
2016 Ye et al. [18]	China	T=17	55.38±60.8	TC	No intervention	24	3	30-60	Balance ability test
		C=22	57.02±8.47						

The first author	Country or region	Sample size	Age	Means of intervention		Intervention does			Outcomes
				TG	CG	weeks	weekly frequency	minutes	
2016 Zhu et al. [19]	China	T=30	64.0±3.0	24-form TC+Original treatment plan	sarcopenia health education + conventional treatment plan	72	5	60	TUGT; BBS
		C=30	64.0±4.0						
2017 Cheng et al. [20]	China	T=20	60.2±2.60	TC	No intervention	24/48	unclear	unclear	Ankle Kinesthesia test
		C=19	60.3±2.87						
2017 Guan et al. [21]	China	T=40	≥60	24-form simplified TC + conventional treatment	Parkinson basic treatment and routine training	24	≥5	≥60	BBS
		C=40	≥60						
2017 Pan et al. [22]	China	T=23	68.61±3.40	24-form TC	Health education	24	unclear	60	TUGT; FR; BBS; Ankle isokinetic strength test
		C=23	64.53±3.43						
2017 Ye et al. [23]	China	T=25	61.9±6.62	24-form simplified TC	No intervention	12	3	45	Balance ability test
		C=25	68.9±8.67						
2019 Penn et al. [24]	China	T=15	75.27±5.20	TC	Health education	8	3	30	BBS; TUGT; FR; Lower-extremity muscle strength
		C=15	75.27±5.20						
2020 Liang et al. [25]	China	T=25	60.5±4.5	24-form TC	No intervention	16	3~5	60~90	Ankle isokinetic strength test; Balance ability test
		C=25	60.2±4.8						
2020 Ma et al. [26]	China	T=50	68.15±4.67	24-form simplified TC	No intervention	24	>4	>30	BBS
		C=45	66.69±4.11						
2022 Jing et al. [27]	China	T=60	71.04±5.86	Chen-style TC	Walking	72	6	60	Ankle isokinetic strength test
		C=60	70.49±5.10						

Note: **BBS** Berg Balance Scale; **EMG** Electromyogram; **FR** Function Reaching Test; **SLC** Single leg stance with eyes closed; **SLO** Single leg stance with eyes open; **TSC** Tandem stance with eyes closed; **TUGT** Timed Up and Go Test

Meta analysis

Many studies have shown [28] that the decline in ankle joint function in the elderly may be related to changes in muscle activation rate, impaired proprioception, and decreased balance control. Since the important structures to maintain the stability of the ankle joint are the large and small muscle groups around the ankle joint, as well as the proprioception of the ankle joint and the control of muscle nerves [29], changes in these factors will inevitably affect the stability of the ankle joint.

Ankle muscle strength

A total of 8 literatures [8, 10, 12, 14, 22, 24, 25, 27] were included. The results of heterogeneity analysis showed: $I^2 = 74\%$, $p < 0.00001$, using random effect model (Figure 4 and 5).

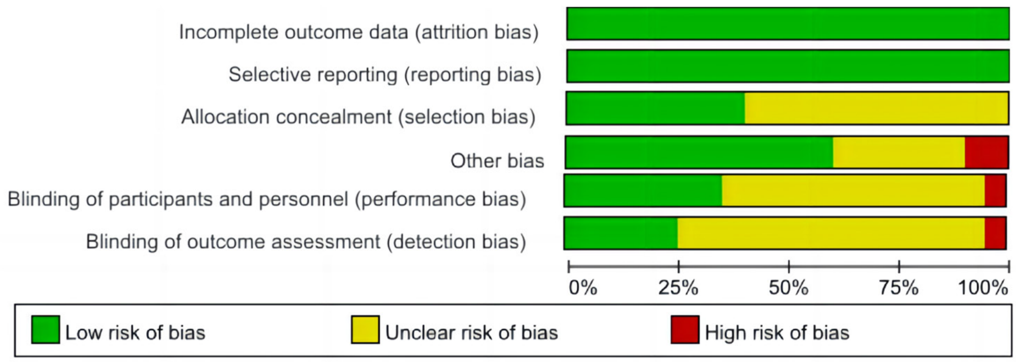

Figure 2. Percentage of text bias items (ordinal variable: from the largest proportion of declarations of "low…" in each result set).

