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Review article

Rehabilitative effects of Baduanjin in Chinese stroke patients: A systematic review and *meta*-analysis

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ABSTRACT

Objective: This study aims to systematically assess the rehabilitative effects of Baduanjin in stroke patients.
Methods: Ten electronic databases were systematically searched using MeSH and free terms for relevant studies written in the English or Chinese language, and published on or before 15 February 2023. Studies in which Baduanjin was the only difference in treatment administered to experimental and control groups were included in the review. The studies' risk of bias was evaluated using the Cochrane criteria.
Results: Twenty one studies that involved 1,649 participants were included. Compared to the control group, Baduanjin increased the scores for the Fugl-Meyer Assessment (including both upper and lower extremity components), Berg Balance Scale, Trunk Impairment Scale, Functional Ambulation Categories, 6-minute Walking Distance, Modified Barthel Index, Barthel Index, and total effective rate, but reduced the scores for the Pk254 balance function detection system, National Institutes of Health Stroke Scale and neurological deficit scale ($P <$ 0.05, for all).
Conclusion: The present study findings revealed the potential benefits of Baduanjin in improving movement, balance, trunk, ambulation and neurological functions, and the ability to perform activities of daily living in stroke patients. Larger randomized controlled trials with more standardized intervention protocols are required to obtain more robust evidence.

1. Introduction

As one of the most prevalent neurological diseases, stroke is the leading cause of death and long-term disability.(Gbd, 2021 Oct) There are approximately 101 million stroke patients worldwide, and approximately 5.7 million people die of stroke each year.(Papanagiotou and White, 2016) It has been reported that approximately 80 % of stroke patients survive in the acute phase, but two-thirds of these patients have long-lasting functional disability to some degree.(Kaji, 2019) Neurological deficits induced by stroke are often accompanied by motor impairment, which mainly include limb weakness, and trunk control or balance deficits. It has been suggested that more than 50 % of stroke patients cannot independently walk after discharge from the hospital.(Hornby et al., 2019; Katan and Luft, 2018) These problems lead to worsening of their activities of daily living (ADLs), decreased quality of life, and limited participation in family and community activities, which should be considered as important targets of rehabilitation.(Laver et al., 2020;1(1):CD010255.) Therefore, it is critical to develop effective rehabilitative strategies to help stroke patients restore impaired functions.

Substantial evidence has demonstrated that physical exercise is an effective rehabilitative approach to improve the consequences of stroke.(Lee et al., 2022) The practice guidelines of the American Stroke Association recommend aerobic exercise for stroke rehabilitation, which has the potential to positively influence physical performance and specific functional activities.(Xing et al., 2018) Traditional Chinese mind–body exercises are considered as low-to-moderate-intensity aerobic exercises, which integrate balance, flexibility and neuromuscular coordination training. Previous studies have suggested that traditional Chinese mind–body exercises are beneficial to stroke patients with motor impairment or functional limitations.(Billinger et al., 2014) As one of the representative traditional Chinese mind–body exercises, Baduanjin is characterized by deep rhythmic breathing, body coordinated movements and meditation, and mainly comprises of eight effortless and separate movements, such as arm raising, head shaking, and feet turning, which consumes 3–5 metabolic equivalents (MET).(Song et al.,

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2017) Therefore, Baduanjin has been considered as an effective exercise for promoting mind–body health, and systematic analysis is needed to investigate its rehabilitative effect in stroke patients.(Wang et al., 2021).

To date, two systematic review has been conducted to investigate the rehabilitative effects of Baduanjin in stroke patients.(Wei et al., 2023; Zou et al., 2018 Mar 27) Chen et al.(Wei et al., 2023) included an impure stroke population, and some had post-stroke comorbidities, such as post-stroke depression, which may lead to biased results. Zou et al.(Zou et al., 2018 Mar 27) conducted a *meta*-analysis that focused on balance, and reported that Baduanjin has significant benefits in improving balance in stroke patients. However, there were several drawbacks that limited the quality of the systematic review. First, merely four studies were included in the *meta*-analysis. Thus, the statistical power was insufficient. Second, that systematic review only described the motor, neurological and ADL indicators in the included studies, and did not perform a *meta*-analysis.

In addition to Baduanjin, some reviews evaluated the effects of Chinese traditional exercises on stroke rehabilitation.(Chen et al., 2015 Aug 20; Ge et al., 2017 Nov) Chen *et al.*(Chen et al., 2015 Aug 20) reported that Chinese traditional exercises have a beneficial effect in improving balance in stroke patients, and may have a tendency to improve gait. Ge *et al.*(Ge et al., 2017 Nov) reported that Chinese traditional exercises have a beneficial effect in improving multiple functions in stroke patients, such as motor and neurological functions, balance, and ADL. However, both reviews merely included a small number of Baduanjin studies. Chen *et al.*(Chen et al., 2015 Aug 20) included merely two Baduanjin studies, while Ge *et al.*(Ge et al., 2017 Nov) included six Baduanjin studies. No further analysis was conducted on the effects of Baduanjin in stroke rehabilitation. Therefore, the rehabilitative effects of Baduanjin in improving functions in stroke patients remain unclear. The present study conducted a systematic review and *meta*-analysis of related randomized controlled trials (RCTs) that involved Baduanjin, in order to evaluate its rehabilitative effect in stroke patients. The rest of the review is outlined as follows. In section 2, we present the methodology applied in the review. In section 3, we apply these methods and present the results. In section 4, we mainly discussed the therapeutic efficacy and possible mechanisms of Baduanjin. Finally, the review concludes with limitations and conclusions.

2. Methods

This review followed the statement of Preferred Reporting Items For Systematic Reviews and Meta-Analyses (PRISMA). This study was registered in PROSPERO (No.CRD42023437419).

2.1. Search strategy

The following Chinese and English language databases were systematically searched for relevant studies published on or before 15 February 2023. The databases included the Cochrane Library, PubMed, Web of Science, Embase, OVID, EBSCOhost, China National Knowledge Infrastructure, VIP, Wanfang, and SinoMed. For completeness and accuracy, the MeSH and free terms were combined during the literature search, and the final search strategy was determined after multiple pre-searches. The search terms included the following: Baduanjin, stroke, Qigong, mind–body exercise, apoplexy, etc. The detailed search strategies are presented in Appendix A.

2.2. Inclusion and exclusion criteria

The inclusion criteria for the studies were, as follows: (1) RCT design; (2) studies that targeted stroke patients; (3) the control group received conventional medical treatment, balance training, conventional rehabilitation training, etc., while the experimental group was given Baduanjin interventions on this basis; (4) the outcome indicators included at least one functional measurement (*e.g.* motor, balance, neurological, or trunk function).

The exclusion criteria for the studies were, as follows: (1) the control group included Baduanjin; (2) the experimental group received other interventions in addition to Baduanjin and conventional treatments (*e.g.* Baduanjin and isokinetic strength training); (3) reviews, editorials, conference abstracts, animal experiments, etc.; (4) no outcome measure was analyzed or reported; (5) duplicated studies.

2.3. Study selection and data extraction

Two researchers independently screened each retrieved studies based on the inclusion and exclusion criteria, in order to determine the eligibility of each study. If the two researchers arrived at different opinions for one study, the decision was judged by a third experienced researcher. Furthermore, two researchers independently extracted the relevant data using a self-designed data collection form. The data collection form included the following items: first author, year of publication, location, participants age, sample size, interventions, intervention frequency and duration, adverse events, and outcome measures.

