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Review Article (Meta-Analysis)

Efficacy of Aquatic Therapy in Improving Balance in Patients With Stroke: A Systematic Review and Meta-Analysis

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KEYWORDS
Aquatic exercise;
Aquatic therapy;
Aquatic training;
Balance;
Cerebrovascular disease;
Rehabilitation;
Stroke

Abstract *Objective:* To evaluate the efficacy of aquatic therapy in improving balance, gait speed, and fall risk in patients with stroke.
Data Sources: MEDLINE, Cumulative Index to Nursing and Allied Health Literature, PubMed, Scopus, Web of Science, and Physiotherapy Evidence Database were searched for studies published from 2013 to October 2024.
Study Selection: Experimental studies comparing aquatic therapy with conventional rehabilitation, land-based interventions, or no intervention. The primary outcome was balance, assessed using the Berg Balance Scale. Secondary outcomes included gait speed and fall risk.
Data Extraction: Study design characteristics, number of participants, interventions characteristics, and outcomes were extracted.
Data Synthesis: Twenty-seven interventional studies with 1134 participants (236 women and 225 men approximately) were included in the systematic review, among which 19 contributed to the meta-analysis. Ages ranged from 49.5 to 69.1 years. The time since injury varied from approximately 30 days to 5.4 years. Risk of bias of included studies was assessed using Cochrane Risk of Bias tool 2. Aquatic therapy significantly improved balance (Berg Balance Scale: MD, −5.10; 95% CI, −8.85 to −1.36; P=.008), gait speed (MD, −5.10; 95% CI, −8.85 to −1.36; P=.008), and reduced fall risk (MD, −4.38; 95% CI, −7.17 to −1.59; P=.002). Subgroup analyses based on session frequency (>20 sessions vs 10-20 sessions) showed similar effects.
Conclusions: This meta-analysis suggests that aquatic therapy may be effective in enhancing balance and gait speed and in reducing fall risk among individuals with stroke; however, these findings should be interpreted with caution because of the high heterogeneity observed across studies.

List of abbreviations: 2MWT, 2-minute walk test; 10MWT, 10-meter walk test; BBS, Berg Balance Scale; MD, mean difference; MDC, minimal detectable change; PNF, proprioceptive neuromuscular facilitation; RoB 2, Cochrane Risk of Bias 2; TUG, timed Up and Go test.
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Stroke is a highly prevalent neurologic condition that impairs mobility and leads to alterations in sensorimotor functions, language, recognition, and perception, depending on the affected area and the extent of the damage.[1,2] Approximately 80% of individuals who experience a stroke survive and regain independent walking ability, with 64%-80% achieving this through rehabilitation.[3] Common causes of gait disturbances include muscle weakness, reduced coordination, impaired balance, and spasticity.[4-6] Impaired balance often increases the risk of falls, which is associated with higher rates of injury, fear of falling, and loss of confidence, thereby reducing activity and social participation.[7] Gait speed, which can improve even in the chronic stages of stroke, is another variable that can affect activity and social participation.[8] The most commonly used observational assessment scales in research studies for evaluating balance and fall risk include the timed Up and Go (TUG) test, Functional Reach Test or modified Functional Reach Test, and the Berg Balance Scale (BBS).[1]

Studies by Sherrington et al,[9] van Duijnhoven et al,[10] and Li et al[11] have demonstrated that therapeutic ground exercises improve strength, gait, balance, and motor function. However, these exercises may have negative effects on patients' joints and musculature, potentially leading to falls and muscle pain, which can reduce physical activity.[10,11]

Water is an excellent medium for therapeutic exercise because of its unique physical properties.[11] Buoyancy and hydrostatic pressure reduce body weight and joint loading, while viscosity and hydrostatic pressure provide resistance that enhance strength and proprioception.[12,13] These characteristics facilitate smoother, more coordinated movements with less effort compared to land environments.[14-16] Additionally, warm water, commonly used in the included studies, has been shown to reduce pain, promote muscle relaxation, and improve mobility.[14]

Hydrotherapy, defined as the use of water for therapeutic purposes, includes balneotherapy, thalassotherapy, and other methods of aquatic therapy.[17] Aquatic therapy performed by physiotherapists involves various activities and exercises to improve balance and is particularly useful in neurorehabilitation.[13,18]

Several studies included in this review implemented structured aquatic therapy techniques that may not be widely known outside specialized rehabilitation contexts.[19] These approaches include Ai Chi,[20-23] a method combining deep breathing with slow, controlled movements to promote postural stability and relaxation; the Halliwick concept (implemented in 2 studies),[20,24] a rotational movement-based technique designed to improve balance and core control in water; the Bad Ragaz Ring Method,[25] which uses flotation devices and therapist-guided resistance exercises to enhance neuromuscular coordination, and proprioceptive neuromuscular facilitation (PNF),[26,27] which applies specific movement patterns in water to improve motor control and functional mobility. Several variations of these exercises have been described across studies.

The therapeutic benefits of aquatic therapy have been recognized since ancient times, with historical use documented in Greek and Chinese traditions. Contemporary scientific literature further supports its clinical value in stroke rehabilitation.[1,4,19,28-30] The primary objective of this study was to conduct a systematic review and meta-analysis to evaluate the efficacy of aquatic therapy in improving balance in patients with stroke. Secondary objectives included reviewing and meta-analyzing evidence regarding the efficacy of aquatic therapy in improving walking speed and reducing the risk of falls in this population.

Methods

Study design and registration

This study is a systematic review and meta-analysis of the current evidence on the effectiveness of aquatic therapy in improving balance in patients who have experienced a stroke. To this end, the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Declaration[31] were considered. The protocol was registered a priori in the PROSPERO Database (Registration number CRD42024503897) in January 2024.

Eligibility criteria

Studies in this review were in the English and Spanish languages. The selection was based on the following eligibility criteria. Inclusion criteria were randomized clinical trials involving adult patients (≥18y) who had experienced a stroke. Studies had to include aquatic therapy as the intervention, with comparisons made to land-based therapy, conventional rehabilitation, or control groups. Eligible studies assessed outcomes related to balance, gait speed, and fall risk. Exclusion criteria included studies published >10 years ago and those in which swimming or balneotherapy were considered aquatic therapy interventions.

Search strategy

For the present systematic review, a literature search was conducted in MEDLINE, Cumulative Index to Nursing and Allied Health Literature, PubMed, Scopus, Web of Science, and Physiotherapy Evidence Database for studies published from 2013 to October 2024 (date of last search). Table 1 lists the search strategies used for each database.

In the search of PubMed, MEDLINE, Cumulative Index to Nursing and Allied Health Literature, Web of Science, and Scopus databases, we selected studies since 2013 (the first search was conducted in 2023; the last 10y were considered for evaluating the most recent studies), in English and Spanish, and filtered by "clinical trial." Reviews were excluded to obtain all the results.

Table 1 Search strategy in the different databases.

Databases	Stroke Search
MEDLINE CINAHL PubMed	("aquatic therapy" or "aquatic training" or "aquatic exercise") and ("balance") and ("stroke" or "cerebrovascular disease")
WOS Scopus	("aquatic therapy" or "aquatic training" or "aquatic exercise") and ("balance") and ("stroke" or "cerebrovascular disease")
PEDro	"aquatic therapy" AND "balance"

Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health Literature; PEDro, Physiotherapy Evidence Database; WOS, Web of Science.

Selection process

Studies were screened by title, abstract, and full text by 2 independent reviewers (L.G.A. and I.R.C.) while discrepancies were resolved by a third independent reviewer (M.C.S.). Duplicated records were deleted. The selected studies were filtered, initially eliminating those in which aquatic therapy was not applied to patients who had experienced a stroke. Of the remaining studies, the study abstracts were analyzed to determine whether they assessed balance, gait speed or risk of falling with different scales or indices, eliminating those that did not. Studies that appeared to meet eligibility criteria and studies that could not be evaluated based on information in the title or abstract were assessed by the full text. The last date of searching was in October 2024.

Assessment of risk of bias

The Cochrane Risk of Bias 2 (RoB 2) tool was used to score studies methodologically. Two independent reviewers (L.G.A. and I.R.C.) assessed the items of the individual included studies based on their judgment and reported reasoning. Automation tools were not used in this process.

Data extraction

The following information was extracted by 2 independent reviewers (L.G.A. and I.R.C.): (1) subject characteristics (number, age, sex, time since stroke onset, hemorrhagic/ischemic type, right/left injury location, cortical/subcortical); (2) characteristics of included studies (authors, study design, sample size, intervention dosage, duration of follow-up, outcome measurement tools, and reported findings); and (3) intervention description (number of intervention sessions, duration, and type of intervention).

Statistical analysis

A meta-analysis was conducted using Review Manager (RevMan 5.3)[a] from the Cochrane Collaboration. Results are shown as mean difference (MD) or standardized MD, calculated using means and SDs depending on the measurement instruments used. The inverse variance method was applied for quantitative variables. A random-effects model, which accounts for both within-study and between-study variability, was used to pool results. The overall effect was assessed using Z-statistics, with statistical significance set at $P<.05$.

Heterogeneity was assessed using the I^2 statistic, following the Cochrane Handbook for Systematic Reviews of Interventions (version 6.3). The interpretation of I^2 values is: <40%, heterogeneity may not be important; 30%-60%, moderate heterogeneity; 50%-90%, substantial heterogeneity; 75%-100%, considerable heterogeneity. These categories are indicative rather than absolute and should be interpreted in the context of magnitude and direction of effects and the strength of evidence for heterogeneity.[32] Cochran Q statistic was calculated with significance set at $P<.10$ indicating potential differences among studies.

Sensitivity analysis

To investigate the cause of heterogeneity, each study was removed from the model to assess its effect on the overall results.

