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Alice Mary Iliescu

Amanda McIntyre

Joshua C. Wiener
Western University, jwiener2@uwo.ca

Jerome Iruthayarajah

Andrea Lee

See next page for additional authors

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Authors

Alice Mary Iliescu, Amanda McIntyre, Joshua C. Wiener, Jerome Iruthayarajah, Andrea Lee, Sarah Caughlin, and Robert Teasell

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Evaluating the effectiveness of aquatic therapy on mobility, balance, and level of functional independence in stroke rehabilitation: A systematic review and meta-analysis

Abstract

Objective: To investigate the effectiveness of aquatic therapy in improving mobility, balance, and level of functional independence after stroke through a meta-analysis and systematic review.

Data Sources: A literature search using databases Medline, Embase, CINAHL, PsycINFO, and Scopus for journal articles published up to June 21, 2018.

Study Selection: Included studies met the following inclusion criteria: 1) in English, 2) adult stroke population 3) randomized or non-randomized prospectively controlled trial (RCT or PCT) study design 4) the experimental group received an aquatic therapy program that was longer than a single session, and 4) the study reported at least one clinical outcome measure of mobility, balance, or functional independence.

Data Extraction: Participant characteristics, treatment protocols, between-group outcomes, point measures and measures of variability were extracted. Methodological quality was assessed and pooled mean differences (MD) ± standard error and 95% confidence intervals (CI) were calculated for the Berg Balance Scale (BBS), Functional Reach Test (FRT); Timed Up and Go Test (TUG); and gait speed.

Data Synthesis: A total of 16 studies, consisting of 14 RCTs and 2 PCTs, were included (total sample size of 559 participants). Nine were of fair quality and 7 were of good quality. The meta-analysis demonstrated statistically significant improvements for aquatic therapy over land therapy on the BBS (MD=2.282±0.556; 95% CI: 1.192 to 3.372; $p<0.001$), FRT

(MD=3.511±1.597; 95% CI: 0.381 to 6.642; p=0.028), TUG (MD=2.229±0.513; 95% CI: 1.224 to 3.234; p<0.001), but not gait speed (MD=0.028±0.018; 95% CI: -0.007 to 0.062; p=0.117). Non-quantitative synthesis demonstrated that results on other outcome measures consisted of a mix of positive and negative results.

Conclusions: The evidence suggests a significant benefit of aquatic therapy on certain aspects of mobility, balance, gait, and functional independence after a stroke as compared to land-based therapy.

Keywords: stroke, hydrotherapy, rehabilitation, review

List of Abbreviations

10MWT, 10 Meter Walk Test; BBS, Berg Balance Scale; BI, Barthel Index; CB&M, Community Balance and Mobility Test; CI, Confidence Interval; FAC, Functional Ambulation Category Score; FGA, Functional Gait Assessment; FIM, Functional Independence Measure; FRT, Functional Reach Test; FTSTS, Five-Time Sit to Stand Test; MCID, Minimally Clinically Important Difference; MD, Mean Difference; M-MAS, Modified Motor Assessment Scale; NDT, Neurodevelopmental Treatment; OLST, One Leg Stand Test; PCT, Prospectively Controlled Trial; PEDro, Physiotherapy Evidence Database Rating Scale; PNF, Proprioceptive Neuromuscular Facilitation; POMA, Performance Oriented Mobility Assessment; PRISMA, Preferred Reporting Items for Systematic Review and Meta-Analyses; RCT, Randomized Controlled Trial; RMI, Rivermead Mobility Index; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go Test.

Following stroke, individuals often experience residual physical impairment.[1] Approximately half of individuals have mobility issues at three months post stroke, while a quarter of individuals never regain full mobility.[2] Stroke can also have a profound impact on balance and gait, as paresis and spasticity of the muscles reduce the strength, movement, and control of the limbs.[3] Common balance disorders post stroke, such as postural instability, excessive sway, and delayed equilibrium reaction, often attenuate functional movement and increase the risk of falls.[4-6] Asymmetric gait pattern, reduced stride length, and increased double-limb support duration are common post-stroke disorders of gait, which can result in decreased speed and endurance during ambulation,[2,7,8] These disorders of mobility and balance often delay the recovery of functional independence – the ability to perform and participate in activities of daily living – following stroke.[9] As such, the restoration and maintenance of mobility is a central component of stroke rehabilitation.

Aquatic therapy, also known as hydrotherapy or hydrokinesiotherapy, refers to water-based exercises that are specifically designed to utilize the physical properties of water.[10] It has been suggested that water provides an ideal medium for motor rehabilitation as: 1) the buoyancy of water provides increased body weight support, decreased impact on joints, and reduced risk of falls; 2) the hydrostatic pressure of water enhances sensory input and promotes equal resistance in the muscles; 3) the density and viscosity of water can encourage increased energy expenditure as compared to land-based activity; and 4) the thermodynamic properties of water can provide therapeutic relief for muscles and joints.[11] Thus, an aquatic setting provides a safe and comfortable environment, while accommodating varying levels of function and capacity which may enhance performance for individuals undergoing motor rehabilitation.[11]

From a thermodynamic point of view, water is thermally conductive and possesses a high specific heat capacity which allows for water to retain and transfer heat energy to the body.[11] It has been suggested that administering aquatic therapy at varying temperatures can produce differing effects during rehabilitation.[11] For example, a cool temperature range (26 to 29.5°C) is where most pool temperature are set at for the purpose of vigorous exercise. A neutral temperature range (33.5 to 35.5°C) is most commonly used for aquatic therapy protocols through providing a comfortable ambient temperature during longer therapy programs.[11] Lastly, warm temperature ranges (36 to 38.5°C) are close to water temperatures provided in hot tubs and are appropriate for relaxation.[11]

Aquatic therapy can encompass an array of approaches to rehabilitation, including traditional functional therapies, neurodevelopmental treatment (NDT), proprioceptive neuromuscular facilitation (PNF), and task-specific training. Trunk training is an example of a traditional functional therapy that can be applied in an aquatic environment as an intervention. The Halliwick Method is a motor relearning program rooted in NDT in which movements are directed by a therapist while the individual is fully immersed in water, and it incorporates hydrodynamic elements to improve core stability.[12] The Bad Ragaz Ring Method utilizes PNF to increase passive and active range of motion.[13] The individual lays supine on the water surface, supported by flotation devices, while the therapist guides their limbs through stretches.[13] Dual-task training is an example of a task-specific training intervention that can be applied underwater. Techniques from complementary and alternative medicine focus on relaxation and have also been integrated into some aquatic therapy protocols. Ai chi, which is rooted in the principles of tai chi, involves deep, mindful breathing while performing slow, broad, continuous movements.[14] Another technique, Watsu, is derived from shiatsu and consists of massage, assisted stretching, and joint manipulation.[15] Although conventional rehabilitation is primarily land-based, many aquatic therapies have become increasingly popular in recent years due to their potential versatility.[16]