2.4. Risk of bias

The risk of bias for each included study was independently evaluated by two researchers using the criteria outlined in the Cochrane risk of bias assessment tool.[16] Each item was rated as "low risk", "high risk", or "unclear", based on the following criteria: random sequences, allocation concealment, blinding of researchers and participants, blinding of outcome assessment, completeness of outcome indicators, selective outcome reporting, and other biases. If the opinions of the two researchers were inconsistent, the decision was judged by a third researcher.

2.5. Statistical analysis

Cochrane Review Manager version 5.4 was used for the statistical analysis. The effect size for continuous variables was expressed in mean difference (MD). The effect size for categorical variables was expressed in odds ratio (OR). $I^2 \leq 50$ % means that the included studies were considered homogeneous, and a fixed-effects model was adopted for the *meta*-analysis. $I^2 > 50$ % means that the included studies were considered heterogeneous, and a random-effects model was adopted. A sensitivity or subgroup analysis was also performed for highly heterogeneous outcomes, in order to identify the possible causes of heterogeneity. The significant differences between groups were set as $P < 0.05$ for all analyses in present study. Publication bias was evaluated by using funnel plots of analyses that included a minimum of 10 studies.

3. Results

3.1. Search results

A total of 1243 potentially eligible studies were identified through the extensive search of the 10 databases. After removing all duplicates, the title and abstract of the remaining 523 studies were screened, and another 488 irrelevant studies were excluded. Thus, 35 studies progressed to the next stage for full-text evaluation, and 21 studies were finally included for the *meta*-analysis.(Liu et al., 2022; Liu, 2022; Zhou et al., 2021; Duan and Zeng, 2021; Yuan, 2021; Chen, 2020; Li, 2020; Yu et al., 2020; Wang, 2020; Zhuang et al., 2019; Cui and Yang, 2019; Xie et al., 2019; Ding et al., 2019; Cui et al., 2018; Lin, 2018; 2018; Tian, 2017; Zhang and Li, 2016; Zhang et al., 2013; Guo et al., 2013; Bai et al., 2011) The details are presented in Fig. 1.

3.2. Characteristics of the included studies

The present *meta*-analysis included 21 eligible studies (all of these were RCTs),(Liu et al., 2022; Liu, 2022; Zhou et al., 2021; Duan and

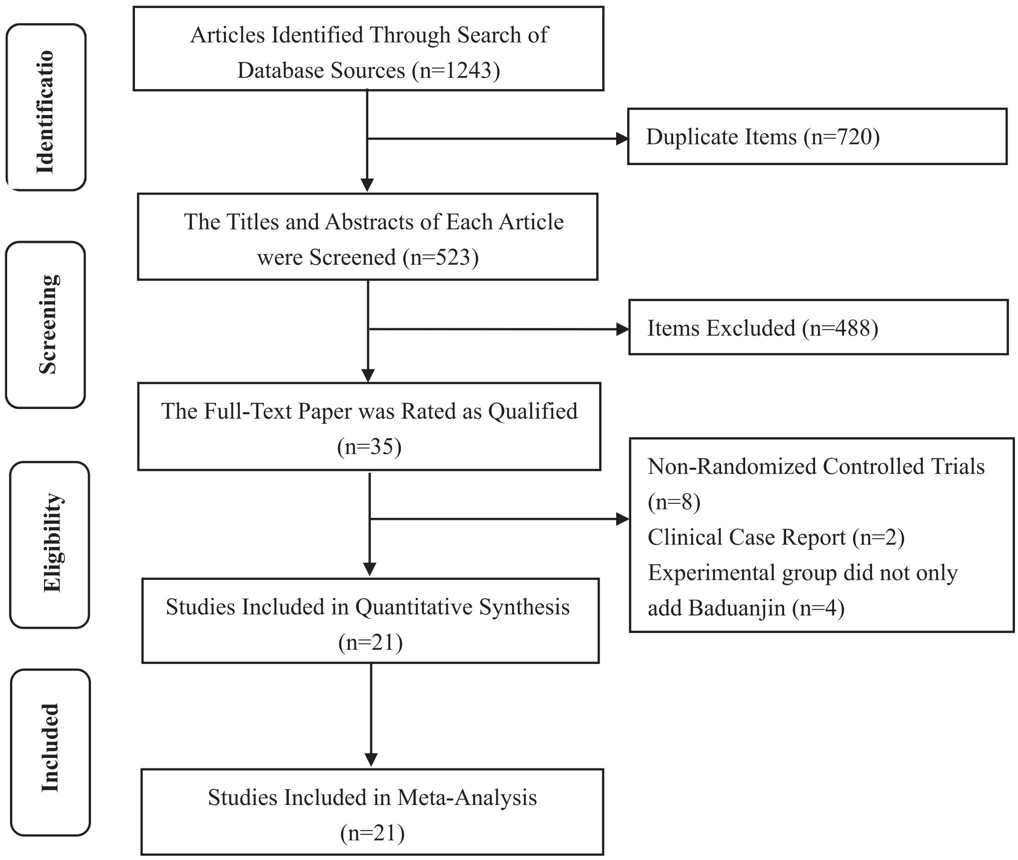

Fig. 1. Literature screening process.

Zeng, 2021; Yuan, 2021; Chen, 2020; Li, 2020; Yu et al., 2020; Wang, 2020; Zhuang et al., 2019; Cui and Yang, 2019; Xie et al., 2019; Ding et al., 2019; Cui et al., 2018; Lin, 2018; 2018; Tian, 2017; Zhang and Li, 2016; Zhang et al., 2013; Guo et al., 2013; Bai et al., 2011) with a total of 1,649 S participants (age: 30–82 years old). All studies were published between 2011 and 2022, and the experimental sites were all located in China. For all these RCTs, the control group was treated with conventional medical treatment, conventional rehabilitation training, balance training, etc., while the experimental group was given Baduanjin intervention on this basis. For all the included RCTs, the duration of the Baduanjin intervention varied from 3 to 24 weeks, the frequency varied from 3 to 7 sessions per week, and the exercise duration lasted for 20–60 min per session. The outcome indicators included the following: Fugl-Meyer Assessment (FMA; including both upper and lower extremity components, FMA-UE and FMA-LE, respectively) for motor function; Berg Balance Scale (BBS), Pk254 balance function detection system, Fugl-Meyer balance subscale (FMB) for balance function; Trunk Impairment Scale (TIS) for trunk function; functional ambulation categories (FAC), 6-minute walking distance (6MWD) for ambulation ability; neurological deficit scale (NDS), National Institutes of Health Stroke Scale (NIHSS) for neurological function; Barthel Index (BI), modified Barthel Index (MBI) for ADL; the 36-Items Short Form Health Survey (SF-36) for quality of life; manual muscle test (MMT) for muscle strength; modified Ashworth spasticity scale (MAS) for spasticity; total effective rate. For all indicators included for the present review, higher scores for the NDS, NIHSS, MAS, and Pk254 balance function detection system indicated the worse functions, while higher scores for the remaining indicators suggested better functions. Table 1 presents the details for the characteristics of the included studies.