Subgroup analysis

The effects of aquatic therapy were analyzed based on the number of sessions (>20 or 10-20 sessions). Subgroup analysis by session number was conducted to examine whether treatment frequency influences outcomes, allowing assessment of potential dose-response effects.

Publication bias

Publication bias was assessed using funnel plots. Symmetry suggests no publication bias, whereas asymmetry indicates potential bias.

Results

Study selection

A total of 27 records were included in this systematic review. The PRISMA flow diagram (fig 1) illustrates the steps taken in the search and selection of studies. Initially, 274 records were identified from the databases. After the application of search filters such as randomized clinical trial studies conducted in English and Spanish since 2013, 171 articles were removed. Subsequently, 62 duplicate studies were removed. Additionally, 3 studies that were not related to the topic of balance were eliminated based on their abstracts, resulting in a total of 33 studies. Six articles were excluded based on the inclusion and exclusion criteria, resulting in a total of 27 studies included in this systematic review. Nineteen records were included in the meta-analysis.

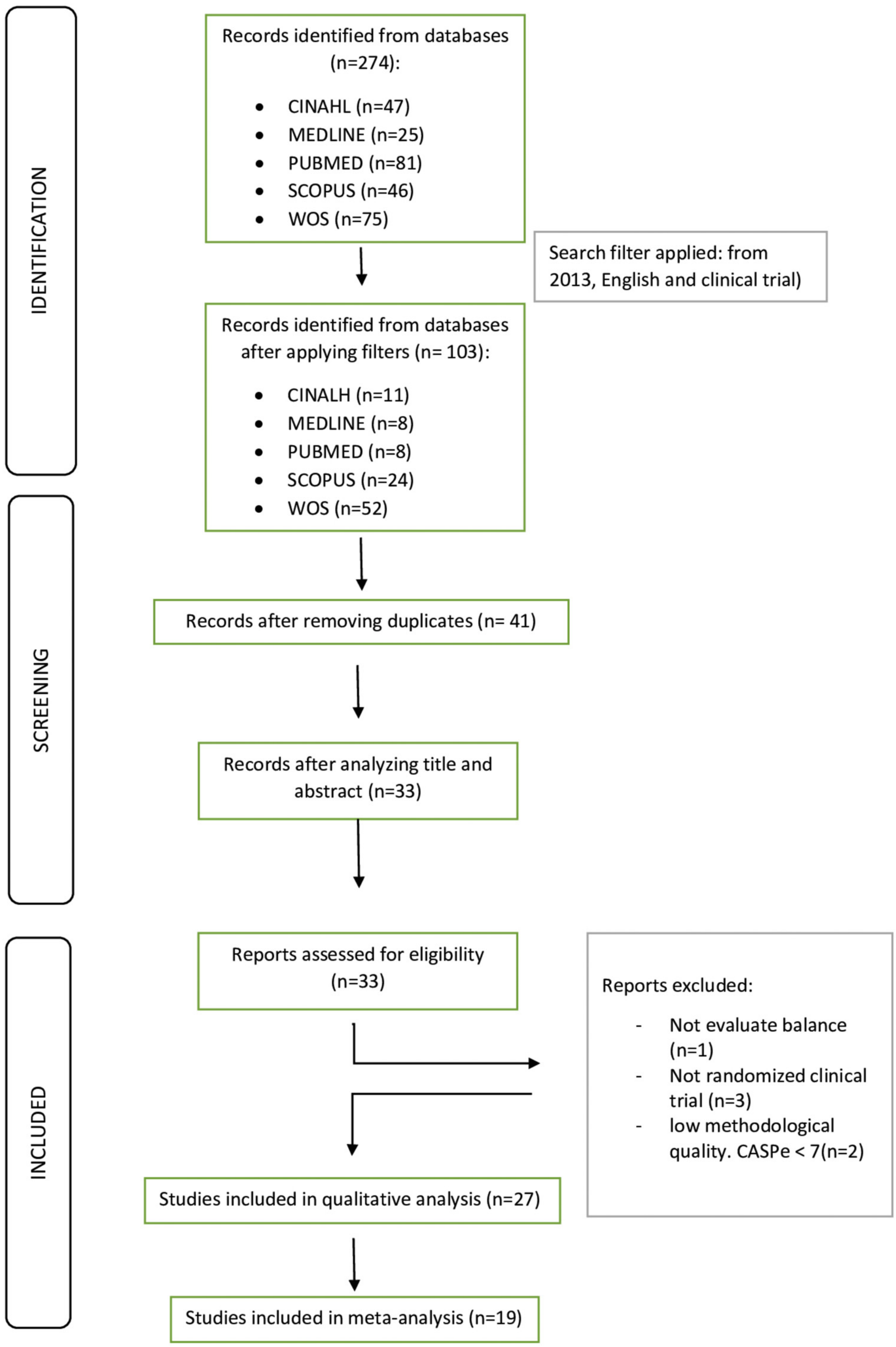

Fig 1 PRISMA flow diagram. CASPe, Critical Appraisal Skills Programme Español; CINAHL, Cumulative Index to Nursing and Allied Health Literature; WOS, Web of Science.

Study characteristics

In total, 1134 patients with stroke were included in this study. The characteristics of the subjects, in terms of age, sex, and years of injury, are shown in table 2.[20-27,33-51] The ages of the participants ranged from 49.5 to 69.1 years. Among the studies that provided information on the sample, 236 women and 225 men were identified. The time since injury varied from approximately 30 days to 5.4 years. Many studies included participants who were able to walk and follow verbal commands (minimum >24 on the Mini Mental Test).

Some publications indicated stroke type and most affected side, as illustrated in table 3.[20-27,33-51] In these

Table 2 Subjects' characteristics (I).

Study	N	EG/Shallow ATG			CG/EG2/Deep ATG			ATG+LT/CG/CG		
		Sex (W:M)	Age (y)	Injury (y)	Sex (W:M)	Age (y)	Injury (y)	Sex (W:M)	Age (y)	Injury (y)
Babaeipour et al[33] (2018)	36	0:12	59.50±7.10	6-24 mo	0:12	60.17±7.38	0.5-2	0:12	60.83±5.48	0.5-2
Bei et al[34] (2023)	160	20:60	62.63±6.79	0.05±0.008	28:52	62.68±6.56	0.06±0.008			
Cha et al[25] (2017)	22	5:6	64	1.38	4:7	63.3	1.575			
Chan et al[35] (2016)	25	3:10	66	0.263	9:3	64	0.265			
Eyvaz et al[36] (2018)	60	12:18	58.5	1.95	17:13	58.3	2.016			
Franciulli et al[37] (2019)	12	5:1	61.67	5.64	5:1	54.8	4.72			
Furnari et al[20] (2014)	40	10:10	68±3	0.58±0.13	10:10	72±5	0.5±			
Gu et al[38] (2022)	56	14:15	62.90	0.15	12:15	62.07	0.16			
Han et al[39] (2013)	62	16:15	56.1±7.3	1.27±0.42	18:13	56.6±10	1.34±0.42			
Iatridou et al[40] (2025)	51	9:16	57.80	1.03	1:15	55.50	1			
Kim et al[26] (2015)	20	5:5	65.9±6.2	0.94±0.09	5:5	64.1±3.6	1.025±0.11			
Kim et al[27] (2015) (II)	20	5:5	69.1±3.2	0.81±0. 1	5:5	68±3.1	0.85± 0.11			
Kim et al[41] (2016)	20	5:5	69.1	0.875	5:5	68	0.942			
Ku et al[21] (2020)	20	3:7	55±7.3	0.63±0.91	3:7	66.5±11.8	1.83±1.65			
Lee et al[42] (2018)	32	10:9	57.58	0.083	8:10	63.67	0.080			
Matsumoto et al[43] (2016)	120	18:42	62.4±10.7	1.9±0.1	14:46	63.2±11.5	2.03±0.12			
Park and Chung[44] (2018)	27	3:6	62.88±12.90	0.60±0.09	4:4	66.37±10.28	0.56±0.07	5:5	67.10±7.63	0.50±0.07
Park and Chung[45] (2018) (II)	40	5:8	55.5±9.98	0.6±0.09	3:9	56.9±4.42	0.59±0.15	6:9	57±10.9	0.65±0.14
Park et al[46] (2019)	29	4:10	56.23±13.74	0.76±0.41	3:12	57.13±11.73	1.07±0.5			
Pérez-de la Cruz[23] (2020)	40	7:6	54.2	5.4	7:7	54.6	5.7	5:8	53.1	6.6
Pérez-de la Cruz[22] (2021)	45	8:7	63.8	5.1	9:8	62.7	5.2	5:8	61.4	5.6
Saleh et al[47] (2019)	50	12:13	49.53	0.76	14:11	50	0.736			
Temperoni et al[48] (2020)	33	4:14	52.44±10.51	1.11±0.59	8:7	52.01±17.10	1.57±1.14			
Tripp & Krakow[24] (2014)	30	5:9	64.8±15	0.142±0.1	6:10	65±15.1	0.10±0.07			
Vakilian et al[49] (2021)	36		59.5			60.17			60.83	
Yang and Choi[50] (2015)	20	6:4	63.4±9.0	1.9				4:6	64.9±10.0	1.9
Zhu et al[51] (2016)	28	2:12	56.5	0.67	4:10	57.1	0.72			
TOTAL	1134	236:225			207:239			25:48		

Abbreviations: ATG+LT, aquatic therapy group associated with land therapy; deep ATG, deep aquatic therapy group; EG, experimental group; EG2, second experimental group; shallow ATG, shallow aquatic therapy group; M, men; W, women.