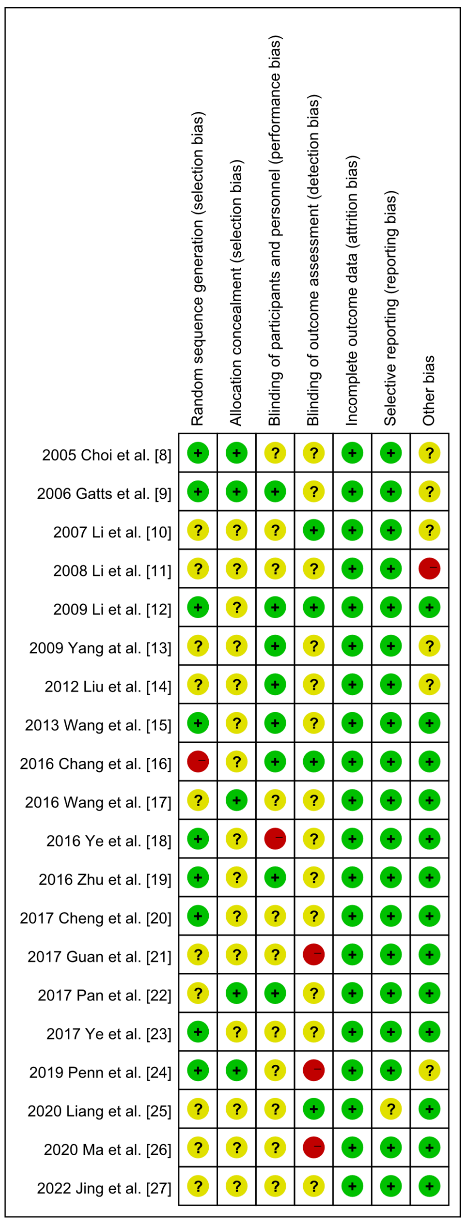

Figure 3. Visualization of the data presented in Table 1 and Figure 2.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
2005 Choi et al. [8]	0.22	6.38	29	-6.87	6.94	30	6.9%	1.05 [0.50, 1.60]
2005 Choi et al. [8]	2.22	4.01	29	-2.56	4.87	30	6.9%	1.06 [0.51, 1.60]
2007 Li et al. [10]	59	28	11	23	15	9	4.5%	1.49 [0.47, 2.51]
2009 Li et al. [12]	1.22	3.54	25	-0.74	2.66	25	6.8%	0.62 [0.05, 1.18]
2009 Li et al. [12]	14.21	12.09	25	9.85	10.26	25	6.8%	0.38 [-0.18, 0.94]
2012 Liu et al. [14]	0.98	0.1	20	0.82	0.04	20	5.6%	2.06 [1.28, 2.84]
2012 Liu et al. [14]	1.01	0.1	20	0.92	0.1	20	6.3%	0.88 [0.23, 1.53]
2012 Liu et al. [14]	0.31	0.04	20	0.22	0.03	20	5.3%	2.50 [1.65, 3.34]
2012 Liu et al. [14]	0.34	0.03	20	0.26	0.03	20	5.2%	2.61 [1.75, 3.48]
2017 Pan et al. [22]	0.04	0.14	23	0.03	0.14	23	6.7%	0.07 [-0.51, 0.65]
2017 Pan et al. [22]	0.01	0.04	23	-0.01	0.05	23	6.7%	0.43 [-0.15, 1.02]
2019 Penn et al. [24]	14	2.8	15	11.81	2.69	15	5.8%	0.78 [0.03, 1.52]
2019 Penn et al. [24]	14.47	3.18	15	11.52	2.78	15	5.7%	0.96 [0.20, 1.72]
2020 Liang et al. [25]	41.3	7.6	25	35.3	7.1	25	6.7%	0.80 [0.22, 1.38]
2020 Liang et al. [25]	17.7	4.1	25	13.1	3	25	6.5%	1.26 [0.65, 1.87]
2022 Jing et al. [27]	140.94	27.98	60	125.65	20.12	60	7.8%	0.62 [0.26, 0.99]
Total (95% CI)			**385**			**385**	**100.0%**	**1.03 [0.73, 1.34]**

Heterogeneity: Tau² = 0.28; Chi² = 57.42, df = 15 (p < 0.00001); I² = 74%
Test for overall effect: Z = 6.61 (p < 0.00001)

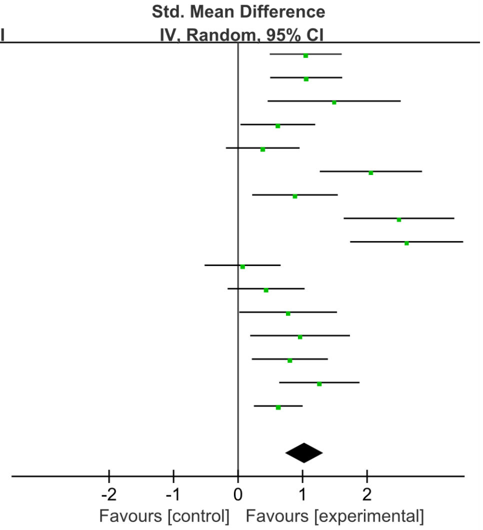

Figure 4. The forest plot of the meta analysis of ankle muscle strength in the *tai chi* group and the control group.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
9.1.1 ≤16								
2005 Choi et al. [8]	0.22	6.38	29	-6.87	6.94	30	6.9%	1.05 [0.50, 1.60]
2005 Choi et al. [8]	2.22	4.01	29	-2.56	4.87	30	6.9%	1.06 [0.51, 1.60]
2009 Li et al. [12]	1.22	3.54	25	-0.74	2.66	25	6.8%	0.62 [0.05, 1.18]
2009 Li et al. [12]	14.21	12.09	25	9.85	10.26	25	6.8%	0.38 [-0.18, 0.94]
2012 Liu et al. [14]	0.98	0.1	20	0.82	0.04	20	5.6%	2.06 [1.28, 2.84]
2012 Liu et al. [14]	1.01	0.1	20	0.92	0.1	20	6.3%	0.88 [0.23, 1.53]
2012 Liu et al. [14]	0.31	0.04	20	0.22	0.03	20	5.3%	2.50 [1.65, 3.34]
2012 Liu et al. [14]	0.34	0.03	20	0.26	0.03	20	5.2%	2.61 [1.75, 3.48]
2019 Penn et al. [24]	14	2.8	15	11.81	2.69	15	5.8%	0.78 [0.03, 1.52]
2019 Penn et al. [24]	14.47	3.18	15	11.52	2.78	15	5.7%	0.96 [0.20, 1.72]
2020 Liang et al. [25]	17.7	4.1	25	13.1	3	25	6.5%	1.26 [0.65, 1.87]
2020 Liang et al. [25]	41.3	7.6	25	35.3	7.1	25	6.7%	0.80 [0.22, 1.38]
Subtotal (95% CI)			**268**			**270**	**74.4%**	**1.19 [0.83, 1.55]**
Heterogeneity: Tau² = 0.28; Chi² = 39.69, df = 11 (p < 0.0001); I² = 72%								
Test for overall effect: Z = 6.52 (p < 0.00001)								
9.1.2 >16								
2007 Li et al. [10]	59	28	11	23	15	9	4.5%	1.49 [0.47, 2.51]
2017 Pan et al. [22]	0.04	0.14	23	0.03	0.14	23	6.7%	0.07 [-0.51, 0.65]
2017 Pan et al. [22]	0.01	0.04	23	-0.01	0.05	23	6.7%	0.43 [-0.15, 1.02]
2022 Jing et al. [27]	140.94	27.98	60	125.65	20.12	60	7.8%	0.62 [0.26, 0.99]
Subtotal (95% CI)			**117**			**115**	**25.6%**	**0.54 [0.12, 0.96]**
Heterogeneity: Tau² = 0.09; Chi² = 6.18, df = 3 (p = 0.10); I² = 51%								
Test for overall effect: Z = 2.54 (p = 0.01)								
Total (95% CI)			**385**			**385**	**100.0%**	**1.03 [0.73, 1.34]**