3.3. *Risk of bias*

The risk of bias results for the included studies are presented in Fig. 2. For the random sequence generation, three studies were rated as “high risk” (two study(Zhang et al., 2013; Guo et al., 2013) was assigned by admission order, and one study(Zhuang et al., 2019) was assigned by disease type), and six studies(Chen, 2020; Yu et al., 2020; Cui and Yang, 2019; Cui et al., 2018; Lin, 2018; Tian, 2017) were rated as “unclear” for not reporting the method of randomization. Allocation concealment was rated as “unclear” in 18 studies.(Liu, 2022; Zhou et al., 2021; Duan and Zeng, 2021; Yuan, 2021; Chen, 2020; Yu et al., 2020; Zhuang et al., 2019; Cui and Yang, 2019; Xie et al., 2019; Ding et al., 2019; Cui et al., 2018; Lin, 2018; 2018; Tian, 2017; Zhang and Li, 2016; Zhang et al., 2013; Guo et al., 2013; Bai et al., 2011) The blinding of researchers and participants was rated as “unclear” for all the included studies. Furthermore, the blinding of outcome assessment was rated as “unclear” in 17 studies,(Liu et al., 2022; Liu, 2022; Zhou et al., 2021; Duan and Zeng, 2021; Yuan, 2021; Chen, 2020; Yu et al., 2020; Zhuang et al., 2019; Cui and Yang, 2019; Ding et al., 2019; Cui et al., 2018; Lin, 2018; Tian, 2017; Zhang and Li, 2016; Zhang et al., 2013; Guo et al., 2013; Bai et al., 2011) because the information in these studies was not sufficient to arrive at a decision. The remaining studies were rated as “low risk” in the above domains. No incomplete outcome data, selective reporting, or other source of bias was detected, and all the included studies were rated as “low risk” in those domains.

3.4. *Meta-analysis*

3.4.1. *Motor function*

The FMA includes five domains: motor, sensation, joint range of motion, pain and balance. This has been widely used for assessing motor impairment following stroke.(Gladstone et al., 2002) For the motor

Table 1
Basic characteristics of the included studies.

Study	Location (language)	Age	Sample C	Sample E	Intervention C	Intervention E	Frequency	Duration (Week)	Intervention sites	Outcomes
Liu W, 2022 (Higgins and Green, 2011)	Hubei, China (Chinese)	40–65	22	21	CMT + CRT	CMT + CRT + Baduanjin	30 min/ session, 2session/d, 6d/wk	4	Hospital	BBS
Liu GG, 2022 (Liu et al., 2022)	Jiangsu, China (Chinese)	36–78	50	50	CRT	CRT + Baduanjin	20–30 min/ session, 1session/d, 3d/wk	8	Hospital	Pk254 balance function detection system, NIHSS, total effective rate
Zhou HY, 2021 (Liu, 2022)	Sichuan, China (Chinese)	61–82	35	35	CRT	CRT + Baduanjin	60 min/ session, 1session/d, 5d/wk	12	Hospital	BBS, NDS, FMA, SF-36
Duan XY, 2021 (Zhou et al., 2021)	Sichuan, China (Chinese)	45–79	30	30	Basic nursing + Psychological nursing	Basic nursing + Psychological nursing + Baduanjin	20 min/ session, 1session/d, 5d/wk	4	Hospital	NIHSS, BI
Yuan YP, 2021 (Duan and Zeng, 2021)	Henan, China (Chinese)	53–75	32	33	CMT	CMT + Baduanjin	40 min/ session, 1session/d, 3d/wk	24	Hospital	FMA, 6MWD, FAC, MBI, SF-36
Chen XJ, 2020 (Yuan, 2021)	Ninxia, China (Chinese)	C: 63. 18 ± 7. 02 E: 62. 38 ± 6. 39	31	31	CRT	CRT + Baduanjin	40 min/ session, 1session/d, 7d/wk	8	Hospital	NIHSS, FMA, total effective rate
Li X, 2020 (Chen, 2020)	Beijing, China (Chinese)	40–65	11	13	CRT	CRT + Baduanjin	45 min/ session, 1session/d, 5d/wk	4	Hospital	MBI, BBS
Yu L, 2020 (Li, 2020)	Guangzhou, China (Chinese)	65–81	38	38	CRT	CRT + Baduanjin	35 min/ session, 2 session/d, 6d/ wk	14	Hospital	FMA-LE, BBS, FAC, TIS
Wang YZ, 2020 (Yu et al., 2020)	Fujian, China (Chinese)	35–65	29	28	Conventional treatment + Conventional nursing	Conventional treatment + Conventional nursing + Baduanjin	20 min/ session, 1session/d, 6d/wk	4	Hospital	FMA-UE, MMT, MAS, MBI
Zhuang KC, 2019 (Wang, 2020)	Shanghai, China (Chinese)	≥60	35	35	CRT	CRT + Baduanjin	50 min/ session, 1session/d, 7d/wk	12	Hospital	TIS, BBS, FAC
Cui YS, 2019 (Zhuang et al., 2019)	Haerbin, China (Chinese)	≤70	24	28	CRT	CRT + Baduanjin	45 min/ session, 1session/d, 5d/wk	8	Hospital	Pk254 balance function detection system
Xie BJ, 2019 (Cui and Yang, 2019)	Shanghai, China (Chinese)	25–75	20	20	CRT	CRT + Baduanjin	50 min/ session, 1session/d, 5d/wk	3	Hospital	FMA, BBS, BI, 6MWD
Ding Y, 2019 (Xie et al., 2019)	Shandong, China (Chinese)	30–70	56	57	CMT + CRT	CMT + CRT + Baduanjin	20 min/ session, 2session/d, 5d/wk	4	Hospital	BBS, FMB
Cui YS, 2018 (Ding et al., 2019)	Haerbin, China (Chinese)	≤70	19	24	CRT	CRT + Baduanjin	45 min/ session, 1session/d, 5d/wk	8	Hospital	FMA-LE, FMA-UE, Pk254 balance function detection system
Lin Q, 2018 (Cui et al., 2018)	Fujian, China (Chinese)	61–79	45	45	TCM treatment	TCM treatment +Baduanjin	30 min/ session, 1session/d, 7d/wk	24	Hospital	NDS, BI, total effective rate
Ye T, 2018 (Lin, 2018)	Heilongjiang, China (Chinese)	40–75	30	30	CRT + Scalp Acupuncture	CRT + Scalp Acupuncture + Baduanjin	20 min/ session, 2session/d, 5d/wk	6	Hospital	FMA-LE, BBS, MBI

(continued on next page)

Table 1 (*continued*)

Study	Location (language)	Age	Sample C	Sample E	Intervention C	Intervention E	Frequency	Duration (Week)	Intervention sites	Outcomes
Tian H, 2017 (2018)	Qingdao, China (Chinese)	40–69	30	30	CRT	CRT + Baduanjin	30–40 min/ session, 2session/d, 7d/wk	12	Hospital	BBS, FMB
Zhang Y, 2016 (Tian, 2017)	Shandong, China (Chinese)	40–70	31	31	Balance training	Balance training + Baduanjin	20 min/ session, 2session/d, 5d/wk	7	Hospital	BBS, FMA-LE
Zhang M, 2013 (Zhang and Li, 2016)	Henan, China (Chinese)	30–70	106	115	Conventional treatment + CRT	Conventional treatment + CRT + Baduanjin	20 min/ session, 2session/d, 7d/wk	6	Hospital	BBS
Guo J, 2013 (Zhang et al., 2013)	Henan, China (Chinese)	33–82	106	115	CMT + Bobath Technology	CMT + Bobath Technology + Baduanjin	40 min/ session, 1session/d, 7d/wk	6	Hospital	NIHSS, total effective rate
Bai YJ, 2011 (Guo et al., 2013)	Hainan, China (Chinese)	30–65	30	30	Balance training	Balance training + Baduanjin	20 min/ session, 2session/d, 7d/wk	6	Hospital	BBS

Note: C, control group; E, experiment group (Baduanjin group); CMT, Conventional Medical Treatment; CRT, Conventional Rehabilitation Training; TCM, Traditional Chinese Medicine.