Table 3 Subjects' characteristics (II)

Study	Ischemic: Hemorrhagic			Right: Left			Cortical: Subcortical	
	EG	EG2	CG	EG	EG2	CG	EG	CG
Babaeipour et al[33] (2018)	12:0	12:0	12:0					
Bei et al[34] (2023)	40:40		40:40	48:32		30:50		
Cha et al[25] (2017)	7:4		9:2					
Chan et al[35] (2016)				5:8		5:7		
Eyvaz et al[36] (2018)	27:3		23:7	12:18		16:14		
Franciulli et al[37] (2019)	6:0		6:0	2:4		4:2		
Furnari et al[20] (2014)								
Gu et al[38] (2022)				16:13		15:12		
Han et al[39] (2013)				14:17		15:16		
Iatridou et al[40] (2025)	20:5		21:5	13:12		14:12		
Kim et al[26] (2015)				5:5		5:5		
Kim et al[27] (2015) (II)				5:5		5:5		
Kim et al[41] (2016)				5:5		5:5		
Ku et al[21] (2020)	7:2:1		6:2:2	3:7		4:6		
Lee et al[42] (2018)	11:8		9:9	9:10		10:9	9:10	7:11
Matsumoto et al[43] (2016)	41:19		39:21	28:32		24:36	28:32	24:36
Park and Chung[44] (2018)	8:1	7:1	6:4	3:6	4:4	6:4		
Park and Chung[45] (2018) (II)	9:4	4:8	6:9	3:10	8:4	7:8		
Park et al[46] (2019)	7:7		8:7	5:9		7:8		
Pérez-de la Cruz[23] (2020)								
Pérez-de la Cruz[22] (2021)								
Saleh et al[47] (2019)	15:10		13:12	13:12		12:13		
Temperoni et al[48] (2020)	7:11		8:7	8:10		8:7		
Tripp and Krakow[24] (2014)	12:2		15:1	10:4		10:6		
Vakilian et al[49] (2021)								
Yang & Choi[50] (2015)				5:5		5:5		
Zhu et al[51] (2016)	10:4		11:3	6:8		3:11		
TOTAL	246:120		220:129	218:232		220:240		

Abbreviations: CG, control group; EG, experimental group; EG2, second experimental group.

studies, 477 subjects had experienced ischemic stroke and 258 had experienced hemorrhagic stroke. Furthermore, in 450 subjects, the right side was most affected, whereas in 480, the left side was most affected.

The settings in which aquatic therapy interventions were conducted varied across studies. Most interventions took place in therapeutic pools located in rehabilitation centers or hospital facilities, whereas others used aquatic treadmills or deep pools with flotation devices. Reported water temperature ranged from 30°C to 38°C. Table 4[20-27,33-51] summarizes the facility types and water conditions described in the included studies.

Risk of bias of the included studies

The results of the RoB 2 scale are categorized into various domains, including the randomization process (D1a), participant identification or recruitment (D1b), deviations from the intended interventions (D2), missing outcome data (D3), measurement of the outcome (D4), selection of the reported result (D5). The outcomes of the studies included in this review are illustrated in figure 2. Five studies had a low risk of bias, whereas the remaining studies had a high risk of bias because of the loss of subjects between measurements and the therapists having knowledge of the intervention performed by each group (lack of blinding) in most studies.[21,25-27,34-36,39,42,44-46,49,51]

The results of the studies included in the RoB 2 scale are shown in figures 2 and 3. The selected studies had a low risk of bias in the outcome selection process. More than 85% of the studies showed a low risk of bias in the randomization process and data loss. Forty percent of the studies reported deviations from the intervention or differences between intervention groups, and 60% of the studies employed a measurement process in which the therapists were aware of the intervention, thus classifying it as having a high risk of bias.

Results of individual studies

The 27 studies analyzed in this review evaluated the improvement in balance after aquatic intervention in people who had experienced a stroke (table 5[20-27,33-51]). Of the 27 articles, 4 used measurement systems such as Biodex[25,49,47] or Sporkat.[36] The rest of the studies used scales such as the BBS[21,22,24,26,27,33-38,40-42,44-46,48,50,51] and TUG test.[22,25,27,35,37,38,41,44-46,50-52]

There was considerable variability in the aquatic therapy interventions employed across the included studies. Some studies used the Ai Chi program,[20-22,53] which combines the concept of Tai Chi with conventional aquatic therapy techniques. The 2 studies that applied the Halliwick concept[20,24] were based on the 10-point program, which focuses on developing balance control in the aquatic environment and enhancing functional abilities in water. The Bad Ragaz Ring Method[25] utilizes flotation devices to facilitate passive and active movements in water, emphasizing proprioceptive neuromuscular facilitation. These techniques were applied either in isolation or in combination with conventional land-

Table 4 Settings of Aquatic Therapy Interventions in the Included Studies

Study	Facility Type	Water Temperature
Babaeipour et al[33] (2018)	Therapeutic pool	33-35°C
Bei et al[34] (2023)	Hydrotherapy area	Not specified (warm water)
Cha et al[25] (2017)	Hydrotherapy pool	34°C
Chan et al[35] (2016)	Therapeutic pool	34.5°C
Eyvaz et al[36] (2018)	Therapeutic pool	33°C
Franciulli et al[37] (2019)	Deep pool with flotation belt	Not specified
Furnari et al[20] (2014)	Pool	33-34°C
Gu et al[38] (2022)	Hydrotherapy pool	35-38°C
Han et al[39] (2013)	Therapeutic pool	33.5 °C
Iatridou et al[40] (2025)	Therapeutic pool	34°C
Kim et al[27] (2015) (II)	Therapeutic pool	32-34°C
Kim et al[26] (2015)	Therapeutic pool	33-35°C
Kim et al[41] (2016)	Therapeutic pool	32-34°C
Ku et al[21] (2020)	Therapeutic pool	Not specified
Lee et al[42] (2018)	Aquatic treadmill	Not specified
Matsumoto et al[43] (2016)	Therapeutic pool	30-31°C
Park and Chung[45] (2018)	Therapeutic pool	30-32°C
Park and Chung[44] (2018)	Aquatic treadmill	30-32°C
Park et al[46] (2019)	Rehabilitation room with aquatic exercises	Not specified
Pérez-de la Cruz[23] (2020)	Therapeutic pool	34±0.5°C
Pérez-de la Cruz[22] (2021)	Pool	30±0.5°C
Saleh et al[47] (2019)	Therapeutic pool	Not specified
Temperoni et al[48] (2020)	Rehabilitation pool	30-32°C
Tripp and Krakow[24] (2014)	Pool	Not specified
Vakilian et al[49] (2021)	Pool	34-36°C
Yang and Choi[50] (2015)	Underwater treadmill	33°C
Zhu et al[51] (2016)	Therapeutic pool (1.4m) with underwater treadmill	34-36°C

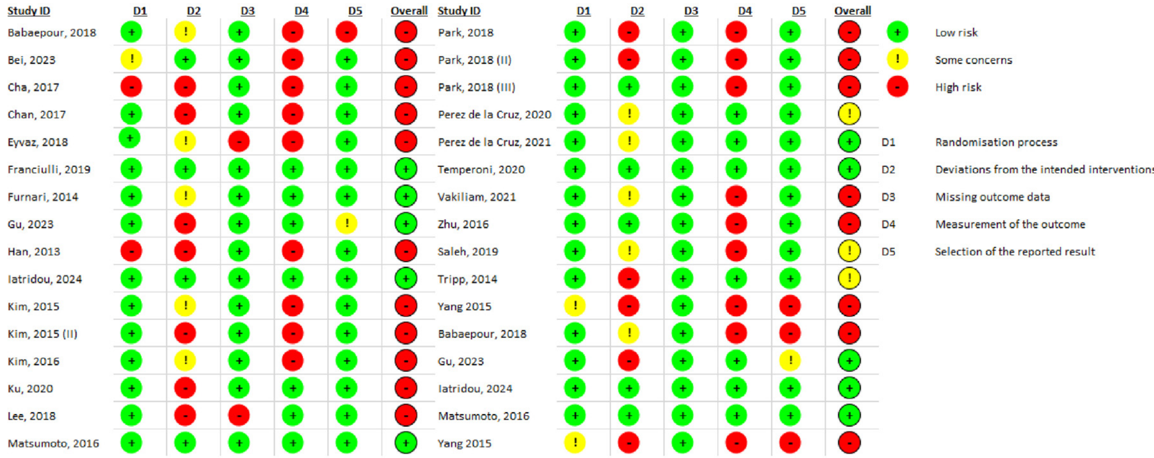

Fig 2 Results from Cochrane Risk of Bias 2 scale (I).

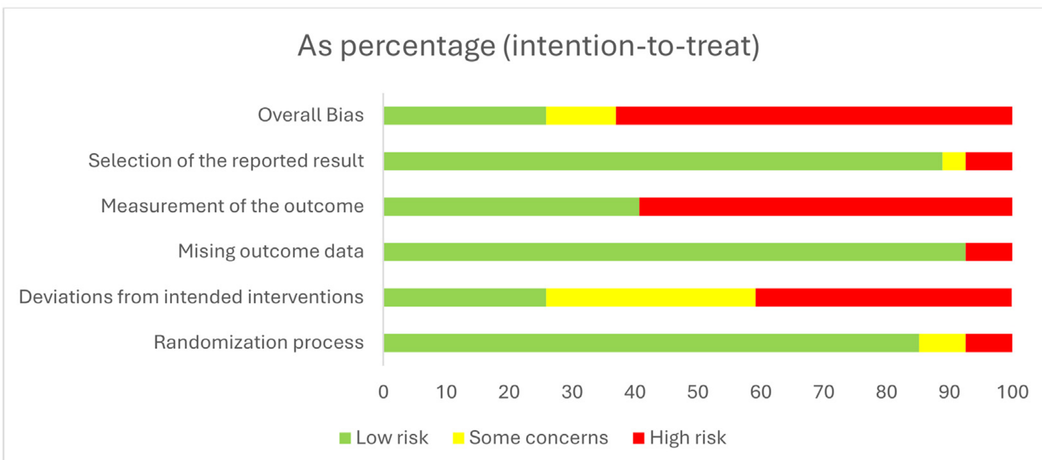

Fig 3 Results from Cochrane Risk of Bias 2 scale (II).

based therapy, contributing to the diversity of protocols observed in the review.