Heterogeneity: Tau² = 0.28; Chi² = 57.42, df = 15 (p < 0.00001); I² = 74%
Test for overall effect: Z = 6.61 (p < 0.00001)
Test for subgroup differences: Chi² = 5.33, df = 1 (p = 0.02), I² = 81.3%

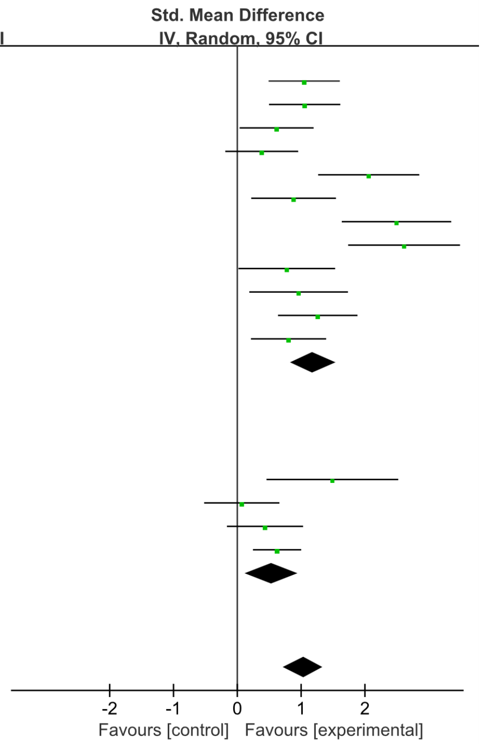

Figure 5. Subgroup analysis of ankle muscle strength in *tai chi* group and control group.

Due to the large heterogeneity of the results, subgroup analysis was carried out, and the subgroups were grouped according to the intervention duration. For the subgroup with the intervention duration ≤16 weeks [8, 12, 14, 24, 25], there was a statistically significant difference in the test results between the intervention group and the control group [SMD = 1.19, 95% CI (0.83, 1.55), p<0.00001]; and the subgroup with the intervention duration 16 weeks [10, 22, 27], the difference was statistically significant [SMD = 0.54, 95% CI (0.12, 0.96), p<0.00001] (Figure 5).

Ankle proprioception

A total of 4 literatures [11, 14, 16, 20] were included. The results of heterogeneity analysis showed: I^2 = 81%, p<0.00001, using random effect model (Figure 6).

Due to the large heterogeneity of the results, subgroup analysis was carried out, and the subgroups were grouped according to the intervention duration. For the subgroup with the intervention duration ≤16 weeks [11, 14], there was a statistically significant difference in the test

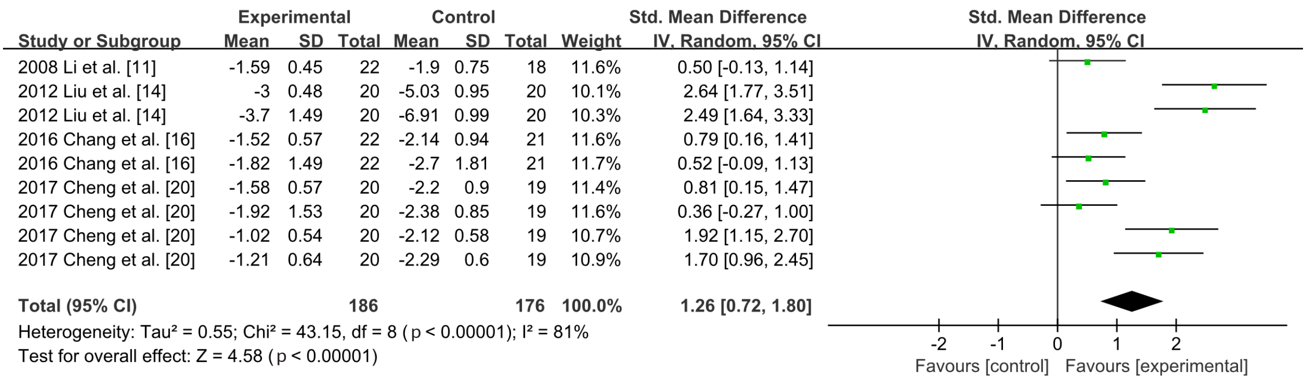

Figure 6. Forest plot of meta analysis of ankle joint proprioception in *tai chi* group and control group.