Outcomes: BBS, Berg Balance Scale; NIHSS, National Institutes of Health Stroke Scale; NDS, Neurological Deficit Scale; FMA, Fugl-Meyer Assessment; SF-36, the 36-items short form health survey; FMA-LE, Fugl-Meyer Assessment of Lower Extremity; FAC, Functional Ambulation Categories; TIS, Trunk Impairment Scale; FMA-UE, Fugl-Meyer Assessment of Upper Extremity; MMT, Manual Muscle Test; MAS, Modified Ashworth Spasticity Scale; MBI, Modified Barthel Index; BI, Barthel Index; 6MWD, 6-minute Walking Distance; FMB, Fugl-Meyer balance subscale.

function domain, the upper extremity component consisted of 33 items, which ranged within 0–66 points, while the lower extremity component consisted of 17 items, which ranged within 0–34 points. For both components, higher scores indicated lower levels of impairment.(Kim et al., 2021) The FMA total motor scores were used to assess the overall motor impairment in four studies that included 238 participants.(Zhou et al., 2021; Yuan, 2021; Chen, 2020; Xie et al., 2019) The *meta*-analysis results revealed a significant improvement in motor function in the experimental group, when compared to the control group (MD: 9.55, 95 % CI: 6.07 to 13.03, $P < 0.00001$, $I^2 = 70$ %; Fig. 3A). Subgroup analyses were conducted to determine whether the intervention duration of Baduanjin has an influence on improving motor function in stroke patients. The *meta*-analysis of two studies(Chen, 2020; Xie et al., 2019) with intervention duration of < 12 weeks showed the following results: MD: 11.47, 95 % CI: 10.08 to 12.87, $P < 0.00001$, $I^2 = 0$ %. The *meta*-analysis of two studies(Zhou et al., 2021; Yuan, 2021) with intervention duration of ≥ 12 weeks showed the following results: MD: 6.98, 95 % CI: 4.41 to 9.55, $P < 0.00001$, $I^2 = 0$ % (Fig. 3B). The FMA-UE was used to assess the upper extremity motor function in two studies that included 100 participants.(Wang, 2020; Cui et al., 2018) The *meta*-analysis results revealed a significant improvement in upper extremity motor function in the experimental group, when compared to the control group (MD: 1.47, 95 % CI: 0.35–2.59, $P = 0.010$, $I^2 = 0$ %; Fig. 3C). The lower extremity motor function was assessed by the FMA-LE in four studies that included 241 participants.(Yu et al., 2020; Cui et al., 2018; 2018; Zhang and Li, 2016) The *meta*-analysis results revealed a significant improvement in lower extremity motor function in the experimental group, when compared to the control group (MD: 3.65, 95 % CI: 0.43–6.87, $P = 0.03$, $I^2 = 93$ %; Fig. 3D). These results indicate that Baduanjin has a better rehabilitative effect on motor function in stroke patients, when compared to conventional training.

3.4.2. Balance function

The balance function was assessed using the BBS in twelve studies (Liu et al., 2022; Zhou et al., 2021; Li, 2020; Yu et al., 2020; Zhuang et al., 2019; Xie et al., 2019; Ding et al., 2019; 2018; Tian, 2017; Zhang and Li, 2016; Zhang et al., 2013; Bai et al., 2011) that included 898 participants. The BBS consisted of a series of 14 functional balance tasks to examine the balance in different postures, in which higher scores indicated greater balance.(Berg et al., 1995) The *meta*-analysis results revealed that the BBS score was higher in the experimental group, when compared to the control group (MD: 8.28, 95 % CI: 5.04 to 11.51, $P < 0.00001$, $I^2 = 95$ %; Fig. 4A). Subgroup analyses were conducted to determine whether the intervention duration of Baduanjin has an influence in improving balance in stroke patients. The *meta*-analysis of eight studies(Liu et al., 2022; Li, 2020; Xie et al., 2019; Ding et al., 2019; 2018; Zhang and Li, 2016; Zhang et al., 2013; Bai et al., 2011) with an intervention duration of < 12 weeks revealed the following results: MD: 7.99, 95 % CI: 3.45 to 12.53, $P = 0.0006$, $I^2 = 96$ %. The *meta*-analysis of four studies(Zhou et al., 2021; Yu et al., 2020; Zhuang et al., 2019; Tian, 2017) with an intervention duration of ≥ 12 weeks revealed the following results: MD: 8.70, 95 % CI: 5.68–11.71, $P < 0.00001$, $I^2 = 73$ % (Fig. 4B). In addition, three studies(Liu, 2022; Cui and Yang, 2019; Cui et al., 2018) (which included a total of 195 participants) assessed the balance function using the Pk254 balance function detection system. This system can measure the ability of micro-control of the center of gravity (including X speed and Y speed), and the degree of center of gravity shake (including the track length [TL], Area, X deviation, and Y deviation), in which lower scores indicated greater balance. The *meta*-analysis results revealed the following results: X speed (MD: −1.12, 95 % CI: −1.56 to −0.68, $P < 0.00001$, $I^2 = 0$ %), Y speed (MD: −0.45, 95 % CI: −0.72 to −0.17, $P = 0.001$, $I^2 = 0$ %), TL (MD: −68.32, 95 % CI: −102.53 to −34.11, $P < 0.0001$, $I^2 = 0$ %), Area (MD: −59.05, 95 % CI: −93.50 to −24.60, $P = 0.0008$, $I^2 = 1$ %), X deviation (MD: −1.35, 95 % CI: −1.58 to −1.13, $P < 0.00001$, $I^2 = 0$ %), and Y deviation (MD: −0.31, 95 % CI: −0.47 to −0.16, $P < 0.0001$, $I^2 = 0$ %) (Fig. 5). These findings indicate that Baduanjin has a better effect on balance in stroke patients, when compared to conventional training.

3.4.3. Trunk function

Trunk function was assessed using the TIS in two studies(Yu et al., 2020; Zhuang et al., 2019) that included 148 participants. The TIS assesses the trunk movement impairment after stroke, which includes static and dynamic sitting balance, and trunk coordination. The TIS scores ranged within 0–23, and higher scores indicated better trunk control.(Verheyden et al., 2004) The *meta*-analysis results revealed that the TIS scores were higher in the experimental group, when compared to the control group (MD: 2.26, 95 % CI: 1.33–3.19, $P < 0.00001$, $I^2 = 39$

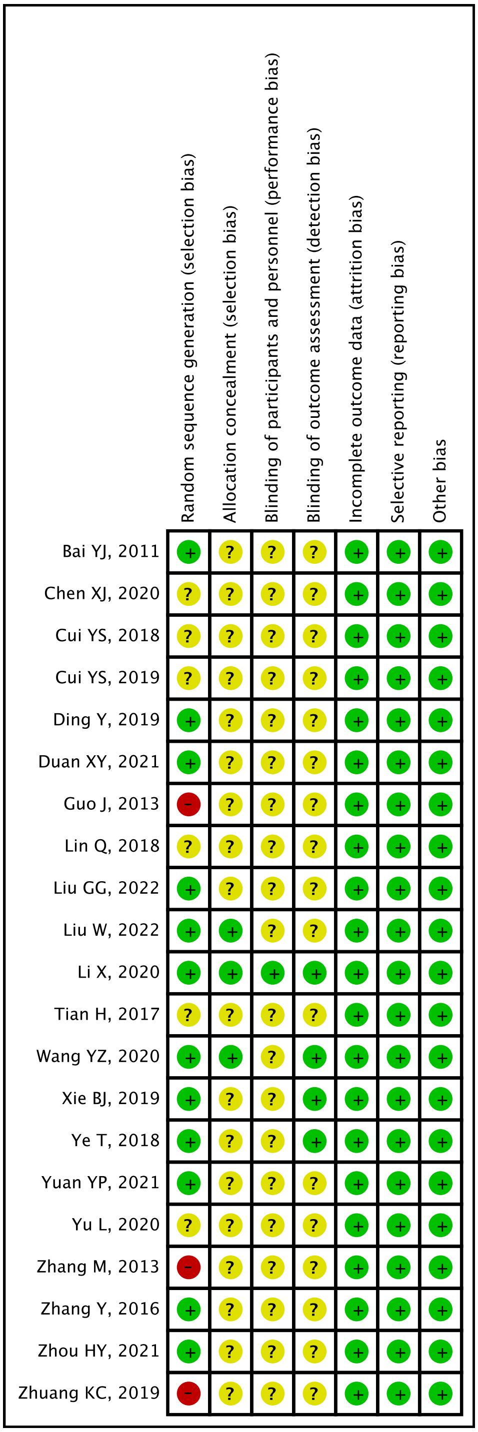

Fig. 2. Summary of risk of bias.