Qualitative synthesis of balance

In the comparison of combined aquatic and land-based therapy versus land-based therapy alone, Pérez-de la Cruz et al[22,23] found that combining Ai Chi with ground exercises significantly improved BBS scores, unlike ground exercises alone. Both studies involved 24 sessions over 12 weeks. In 2019, Park et al[46] also reported significant BBS improvements with Halliwick combined with Bobath compared with Bobath alone.

Tripp and Krakow[24] observed significant BBS score differences (P<.05) between Halliwick plus conventional therapy and conventional therapy alone. Kim et al[41] found significant Tinetti scale improvements (P<.05) with dual-task water training plus conventional therapy versus conventional therapy alone. Chan et al[35] showed significant BBS improvements with aquatic plus land-based therapy over land-based therapy alone, with 73% of the aquatic group improving compared with 27% of the control group. These studies, with treatment durations ranging from of 6 weeks[35,41] to 12 weeks,[22,23] concluded that combining aquatic and land-based therapy is more effective for improving balance than either method alone.

In the comparison of aquatic therapy versus land-based treatment, Ku et al[21] found no statistically significant improvements in BBS scores between groups performing Ai Chi exercises and those performing stretching, resistance, and walking exercises on land. Both groups showed significant improvements (P<.05), but no significant differences were observed between them. Similarly, Zhu et al[51] reported significant improvements in BBS scores for groups performing balance and coordination exercises in water and on land, with no significant differences between the groups. Iatridou et al[40] found no significant differences in BBS and force plate measurements pre- and postintervention in both groups. Eyvaz et al[36] also reported significant improvements in BBS scores for groups performing balance and stretching exercises in water and on land, with no significant differences between the groups.

Conversely, other studies reported statistically significant differences in BBS scores favoring aquatic therapy. Bei et al[34] found significant improvements (P<.001) in

Table 5 Characteristics of included studies

Author	N	Experimental Group (EG)	Control Group (CG)	Dosage	Outcome Measurements	Duration of Follow-up	Reported Findings
Babaeipour et al[33] (2018)	36	Aquatic training (1) water up to hip height (shallow group) (2) water up to chest height (deep group)	Aquatic training	6 wk (3 sessions of exercise/wk)	TUG, BBS	No follow-up	The 2 different depths of water produced no different effect on the mean scores of the outcome variables, but the protocol of aquatic training in this study could be considered a safe and effective method.
Bei et al[34] (2023)	160	Water exercise training + traditional rehabilitation	Traditional rehabilitation	40 min/d 6 d/wk 48 wk	FMA, FAC, BBS	No follow-up	There was no significant difference in FMA, FAC, and BBS between groups before treatment ($P>.05$). However, after 8 wk of treatment, there was a significant difference in FMA, FAC, and BBS between groups ($P=.00035$).
Cha et al[25] (2017)	22	Bad Ragaz + comprehensive rehabilitation	Comprehensive rehabilitation alone	30 min/d 3 d/wk 6 wk	Balance index, TUG	No follow-up	EG showed significant improvements in balance index and TUG test compared with preintervention ($P<.05$), whereas the CG showed significant improvement in TUG ($P<.05$). Significant difference in posttraining gains in balance index were observed between the EG and CG ($P<.05$).
Chan et al[35] (2016)	32	Water and land exercises	Land exercises only	60 min 2 d/wk 6 wk	BBS, CBM, TUG, 2MWT	No follow-up	No significant changes between groups in BBS ($P=.391$), CBM ($P=.621$), TUG ($P=.862$), and 2MWT ($P=.709$). More patients in EG showed change scores exceeding the published minimal detectable change score.
Eyvaz et al[36] (2018)	60	Stretching, trunk mobility, balance, and gait in water (3 d) and on land (2 d)	Land-based exercise alone (5 d)	60 min 5 d/wk 6 wk	BBS, FIM, Sporkat, TUG	No follow-up	Posttreatment results showed significant improvements ($P<.001$) in BBS, FIM, TUG, and dynamic and static balance. No significant difference between groups.
Franciulli et al[37] (2019)	12	Deep-water walking with a swimming belt	Treadmill walking on land	40 min/d 3 d/wk 9 wk	BBS, TUG	No follow-up	Improvement of TUG ($P=.02$) and BBS ($P=.00$). No significant difference between groups TUG ($P=.5$) and BBS ($P=.63$).
Furnari et al[20] (2014)	40	Halliwick, Ai Chi, and strength exercises in water (3 d) + conventional physical therapy (3 d)	Strength exercises and postural control and gait training on land	60 min/d 6 d/wk 8 wk	FIM, MAS, Tinetti	No follow-up	EG improved significantly in static analysis ($P<.01$) and dynamic analysis ($P<.001$) of Barthel Index, FIM, MAS, and Tinetti. Correlations more significant in EG than in CG.
Gu et al[38] (2022)	56	Conventional hydrotherapy combined with aquatic lower extremity strength training	Conventional hydrotherapy	6 wk 45 min/d 5 d/wk	TUG, BBS, 2MWMT, Gait analysis	No follow-up	Both groups showed significant improvements compared with baseline evaluations ($P<.05$). Notably, compared with the CG, BBS, TUG, and mTUG, 2MWMT, and Gait analysis ($P<.05$).

(*continued*)

Table 5 (*Continued*)

Author	N	Experimental Group (EG)	Control Group (CG)	Dosage	Outcome Measurements	Duration of Follow-up	Reported Findings
Han et al[39] (2013)	62	Conventional treatment + unstable surface exercise in water	Conventional treatment + unstable surface exercise on land	40 min/d 3 d/wk 6 wk	Different static positions, Biometrics, BBS, Good balance system	No follow-up	Joint position sense, sway area, and BBS showed sig. improvements in both groups. However, the joint position sense test, sway area, and BBS showed more improvement in the underwater exercise group than in the land exercise group.
Iatridou et al[40] (2025)	51	Aquatic therapy group conducted the exercise program in a swimming pool	Conventional therapy group performed an exercise on land	6 wk 3 d/wk	BBS, BS, Motricity Index, muscle strength tests, Ashworth Scale, TCT, FIM	No follow-up	Conventional therapy was superior to aquatic therapy in improving spasticity. Comparable results in postural balance, muscle strength and of the paretic limb, trunk control, functional ability of hemiplegic patients treated with either conventional or aquatic therapy.
Kim et al[26] (2015)	20	Neurodevelopment treatment + PNF underwater (sprinter and skate patterns)	Neurodevelopment treatment	30 min/d + PNF underwater in the EG 5 d/wk 6 wk	BBS, FRT, 10MWT, TUG	No follow-up	Difference pre/post in both groups. Significant improvement of the EG ($P<.05$)in BBS, FRT, 10MWT, TUG.
Kim et al[27] (2015) (II)	20	PNF lower extremity patterns in water	PNF lower extremity patterns on land	30 min/d 5 d/wk 6 wk	BBS, TUG, FRT, OLST, FIM	No follow-up	Significant difference in pre-post in both groups ($P<.05$). Significant improvements of the EG compared with the CG ($P<.05$).
Kim et al[41] (2016)	20	Neurodevelopmental treatment + aquatic dual-task training	Neurodevelopmental treatment	30 min/d (+ aquatic dual-task in EG 30 min/d) 5 d/wk 6 wk	BBS, FTSTS, FRT, 10MWT, TUG, FGA	No follow-up	In the intragroup comparison, the EG showed a significant change after the experiment in all balance and gait assessment tests. In the intergroup comparison, the EG showed relatively more significant change after the experiment in all balance and gait assessment tests.
Ku et al[21] (2020)	20	Ai Chi	Conventional water-based exercise	60 min/d 3 d/wk 6 wk	Limit of stability test, BBS, FMA, gait performance	No follow-up	Both groups showed significant improvement in BBS and FMA but the Ai Chi group demonstrated significantly better results than CG ($P=.025$).

(*continued*)

Table 5 (*Continued*)

