

Water-Based Exercise on Functioning and Quality of Life in Poststroke Persons: A Systematic Review and Meta-Analysis

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Objective: To investigate the effects of water-based exercise on functioning and quality of life in poststroke persons. **Data Sources:** We searched the following electronic database: MEDLINE, PeDro, Scielo, and the Cochrane Central Register of Controlled Trials up to September 2018. **Study Selection:** Only randomized controlled trials were included. Two review authors screened the titles and abstracts and selected the trials independently. **Data Extraction:** Two review authors independently extracted data of the included trials, using standard data-extraction model. We analyzed the pooled results using weighted mean differences, and standardized mean difference and 95% confidence intervals (CIs) were calculated. **Data Synthesis:** Twenty-four studies met the study criteria, but only 15 studies were included on meta-analyses. The studies presented moderate methodological quality, due to the lack of blinding of subjects and therapists and the nonperformance of the intention-to-treat analysis. Water-based exercise compared with land exercise had a positive impact on: muscle strength balance gait speed and mobility aerobic capacity and functional reach. Combined water-based exercise and land exercise was more effective than land exercise for improving balance, gait speed, and functional reach. The meta-analysis showed significant improvement in role limitations due to physical functioning and emotional problems, in vitality general mental health, social functioning, and bodily pain for participants in the water-based exercise and land exercise group versus land exercise group. **Conclusions:** Water-based exercise may improve muscle strength, balance, mobility, aerobic capacity, functional reach, joint position sense, and quality of life in poststroke persons and could be considered for inclusion in rehabilitation programs. **Key Words:** Stroke—hydrotherapy—postural balance—quality of life—rehabilitation
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Introduction

Stroke is a global health problem and an important cause of both disability and mortality around the world.¹ The effects of stroke range in severity from

minor disabilities that may resolve rapidly to severe and long-lasting disabilities.² Impaired motor function and gait, low fitness, and other impairments interact to limit

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poststroke activity, restrict participation, and lead to poor health-related quality of life.³ Many of these disabilities improve if persons with stroke receive specialized rehabilitation.⁴ Thus, both the assessment and treatment of functioning and disability, is at the core of healthcare and stroke rehabilitation.^{4,5}

Many different rehabilitation approaches have been used to improve disability after stroke. Exercise-based rehabilitation is a well-established method to improve disability in poststroke persons.^{5,6} However, the most efficient modality is unknown.⁵⁻⁷ In this context, water-based exercises, also called aquatic therapy or hydrotherapy, provides an environment in which persons with stroke can initiate their exercise earlier when they are not able to control weight bearing on land.^{8,9} The buoyancy of water allows limbs to move more efficiently with little strength, increasing the coordination of motion.⁹

In 2015, Marinho-Buzelli et al¹⁰ published a systematic review evaluating the effects of aquatic therapy on the mobility of individuals with neurological diseases whose participants with multiple sclerosis and stroke were predominant among studies; however, it included nonexperimental and/or quasi-experimental studies, which can decrease the confidence in the results found. In addition, the search strategy undertaken by the authors did not identify any published randomised clinical trials. Besides, a meta-analysis was not performed. Recently, a new systematic review evaluating the effects of hydrokinesiotherapy in hemiplegic persons after stroke was published.¹¹ However, in this review, the authors investigated the effects only for the outcome of postural balance. Thus, the aim of this systematic review with a meta-analysis was to analyse the published randomised clinical trials that investigated the effects of water-based exercise on both functioning and quality of life in poststroke persons.

Methods

This systematic review adheres to the PRISMA guidelines.¹²

Eligibility Criteria

Design

We considered randomised controlled trials, regardless of their publication status or language. To be eligible, the clinical trial should have randomised persons with stroke to at least 1 group of water-based exercise.

Participants

To be eligible for inclusion, trials had to involve adult participants with any disability following stroke.

Interventions

The experimental intervention was water-based exercise that consists of exercise protocols against water resistance. The control intervention was land exercise.

Outcome Measures

Eight outcomes were of interest: muscle strength, balance, gait speed, mobility, aerobic capacity, reach function, quality of life, and joint position sense.

Information Sources and Search

We searched the following electronic databases: MEDLINE, the Physiotherapy Evidence database (PEDro), Scientific Electronic Library Online, and the Cochrane Central Register of Controlled Trials up to July 2018. There was no language restriction. Results were limited to studies with human subjects and clinical trials. We used Medical Subject Headings and text word terms and tailored the search to individual databases. Keywords and synonyms to sensitise the search were used. In the search strategy, there were 4 groups of keywords: study design, participants, interventions, and outcome measures.

Reference lists of all primary studies and review articles were manually checked for potentially eligible articles. For ongoing studies, or when the confirmation of any data or additional information was needed, the authors were contacted by e-mail. The full search strategy can be found in Supplementary File 1 for independent replication.

Data Collection and Analysis

A search strategy was used to obtain titles and abstracts of studies that might be relevant for this review. Each abstract identified in the research was independently examined by 2 authors. If at least 1 of the authors considered 1 reference eligible, the full text was obtained for a complete assessment. Two reviewers independently evaluated full-text articles for eligibility criteria. In case of any disagreement, all authors discussed the reasons for their decisions, and a final decision was made by consensus.