%; Fig. 6A). This result suggests that Baduanjin can better improve trunk function in stroke patients, when compared to conventional trainings.

3.4.4. Ambulation

Functional ambulation was assessed using FAC in two studies(Yu et al., 2020; Zhuang et al., 2019) that included 148 participants. FAC classifies ambulation into six levels, based on the amount of physical support required (from “unable to walk” [FAC 0] to “able to independently walk anywhere” [FAC 5]), and this has been widely used as an assessment tool to measure ambulation in stroke.(Holden et al., 1984) The *meta*-analysis results revealed that the experimental group had a higher FAC score, when compared to the control group (MD: 0.68, 95 % CI: 0.32–1.04, $P = 0.0002$, $I^2 = 44$ %; Fig. 6B). These results indicate that Baduanjin has a better effect on functional ambulation in stroke patients, when compared to conventional training. In addition, two studies (Yuan, 2021; Xie et al., 2019) (including a total of 105 participants) assessed ambulation using 6MWD. The 6MWD is a method of assess ambulation by instructing patients to walk for six minutes, and recording the longest distance the subject could walk.(Parry et al., 2021) The results of *meta*-analysis showed that the experimental group had higher 6WMD score compared with the control group (MD: 37.18, 95 % CI: 27.95 to 46.41, $P < 0.00001$, $I^2 = 0$ %; Fig. 6C).

3.4.5. Neurological function

Both NIHSS and NDS have been used to evaluate the severity of neurological deficits in stroke patients, with higher scores indicating greater neurological deficits.(Vuillier et al., 2004) Four studies(Liu, 2022; Duan and Zeng, 2021; Chen, 2020; Guo et al., 2013) (including a total of 443 participants) assessed neurological function using NIHSS. The results of *meta*-analysis showed that the experimental group had lower NIHSS score compared with the control group (MD: −4.42, 95 % CI: −7.21 to −1.63, $P = 0.002$, $I^2 = 97$ %; Fig. 6D). In addition, neurological function was assessed by the NDS in two studies(Zhou et al., 2021; Lin, 2018) including 160 participants. The results of *meta*-analysis revealed significantly lower neurological deficits compared with control group (MD: −7.14, 95 % CI: −8.06 to −6.22, $P < 0.00001$, $I^2 = 18$ %; Fig. 6E). These results indicate that Baduanjin has a better effect in improving neurological functions in stroke patients, when compared to conventional training.

3.4.6. Activities of daily living

Both BI and MBI are widely used basic ADL measure with good reliability and validity to quantify functional changes after stroke rehabilitation, with higher scores indicating better ability of ADL.(Keith et al., 1987) The ADL was assessed by the BI in two studies[28 31] including 130 participants. The results of *meta*-analysis revealed that the BI score in the experimental group was significantly higher than that in the control group (MD = 16.40, 95 % CI: 11.72 to 21.08, $P < 0.00001$, $I^2 = 28$ %; Fig. 7A). Four studies(Yuan, 2021; Li, 2020; Wang, 2020; 2018) (including a total of 206 participants) assessed ADL using MBI. The results of *meta*-analysis showed that the experimental group had higher MBI score compared with the control group (MD: 7.01, 95 % CI: 2.66 to 11.35, $P = 0.002$, $I^2 = 73$ %; Fig. 7B). This result indicated that Baduanjin can promote more improvement in ADL functions in stroke patients compared with conventional training.

3.4.7. Total effective rate

Four studies(Liu, 2022; Guo et al., 2013) that involved 473 participants described the total effective rate after Baduanjin intervention. The *meta*-analysis results revealed that the total effective rate was higher in the experimental group, when compared to the control group (OR = 4.54, 95 % CI: 2.47 to 8.35, $P < 0.00001$, $I^2 = 0$ %; Fig. 7C). These results indicate that Baduanjin has a better rehabilitative effect on stroke rehabilitation, when compared to the control group.

3.5. Sensitivity analysis

There was statistical heterogeneity ($I^2 > 50$ %) in some outcome indicators in the present review. Thus, the investigators attempted to identify the sources of heterogeneity. The stability of the results was assessed by removing a literature one by one. The FMA, FMA-LE, BBS, NIHSS, and MBI were the outcomes that required the sensitivity analysis. It was observed that the results for the heterogeneity significantly changed after removing some studies ($I^2 \leq 50$ %), but the *meta*-analysis results did not substantially change, indicating that the data evaluated in the present study were relatively credible and stable. The sensitivity analysis results are presented in Table 2.

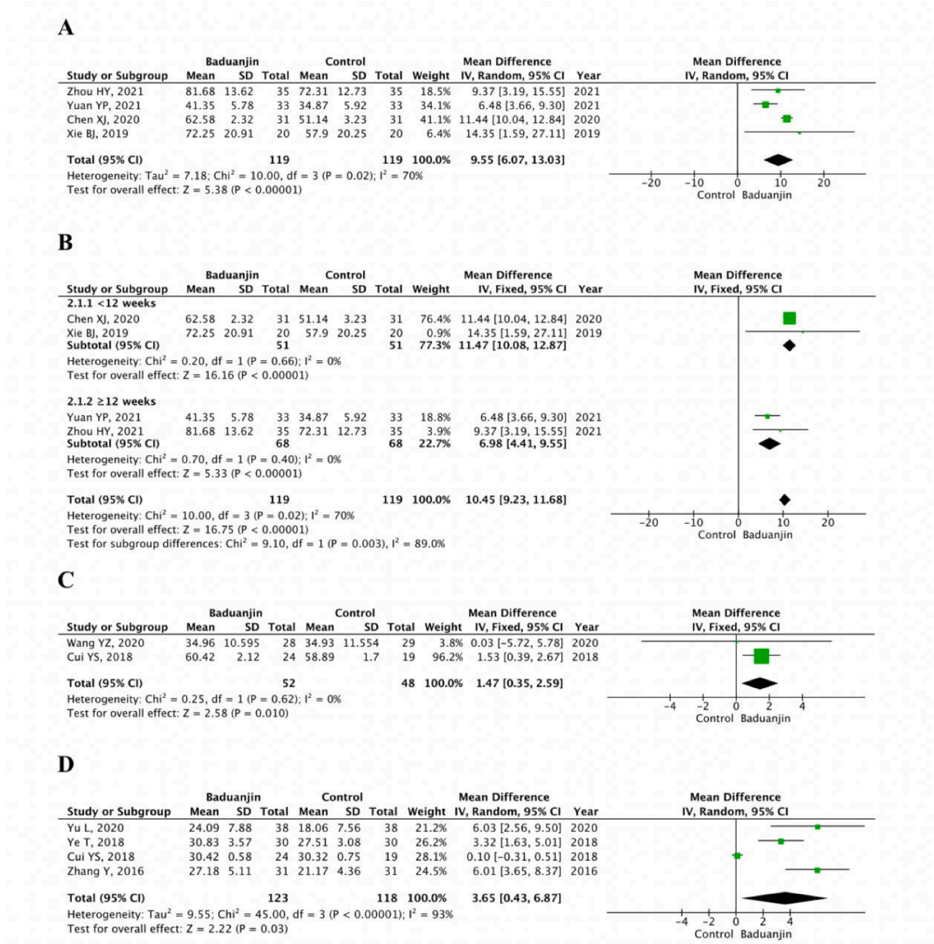

Fig. 3. Meta-analysis results for the FMA scores. (A) FMA total motor scores after the Baduanjin exercise; (B) Subgroup analysis of the FMA scores after the Baduanjin exercise, according to intervention duration; (C) FMA-UE scores after the Baduanjin exercise; (D) FMA-LE scores after the Baduanjin exercise.