Author	N	Experimental Group (EG)	Control Group (CG)	Dosage	Outcome Measurements	Duration of Follow-up	Reported Findings
Lee et al[42] (2018)	32	Aerobic exercise on a motorized aquatic treadmill (30 min) + conventional treatment (30 min)	Land-based aerobic exercise using ergometers + conventional treatment (30 min)	30 min/d 5 days/wk 4 wk	FMA and FMA-LL, BBS	No follow-up	Improvements in FMA (*P*=.03), FMA-LL (*P*=.01), and BBS (*P*=.01) in the EG.
Matsumoto et al[43] (2016)	120	Repeated underwater exercise and conventional rehabilitation therapy	Conventional rehabilitation therapy	24 sessions 2 d/wk	10MWT, Ashworth scale, QOL	No follow-up	Improvements in 10MWT results and spasticity parameters were greater in the EG than in the CG (*P*<.01). Significant differences between the groups were observed in changes of all QOL parameters (*P*<.01).
Park and Chung[44] (2018)	27	(1) Aquatic treadmill (30 min) + conventional treatment (2) Antigravity treadmill (30 min) + conventional treatment	Conventional treatment	30 min/d 3 d/wk + conventional treatment 5 d/wk 4 wk	BBS, TUG, 10MWT	No follow-up	In EG, BBS, TUG, and 10MWT scores significantly improved postintervention (*P*<.05), and the CG also had significantly improved in all areas pre-post intervention (*P*<.05). In addition, aquatic treadmill group and antigravity treadmill group significantly improved in BBS, TUG, and 10MWT scores compared with the CG (*P*<.05). However, no significant difference found between the aquatic treadmill and the antigravity treadmill groups.
Park and Chung[45] (2018) (II)	40	(1) Additional weight aquatic exercise (2) Aquatic exercise	Conventional treatment	30 min/d 3 d/wk and conventional treatment 5 d/wk 6 wk	BBS, TUG, 10MWT	No follow-up	BBS, TUG, and 10MWT scores significantly improved postintervention (*P*<.05), and the CG also significantly improved in all areas posttreatment (*P*<.05). In addition, the additional weight aquatic exercise group had significantly improved in BBS and TUG scores compared with the aquatic exercise and CG (*P*<.05).
Park et al[46] (2019)	29	Land-based and aquatic trunk exercise (30 min) + conventional physical therapy (30 min)	Conventional physical therapy only (30 min)	60 min/d 5 d/wk 4 wk	K-TIS, PASS-3L, BBS-3L, MBI, FRT	No follow-up	EG exhibited improvements in K-TIS, PASS-3L, BBS-3L, and FRT distance compared with the CG (*P*<.05).
Pérez-de la Cruz[23] (2020)	40	(1) Ai Chi (2) Ai Chi (2 d/wk) + dry-land therapy (2 d/wk)	Dry-land therapy (walking exercises, trunk mobility, and extremities exercises)	45-50 min 2 d/wk 12 wk	Tinetti, 360° turn test, OLST, CS-30	No follow-up	Results were significantly better for the combined therapy group and the EG compared to the dry-land therapy group (*P*<.01) in the CS-30, and 360° turn, although improvements were also found in the aquatic therapy group. In total, for the Tinetti scale and OLTS, differences between groups were evident but not statistically significant (*P*=.001).

(*continued*)

Table 5 (*Continued*)

Author	N	Experimental Group (EG)	Control Group (CG)	Dosage	Outcome Measurements	Duration of Follow-up	Reported Findings
Pérez-de la Cruz[22] (2021)	45	(1) Ai Chi (2) Ai Chi (2 d/wk) + dry-land therapy (2 d/wk)	Dry-land therapy	45-50 min 2 d/wk 12 wk	BBS, TUG, FTSTS, tandem stance	No follow-up	Results improved significantly for the combined therapy group (*P*<.01), and were significantly higher than the dry-land therapy group (*P*<.01). In addition, improvements were also found in the aquatic Ai Chi therapy group.
Saleh et al[47] (2019)	50	Walking exercises + dual-task training in water	Walking exercises + dual-task training on land	45 min 3 d/sem 6 weeks	Biodex Balance System and Biodex Gait Trainer	No follow-up	Significant improvement in all outcome variables post treatment compared with pretreatment in both groups (*P*<.05). Significant improvement in patients who received underwent motor dual-task training in water compared with patients treated on the land in overall stability index (*P*=.02), anteroposterior stability index (*P*=.03), mediolateral stability index (*P*=.002), walking speed (*P*=.01), step length of affected limb (*P*=.03), step length of nonaffected limb (P=.01), and time of support on the affected limb (*P*=0.002).
Temperoni et al[48] (2020)	33	Water-based sequential preparatory approach	Conventional aquatic therapy	45 min 2 d/wk 4 wk	BBS, MBI, Tinetti, MAS	One month follow-up	Significant differences (*P*<.05) between the groups on the BBS (*P*=.01). Furthermore, the EG showed a significantly greater percentage of improvement on the BBS (*P*=.02). Both groups showed a significantly improved MAS score (*P*<.01).
Tripp and Krakow[24] (2014)	30	Halliwick (3 d/wk) + conventional therapy (2 d/wk)	Conventional therapy (5 d/wk)	45 min 5 days/sem 2 wk	BBS, FRT, FAC	No follow-up	Compared with the CG, significantly more subjects in the EG (83.3% vs 46.7%) showed significant improvement in the BBS (*P*<.05). Improvement of the functional gait ability was significantly higher in the EG than in the CG. The mean difference in improvements in FRT and basic functional mobility were not significant between groups.
Vakilian et al[49] (2021)	36	(1) Exercises in shallow water (2) Exercises in deep-water	No aquatic treatment	50-60 min 3 d/wk 6 wk	Biodex Balance system	No follow-up	No significant difference between the 2 intervention groups (shallow and deep) in the balance assessment posttest (*P*>.05), yet there was a significant difference between the 2 intervention groups (shallow and deep) with the CG in the semidynamic balance (total) score (*P*<.05); the semidynamic balance (total) of the 2 intervention groups (shallow and deep) was higher than that of the CG (*P*<.05).

(*continued*)

Table 5 (*Continued*)

Author	N	Experimental Group (EG)	Control Group (CG)	Dosage	Outcome Measurements	Duration of Follow-up	Reported Findings
Yang and Choi[50] (2015)	20	Underwater treadmill gait training	Overground treadmill gait training	4 wk 30 min/d 3 d/wk	BBS, TUG, 10MWT	No follow-up	All the studied variables were significantly improved in both groups ($P<.05$) at the end of the study. There was significant between-group difference in all of the variables, except in the 10 MWT ($P>.05$). These findings suggest that underwater is more effective than overground in improving the balance.
Zhu et al[51] (2016)	28	Hydrotherapy	Land-based therapy	45 min 5 d/wk 4 wk	BBS, FRT, 2MWT, TUG	No follow-up	BBS, FRT, 2MWT, and TUG scores improved significantly in each group ($P<.05$). The mean improvement of the FRT and 2MWT were significantly higher in the aquatic group than in the control group $P<.01$). The differences in the mean values of the improvements in the BBS and TUG were not significant.

Abbreviations: 2MWT, 2-minute walk test; 10MWT, 10-meter walk test; BBS, Berg Balance Scale; BBS-3L, 3-level Berg Balance Scale; BS, Brunnstrom scale; CBM, community balance and mobility score; CG, control group; CS-30, 30-second chair stand test; EG, experimental group; FAC, functional ambulation categories; FGA, Functional Gait Assessment; FMA, Fugl Meyer Assessment; FMA-LL, Fugl Meyer Assessment-Lower Limb; FRT, Functional Reach Test; FTSTS, Five Times Sit To Stand; K-TIS, Korean Trunk Impairment Scale; MAS, Modified Ashworth Scale; MBI, Modified Barthel Index; MCD, minimal change detectable; mTUG, Modified Timed Up and Go; OLST, one leg stand test; PASS, Postural Assessment Scale for Stroke; PASS-3L, 3-level Posural Assessment Scale for Stroke; PNF, proprioceptive neuromuscular facilitation; QOL, quality of life; TCT, Trunk Control Test; TUG, timed Up and Go test.

BBS scores for a group performing strength, balance, and walking exercises in water compared to a land-based group. Kim et al[26,27] reported significant differences ($P<.05$) in BBS scores for groups undergoing lower extremity neuromuscular interventions in water versus on land. Saleh et al[47] and Han et al[39] also found significant differences in BBS scores favoring aquatic therapy over land-based exercises.

Furnari et al[20] reported that a combined Ai Chi and Halliwick program over 8 weeks resulted in more significant improvements in the Barthel Index, FIM, Modified Ashworth Scale, and Tinetti scores compared with a land-based exercise program, although no significant differences were observed between the groups. Yang and Choi[50] found significant improvements in walking speed (10-meter walk test [10MWT]) and BBS scores for a treadmill intervention in water compared with one on land, with the experimental group showing greater improvements except in walking speed.

Vakilian et al[49] and Babaeipour et al[33] investigated the effects of aquatic therapy at different water depths by dividing participants into 3 groups: (1) a deep-water therapy group, where exercises were performed at a depth reaching the xiphoid process; (2) a shallow water therapy group, with water reaching the anterior superior iliac spine; and (3) a control group receiving no aquatic intervention. All groups participated in sessions 3 times per week over a 6-week period. Both aquatic therapy groups demonstrated significant improvements in static and dynamic balance, as assessed by the Biodex Balance Index system,[49] as well as in BBS and TUG scores.[33] In contrast, the control group showed no significant changes.

Park and Chung[45] conducted a 6-week intervention with 3 groups. All groups received conventional therapy, but the control group received no additional treatment. One group performed water-based exercises using weights to increase resistance and muscle activation, while the other performed aquatic exercises without weights. The group using weights showed significant improvements in BBS scores compared with the group without weights and the control group ($P<.05$).

Overall, the studies reviewed consistently demonstrate that aquatic therapy—whether applied alone or in combination with land-based interventions—leads to significant improvements in balance among individuals with stroke. Techniques such as Ai Chi, Halliwick, and dual-task water training were particularly effective. Although some studies found no differences between aquatic and land-based approaches, most reported superior outcomes with aquatic therapy, especially when integrated into multimodal programs.

Qualitative synthesis of gait speed

Kim et al[41] found that the experimental group undergoing aquatic dual-task training showed significant improvement in gait speed, as measured by the 10MWT, compared with the conventional therapy group ($P<.05$). Similarly, Saleh et al[43] reported significant improvements in gait speed for the water-based exercise group compared with the land-based exercise group ($P<.05$).

Matsumoto et al[43] observed significant differences in gait speed and cadence in the 10MWT for the group receiving both aquatic and conventional therapy compared with the conventional therapy group. Park et al[44] demonstrated that groups performing aquatic treadmill and antigravity treadmill exercises showed significant improvements in gait speed, measured by the 10MWT, compared to the standard treadmill exercise group (P<.05).

Zhu et al[51] showed that the experimental group performing coordination and balance exercises in water had significant improvements in the 2-minute walk test (2MWT) compared with the land-based exercise group. Gu et al[38] found that the experimental group performing aquatic lower extremity strength training and conventional aquatic therapy showed significant differences in the 2MWT compared with the control group receiving conventional water therapy (P<.05).