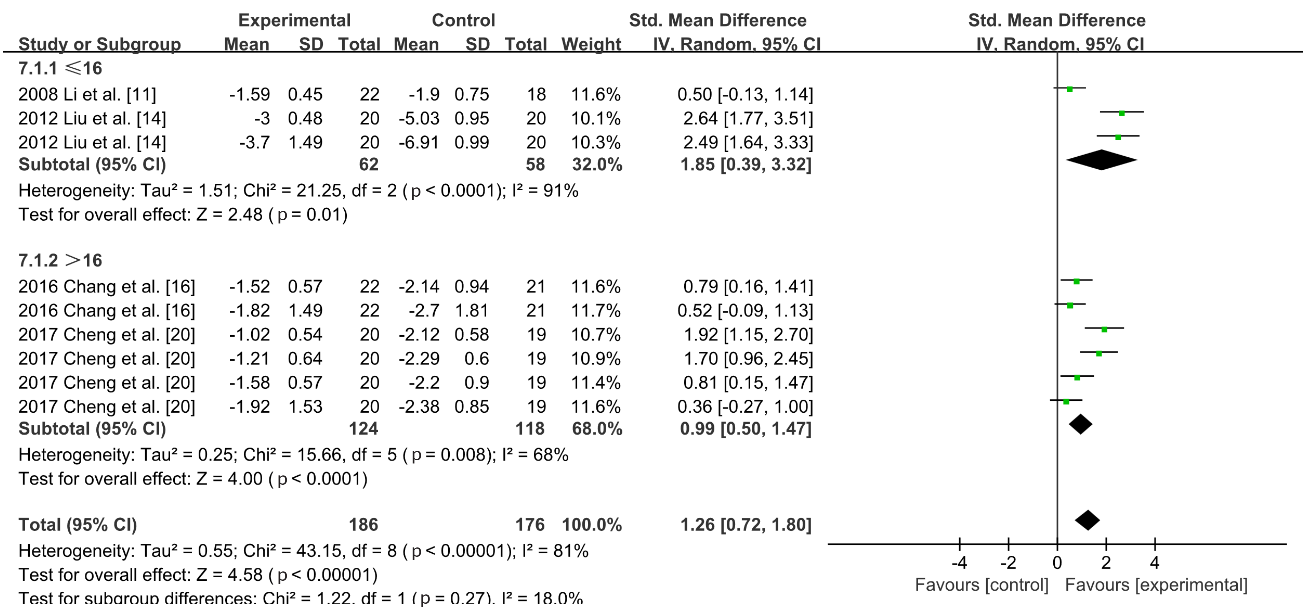

Figure 7. Subgroup analysis of ankle proprioception in *tai chi* group and control group.

results between the intervention group and the control group [SMD = 1.85, 95% CI (0.39, 3.32), p<0.00001]; and the subgroup with the intervention duration >16 weeks [16, 20], the difference was statistically significant [SMD = 0.99, 95% CI (0.50, 1.47), p<0.00001], (Figure 7).

Ankle balance

A total of 15 articles were included [8-11, 13, 15, 17, 18, 19, 21-26]. The results of heterogeneity analysis showed: I^2 = 35%, p<0.00001, the heterogeneity was small, and the random effect model was adopted (Figure 8).

Subgroup analysis was performed, grouped according to the duration of the intervention, the subgroup with the intervention duration ≤16 weeks [8, 9, 11, 13, 17, 23-25], the difference in the test results between the intervention group and the control group was statistically significant [SMD = 0.69, 95% CI (0.56, 0.82), p<0.00001]; The subgroup with the intervention duration >16 weeks [10, 15, 18, 19, 21, 22, 26] had a statistically significant difference [SMD = 0.68, 95% CI (0.59, 0.77), p<0.00001], (Figure 9).