3.6. Descriptive analysis

Two studies(Ding et al., 2019; Tian, 2017) used the FMB to evaluate the balance function, and two studies[19 21] used the SF-36 to evaluate the quality of life. Due to the high heterogeneity and small number of pooled studies, the source of heterogeneity could not be identified. Thus, a *meta*-analysis was not performed for those domains. One study[25] used the MMT to assess the muscle strength, and used the MAS to assess the spasticity. All studies above revealed that Baduanjin has better rehabilitative effects in stroke patients, when compared to the control group.

All the included studies did not report any adverse effects for Baduanjin, suggesting that Baduanjin may be a safe exercise for stroke patients.

3.7. Publication bias

A funnel plot was generated to visually evaluate publication bias in 12 RCTs(Liu et al., 2022; Zhou et al., 2021; Li, 2020; Yu et al., 2020; Zhuang et al., 2019; Xie et al., 2019; Ding et al., 2019; 2018; Tian, 2017; Zhang and Li, 2016; Zhang et al., 2013; Bai et al., 2011) that performed BBS. The asymmetric shape of this plot suggested publication bias (Fig. 8).

4. Discussion

The present study revealed that Baduanjin has better effects in increasing the FMA, BBS, TIS, FAC, 6MWD, MBI and BI scores, and total effective rate, and reducing the Pk254 balance function detection system, NIHSS and NDS scores, when compared to the control group. These results suggest that Baduanjin has a positive effect in improving motor, balance, trunk, ambulation, and neurological functions, and has the ability of completing ADLs in stroke patients.

Stroke patients suffer from damage to the central nervous system, resulting in impairments in motor or sensory transmission pathways, which possibly causes motor deficits and difficulties in trunk control. It has been suggested that loss of trunk control may lead to balance and walking limitations.(Sorrentino et al., 2018) Previous studies have suggested that physical exercise can regulate neural activities in the brain, and facilitate cortical reorganization to compensate for the damage by establishing new connections between undamaged neurons, which can promote functional recovery following stroke.(Pin-Barre and Laurin, 2015) It has been proven that the long-term practice of Baduanjin can promote blood circulation in the extremities and lower back, and facilitate neural transmission in the central nervous system. (Guo et al., 2023) Furthermore, Baduanjin can promote neural regeneration and migration in the central nervous system by upregulating neurotrophic factors, such as the brain-derived neurotrophic factor and vascular endothelial growth factor.(Yi et al., 2022) These above findings underly the neural mechanisms for Baduanjin's positive effects on functional recovery following stroke.

Several RCTs have revealed that sustained exercise can improve trunk control, mobility, and neurological function in stroke patients, and this is consistent with the findings of the present review.(Lund et al., 2018; Kim et al., 2015) Baduanjin is a moderate-intensity aerobic

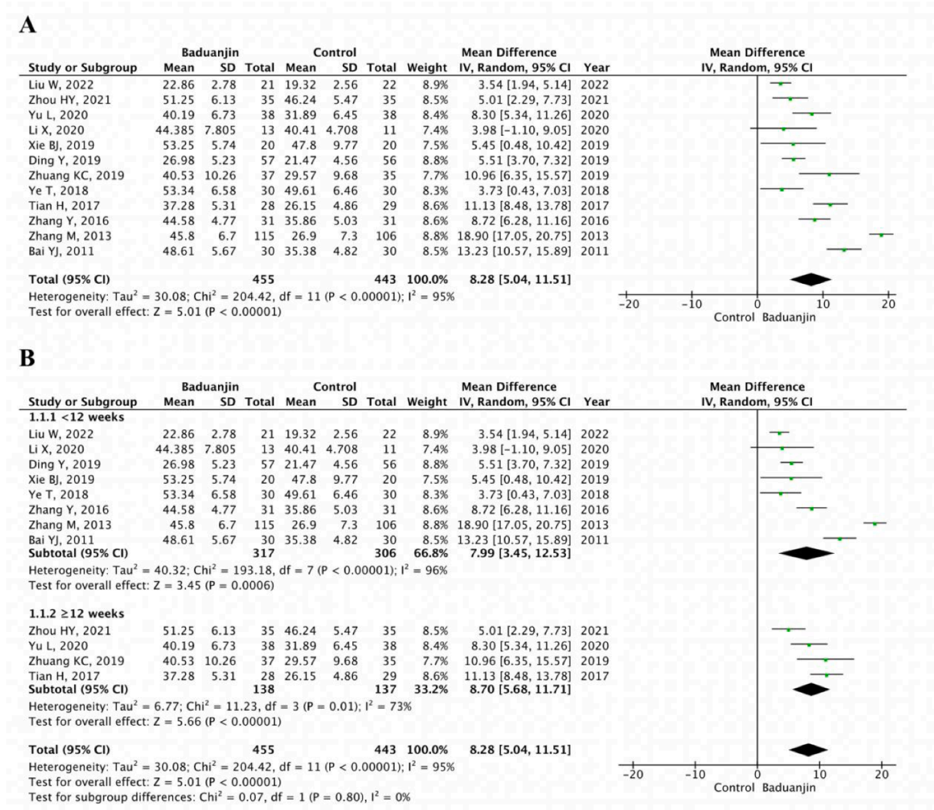

Fig. 4. Meta-analysis results for the BBS scores. (A) BBS scores after the Baduanjin exercise; (B) Subgroup analysis of the BBS scores after the Baduanjin exercise, according to intervention duration.