The evidence indicates that aquatic therapy contributes to meaningful improvements in gait speed in individuals with stroke. Interventions involving aquatic treadmills, dual-task training, and strength exercises in water showed statistically significant gains compared with conventional therapy. Although some studies reported comparable effects between aquatic and land-based modalities, aquatic therapy generally provided enhanced outcomes in walking performance.

Qualitative synthesis of fall risk

Ku et al[21] noted differences in BBS regarding fall risk. A BBS score ≤49 indicates an increased fall risk in patients with stroke.[54] At baseline, 8 individuals in the Ai Chi group were at increased risk, with 5 (62%) reducing their risk (BBS >49). In the control group, 5 were at increased risk, but only 1 (20%) reduced their risk.

According to the BBS scale, changes of >6 points are clinically significant.[55] Gu et al[38] found a higher proportion of patients with clinically relevant changes in the experimental group compared with the control group. Babaeipour et al[33] reported significant differences in TUG and BBS scores for aquatic therapy groups at different depths, but these differences were not detected in the control group.

Pérez-de la Cruz[22] showed significant improvements in the Five Times Sit to Stand, tandem, and TUG tests for the Ai Chi and land exercise group, whereas the Ai Chi-only group improved significantly in all but the TUG test. Cha et al[25] found significant improvements in balance index and TUG for the Bad Ragaz method group, whereas the control group only improved in TUG.

Zhu et al[51] and Eyvaz et al[36] reported significant TUG improvements in both experimental and control groups, with no significant differences between groups. Studies by Park and Chung[45] and Kim et al[26,27,41] showed statistically significant improvements in the TUG test favoring the experimental groups.

Aquatic therapy appears to be effective in reducing fall risk in individuals with stroke, as measured by improvements in BBS and TUG scores. Programs incorporating Ai Chi, Bad Ragaz, and underwater strength training demonstrated favorable results. Although a few studies found no significant differences between intervention groups, the majority reported clinically relevant reductions in fall risk after aquatic therapy interventions.

Quantitative synthesis of balance

Eighteen articles were included for meta-analysis of BBS. The findings indicated that the aquatic therapy-based intervention had a statistically significant difference on balance, as measured by the BBS (MD, 6.81; 95% CI, 4.84-8.78; P<.001). Nevertheless, considerable heterogeneity was evident among the included studies (I^2=90%) (fig 4).

Quantitative synthesis of gait speed

Six records were meta-analyzed for gait speed. The results demonstrated that an intervention based on aquatic therapy significantly reduced the time taken to walk 10 m in these patients (MD, −5.10; 95% CI, −8.85 to −1.36; P=.008). However, substantial heterogeneity was observed among the included studies (I^2=95%) (fig 5).

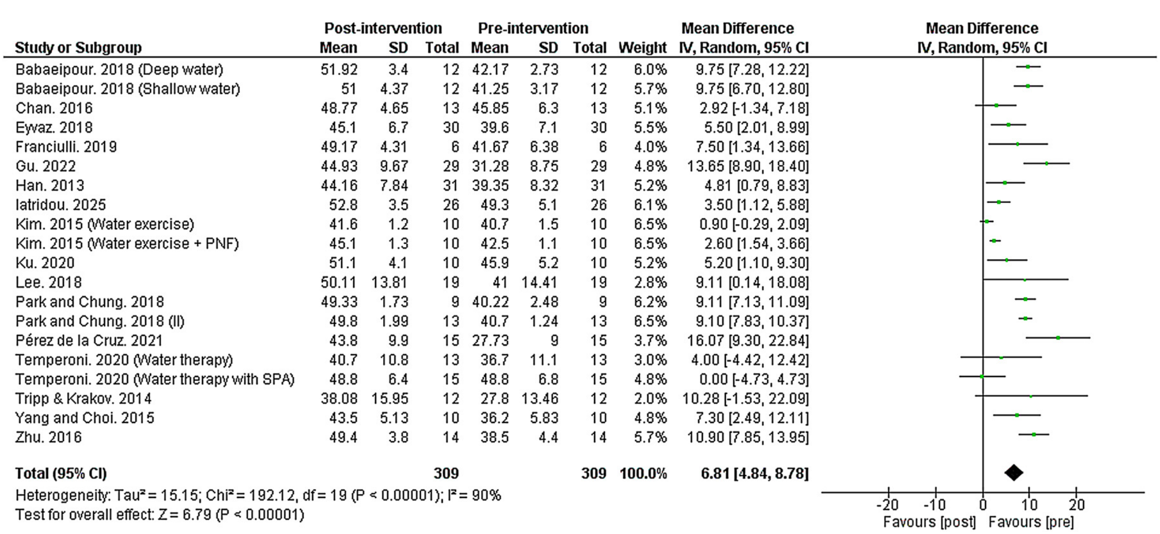

Fig 4 Forest plot of balance assessed through the Berg Balance Scale. IV, inverse variance; PNF, proprioceptive neuromuscular facilitation; SPA, sequential preparatory approach.

Study or Subgroup	Post-intervention Mean	SD	Total	Pre-intervention Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Park and Chung. 2018	17.44	7.1	9	30.56	9.32	9	11.0%	-13.12 [-20.77, -5.47]
Park and Chung. 2018 (II)	17.3	1.43	13	28.3	3.31	13	19.4%	-11.00 [-12.96, -9.04]
Yang and Choi. 2015	20.64	6.27	10	24.49	8.79	10	12.4%	-3.85 [-10.54, 2.84]
Matsumoto. 2016	31.2	10.5	60	34.3	10.6	60	16.9%	-3.10 [-6.88, 0.68]
Kim. 2015 (Water exercise + PNF)	12.6	1.7	10	14.6	1.1	10	20.0%	-2.00 [-3.25, -0.75]
Kim. 2015 (Water exercise)	14.3	0.9	10	14.9	1.1	10	20.2%	-0.60 [-1.48, 0.28]
Total (95% CI)			**112**			**112**	**100.0%**	**-5.10 [-8.85, -1.36]**

Heterogeneity: Tau² = 17.82; Chi² = 98.22, df = 5 (P < 0.00001); I² = 95%
Test for overall effect: Z = 2.67 (P = 0.008)

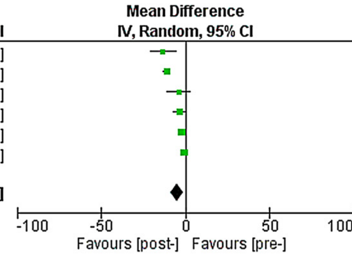

Fig 5 Forest plot of gait velocity. IV, inverse variance.

Quantitative synthesis of risk of falling

Ten studies were included in meta-analysis for risk of falling. The results showed that the aquatic therapy-based intervention significantly reduced the risk of falls in these patients, as assessed by the TUG (MD, −4.38; 95% CI, −7.17 to −1.59; *P*=.002). The studies included in this analysis demonstrated significant heterogeneity (I^2=95%) (fig 6).

Additional analysis results

Sensitivity analysis

Sensitivity analysis was performed to determine the robustness of the results, and no significative differences were observed when each study was independently excluded from the analysis. Nevertheless, the heterogeneity did not diminish in any of these additional analyses, indicating that no individual study was solely responsible for this heterogeneity.

Subgroup analysis

Heterogeneity may be because of clinical or methodological differences or variations. Therefore, we performed a subgroup analysis according to the number of sessions for each variable studied.

In the subgroup analysis for balance, analysis of the data obtained from the 2 subgroups divided based on the number of sessions used in each study showed that both subgroups, including studies that conducted >20 sessions and those that conducted between 10-20 sessions, exhibited statistical significance improvements in BBS (MD, 6.14; 95% CI, 3.75-8.52; *P*<.0001 and MD, 7.80; 95% CI, 5.95-9.65; *P*<.0001, respectively). However, no differences were observed between the 2 subgroups (*P*=.28). A substantial degree of heterogeneity was observed in the 2 subgroups (I^2=85% in the >20 sessions subgroup and I^2=74% in the 10-20 sessions subgroup) (fig 7).

When analyzing the data from the different subgroups according to the number of sessions used in each study for gait speed, both the group that carried out >20 sessions and the group that carried out 10-20 sessions showed statistical significance. Improvements in gait speed (standardized MD, −0.60; 95% CI, −1.17 to −0.02; *P*=.04 and −1.98; 95% CI, −3.92 to −0.04; *P*=.05), with no statistically significant differences between subgroups (*P*=.18). Regarding heterogeneity, in the subgroup of studies in which >20 sessions were performed, the heterogeneity was moderate (I^2=49%). However, in the subgroup in which 10-20 sessions were performed, heterogeneity was substantial (I^2= 89%) (fig 8).

In the subgroup analysis for risk of falling based on the TUG test, no statistically significant differences were found in the subgroup that conducted >20 sessions (MD, −2.37; 95% CI, −6.20 to −1.46; *P*<.22). Meanwhile, the 10-20 sessions subgroup showed a statistically significative improvement (−7.09; 95% CI, −11.66 to −2.52; *P*=.002). However, no statistically significant differences were observed between the 2 subgroups (*P*<.12).

In terms of heterogeneity, both groups displayed considerable heterogeneity (I^2=94% for the group that completed >20 sessions and I^2=94% for the group that completed 10-20 sessions). However, when the Babaeipour et al[33] study was excluded from the analysis, heterogeneity in the second subgroup was eliminated (I^2=0%), while the improvements remained statistically significant (*P*<.001), and statistically significant differences also emerged between the subgroups (*P*<.001) (fig 9).