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
2005 Choi et al. [8]	0.99	2.68	29	-0.14	1.59	30	2.7%	0.51 [-0.01, 1.03]
2005 Choi et al. [8]	1.65	2.3	29	-0.44	3.41	30	2.7%	0.71 [0.18, 1.23]
2005 Choi et al. [8]	4.1	5.86	29	-0.37	5.66	30	2.6%	0.77 [0.24, 1.30]
2006 Gatts et al. [9]	13.06	10.78	11	0.19	10.32	8	0.7%	1.16 [0.16, 2.16]
2006 Gatts et al. [9]	12.58	7.99	11	0.3	7.44	8	0.7%	1.51 [0.45, 2.57]
2006 Gatts et al. [9]	3.31	2.09	11	2.9	2.18	8	0.9%	0.18 [-0.73, 1.10]
2006 Gatts et al. [9]	3.53	1.62	11	0.08	1.61	8	0.5%	2.04 [0.87, 3.21]
2007 Li et al. [10]	7.3	5.2	11	3	1.3	9	0.8%	1.04 [0.09, 1.99]
2008 Li et al. [11]	50.27	15.59	22	42.79	19.15	18	1.9%	0.42 [-0.21, 1.06]
2008 Li et al. [11]	6.42	4.59	22	4.88	4.09	18	1.9%	0.35 [-0.28, 0.97]
2008 Li et al. [11]	43.54	21.87	22	41.63	20.15	18	1.9%	0.09 [-0.53, 0.71]
2009 Yang at al. [13]	0.9	1.7	41	1	2.2	39	3.8%	-0.05 [-0.49, 0.39]
2013 Wang et al. [15]	3.9	9.33	40	-3.2	11.42	40	3.6%	0.67 [0.22, 1.13]
2013 Wang et al. [15]	1	2.15	40	0	2.26	40	3.7%	0.45 [0.00, 0.89]
2013 Wang et al. [15]	0.7	2.26	40	-0.9	2.81	40	3.7%	0.62 [0.17, 1.07]
2013 Wang et al. [15]	67.3	133.48	40	-30.4	147.55	40	3.6%	0.69 [0.24, 1.14]
2013 Wang et al. [15]	54.9	105.74	40	-54.3	132.24	40	3.5%	0.90 [0.44, 1.36]
2013 Wang et al. [15]	6.3	12.23	40	-2.7	13.47	40	3.6%	0.69 [0.24, 1.14]
2013 Wang et al. [15]	5.1	9.08	40	-0.8	9.18	40	3.6%	0.64 [0.19, 1.09]
2016 Wang et al. [17]	27.27	22.13	20	22.98	23.77	20	1.9%	0.18 [-0.44, 0.80]
2016 Wang et al. [17]	25.93	19.98	20	21.94	20.16	20	1.9%	0.19 [-0.43, 0.82]
2016 Ye et al. [18]	8.33	7.6	17	3.22	9.84	22	1.8%	0.56 [-0.09, 1.21]
2016 Ye et al. [18]	116.67	119.98	17	11.11	193.35	22	1.8%	0.62 [-0.03, 1.27]
2016 Zhu et al. [19]	55.4	0.8	28	53.7	1.7	27	2.2%	1.27 [0.69, 1.85]
2016 Zhu et al. [19]	0.9	0.72	28	0.2	0.62	27	2.3%	1.03 [0.46, 1.59]
2017 Guan et al. [21]	45.85	4.16	40	43.56	3.99	40	3.7%	0.56 [0.11, 1.00]
2017 Pan et al. [22]	54.95	1.16	23	54.58	0.96	23	2.2%	0.34 [-0.24, 0.92]
2017 Pan et al. [22]	29.6	6.23	23	25.33	5.11	23	2.1%	0.74 [0.14, 1.34]
2017 Pan et al. [22]	0.72	1.13	23	0.27	1.16	23	2.2%	0.39 [-0.20, 0.97]
2017 Ye et al. [23]	0.75	1.37	25	-1.64	3.88	25	2.2%	0.81 [0.23, 1.39]
2017 Ye et al. [23]	1.88	1.6	25	-0.44	1.32	25	1.8%	1.56 [0.92, 2.20]
2017 Ye et al. [23]	0.92	1.68	25	-1.04	2.2	25	2.1%	0.99 [0.40, 1.58]
2019 Penn et al. [24]	51.33	4.79	15	45.87	12.36	15	1.4%	0.57 [-0.17, 1.30]
2019 Penn et al. [24]	25.52	4.11	15	22.03	6.65	15	1.4%	0.61 [-0.12, 1.35]
2019 Penn et al. [24]	0.77	1.84	15	0.72	9.25	15	1.4%	0.01 [-0.71, 0.72]
2020 Liang et al. [25]	14,368.9	2,124.8	25	11,998.5	1,829.4	25	2.0%	1.18 [0.57, 1.78]
2020 Liang et al. [25]	0.6	0.8	25	-0.2	0.75	25	2.1%	1.02 [0.42, 1.61]
2020 Liang et al. [25]	0.7	1.77	25	-0.4	2.01	25	2.3%	0.57 [0.01, 1.14]
2020 Liang et al. [25]	0.5	0.56	25	-0.1	0.66	25	2.1%	0.96 [0.38, 1.55]
2020 Liang et al. [25]	8.5	9.9	25	-1.7	10.56	25	2.1%	0.98 [0.39, 1.57]
2020 Liang et al. [25]	0.9	0.72	25	-0.1	0.85	25	2.0%	1.25 [0.64, 1.86]
2020 Liang et al. [25]	60.6	52.24	25	-4.7	58.51	25	2.0%	1.16 [0.56, 1.76]
2020 Liang et al. [25]	95.8	105.89	25	-9.4	116.9	25	2.2%	0.93 [0.34, 1.51]
2020 Ma et al. [26]	45	3.15	50	43.2	3.05	45	4.4%	0.58 [0.16, 0.99]
Total (95% CI)			**1138**			**1116**	**100.0%**	**0.68 [0.60, 0.77]**

Heterogeneity: Chi² = 66.03, df = 43 (p = 0.01); I² = 35%
Test for overall effect: Z = 15.57 (p < 0.00001)

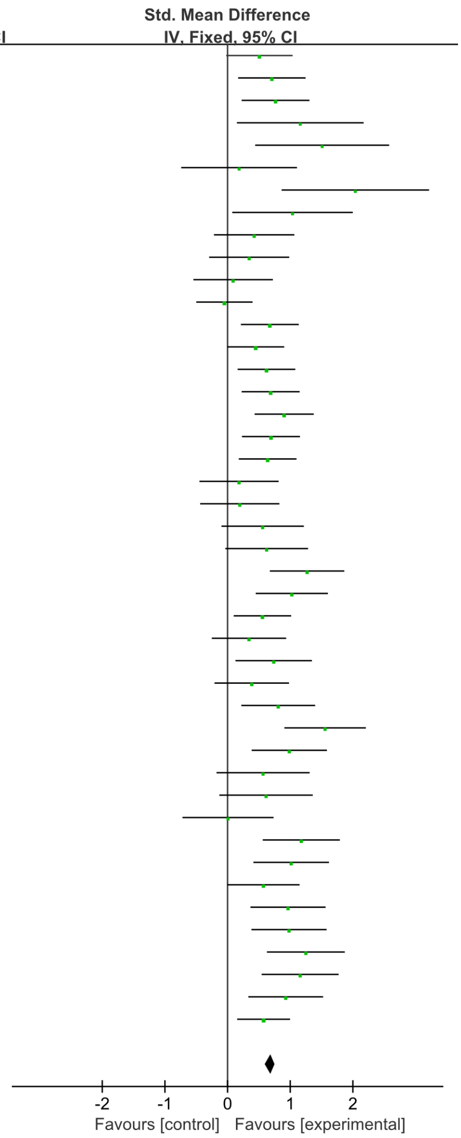

Figure 8. The forest plot of the meta analysis of the ankle joint balance ability of the *tai chi* group and the control group.