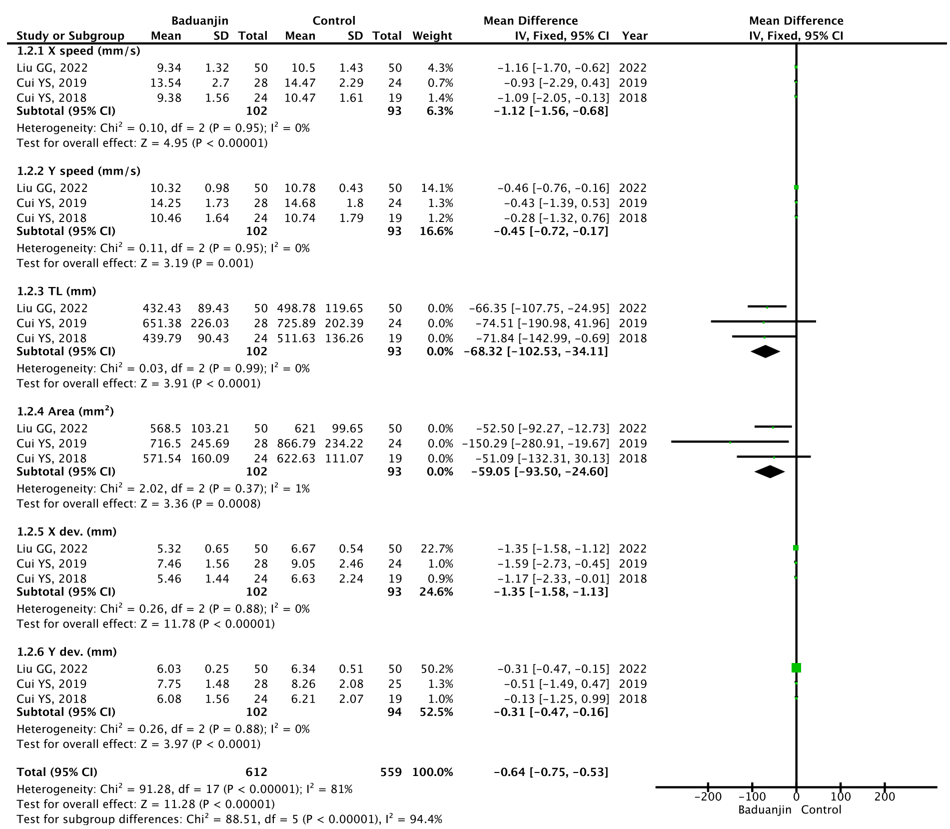

Fig. 5. Meta-analysis results for the Pk254 balance function detection system scores, illustrating the Pk254 balance function detection system scores after the Baduanjin exercise.

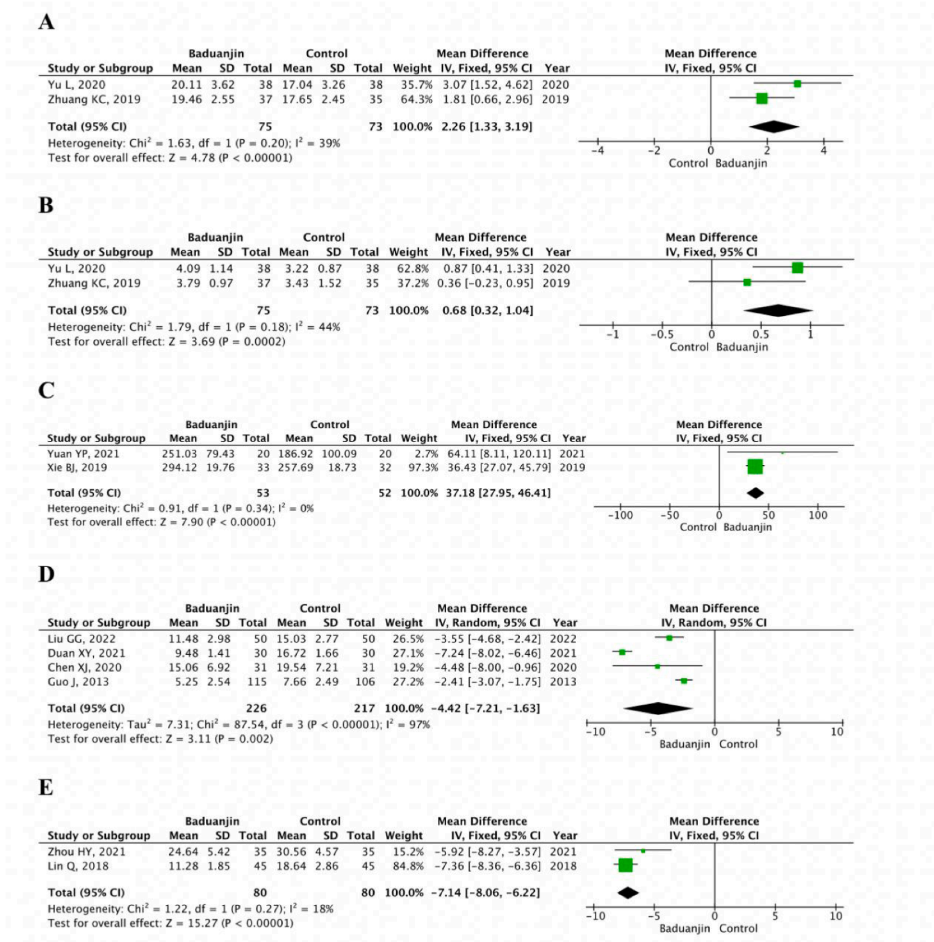

Fig. 6. Meta-analysis results for the TIS, FAC, 6MWD, NIHSS, and NDS scores. (A) TIS scores after the Baduanjin exercise; (B) FAC scores after the Baduanjin exercise; (C) 6MWD scores after the Baduanjin exercise; (D) NIHSS scores after the Baduanjin exercise; (E) NDS after the Baduanjin exercise.

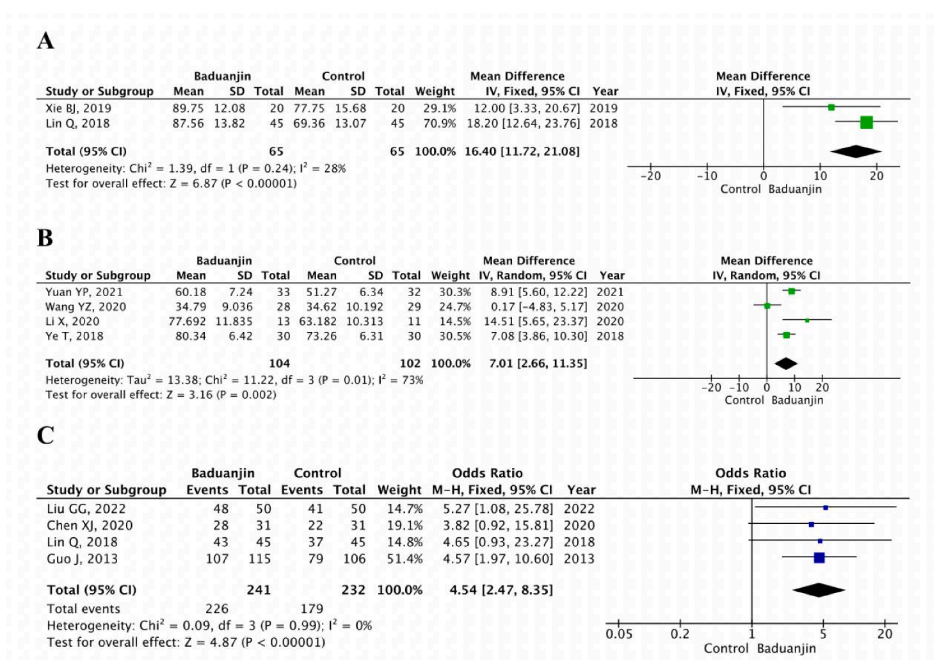

Fig. 7. Meta-analysis results for the BI and MBI scores, and total effective rate. (A) BI scores after the Baduanjin exercise; (B) MBI scores after the Baduanjin exercise; (C) Total effective rate scores after the Baduanjin exercise.

Table 2
Sensitivity analysis results.