The effectiveness of aquatic therapy has been evaluated in a variety of chronic conditions to assess its impact on rehabilitation outcomes. Among individuals with musculoskeletal disorders such as arthritis and fibromyalgia, aquatic therapy has shown moderate beneficial effects on pain, quality of life, and general physical function when compared to no therapy, but showed no advantage over land-based therapy.[17] Individuals with neurological disorders, including brain injury, spinal cord injury, and neurodegenerative diseases, have demonstrated considerable improvements in mobility, strength, coordination, and fitness following aquatic therapy.[18,19] While some studies reported greater treatment effects following aquatic therapy in comparison to land therapy, the findings were not consistent among neurological disorders or specific aquatic therapies. Overall, aquatic therapy appears to be a safe and feasible form of rehabilitation.[11]

In stroke, aquatic therapy has demonstrated mixed findings, with considerable variation between studies in therapeutic technique and time post stroke. A 2011 Cochrane Review found that aquatic therapy was superior to land-based therapy in improving muscle strength and functional independence in individuals with stroke, but no significant differences were found in balance, gait, or cardiorespiratory fitness.[20] The authors recommended further investigation given the limitations of the review, with only four low-quality trials included. More recently, a meta-analysis of 11 aquatic therapy trials demonstrated statistically significant improvements in balance when compared to land-based therapy.[21] However, the authors did not further examine the impact of the intervention on additional outcomes beyond balance, nor did they evaluate the clinical significance of their findings.[22] Despite the existing evidence, a systematic review on the effectiveness of aquatic therapy post stoke that provides a comprehensive, conclusive, and clinically relevant overview has yet to be published. Therefore, the objective of the current systematic review and meta-analysis is to evaluate the efficacy of aquatic therapy in improving mobility, balance, and functional independence following stroke in comparison to land-based therapy.

Methods

This systematic review and meta-analysis followed the guidelines set out by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.

Search Strategy

A systematic literature search was conducted using the databases MEDLINE, Embase, CINAHL, PsychINFO, and Scopus to identify all articles published up until June 21, 2018. The main keywords used included: “stroke”, “cerebrovascular accident”, “aqua*”, “hydro*”, “water*”, “exercise”, and “therapy”. Variations of the keywords and suggested medical subject headings were chosen based on the database. Filters were applied in all databases to limit studies to only those published in English and that involved human participants. In Scopus, additional filters were applied to further limit results to journal articles and to exclude studies with unrelated keywords because of the very large cull. **Appendix 1** details the full search strategies for each database. Additionally, the references of all included studies were reviewed to ensure that relevant studies were not missed.

Study Selection

Studies were included in this review based on the following a priori criteria:

1. the study was published in English;
2. the study population consisted of human adults post-stroke who were over 18 years of age (whenever reported);
3. the study design was a randomized or non-randomized prospectively controlled trial (RCT or PCT);
4. the participants in the experimental group received a water-based exercise therapy program that was longer than a single session;
5. the study reported at least one clinical outcome measure that assessed mobility, balance, or level of functional independence (i.e., activities of daily living).

Studies were screened by title, abstract, and full text. The remaining studies were screened upon reading the full-text article. Studies were screened for eligibility by two independent reviewers (AI, AL), while discrepancies were resolved by a third independent reviewer (AMc).

Data Extraction and Synthesis

Information relating to study and participant characteristics were extracted, including author(s), publication year, country of origin, study design, sample size, gender, age, time since stroke onset, as well stroke type and location. Details of the therapy program, water conditions, and clinical outcome measures related to mobility and level of functional independence were also extracted for each study. Only clinical outcome measures were extracted, with the exception of gait speed which was presented as a kinematic outcome in some studies. Outcomes that were unrelated to mobility, balance, or level of functional independence were not extracted.

[10]

Methodological Quality Assessment

The Physiotherapy Evidence Database (PEDro) rating scale[23] was used to assess the methodological quality of all studies included in this review. The scale assesses the internal validity of the trial and whether it has presented sufficient statistical information to support the reported results. The PEDro score is obtained by evaluating whether 11 criteria are fulfilled (score of 1), or not (score of 0). The first item does not contribute to the total score and thus the final score is out of 10. Scores are used to describe the methodological quality with scores ≤ 4 considered as poor quality, scores of 4-5 considered fair, scores of 6-8 considered good, and scores of 9-10 considered excellent.[24] The PEDro scores were assessed independently by one of the authors (AI) and were compared to the online Physiotherapy Evidence Database (www.pedro.org.au) scores; discrepancies were resolved by a second reviewer (JW).

Data Analysis

Results of clinical outcome measures were quantitatively pooled if reported in at least three studies. Statistical analysis was performed using Comprehensive Meta-Analysis software (Version 2; Biostat, Inc.; Englewood, NJ, USA) using a random effects model with treatment effects reported as a mean difference (MD) ± standard error and 95% confidence interval (CI), with statistical significance set at $p<0.05$. Both the I^2 statistic and the Cochrane's Q test were used to evaluate statistical heterogeneity.[25] The I^2 statistic was used to interpret heterogeneity as being low at 25%, moderate at 50%, and high at 75%.[26] Cochrane's Q test was used to determine statistically significant heterogeneity at $p<0.01$.[26]

Clinical Outcome Measures

The following mobility and balance outcome measures were evaluated using meta-analysis:

Berg Balance Scale (BBS) is a measure of functional mobility and balance that consists of 14 items, scored from 0 to 4, with a higher score indicating superior balance.[27,28] It is one of the most commonly used assessment tools within the stroke population and has been found to have excellent internal consistency, as well as test-retest and inter-/intra-rater reliability.[28] It has also shown validity in comparison to other outcome measures and has shown moderate to excellent sensitivity.[28]

Functional Reach Test (FRT) is a measure of functional mobility and balance in which the participant's maximal forward reach is measured while maintaining a standing position.[29] It has demonstrated reliability and precision in detecting balance impairment and change in postural control over time.[30] Moreover, the modified version of the FRT has been shown to reliably measure the responsiveness of the paretic side in sub-acute stroke patients, along with moderate responsiveness for the non-paretic side.[31]

Timed Up and Go Test (TUG) is a measure of functional mobility and balance in which the amount of time it takes to stand, walk 3 meters, turn, walk back, and sit back down is measured.[32,33] It has demonstrated reliability and validity in a stroke population as a measure of functional mobility.[34]

Gait Speed was measured primarily using the 10-Meter Walk Test (10MWT) along with other general kinematic assessments of gait speed. It measures aspects of functional mobility through assessing the time it takes participants to walk a certain distance.[35]

Additional outcome measures relating to mobility that were not consistently reported across studies were analyzed qualitatively. These measures included: Community Balance and Mobility Test (CB&M), One Leg Stand Test (OLST), Functional Gait Assessment (FGA), Five-Time Sit to Stand Test (FTSTS), Performance Oriented Mobility Assessment (POMA), Short Physical Performance Battery (SPPB), Functional Ambulation Category Score (FAC), and the Rivermead Mobility Index (RMI). Level of functional independence was assessed using the Barthel Index (BI), Functional Independence Measure (FIM), and the Modified Motor Assessment Scale (M-MAS).