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
10.1.1 ≤16								
2005 Choi et al. [8]	0.99	2.68	29	-0.14	1.59	30	2.9%	0.51 [-0.01, 1.03]
2006 Gatts et al. [9]	13.06	10.78	11	0.19	10.32	8	0.8%	1.16 [0.16, 2.16]
2006 Gatts et al. [9]	12.58	7.99	11	0.3	7.44	8	0.7%	1.51 [0.45, 2.57]
2006 Gatts et al. [9]	3.31	2.09	11	2.9	2.18	8	0.9%	0.18 [-0.73, 1.10]
2006 Gatts et al. [9]	3.53	1.62	11	0.08	1.61	8	0.6%	2.04 [0.87, 3.21]
2008 Li et al. [11]	50.27	15.59	22	42.79	19.15	18	2.0%	0.42 [-0.21, 1.06]
2008 Li et al. [11]	6.42	4.59	22	4.88	4.09	18	2.0%	0.35 [-0.28, 0.97]
2008 Li et al. [11]	43.54	21.87	22	41.63	20.15	18	2.0%	0.09 [-0.53, 0.71]
2009 Yang at al. [13]	0.9	1.7	41	1	2.2	39	4.1%	-0.05 [-0.49, 0.39]
2016 Wang et al. [17]	27.27	22.13	20	22.98	23.77	20	2.0%	0.18 [-0.44, 0.80]
2016 Wang et al. [17]	25.93	19.98	20	21.94	20.16	20	2.0%	0.19 [-0.43, 0.82]
2017 Ye et al. [23]	0.75	1.37	25	-1.64	3.88	25	2.3%	0.81 [0.23, 1.39]
2017 Ye et al. [23]	1.88	1.6	25	-0.44	1.32	25	1.9%	1.56 [0.92, 2.20]
2017 Ye et al. [23]	0.92	1.68	25	-1.04	2.2	25	2.2%	0.99 [0.40, 1.58]
2019 Penn et al. [24]	51.33	4.79	15	45.87	12.36	15	1.5%	0.57 [-0.17, 1.30]
2019 Penn et al. [24]	25.52	4.11	15	22.03	6.65	15	1.4%	0.61 [-0.12, 1.35]
2019 Penn et al. [24]	0.77	1.84	15	0.72	9.25	15	1.5%	0.01 [-0.71, 0.72]
2020 Liang et al. [25]	8.5	9.9	25	-1.7	10.56	25	2.2%	0.98 [0.39, 1.57]
2020 Liang et al. [25]	0.9	0.72	25	-0.1	0.85	25	2.1%	1.25 [0.64, 1.86]
2020 Liang et al. [25]	60.6	52.24	25	-4.7	58.51	25	2.1%	1.16 [0.56, 1.76]
2020 Liang et al. [25]	95.8	105.89	25	-9.4	116.9	25	2.3%	0.93 [0.34, 1.51]
2020 Liang et al. [25]	14,368.9	2,124.8	25	11,998.5	1,829.4	25	2.1%	1.18 [0.57, 1.78]
2020 Liang et al. [25]	0.6	0.8	25	-0.2	0.75	25	2.2%	1.02 [0.42, 1.61]
2020 Liang et al. [25]	0.7	1.77	25	-0.4	2.01	25	2.4%	0.57 [0.01, 1.14]
2020 Liang et al. [25]	0.5	0.56	25	-0.1	0.66	25	2.3%	0.96 [0.38, 1.55]
Subtotal (95% CI)			**540**			**515**	**48.6%**	**0.69 [0.56, 0.82]**
Heterogeneity: Chi² = 54.95, df = 24 (p = 0.0003); I² = 56%								
Test for overall effect: Z = 10.68 (p < 0.00001)								
10.1.2 >16								
2007 Li et al. [10]	7.3	5.2	11	3	1.3	9	0.9%	1.04 [0.09, 1.99]
2013 Wang et al. [15]	67.3	133.48	40	-30.4	147.55	40	3.8%	0.69 [0.24, 1.14]
2013 Wang et al. [15]	54.9	105.74	40	-54.3	132.24	40	3.7%	0.90 [0.44, 1.36]
2013 Wang et al. [15]	6.3	12.23	40	-2.7	13.47	40	3.8%	0.69 [0.24, 1.14]
2013 Wang et al. [15]	5.1	9.08	40	-0.8	9.18	40	3.9%	0.64 [0.19, 1.09]
2013 Wang et al. [15]	3.9	9.33	40	-3.2	11.42	40	3.8%	0.67 [0.22, 1.13]
2013 Wang et al. [15]	1	2.15	40	0	2.26	40	4.0%	0.45 [0.00, 0.89]
2013 Wang et al. [15]	0.7	2.26	40	-0.9	2.81	40	3.9%	0.62 [0.17, 1.07]
2016 Ye et al. [18]	8.33	7.6	17	3.22	9.84	22	1.9%	0.56 [-0.09, 1.21]
2016 Ye et al. [18]	116.67	119.98	17	11.11	193.35	22	1.8%	0.62 [-0.03, 1.27]
2016 Zhu et al. [19]	55.4	0.8	28	53.7	1.7	27	2.3%	1.27 [0.69, 1.85]
2016 Zhu et al. [19]	0.9	0.72	28	0.2	0.62	27	2.4%	1.03 [0.46, 1.59]
2017 Guan et al. [21]	45.85	4.16	40	43.56	3.99	40	3.9%	0.56 [0.11, 1.00]
2017 Pan et al. [22]	54.95	1.16	23	54.58	0.96	23	2.3%	0.34 [-0.24, 0.92]
2017 Pan et al. [22]	29.6	6.23	23	25.33	5.11	23	2.2%	0.74 [0.14, 1.34]
2017 Pan et al. [22]	0.72	1.13	23	0.27	1.16	23	2.3%	0.39 [-0.20, 0.97]
2020 Ma et al. [26]	45	3.15	50	43.2	3.05	45	4.6%	0.58 [0.16, 0.99]
Subtotal (95% CI)			**540**			**541**	**51.4%**	**0.67 [0.55, 0.79]**
Heterogeneity: Chi² = 10.92, df = 16 (p = 0.81); I² = 0%								
Test for overall effect: Z = 10.65 (p< 0.00001)								
Total (95% CI)			**1080**			**1056**	**100.0%**	**0.68 [0.59, 0.77]**
Heterogeneity: Chi² = 65.92, df = 41 (p = 0.008); I² = 38%								
Test for overall effect: Z = 15.09 (p< 0.00001)								
Test for subgroup differences: Chi² = 0.05, df = 1 (p = 0.82), I² = 0%								