Two review authors independently extracted data of included trials using a standard data-extraction model.¹³ Aspects of the study population, intervention performed, follow-up and loss to follow-up, outcome measures, and results were reviewed.

Quality of Meta-Analysis Evidence

The PEDro scale was used for scoring the methodological quality of trials. The PEDro scale is based on a Delphi list and consisted of 11 items. It is a useful tool for scoring the quality of physical therapy trials.^{14,15} The PEDro scale assigns a score ranging from 0 to 10.¹⁶

We assessed the certainty of evidence and the strength of recommendations for the included outcomes using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system's GRADEpro software, the results of which are presented in the Summary of Findings Table.¹³ The assessment involved 5 items: risk of bias, imprecision, inconsistency, indirectness, and publication bias. Each item was graded as follows: none (no reduction in points), serious (reduction of 1 point), and very serious (reduction of 2 points). The quality of evidence was interpreted as high quality, moderate quality, low quality, or very low quality.¹³

Data Synthesis and Analysis

We analysed the pooled results using weighted mean differences and/or standardised mean difference (SMD). Values were expressed as the weighted mean difference between groups. When the SD of change was not available, the SD of the baseline measure was used. Fixed and random-effects models were used. We only pooled data if there were at least 2 trials of comparable water-based exercise with the same conditions and comparable outcome measurements. Three comparisons were made: water-based exercise versus land exercise, water-based exercise and land exercise versus land exercise, and water-based exercise and physical therapy versus land exercise and physical therapy. An α value of .05 was considered significant. Heterogeneity was regarded as high if I^2 was more than 40%.¹⁷ For the meta-analysis, we used a random-effects model in the presence of high heterogeneity ($I^2 > 40\%$). Analyses were performed using Review Manager Version 5.3 (Cochrane Collaboration).¹⁸

Results

Description of Selected Studies

The initial search led to the identification of 93 studies, 24 of which were considered potentially relevant and were retrieved for detailed analysis. Twenty-four randomised controlled trials met the eligibility criteria. [Figure 1](#) summarises the search and selection process based on included and excluded studies.

The remaining randomised controlled trials¹⁹⁻⁴² were thoroughly analysed, approved by both reviewers and had their data extracted. Each randomised controlled trial was scored using the PEDro scale. According to the PEDro scale, the studies presented moderate methodological quality, due to the lack of blinding of subjects and therapists and the nonperformance of the intention-to-treat analysis. The scores of the PEDro scale are presented individually in [Table 1](#).

Study Characteristics

Characteristics of randomised controlled trials are summarised in [Table 1](#). The number of participants in the

included studies ranged from 12¹⁹ to 120.³⁷ The mean age of participants ranged from 44.2³⁸ to 70^{28,29} years. All randomised controlled trials included persons of both genders, but there was a predominance of 58.2% males. [Table 2](#) summarises the characteristics of included studies.

Water-based exercise included aerobic and strength exercises in warm water, and the duration of programmes ranged from 2³¹ to 12^{20,22,26,29,37,41} weeks. The parameters used were reported in most studies. The length of sessions varied from 30^{23,25,30,32,33,36-39} to 60^{19-21,28,41,42} minutes. The frequency of sessions varied from 2 times per week^{20,26,37,39,41} to 6 times per week²⁴ ([Table 3](#)).

Water-Based Exercise Versus Land Exercise

Muscle Strength

Three randomised controlled trials assessed muscle strength as an outcome.^{19,21,35} Due to the difference between the tests used in the assessment of muscle strength, we performed a meta-analysis with the SMD. The meta-analysis showed a significant improvement in muscle strength at .63 (95% confidence interval [CI]: .15, 1.12; $N = 69$) for participants in the water-based exercise group compared with the land exercise group ([Fig 2A](#)).

Balance

Four randomised controlled trials assessed balance as an outcome.^{19,21,33,34} Balance was assessed by the Berg Balance Scale (0-56 points). The meta-analysis showed a significant improvement in balance at 1.55 (95% CI: .5, 2.6; $N = 80$) for participants in the water-based exercise group compared with the land exercise group ([Fig 2B](#)).

Gait Speed

Three randomised controlled trials assessed gait speed as an outcome.^{19,25,38} Due to the difference between the tests used in the assessment of gait, we performed a meta-analysis with the SMD. The meta-analysis showed a non-significant difference in gait speed of .23 (95% CI: -.3, .7; $N = 61$) for participants in the water-based exercise group compared with the land exercise group ([Fig 2C](#)).

Mobility

Two randomised controlled trials assessed mobility as an outcome.^{33,34} Mobility was assessed by the Timed Up and Go test. The meta-analysis showed a significant improvement in mobility at -1.2 seconds (95% CI: -2.04, -.4; $N = 48$) for participants in the water-based exercise group compared with the land exercise group ([Fig 2D](#)).