Results

Study and Participant Characteristics

A total of 16 studies met inclusion criteria for this review (**Figure 1**). Details relating to study and participant characteristics are presented in **Table 1**. There were 2 PCTs and 14 RCTs, of which 9 were of fair quality and 7 were of good quality. The pooled sample size at randomization was 559 (543 at follow-up), with a mean sample size of 35 participants (range 12 to 120). Of the total pooled sample, 328 were males and 224 were females. In 2 studies,[36,37] participant characteristics were only provided for those included in the final analysis. The mean age of participants was 60.7 years (range 43.8 to 68.6 years) and the mean time since stroke onset was 15.1 months (range 1.5 to 43.2 months). Park et al.[38] did not report a specific time since stroke onset, only that all participants were recruited more than 7 months post-stroke. Four RCTs[37,39-41] were conducted during the subacute phase of stroke (1 to 6 months), and the remaining 12 studies[36,38,42-51] were conducted during the chronic stage (>6 months). Among the 10 studies[38-42,47-51] reporting the type of stroke, ischemic stroke was experienced by 237 participants, and hemorrhagic stroke was experienced by 133 participants. Based on 14 studies[36-42,44-50] reporting the side of lesion, 243 participants were affected on the left side of the brain, and 247 participants were affected on the right side.

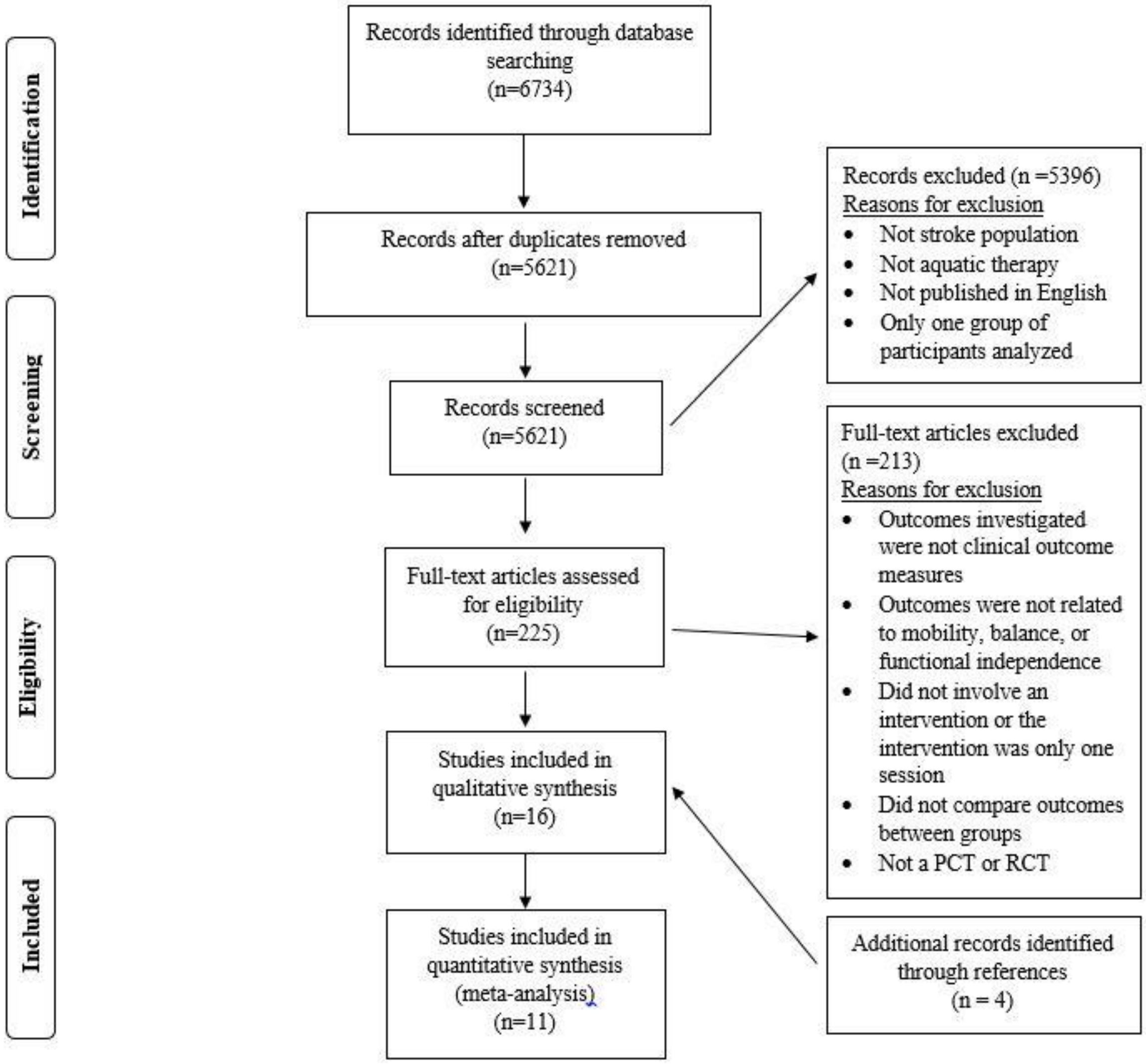

Figure 1. PRISMA flow diagram outlining study selection process.

Table 1. Study and Participant Characteristics

Study	Country	Design	PEDro	Sample (Start / End)	Baseline Data: Gender (M : F)	Mean Age ±SD (y)	Mean Onset ±SD	Type (Isc : Hem)	Side (L : R)
Cha et al.[51]	Korea	RCT	8	N: 22 / 22 I: 11 / 11 C: 11 / 11	13 : 9	I: 64.0 ± 12.1 C: 63.3 ± 12.1	I: 16.6 ± 4.0 mo C: 18.9 ± 5.1 mo	7 : 4 9 : 2	NR
Chan et al.[37]	Canada	RCT	5	N: 32 / 25 I: 17 / 13 C: 15 / 12	13: 12*	I: 66 ± 10* C: 64 ± 12	I: 96 ± 27 d* C: 97 ± 34 d	NR	8 : 5 7 : 5
Chu et al.[42]	Canada	RCT	6	N: 12 / 11 I:6 / 5 C:6 / 6	11 : 1	I: 61.9 ± 9.4 C: 63.4 ± 8.4	I: 3.0 ± 2.0 y C: 4.2 ± 2.1 y	3 : 4 5 : 0	4 : 3 3 : 2
Furnari et al.[43]	Italy	RCT	5	N: 40 / NR I: 20 / NR C: 20 / NR	20 : 20	I: 68 ± 3 C: 72 ± 5	I: 7 ± 1.6 mo C: 6 ± 1.4 mo	NR	NR
Han et al.[36]	Korea	PCT	4	N: NR / 62 I: NR / 31 C: NR / 31	28 : 34*	I: 56.1 ± 7.3* C: 56.6 ± 10.0	I: 15.2 ± 5.1 mo* C: 16.1 ± 5.4 mo	NR	17 : 14 16 : 15
Kim et al.[44]	Korea	RCT	4	N: 20 / NR I: 10 / NR C: 10 / NR	10 : 10	I: 69.1 ± 3.2 C: 68.0 ±3.1	I: 9.8 ± 1.3 mo C: 10.3 ± 1.4 mo	NR	5 : 5 5 : 5
Kim et al.[45]	Korea	RCT	4	N: 20 / NR I: 10 / NR C: 10 / NR	10 : 10	I: 65.9 ± 6.2 C: 64.1 ± 3.6	I: 11.3 ± 1.1 mo C: 21.3 ± 1.3 mo	NR	5 : 5 5 : 5
Kim et al.[46]	Korea	RCT	4	N: 20 / NR I: 10 / NR C: 10 / NR	10: 10	I: 69.1 ± 3.2 C: 68.0 ± 3.1	I: 10.5 ± 1.1 mo C: 11.3 ± 1.1 mo	NR	5 : 5 5 : 5
Matsumoto et al.[39]	Japan	PCT	6	N: 120 / 120 I: 60 / 60 C: 60 / 60	88 : 32	I: 62.4 ± 10.7 C: 63.2 ± 11.5	I: 22.8 ± 14.4 wk C: 24.8 ± 12.7 wk	41 : 19 39 : 21	32 : 28 36 : 24
Noh et al.[47]	Korea	RCT	5	N: 25 / 20 I: 13 / 10 C: 12 / 10	11 : 14	I: 61.9 ± 10.1 C: 66 ± 11.4	I: 2.8 ± 3.8 y C: 1.6 ± 1.7 y	6 : 7 7 : 5	6 : 7 7 : 5
Park et al.[38]	Korea	RCT	4	N: 44 / NR I: 22 / NR C: 22 / NR	27 : 17	I: 51.55 ± 8.27 C: 56.09 ± 7.22	>7mo	8 : 14 8 : 14	9 : 13 13 : 9