Outcome measures		Number of included studies	Meta-analysis results before sensitivity analysis	Studies removed from sensitivity analysis	Meta-analysis results after sensitivity analysis
FMA		4	MD: 9.55, 95 % CI: 6.07 to 13.03, $P <$ 0.00001, I^2 = 70 %	Yuan YP	MD: 11.37, 95 % CI: 10.02 to 12.73, $P <$ 0.00001, I^2 = 0 %
FMA-LE		4	MD: 3.65, 95 % CI: 0.43 to 6.87, $P = 0.03$, I^2 = 93 %	Cui YS	MD: 4.47, 95 % CI: 3.19 to 5.75, $P <$ 0.00001, I^2 = 50 %
BBS	all studies	12	MD: 8.28, 95 % CI: 5.04 to 11.51, $P <$ 0.00001, I^2 = 95 %	Bai YJ, Zhang M, Tian H, Zhang Y, Liu W	MD: 5.87, 95 % CI: 4.74 to 7.01, $P <$ 0.00001, I^2 = 40 %
	intervention duration of < 12 weeks	8	MD: 7.99, 95 % CI: 3.45 to 12.53, $P =$ 0.0006, I^2 = 96 %	Bai YJ, Zhang M, Zhang Y	MD: 4.36, 95 % CI: 3.29 to 5.44, $P <$ 0.00001, I^2 = 0 %
	intervention duration of ≥ 12 weeks	4	MD: 8.70, 95 % CI: 5.68 to 11.71, $P <$ 0.00001, I^2 = 73 %	Zhou HY	MD: 10.04, 95 % CI: 8.23 to 11.86, $P <$ 0.00001, I^2 = 6 %
NIHSS		4	MD: −4.42, 95 % CI: −7.21 to −1.63, $P <$ 0.00001, I^2 = 97 %	Duan XY	MD: −2.75, 95 % CI: −3.31 to −2.18, $P <$ 0.00001, I^2 = 48 %
MBI		4	MD: 7.01, 95 % CI: 2.66 to 11.35, $P =$ 0.002, I^2 = 73 %	Wang YZ	MD: 8.39, 95 % CI: 6.15 to 10.62, $P <$ 0.00001, I^2 = 22 %

Note: MD, mean differences; CI, confidence intervals.
Outcomes:FMA, Fugl-Meyer assessment; FMA-LE, Fugl-Meyer Assessment of Lower Extremity; BBS, Berg Balance Scale; NIHSS, National Institutes of Health Stroke Scale; MBI, Modified Barthel Index.

exercise that does not require any equipment or specific training location. These features make Baduanjin suitable for stroke patients in family and community environments. The whole set of movements of Baduanjin focuses on the training of the erector spinae and multifidus muscles, which helps to improve core muscle strength, trunk stability and postural control.(Yuen et al., 2021) In addition, practicing Baduanjin fully stretches the joints in the whole body, and improves joints coordination when completing complex movements in stroke patients.(Dong et al., 2022 Jan) Movements, such as knee bending and squatting movements, can facilitate motor units' recruitment, and promote muscle activation in the lower extremity, thereby improving balance and motor function in stroke patients.(Riemann and Lephart, 2002).

Proprioception refers to the ability to recognize and locate information about the body's position in relation to the environment, which is closely correlated to balance control and ambulation.(Cherup et al., 2021) Evidence has suggested that mind–body exercises (such as Tai Chi, Pilates, Yoga and Meditation) have a positive impact in improving trunk proprioception.(Suner-Keklik et al., 2022 Oct; Lai et al., 2022 Nov 15) As a form of mind–body exercise; Baduanjin not only involves limbs coordination, but also emphasizes breath control and mental concentration (*i.e.* eliminating distracting thoughts), which enhances the proprioception in joints and muscles, thereby improving balance and ambulation.(Lai et al., 2022 Nov 15) In the present review, it was observed that the BI score was higher in the Baduanjin group, when compared to the control group, after intervention, which is consistent with previous suggestions that mind–body exercises can improve the ability of performing ADLs.(Lai et al., 2022 Nov 15) The improved ADLs may have resulted from the stable and independent sitting-standing transfer after practicing Baduanjin.

5. Strengths and limitations

The present study has the following strengths and limitations. The present study closely followed the guidelines for systematic reviews, and was conducted based only on RCTs, strengthening the evidence level of the results. Rigorous literature search strategies were also performed to identify the maximal relevant literature in 10 major databases, making the results of the present review comprehensive. However, the present review still has some limitations. First, the number of included studies was small, and the outcome indicators were diverse among the studies. Therefore, merely a small number of studies were combined for the *meta*-analysis of outcome indicators. This inevitably reduced the statistical power of the *meta*-analysis, and prevented the present review from providing the most powerful evidence. Second, significant heterogeneity was observed in five outcome indicators (FMA, FMA-LE, BBS, NIHSS, and MBI) in the present *meta*-analysis. Thus, a sensitivity analysis was performed to determine the source of heterogeneity. The clinical heterogeneity may have resulted from the differences in frequency, duration, or intensity of exercise. Third, since the follow-up information for long-term effects was unavailable in most of the included studies, the present review did not explore the persistency of the treatment effects induced by Baduanjin. Fourth, due to language restrictions, we only included studies published in Chinese and English, thus missing reports published in other languages.

6. Conclusions

In conclusion, the present review suggests the potential benefits of Baduanjin in improving motor, balance, trunk, ambulation and neurological functions, and ADL in stroke patients. Thus, Baduanjin can be a feasible approach for therapeutic exercise in stroke rehabilitation. Larger RCTs with more standardized intervention protocols are required to obtain more robust evidence.

CRediT authorship contribution statement

Xi Cheng: Investigation, Writing – original draft, Writing – review & editing, Conceptualization, Formal analysis, Methodology. **Yanling Gao:** Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – review & editing. **Xiaofeng Chen:** Formal analysis, Investigation, Supervision, Visualization, Writing – review & editing. **Jinhua Lu:** Formal analysis, Investigation, Writing – review & editing. **Qingyue Dai:** Investigation, Visualization, Writing – review & editing. **Jinghui Lai:** Formal analysis, Investigation, Methodology, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

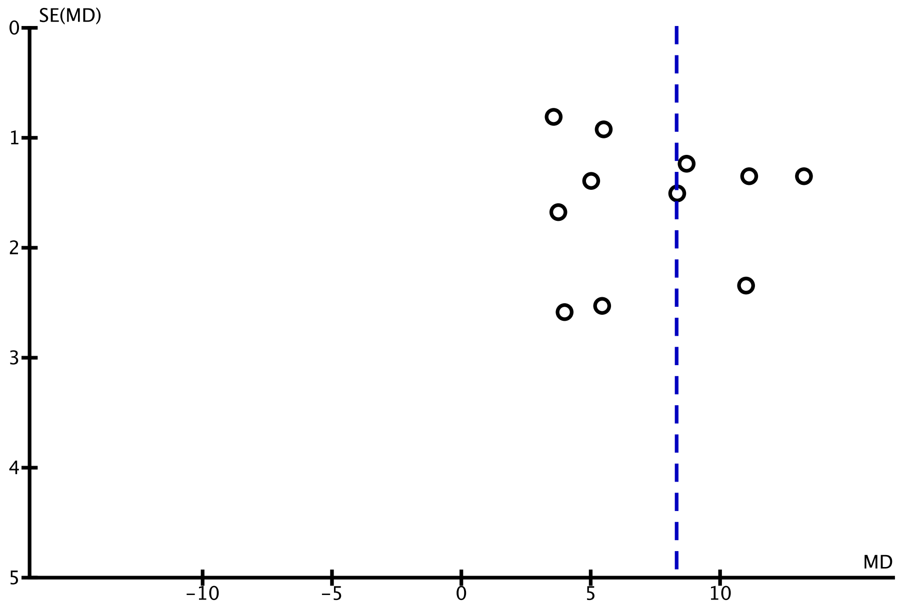

Fig. 8. Funnel plot for Baduanjin intervention with BBS.

Data availability

Data will be made available on request.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102703.

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