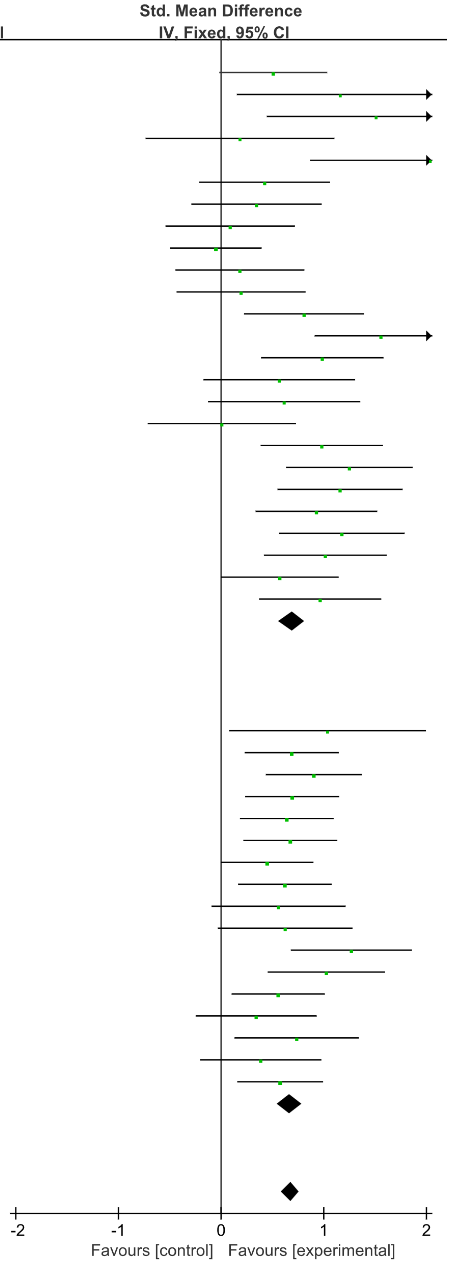

Figure 9. Subgroup analysis of ankle balance ability in *tai chi* group and control group.

DISCUSSION

This study evaluates the effect of *tai chi* on the ankle joint function of the elderly, and the statistical methods and outcome indicators of the 20 included literatures are all clear.

Analysis of the influence of taijiquan on muscle strength of ankle joint

The active muscles of the ankle joint consist of flexors on the back of the calf and extensors on the front of the calf. It has been reported [29] that some accessory muscle groups (especially in the trunk and hip) are also activated in the elderly as a compensatory strategy to maintain balance. During exercise, especially when running and jumping, the electromyography signals of the tibialis longus and peroneus longus are weakened to varying degrees in the elderly, and they need the protection and compensation of other muscles to maintain balance [30]. Khalaj's et al. [31] research also showed that, the weakness of the ankle varus knee, and valgus and knee extensors in the elderly can change the neuromuscular control mechanism of the proximal joint by adjusting the activation mode of the muscles can improve ankle stability. The study of Yu H. and Yu C. [32] also verified this point of view again and found that the instability of the ankle joint will cause changes in the biomechanics of the lower limbs, which will affect other joints and lead to the weakening of the dynamic stability of the ankle joint.

Muscle strength is the source of power for physical activity and the basis for maintaining the stability of the human body. During *tai chi* practice, the body load is carried by the lower limbs, and during the exercise, the muscles near the ankle joint are always in a state of relaxation and contraction, which can effectively enhance the patient's lower limb muscle strength and improve the subject's ankle joint muscle's function. Li and Ji [33] compared the effects of *tai chi* and aerobics on the static balance ability of college students and found that the EMG signals of the tibialis anterior muscle and medial gastrocnemius muscle of the lower limbs of the subjects were significantly increased during *tai chi* exercise, indicating that *tai chi* can effectively enhance strength of the tibialis anterior and medial gastrocnemius muscles in the patient. Wang et al. [34] also found that in the process of 24-style *tai chi* practice, whether it is a professional group or an ordinary group, the activation degree of *tai chi* to the muscles of various parts of the lower limbs was They are all different, so during the *tai chi* exercise, the muscle strength of the calf muscles, hip joints and small muscles around the thigh is higher, which shows that *tai chi* can effectively enhance the muscle strength of the extremity movement muscles and improve the patient's health. motor function. Compared with fitness exercise walking, *tai chi* exercise can drive the alternate conversion of muscle contraction and relaxation, so that the lower limb muscle strength of the subject can be significantly improved during the exercise, and during the exercise, the prime mover and synergistic muscles of the subject Coordinate and cooperate with the antagonistic muscles, so they can exert greater strength, improve the strength of the lower limb muscles of the ankle joint, and enhance the stability of the lower limbs [35].