Park et al. [48 48 48 48 48 48 51 48 48 48 48 48 48 48]	Korea	RCT	4	N: 20 / NR I: 10 / NR C: 10 / NR	9 : 11	I: 51.8 ± 14.4 C: 58.7 ± 8.3	I: 13.1 ± 8.4 mo C: 12.5 ± 8.4 mo	6 : 4 6 : 4	7 : 3 5 : 5
Park et al.[49]	Korea	RCT	6	N: 28 / NR I:13 / NR C:15 / NR	20 : 8	I: 50.5 ± 2.9 C: 37.9 ± 4.4	I: 24.1 ± 3.8 mo C: 17.2 ± 2.2 mo	10 : 3 9 : 6	3 : 10 6 : 9
Tripp et al.[40]	Germany	RCT	7	N: 30 / 27 I: 14 / 12 C: 16 / 15	19 : 11	I: 64.8 ± 15.0 C: 65.0 ± 15.1	I: 51.9 ± 37.7 d C: 39.0 ± 27.9 d	12 : 2 15 : 1	4 : 10 6 : 10
Zhang et al.[41]	China	RCT	7	N: 36 / 36 I: 18 / 18 C: 18 / 18	17 : 19	I: 56.3 ± 8.18 C: 54.7 ± 7.59	I: 0.34 ± 0.07 y C: 0.37 ± 0.08 y	13 : 5 12 : 6	8 : 10 7 : 11
Zhu et al.[50]	China	RCT	8	N: 28 / 28 I: 14 / 14 C: 14 / 14	22 : 6	I: 56.6 ± 6.9 C: 57.1 ± 8.6	I: 247.4 ± 56.6 d C: 262.1 ± 55.4 d	10 : 4 11 : 3	6 : 8 3 : 11

Abbreviations: I=Intervention Group; C=Control Group; N=Total Sample; M=Male; F=Female; L=Left; R=Right; NR=Not Reported; PEDro=Physiotherapy Evidence Database tool; RCT=Randomized Controlled Trial; PCT=Prospective Controlled Trial; d=day; wk=week; mo=month; y=year.

*Only participant characteristics in final analysis were included; data of participants at randomization not provided

Study Protocol

Intervention and control group protocols are described in **Table 2**. Aquatic therapy was administered for 30 to 40 minutes per day, excluding the length of warm-ups, cool-downs, and stretching if the breakdown was provided. The frequency of therapy ranged from 2 to 6 days a week, and the total duration of the programs ranged from 2 to 12 weeks.

The water temperature ranged from cool (26°C) to warm (38°C), with water temperature reported as cool (26-29.5°C) in two studies,[42,48] between cool and neutral in three studies,[39,44,49] neutral (33.5-35.5°C) in eight studies,[36-38,43,45-47,51] between neutral and warm in one study,[50] and warm in one study (36-38.5°C).[41] One study did not report water temperature.[40]

The type of aquatic therapy program varied between studies. Of the 16 studies examined, 5 studies [36-39,42] administered general aquatic therapy with exercises aimed at improving strength, endurance, mobility, and/or flexibility; 5 studies provided Halliwick aquatic therapy in combination with Ai Chi,[43,47] Watsu,[49] or walking;[40,41] 3 studies [44,45,51] implemented programs based on proprioceptive neuromuscular facilitation; 2 studies[48,50] implemented underwater treadmill training; and 1 study[46] implemented dual-task training.

The control programs also differed between studies. Eleven studies[36-41,43,46,47,49,50] administered general land-based therapy with exercises aimed at improving strength, endurance, mobility, and/or flexibility; 3 studies [44,45,51] implemented proprioceptive neuromuscular facilitation, 1 study[42] administered upper extremity exercises, and 1 study[48] administered treadmill training.

Half of the 16 included studies were dose-matched when comparing the protocols of aquatic therapy and land therapy.[36-38,41,44,48,50,51] Four studies[42,43,47,49] were dose-matched in the total intervention length per day when including warm-ups, cool-downs and stretches, but the primary exercises were not administered for the same length of time. The remaining 4 studies[10, 12, 21, 24] were not dose-matched.

It is important to note that 3 studies[44-46] shared significant similarities in: corresponding author, treatment protocol, participant demographics, outcomes measures, and results. Authors were contacted for further clarification but no response was received. Due to the potential overlap between these studies, only the most recent publication was included in meta-analyses when outcome measures overlapped. As such, BBS, FRT, TUG, and gait speed were only analyzed in the most recent study, Kim et al.[46] OLST and FIM were included from an earlier study, Kim et al.,[44] that reported them.

Table 2. Study Protocols

Study and Water Conditions	Intervention	Control
Cha et al.[51] Water depth: 1.3m Water temperature: 33.3-36.7 °C	**Aquatic Therapy (PNF)** Bad Ragaz Ring method body pattern exercises based on PNF and focused on the trunk and limbs of the affected side.	**Land Therapy (NDT)** Therapy based on NDT techniques.
	Aquatic Therapy was administered in conjunction with Land Therapy: I: 30min/d, 3 d/wk, 6wk C: 30min/d, 3 d/wk, 6wk Total: 60min/d, 3 d/wk, 6 wk	Total: 60min/d, 3 d/wk, 6 wk
Chan et al.[37] Water depth: NR Water temperature: 34.5 ° C	**Aquatic Therapy** Exercises focused on balance, stretching, strengthening, and endurance training exercises.	**Land Therapy** Exercises focused on transfer training, balance, stretching, strengthening, endurance training, gait, and stair exercises.
	Aquatic Therapy was administered in conjunction with Land Therapy: I: 30min/d, 2d/wk, 6wk C: 30min/d, 2d/wk, 6wk Total: 60min/d, 2d/wk, 6wk	Total: 60min/d, 2d/wk, 6wk
Chu et al.[42] Water depth: chest Water temperature: 26-28°C	**Aquatic Therapy (Lower Extremity)** Moderate to high intensity aerobic exercise focused on the lower extremity and including stretching, marching, and hopping. 10 min. stretch 5 min. warm-up 30 min. aerobic exercise 5 min. cool down 10 min. stretch	**Land Therapy (Upper Extremity)** Exercises focused on improving upper extremity function including gross and fine motor exercises along with reaching and strengthening exercises. 5 min. warm-up 50 min. 6 stations each for 7 min. 5 min. cool-down
	Total: 60min/d, 3d/wk, 8wk	Total: 60min/d, 3d/wk, 8wk
Furnari et al.[43] Water depth: 1.15m Water temperature: 33-34°C	**Aquatic Therapy (Halliwick and Ai Chi)** Exercises based on Halliwick and Ai Chi methods including balance exercises, walking, and lower extremity strengthening exercises. 10 min. warm-up 15 min. Halliwick method 15 min. Ai Chi method 10 min. lower limb exercises 10 min cool-down	**Land Therapy** Lower and upper extremity range of motion and strengthening exercises, postural control, and gait training. 10 min. warm-up 20 min. strengthening 20 min. postural control 10 min gait training