Study or Subgroup	Post-intervention Mean	SD	Total	Pre-intervention Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Babaeipour. 2018 (Deep water)	8.21	1.65	12	10.48	2.07	12	11.3%	-2.27 [-3.77, -0.77]
Babaeipour. 2018 (Shallow water)	8.55	1.6	12	11.17	1.56	12	11.4%	-2.62 [-3.88, -1.36]
Franciulli. 2019	13.03	7.52	6	26.67	14.56	6	3.3%	-13.64 [-26.75, -0.53]
Gu. 2022	29.66	4.68	29	21.97	4.72	29	10.7%	7.69 [5.27, 10.11]
Kim. 2015 (Water exercise)	18.2	1	10	18.5	1	10	11.5%	-0.30 [-1.18, 0.58]
Kim. 2015 (Water exercise + PNF)	16.1	1.6	10	18.4	1.2	10	11.4%	-2.30 [-3.54, -1.06]
Park and Chung. 2018	21.67	7.39	9	35.11	6.47	9	7.2%	-13.44 [-19.86, -7.02]
Park and Chung. 2018 (II)	14.3	3.17	13	27.1	3.31	13	10.7%	-12.80 [-15.29, -10.31]
Pérez de la Cruz. 2021	13.67	5.2	15	19.13	7.9	15	8.7%	-5.46 [-10.25, -0.67]
Yang and Choi. 2015	25.65	15.43	10	31.32	15.94	10	3.0%	-5.67 [-19.42, 8.08]
Zhu. 2016	21.2	2.6	14	29.7	3.1	14	10.9%	-8.50 [-10.62, -6.38]
Total (95% CI)			**140**			**140**	**100.0%**	**-4.38 [-7.17, -1.59]**

Heterogeneity: Tau² = 17.39; Chi² = 202.89, df = 10 (P < 0.00001); I² = 95%
Test for overall effect: Z = 3.08 (P = 0.002)

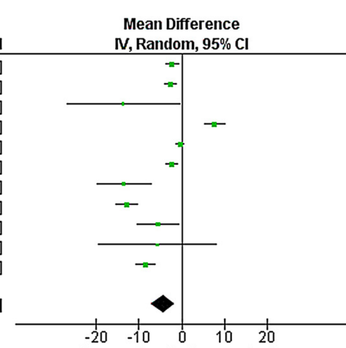

Fig 6 Forest plot of risk of falling. IV, inverse variance.

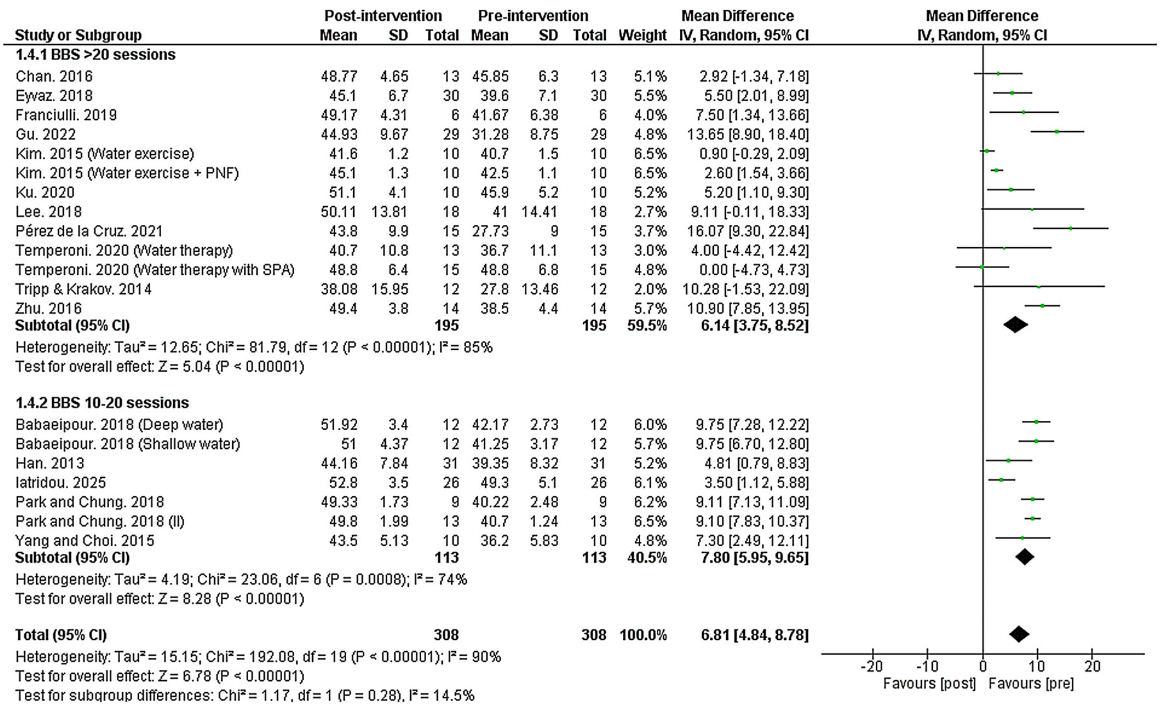

Fig 7 Subgroup analysis for balance. BBS, Berg Balance Scale; IV, inverse variance; PNF, proprioceptive neuromuscular facilitation; SPA, sequential preparatory approach.

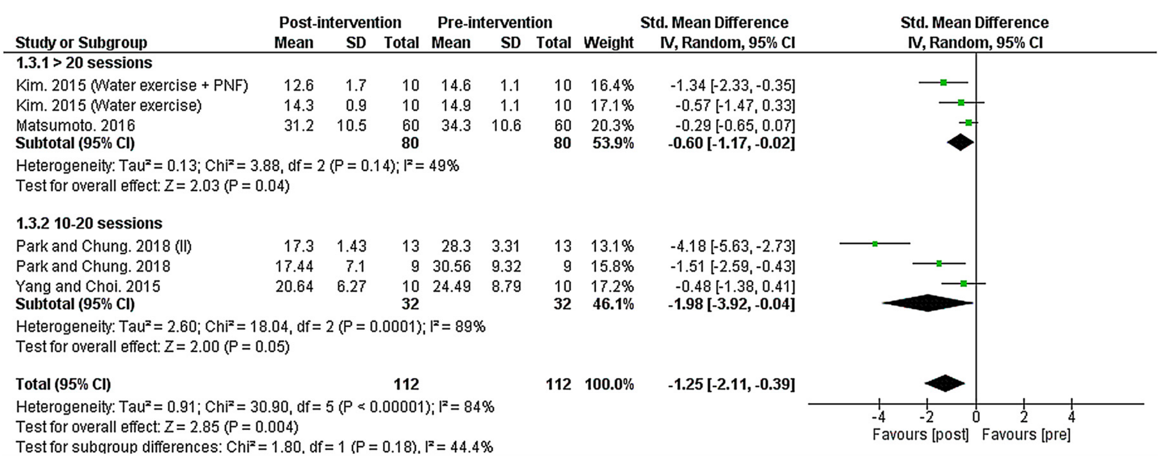

Fig 8 Subgroup analysis for gait speed. IV, inverse variance.

Publication bias

Publication bias was evaluated through the visualization of a funnel plot (fig 10). Figure 10A illustrates the distribution for walking speed; however, because of the limited number of studies examining walking speed, it cannot be definitively concluded that there was no publication bias present for this variable. In contrast, figure 10B shows the plots for balance and fall risk, where the graph indicates a minimal risk of publication bias for these variables.

Discussion

This systematic review and meta-analysis evaluated the efficacy of aquatic therapy in improving balance, gait speed, and reducing fall risk in patients with stroke. Aquatic therapy significantly enhanced balance (BBS: MD, 6.81; 95% CI, 4.84-8.78; P<.001), despite considerable heterogeneity (I^2=90%). It also increased gait speed (MD, −5.10; 95% CI, −8.85 to −1.36; P=.008) and reduced fall risk (MD, −4.38; 95% CI, −7.17 to −1.59; P=.002), with substantial heterogeneity for both outcomes (I^2=95%). Sensitivity analyses confirmed the robustness of the results, with no significant differences when individual studies were excluded, although heterogeneity remained high. Subgroup analysis showed significant improvements in balance and gait speed for both the 10-20 sessions and >20 sessions groups, with moderate to substantial heterogeneity. Funnel plot analysis suggested minimal publication bias for balance and fall risk, but not for gait speed.

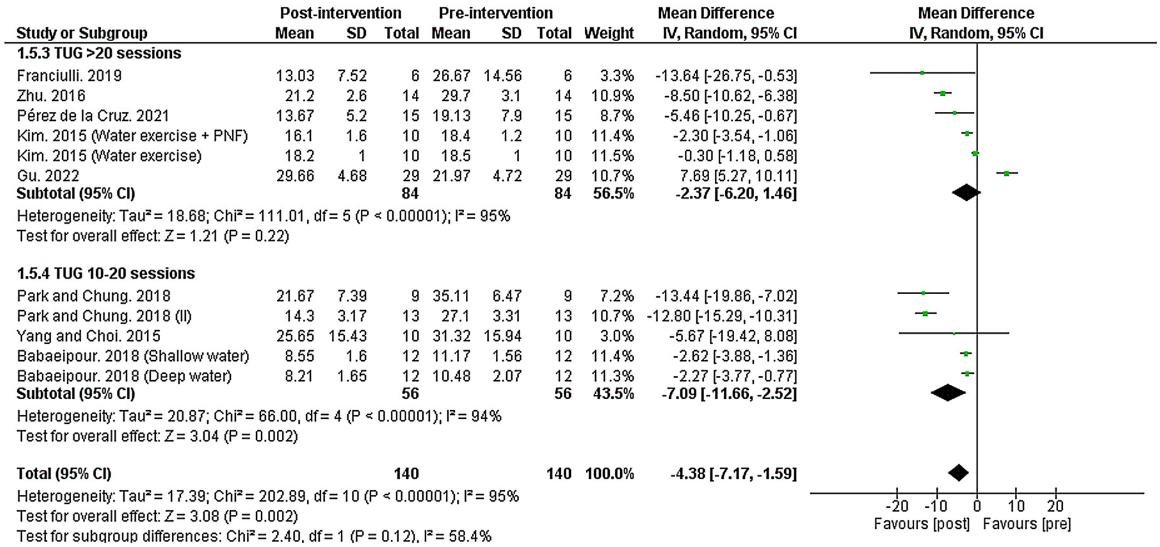

Fig 9 Subgroup analysis for risk of falling. IV, inverse variance; PNF, proprioceptive neuromuscular facilitation; TUG, timed Up and Go test.