Analysis of tai chi's influence on ankle joint proprioception

Proprioception refers to the sensation produced by muscles, tendons, joints, and other motor organs in different states (moving or static), generally including position sense, force sense, and motion sense. Since the control of movement consists of proprioceptive afferents, central nervous processing, and the output of movements [36], alterations in neurological pathways and sensory inputs are often observed in older adults, resulting in a balanced impairment of ability. The study found that older adults had more impaired ankle inversion and eversion kinesthetic sense and active joint position sense than younger adults. Hagen et al. [37] showed that joint position sense is reduced at 24° of supination and that the anatomical subtalar joint axis must be considered when assessing pronation and supination proprioception in the elderly. The position sense of the affected ankle joint of the elderly is weaker than that of normal people. Zhang Y et al. [38] took the 25% maximum isometric peak torque value of the ankle joint plantar flexors as the muscle force sense and found that the elderly had insufficient force sense under low load.

Currently, proprioception is considered to be the most important factor affecting ankle stability. Zou et al. [39] and others found that compared with rehabilitation functional training, *tai chi* intervention can significantly improve the ankle joint position sense of the elderly and improve the muscle force sense of the ankle joint. At the same time, with visual aids, the 16-week *tai chi* intervention has a significant effect on the ankle joint proprioception, but the *tai chi* intervention without visual aids did not achieve the expected effect on the ankle joints, but recent studies have found, people who practiced *tai chi* for a long time (3–5 years) showed better postural stability even without visual aids. Therefore, the 16-week *tai chi* did not achieve the expected effect, which may be caused by insufficient intervention time. Future research needs longer interventions to verify whether *tai chi* intervention without visual aids can achieve the effect of enhancing ankle proprioception. Zou et al. [39] showed in the research on the influence of different exercise methods on the ankle joint proprioception of elderly women that with the prolongation of *tai chi* practice time, the ankle joint plantar flexion proprioception was significantly enhanced, and *tai chi* can maintain the human body for a long time. Utility of ankle proprioception in the foot.

Analysis of the influence of tai chi on the balance ability of the ankle joint

Analysis of the influence of *taijiquan* on the balance ability of the ankle joint balance ability affects the incidence of ankle injuries in the elderly [40]. Lee et al. [41] mentioned functional instability as a cause of repeated ankle injuries in his study. The balance ability of the human body is generally divided into two types: dynamic balance and static balance. The dynamic and static balance abilities of the elderly are weaker than normal people. In addition to impaired proprioception and neuromuscular control, other factors such as muscle strength and joint range of motion (ROM) can also lead to balance disorders in the elderly [42]. Due to the weak ankle proprioception of the elderly, the motor function, space position sense and muscle strength of the patient's ankle joint are greatly weakened, thereby greatly reducing the patient's dynamic balance ability. Two meta analysis [43, 44] showed that whether the balance was assessed by static tests or dynamic tests, the balance ability of the ankles of the elderly was worse than that of the ankles of young people. The study of Doherty et al. [45] also considered that the ankle instability of the elderly showed bilateral and proximal sensorimotor control deficits in the dynamic balance assessment, and these deficits were related to the stance, limb kinematic contours when performing tasks Consistent with changes in COP behaviour.

In the study of *tai chi* improving ankle balance ability, Penn et al. [24] found that whether it is individualized *tai chi* or traditional *tai chi*, the scores of the Berg Balance Scale of the elderly are significantly improved. Li et al. [46] research found that, compared with Kinesiology Taping, 6-week *tai chi* intervention can significantly improve postural control such as dynamic balance and static balance in the elderly. Jing et al. [27] found that after 12 weeks of *tai chi* practice, the subjective stability of the elderly and all measurement directions of SEBT have been significantly improved, indicating that *tai chi* can effectively improve the ankle dynamic balance ability of the elderly. When Zeng [47] studied the effects of *tai chi* and ballroom dancing exercises on the balance ability of elderly women, she found that long-term and regular *tai chi* exercises could significantly improve the dynamic and static balance abilities of the elderly, and *tai chi* exercise had a significant effect on the balance ability of the elderly. Proprioception, vestibular sensation, and lower extremity muscle strength were also significantly improved. Research by Li Y-H and Li Y-K [48] shows that, compared with pure *tai chi* pile training, *tai chi* can be effective due to its single-leg support and cat-walking movement, with its own body weight as the load and the change of the load intensity at the centre of gravity. Improve the subject's dynamic balance ability, and at the same time, the static balance ability of the test patient has also been effectively improved. *Tai chi* was more effective in improving postural stability than resistance-based exercises or low-impact stretching in tasks with limited stability.

In summary, *tai chi* can also improve ankle muscle strength, proprioception, and balance in the elderly. The issue is still open the effect of Chinese traditional exercise on cognitive function improvement in the elderly [49], and also the effect of tai chi exercise on hypertension and hyperlipidemian [50].

This study also has certain limitations. First of all, the search strategy is limited to Chinese and English literature, and there may be studies in other languages that were not included. Secondly, due to the influence of factors such as sample characteristics and evaluation methods of the included studies, the heterogeneity of the results may increase. In addition, some studies did not mention allocation concealment, which may affect the stability of the results. The subjects included in the study were all healthy elderly people, and the results of the study should be used with caution in non-healthy elderly groups.

CONCLUSIONS

The results of this review show that *tai chi* exercise intervention can effectively improve ankle muscle strength, proprioception, and balance in the elderly. In recommendations addressed to people with various diseases particular care should be taken (the review refers to the results of examinations of healthy people) and consultations with specialists in medicine and physiotherapy.

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