	Aquatic Therapy was administered in conjunction with Land Therapy: I: 60min/d, 3d/wk, 8wk C: 60min/d, 3d/wk, 8wk Total: 60 min/d, 6d/wk, 8wk	Total: 60min/d, 6d/wk, 8wk
Han et al.[36] Water depth: 1.1m Water temperature: 33.5°C	**Aquatic Therapy** Exercises consisting of one-leg knee flexion, toe stand, one-leg stance, and weight shifting in water. 5 min. warm-up 30 min. main exercises 5 min. cool-down	**Land Therapy** Exercises consisting of one-leg knee flexion, toe stand, one-leg stance, and weight shifting. 5 min. warm-up 30 min. main exercises 5 min. cool-down
	Total: 40 min/d, 3d/wk, 6wk	Total: 40 min/d, 3d/wk, 6wk
Kim et al.[44] Water depth: 1.1m Water temperature: 31-33°C	**Aquatic Therapy (PNF)** PNF exercise patterns in the lower extremity using the rhythmic initiation (RI) method in water.	**Land Therapy (PNF)** PNF exercise patterns in the lower extremity using the rhythmic initiation (RI) method.
	Total: 30min/d, 5d/wk, 6wk	Total: 30min/d, 5d/wk, 6wk
Kim et al.[45] Water depth: 1m Water temperature: 32-34°C	**Aquatic Therapy (PNF)** PNF exercise patterns under water with a focus on improving coordination.	**Land Therapy (NDT)** NDT included resistance, postural control, functional activity, and mat exercises.
	Aquatic Therapy was administered in conjunction with Land Therapy: I: NR C: 30min/d, 5d/wk, 6wk Total: NR	Total: 30min/d, 5d/wk, 6wk
Kim et al.[46] Water depth: 1m Water temperature: 32-34°C	**Aquatic Therapy (Dual-Task Training)** Dual-task training exercises in water consisting of stability exercises while performing an upper-extremity motor task.	**Land Therapy (NDT)** Therapy based on NDT techniques.
	Aquatic Therapy was administered in conjunction with Land Therapy: I: 30min/d, 5d/wk, 6 wk C: 30min/d, 5d/wk, 6 wk Total: 60min/d, 5d/wk, 6wk	Total: 30min/d, 5d/wk, 6 wk
Matsumoto et al.[39]	**Aquatic Therapy**	**Land Therapy**

Water depth:1.5m, xiphoid process Water temperature: 30-31°C	Exercises focused on improving endurance, strength, postural control, flexibility, mobility and walking under water. Additional exercises added on each week. 5 min. warm-up and stretches 20 min. aquatic exercises 5 min. cool down	Exercises focused on improving range of motion, muscle strength, gait, activities of daily living, and speech.
	Aquatic Therapy was administered in conjunction with Land Therapy: I: 30 min/d, 2d/wk, 12 wk C: 30min/d, 6d/wk, 12wk Total: 30-60 min/d, 6d/wk, 12 wk	Total: 30 min/d, 6d/wk, 12 wk
Noh et al.[47] Water depth: 1.15m Water temperature: 34°C	**Aquatic therapy (Halliwick and Ai Chi Methods)** Program based on Halliwick and Ai Chi methods to improve balance and postural control. 10 min. warm-up 20 min. Halliwick method 20 min. Ai Chi method 10 min. cool-down	**Land Therapy** General conditioning exercises including stretches, range of motion exercise, strength and gait training. 10 min. warm-up 50 min. main exercises
	Total: 60min/d, 3d/wk, 8wk	Total: 60min/d, 3d/wk, 8wk
Park et al.[38] Water depth: 1.3m Water temperature: 33-35 °C	**Aquatic Therapy** Aquatic exercises focused on balance, joint mobility, walking underwater, and jumping. Also received conventional nervous system exercise therapy.	**Land Therapy** Exercises focused on strength and stability and included walking, standing, joint mobility, leg exercises, and stretching. Also received conventional nervous system exercise therapy.
	Total: 35 min/d, 6 d/wk, 6 wk	Total: 35 min/d, 6 d/wk, 6 wk
Park et al.[48]	**Aquatic Treadmill Walking**	**Land Treadmill Walking**
Water depth: T-11 Water temperature: 28-30°C	Total: 30min/d, 4d/wk, 6wk	Total: 30min/d, 4d/wk, 6wk
Park et al.[49] Water depth: xiphoid process Water temperature: 30°C	**Aquatic Therapy (Halliwick, Watsu, and Trunk Training)** Halliwick trunk control program, trunk exercises, Watsu muscular relaxation and stretching. 5 min. warm-up 20 min. trunk exercises 5 min. cool-down based on Hallwick and Watsu exercises	**Land Therapy (Trunk Training)** Exercises included bridge, curl-ups, abdominal and quadruped exercises. 30 min. main exercises
	Total: 30min/d, 3 d/wk, 4 wk	Total: 30min/d, 3 d/wk, 4 wk
Tripp et al.[40] Water depth: NR	**Aquatic Therapy (Halliwick)** Exercises were based on the Halliwick method and included walking.	**Land Therapy**

Water temperature: NR	5 min. warm-up 15 min. Halliwick-based exercise 15 min. underwater walking	Conventional physiotherapy with exercises varied based on the individual, and included mobility exercises and treadmill walking.
	Aquatic Therapy was administered in conjunction with Land Therapy: I: 35min/d, 3d/wk, 2wk C: 45min/d, 2d/wk, 2wk Total: 35-45 min/d, 5d/wk, 2wk	Total: 45min, 5d/wk, 2wk
Zhang et al.[41] Water depth: xiphoid process Water temperature: 37-38°C	**Aquatic Therapy (Halliwick)** Exercises based on the Halliwick method with lower limb exercise and underwater treadmill walking. 5 min. warm-up 25 min. aquatic exercises 10 min. underwater treadmill walking	**Land Therapy** Conventional physiotherapy, daily life activity training, and treadmill walking. 5 min. warm-up 25 min. land exercises 10 min treadmill walking
	Total: 40 min/d, 5d/wk, 8wk	Total: 40 min/d, 5d/wk, 8wk
Zhu et al.[50] Water depth: 1.4m Water temperature: 34-36°C	**Aquatic Therapy** Stretching, strengthening, balance/coordination, and aquatic treadmill walking. 5 min. warm-up 30 min. main exercises 10 min. cool-down	**Land Therapy** Stretching, strengthening, trunk mobility, and treadmill walking. 5 min. warm-up 30 min. main exercises 10 min. cool-down
	Total: 45 min/d, 5d/wk, 4wk	Total: 45 min/d, 5d/wk, 4wk

Abbreviations: I=Intervention; C=Control**;** PNF=Proprioceptive Neuromuscular Facilitation; NDT=Neurodevelopmental Treatment**;** NR = not reported; min=minute; d=day; wk=week.