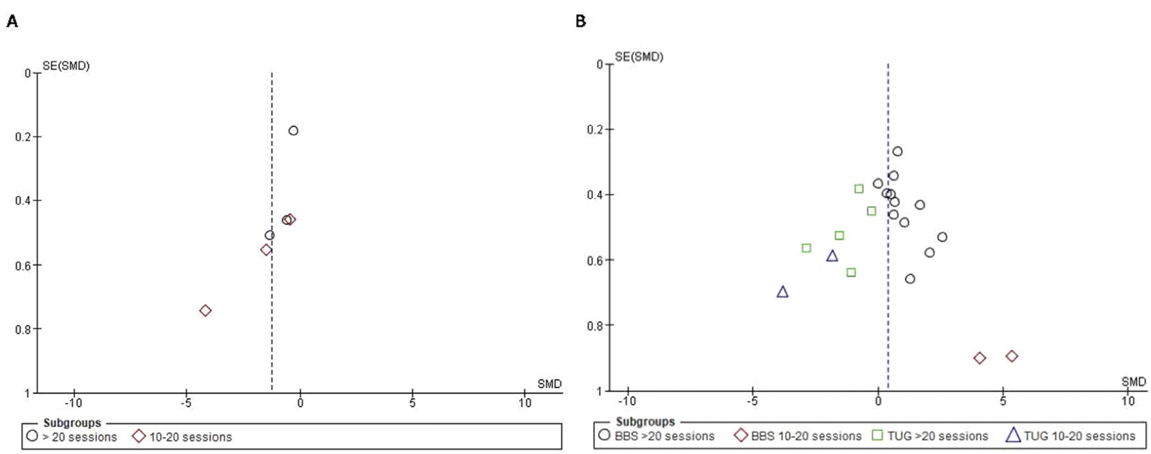

Fig 10 (A) Gait speed funnel plot. (B) Balance and fall risk funnel plot. BBS, Berg Balance Scale; SMD, standardized mean difference; TUG, timed Up and Go test.

Although the meta-analysis demonstrated statistically significant improvements in balance after aquatic therapy, it is important to interpret these findings in light of clinical relevance. Specifically, some of the reported changes in the BBS, although statistically significant, did not exceed the minimal detectable change (MDC) thresholds established for stroke populations. For example, the 2.1-point improvement observed in the study by Kim et al[26] falls below the MDC range of 2.5-6.9 points reported in previous research.[56,57] This suggests that although aquatic therapy may contribute to measurable improvements, not all observed changes may translate into clinically meaningful gains in balance. Future studies should aim to report both statistical and clinical significance to better inform rehabilitation practices.

Regarding gait speed, improvements of $\geq$0.1 m/s in the 10MWT are typically considered clinically important.[58] Although some studies met or exceeded this threshold, others reported smaller gains that may not translate into functional improvements. Similarly, for fall risk assessed via the TUG test, Flansbjer et al[57] reported an MDC of approximately 3.2 seconds in poststroke patients, which can be used as a benchmark for clinically meaningful change. Not all studies included in our review achieved this level of improvement. These considerations underscore the importance of reporting both statistical and clinical significance in future research to better inform rehabilitation practices and guide therapeutic decision making.

Aquatic therapy improves mobility and balance because of water's unique properties.[28] It provides a secure setting for balance rehabilitation, reducing the fear of falling.[28,59,60] Various aquatic techniques, including Ai Chi combined with exercise[22]; strength, balance, and coordination exercises in water[34,39]; PNF underwater[26,27]; Halliwick[24]; Halliwick combined with Bobath[44]; water walking with and without weights (eg, ankle weights or weighted belts)[45]; and aquatic dual-task training showed significant improvements compared with land-based exercises.[41]

Water's high viscosity allows slower movements, giving patients more time to manage postural disturbances.[29]

Studies comparing aquatic therapy with land therapy[20,36] showed no significant differences between groups in balance variables, but results demonstrated significant within-group improvements from pre- to posttest. Moreover, the existing literature and reviewed studies do not mention any adverse effects on balance using aquatic therapy.[28]

Walking speed, assessed using 10MWT, 2MWT, and Biodex Balance System scales, showed significant differences favoring aquatic therapy compared with land-based exercise or conventional therapy.[41,44,47,51] Although both subgroups—those with >20 sessions and those with 10-20 sessions—showed statistically significant improvements in walking speed, the magnitude of change was smaller in the 10-20 session group. Additionally, this subgroup exhibited substantial heterogeneity (I^2=89%), which may affect the consistency of the observed effects. These findings are consistent with previous research suggesting that higher session frequency may be associated with more robust improvements in gait performance.[61]

Regarding fall risk, Ai Chi showed significant differences in the BBS fall risk section compared with the control group.[21] The combination of Ai Chi and exercise resulted in significant differences in the TUG test compared with the application of Ai Chi alone.[22] The application of Bad Ragaz resulted in significant differences with respect to the control group in the Balance Index, but no differences were observed in the TUG test.[25] Exercise in water did not result in significant differences in TUG compared with the application of exercises on land.[36,51] Park andChung[45] and Kim et al[51] reported differences in the TUG variable with respect to the application of ground exercises. This variability in the results obtained corresponds with published evidence.[15,30]

This review aligns with previous studies reporting benefits of aquatic therapy in improving balance and gait speed in people with stroke.[4,29] However, our findings differ from those of Nayak et al,[1] who found no significant differences in balance outcomes between aquatic therapy and land-based interventions, likely because of variations in study design, sample size and protocols. Mixed results reported by Iliescu et al[30] further highlight the need for standardized protocols.

Compared with earlier reviews, our study includes a more recent and comprehensive dataset (27 studies, 1134 participants), adheres to PRISMA guidelines, was previously registered in PROSPERO, and incorporates rigorous methodological tools such as RoB 2. A key strength is the subgroup analysis by session frequency, which provides insight into dose-response effects.

Additionally, our review addresses limitations noted in prior research, such as small sample sizes and lack of follow-up.[4,30] By including larger studies such as those conducted by Bei et al,[34] Pérez-de la Cruz et al,[22,23] Matsumoto et al,[43] Iatridou et al,[40] and Gu et al[38] and identifying the absence of long-term follow-up in all included trials, we emphasize the need for future research to explore sustained effects of aquatic therapy.

Limitations of the evidence included in the review

This systematic review and meta-analysis have several limitations. First, significant heterogeneity among the included studies, particularly in intervention protocols, sample sizes, and outcome measures, may have influenced the overall findings and limits generalizability. Second, the relatively small sample sizes may reduce statistical power and increase the risk of type II errors. Third, the timing of interventions varied from acute to chronic phases, affecting comparability. Additionally, some studies had suboptimal methodological quality, with issues such as lack of blinding and incomplete outcome data introducing potential bias. Furthermore, the lack of long-term follow-up in most studies limits the assessment of sustained effects of aquatic therapy. Finally, publication bias may be present, as indicated by asymmetry in funnel plots for some outcomes. Future research should address these limitations by conducting larger, high-quality randomized controlled trials with standardized protocols and long-term follow-up to better understand the efficacy of aquatic therapy in stroke rehabilitation.

Implications of the results for clinical practice and future research

The findings of this systematic review suggest that a combination of aquatic therapy, land-based exercise, and aquatic treadmill training for approximately 10-20 sessions over a period of 4-6 weeks may be particularly effective for patients who have experienced an acute stroke (<1y prior). However, the evidence supporting this conclusion is limited because of the variability and inconsistency in the samples used across the included studies.

For clinical practice, incorporating aquatic therapy into rehabilitation programs could enhance balance and gait speed for individuals who have survived a stroke. Future research should focus on isolating and examining individual treatment techniques in comparison with control groups and employing more homogeneous sample populations. Additionally, larger, high-quality randomized controlled trials with standardized intervention protocols and long-term follow-up are necessary to better understand the efficacy of aquatic therapy in stroke rehabilitation and to address the current limitations in the evidence.

Conclusions

The meta-analysis showed significant improvements in balance, gait speed, and fall risk in individuals poststroke, supporting its integration into rehabilitation programs. However, these results should be interpreted cautiously because of high heterogeneity, small sample sizes, and variability in intervention protocols. Although sensitivity analyses supported the robustness of findings, these methodological differences may limit generalizability. Although no single aquatic technique demonstrated clear superiority, combining aquatic and land-based exercises appears particularly beneficial, especially in the acute phase of recovery. Given the variability in study designs, sample sizes, and intervention protocols, clinicians should tailor aquatic therapy to individual patient needs, considering factors such as stroke chronicity, functional level, and access to aquatic facilities. The key implication for practice is that aquatic therapy is a promising, safe, and effective adjunct to conventional rehabilitation, but further high-quality studies with standardized protocols and long-term follow-up are essential to strengthen the evidence base and guide clinical decision making.

Supplier

a. Review Manager, version 5.3; Cochrane.

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Authorship Contributions/CRediT statements

L.G.A. and I.S.E. conceptualized the study. I.S.E. and M.C.S. supervised the study. L.G.A. and I.R.C. participated in title and abstract screening and quality assessment. M.D.S.R. and M.C.S. performed statistical analysis. L.G.A., I.S.E., and M. C.S. drafted the manuscript. I.S.E. and M.D.S.R. helped with results interpretation and critically revised the manuscript. All persons listed as authors have approved the final version.

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