Functional Mobility and Balance

BBS was reported in seven studies,[36,37,40,42,46,47,50] of which three studies[36,46,47] reported a significant improvement among those undergoing aquatic therapy compared to land therapy. The other four studies[37,40,42,50] did not find a significant between-group difference. All seven studies,[36,37,40,42,46,47,50] (N=193 participants) were included in the meta-analysis. Aquatic therapy demonstrated a statistically significant treatment effect when compared to land therapy (MD=2.282±0.556; 95% CI: 1.192-3.372; p<0.001) without significant heterogeneity (I^2<0.001; Q=2.287, df=6, p=0.891; **Figure 2a**).

FRT was reported in three studies,[40,46,50] of which two studies,[46,50] found a significant improvement among participants undergoing aquatic therapy compared to land therapy. One study[40] did not detect a significant difference between groups. All three studies,[40,46,50] (N=75 participants) were included in the meta-analysis. Aquatic therapy demonstrated a statistically significant treatment effect when compared to land therapy (MD=3.511±1.597; 95% CI: 0.381-6.642; p=0.028) with moderate heterogeneity (I^2=74.280; Q=7.776, df=2, p=0.020; **Figure 2b**).

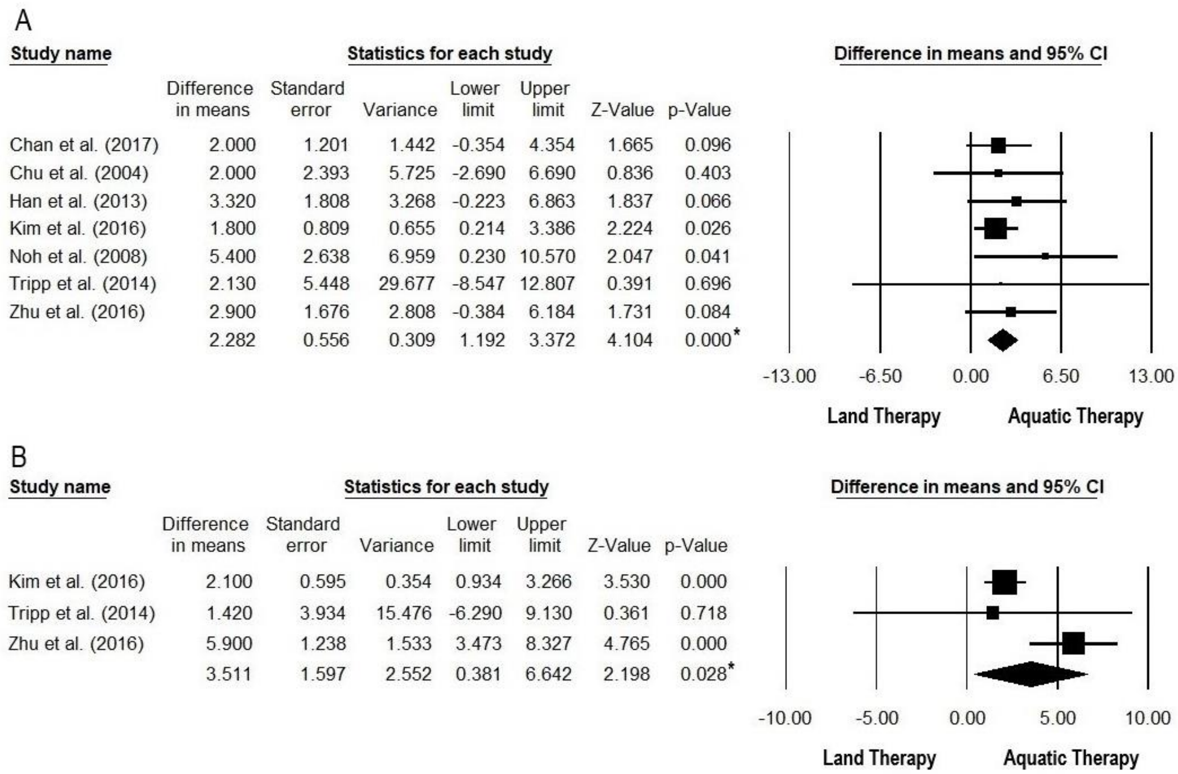

Figure 2. Forest plot comparing the effectiveness of aquatic therapy to land therapy based on (**A**) Berg Balance Scale mean difference scores and (**B**) Functional Reach Test mean difference scores.

TUG was reported in four studies,[37,46,50,51] of which one study[46] found a significant improvement among participants undergoing aquatic therapy compared to land therapy. Three studies[37,50,51] did not detect a significant between-group difference. All four studies,[37,46,50,51] (N=95 participants) were included in the meta-analysis. Aquatic therapy demonstrated a statistically significant treatment effect when compared to land therapy (MD=2.229±0.513; 95% CI: 1.224-3.234; $p<0.001$) without significant heterogeneity ($I^2<0.001$; Q=0.752, df=3, p=0.020; **Figure 3a**).

Gait Speed was reported in seven studies.[37,39,42,43,46,49,50] Five studies[39,42,43,46,50] found a significant between-group difference favoring aquatic therapy over land therapy, while two studies[37,49] did not find a significant between-group difference. Four studies,[39,42,43,49] (N=199 participants) were included in the meta-analysis. The remaining three studies were not included due to the inability to extract pertinent raw data required for meta-analysis. Aquatic therapy demonstrated a non-significant treatment effect when compared to land therapy (MD=0.028±0.018; 95% CI: -0.007-0.062; p=0.117) without significant heterogeneity (I^2=22.545; Q=3.873, df=3, p=0.275; **Figure 3b**).

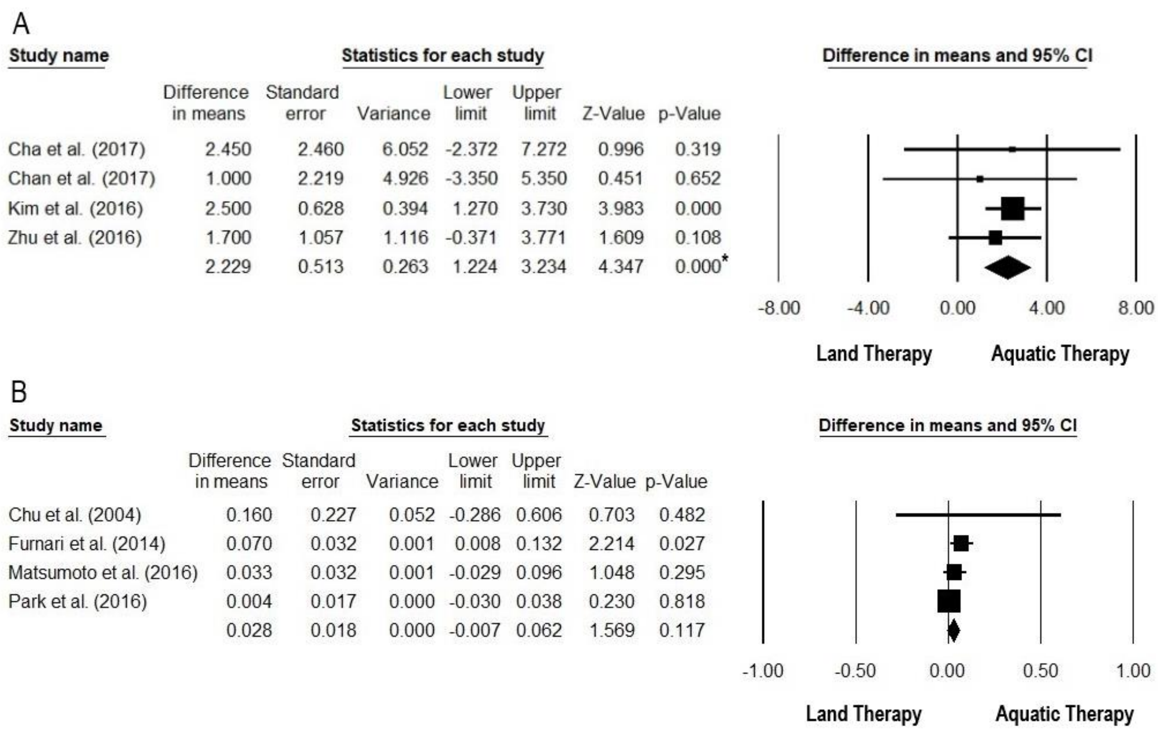

Figure 3. Forest plot comparing the effectiveness of aquatic therapy to land therapy based on (**A**) Timed Up and Go Test mean difference scores and (**B**) gait speed mean difference scores.

FAC was reported in two studies,[40,41] which both reported that aquatic therapy significantly improved scores in comparison to the control group. However, one of the studies[40] did not report the specific p-value, and instead reported that the outcome was significant based on their criteria of $p<0.1$, which does not meet the standard of statistical significance defined in this review (i.e., $p<0.05$; **Table 3**).

OLST,[44] FTSTS,[46] FGA,[46] and the POMA[38] were reported in one study each and demonstrated a significant between-group difference in favor of aquatic therapy over land therapy. The CB&M,[37] PPB,[48] and the RMI,[40] were each reported in one study each and demonstrated no significant difference between aquatic therapy and land therapy.

Table 3. Between-group comparisons of aquatic therapy and land therapy on clinical outcome measures of functional mobility and balance.

Study	Intervention	Control	Outcome Measure	Results
Cha et al.[51]	Aquatic Therapy (PNF)	Land Therapy (NDT)	Timed Up and Go Test	-
Chan et al.[37]	Aquatic Therapy	Land Therapy	Berg Balance Scale Community Balance and Mobility Test Timed Up and Go Test 2-Minute Walk Test	- - - -
Chu et al.[42]	Aquatic Therapy (Lower Extremity)	Land Therapy (Upper Extremity)	Berg Balance Scale Gait Speed	- +
Furnari et al.[43]	Aquatic Therapy (Halliwick and Ai Chi)	Land Therapy	Gait Speed	+
Han et al.[36]	Aquatic Therapy	Land Therapy	Berg Balance Scale	+
Kim et al.[44]	Aquatic Therapy (PNF)	Land Therapy (PNF)	One Leg Stand Test	+
Kim et al.[46]	Aquatic Therapy (Dual-Task Training)	Land Therapy (NDT)	Berg Balance Scale Five-Time Sit to Stand Test Functional Reach Test 10-Meter Walk Test Timed Up and Go Test Functional Gait Assessment	+ + + + + +
Matsumoto et al.[39]	Aquatic Therapy	Land Therapy	10-Meter Walk Test	+

Noh et al.[47]	Aquatic Therapy (Halliwick and Ai Chi)	Land Therapy	Berg Balance Scale	+
Park et al.[38]	Aquatic Therapy	Land Therapy	Performance-Oriented Mobility Assessment	+
Park et al.[48]	Aquatic Treadmill Walking	Land Treadmill Walking	Short Physical Performance Battery	-
Park et al.[49]	Aquatic Therapy (Halliwick, Watsu, and Trunk Training)	Land Therapy (Trunk Training)	Gait Speed	-
Tripp et al.[40]	Aquatic Therapy (Halliwick)	Land Therapy	Berg Balance Scale Functional Reach Test Functional Ambulation Category Score Rivermead Mobility Index	- - + * -
Zhang et al.[41]	Aquatic Therapy (Halliwick)	Land Therapy	Functional Ambulation Category Score	+
Zhu et al.[50]	Aquatic Therapy	Land Therapy	Berg Balance Scale Functional Reach Test Timed Up and Go Test 2-Minute Walk Test	- + - +

Abbreviations: PNF=Proprioceptive Neuromuscular Facilitation; NDT=Neurodevelopmental Treatment
Note: + = significant difference; – = no significant difference; * = study reported significant at p<0.1 which does not reach significance level of p<0.05 used in this analysis (specific p-value not reported)

Functional Independence

BI was reported in two studies,[41,51] which both found a significant between-group difference favoring aquatic therapy over land therapy (**Table 4**). FIM was reported in one study,[44] which found a significant between-group difference favoring aquatic therapy over land therapy. M-MAS was reported in one study,[47] which found no significant difference between aquatic therapy and land therapy.

Table 4. Between-group comparisons of aquatic therapy and land therapy on clinical outcome measures of functional independence

Study	Intervention	Control	Outcome Measure	Results
Cha et al.[51]	Aquatic Therapy (PNF)	Land Therapy (NDT)	Barthel Index	+
Kim et al.[44]	Aquatic Therapy (PNF)	Land Therapy (PNF)	Functional Independence Measure	+

Noh et al.[47]	Aquatic Therapy (Halliwick and Ai Chi)	Land Therapy	Modified Motor Assessment Scale	-
Zhang et al.[41]	Aquatic Therapy (Halliwick and Treadmill Walking)	Land Therapy	Barthel Index Score	+

Abbreviations: PNF=Proprioceptive Neuromuscular Facilitation; NDT= Neurodevelopmental Treatment
Note: + = significant difference; – = no significant difference

Discussion

Sixteen studies provided evidence for the effectiveness of aquatic therapy in improving either mobility, balance, or level of functional independence post stroke, of which 11 were included in the meta-analysis. This review builds on a previously published review[21] which only examined the effects of aquatic therapy on balance post-stroke. In this study, we evaluated various clinical outcome measures related to functional mobility and activities of daily living in addition to balance, thus providing the most comprehensive evaluation of aquatic therapy for stroke rehabilitation to date. The meta-analysis revealed significant treatment effects in favor of aquatic therapy over land therapy on BBS, FRT, and TUG, but not gait speed. Overall, outcome measures that were reported in 2 or fewer studies reported a mixture in significant and non-significant between-group differences. Positive treatment effects were found in favor of aquatic therapy when compared to land-based therapy on measures of mobility including the FAC, OLST, FTSTS, FGA, POMA, and on measures of functional independence including the BI, and FIM. No significant treatment effects were found on other measures of mobility including CB&M, SPPB, RMI and on the M-MAS, which also measures level of functional independence. Overall, despite the heterogeneity of the various aquatic therapy programs examined, a statistically significant treatment effect was demonstrated on a number of clinical outcome measures, suggesting that aquatic therapy may be more useful in the rehabilitation of certain aspects of mobility than traditional land-based therapies for stroke patients.

Of the 7 studies[36,37,40,42,46,47,50] analyzed in the BBS meta-analysis, all 3 studies[36,46,47] that found a significant benefit of aquatic therapy over land therapy on the BBS were conducted in the chronic phase post-stroke. Alternatively, of the 4 studies[37,40-42] that found no significant between-group difference when comparing aquatic therapy to land-based therapy, 2 studies[37,40] were conducted during the subacute phase post-stroke. As such, it is possible that differences in the timing of trials post-stroke may contribute to the differences in results observed on the BBS among studies comparing the effectiveness of aquatic therapy to that of land therapy. While the divide in between-group results based on timing after stroke was not as obvious for the other outcome measures assessed in the review, timing after stroke may play an important role in the observed effectiveness of aquatic therapy. Additional studies are required to investigate whether aquatic therapy is more effective during the chronic phase than during acute or subacute phases post stroke.

Clinical Importance of Findings

In response to the most recent review[21] evaluating the effectiveness of aquatic therapy on outcome measures of balance, a recent letter to the editor[22] raised the concern that only statistical significance was analyzed without also considering clinical significance of the findings. To address this, the literature was consulted to assess whether the significant treatment effects were clinically relevant based on suggested Minimally Clinically Important Difference (MCID) values, where possible. The study by Chan et al.[37] that the letter to the editor[22] references as an MCID study for BBS did not actually conduct an MCID analysis, and the value presented should therefore not be referenced as such. While there is no established MCID for change in BBS scores in a stroke population, a study by Gervasoni et al.[52] concluded that a 3 point difference in BBS was clinically significance overall. Clinical importance was interpreted using the systematic method outlined by Man-Son-Hing et al.,[53] in which various thresholds of clinical importance are described based on where the MCID value falls with respect to the point estimate and the 95% confidence interval. The categories include "definite", "probable", "possible" and "definitely no" clinical importance. Based on our syntheses, the calculated point estimate for BBS (MD=2.282±0.556) was lower than the proposed MCID value (MD=3), but within the confidence interval of the treatment effect (CI: 1.192 to 3.372). Based on the criteria within the review by Man-Son-Hing et al.,[53] it is appropriate to interpret these results as reaching the threshold for possible clinical importance.

To our knowledge, there is no established MCID value for TUG scores in a stroke population, however one study[54] calculated the MCID in a population of patients who had undergone surgery for lumbar degenerative disc disease. Using the Oswestry Disability Index and the Roland-Morris Disability Index as a reference, the MCID scores for TUG were calculated to be 3.2 and 3.6, respectively.[54] When comparing to the proposed MCID value, our analysis indicates that the calculated point estimate for TUG (MD=2.229 ±0.513) was lower than the proposed MCID value (MD= 3.2 to 3.6), but could fall within the confidence interval of the treatment effect (CI: 1.224 to 3.234) depending on which MCID value is used. To be conservative in the interpretation, it is likely that the findings are not clinically important.[53] There is insufficient information on MCID values for FRT to determine whether the results were clinically important.

Based on the current evidence, aquatic therapy was shown to be statistically superior to land therapy on some measures of mobility, with the difference being of possible clinical importance on the BBS. Unfortunately, there is a scarcity of studies reporting MCID values, and especially those reporting values specifically based on outcome measures that are relevant to stroke patients. Additionally, due to differences in how MCID is calculated and interpreted, there is room for ambiguity at every step when determining clinical importance. Clearly, additional studies are necessary in order to establish MCID values for outcome measures that are relevant in rehabilitation after a stroke.

Study Limitations

The evidence provided by this systematic review and meta-analysis is not without limitations. While there are a fair number of trials available in the literature to consult, the protocols applied to study participants were quite heterogeneous, with no standardized protocol for the application of aquatic therapy. Both experimental and control group protocols varied between studies in terms of the exercise applied, as well as the timing, dose, and duration. Differences in water depth and temperature between trials also existed but were not examined in relation to findings within this review although a previous clinical review outlined how therapeutic effects may differ based on temperature.[11] Most studies were of fair methodological quality most commonly due to lack of concealed allocation and blinding, inadequate follow-up, and lack of an intention-to-treat analysis. In addition, to these factors, low sample sizes may have contributed to bias within the results. Furthermore, as mentioned previously, 3 studies[44-46] demonstrated such substantial overlap that some of the reported data in Kim et al.[44] and Kim et al.[45] was omitted from the meta-analysis if those outcome measures had been reported in Kim et al.[46] to avoid potential bias. Despite these limitations, the evidence for the effectiveness of aquatic therapy is mounting, with our analysis corroborating Iatridou et al.[21] findings, and also extending beyond balance to outcome measures related to mobility and level of functional independence.

Conclusion

Aquatic therapy is a viable option post stroke, potentially offering additional benefits in aspects of mobility, balance, and level of functional independence when compared to land therapy alone. Given the potential for recovery that aquatic therapy can offer individuals after stroke, there is a need to further evaluate standardized aquatic therapy protocols (i.e., type, duration, dose) and timing of recruitment post-stroke to further establish whether statistically clinically-meaningful improvements can be made. Additionally, larger multi-center trials are needed to investigate how aquatic therapy can be incorporated into current rehabilitation programs and whether it is feasible for recommendation as a supplemental form of exercise therapy.

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Figure Legends

Figure 1. PRISMA flow diagram outlining study selection process. *PCT: Prospectively Controlled Trail, RCT: Randomized Controlled Trial.*

Figure 2. Forest plot comparing the effectiveness of aquatic therapy to land therapy based on (A) Berg Balance Scale mean difference scores and (B) Functional Reach Test mean difference scores.

Figure 3. Forest plot comparing the effectiveness of aquatic therapy to land therapy based on (A) Timed Up and Go Test mean difference scores and (B) gait speed mean difference scores.

Table Legend

Table 1. Study and participant characteristics

Table 2. Study Protocols

Table 3. Between-group comparisons of aquatic therapy and land therapy on clinical outcome measures of functional mobility and balance.

Table 4. Between-group comparisons of aquatic therapy and land therapy on clinical outcome measures of functional independence.

Appendix

Search Strategy

MEDLINE

(stroke OR cerebrovascular accident) AND (aqua* OR hydro* OR water*) AND (exercise OR therapy).af.

Limits: Language: English, Population: Human

EMBASE

((cerebrovascular accident). kw.) AND ((aqua* OR hydro* OR water*). ab, dj,fi, fx, hw, kw, ot, ti, tw.)

Limits: Language: English, Population: Human

PsycINFO

(stroke OR cerebrovascular accident) AND (aqua* OR hydro* OR water*)

Limits: Language: English, Population: Human

CINAHL

(Stroke [MeSH]) AND (Aquatic Exercises [MeSH]) OR (Hydrotherapy [MeSH]) OR (Body-Weight-Supported Treadmill Training [MeSH])

SCOPUS

(stroke OR cerebrovascular accident) AND (aqua* OR hydro* OR water*) AND (exercise OR therapy). kw, ab, ti.

Limits: Language: English, articles, journal articles, excluded studies with unrelated keywords.