Aerobic Capacity (Peak VO₂)

Two randomised controlled trials assessed Peak VO₂ as an outcome.^{19,40} The meta-analysis showed a significant improvement in Peak VO₂ of 3.64 mL/kg/minute (95%

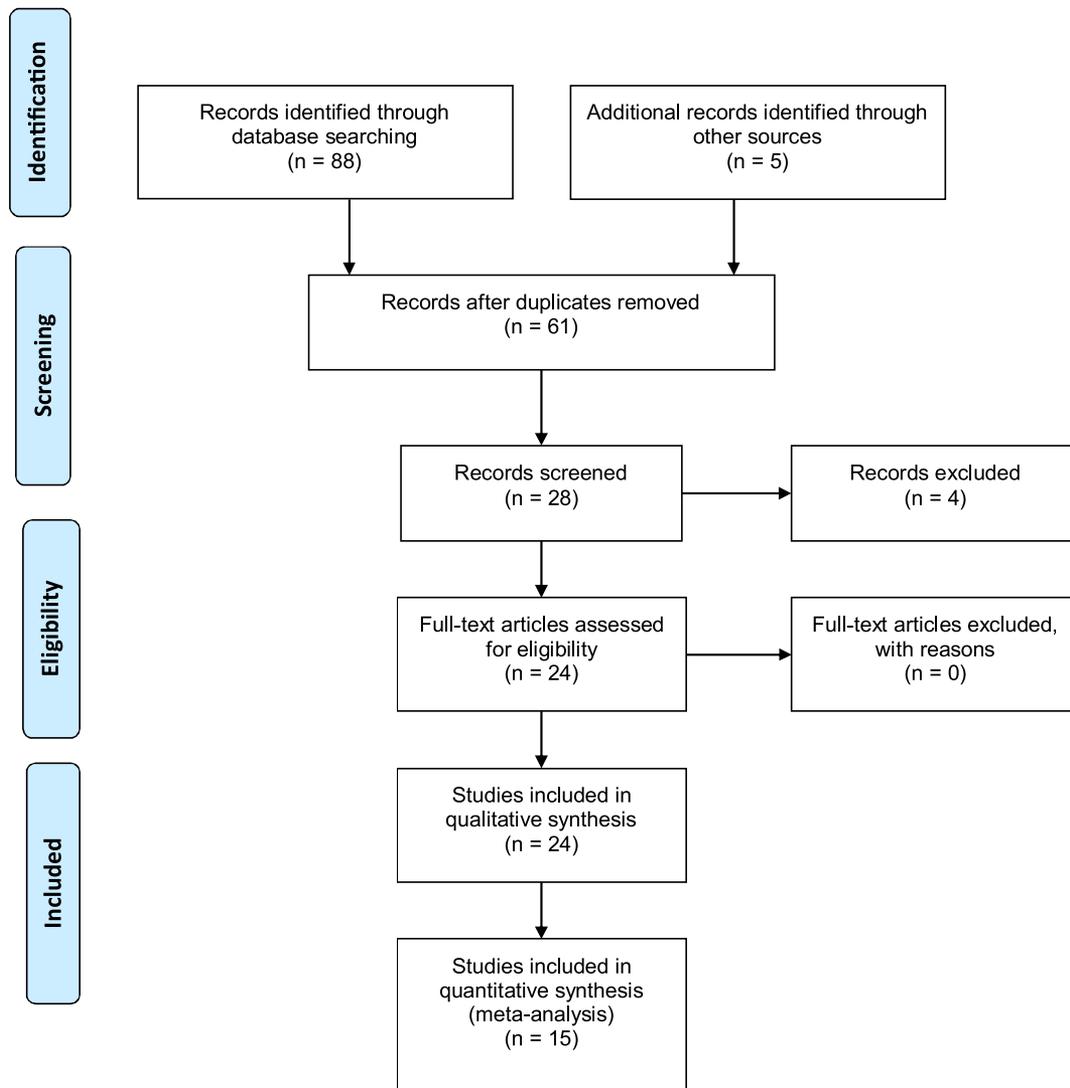


Figure 1. Search and selection of studies for systematic review according PRISMA.

CI: .7, 6.6; $N = 33$) for participants in the water-based exercise group compared with the land exercise group (Fig 2E).

Functional Reach

Two randomised controlled trials assessed functional reach as an outcome.^{33,34} The meta-analysis showed improvement, but not a significant, in Functional Reach of 3.16 cm (95% CI: $-1.82, 8.15$; $N = 48$) for participants in the water-based exercise group compared with the land exercise group (Fig 2F).

Quality of Life

Only 1 study assessed the Quality of life by Short Form-8 (SF-8) health survey.²³ The results showed improvement, but not a significant, in Mental Component (-1.6 ; $P < .01$). However, there were no significant difference in Physical Function (-0.7 ; $P = .76$) between participants in the water-based exercise group compared with the land exercise group.

Water-Based Exercise and Land Exercise Versus Land Exercise

Muscle Strength

Only 1 randomised controlled trial assessed muscle strength as an outcome.⁴² After treatment, significant improvements were observed in both groups in isokinetic measurements of quadriceps and hamstring muscles at 90 and 120 degrees/second angular velocities. However, statistically no significant difference was observed between groups, in the quadriceps and hamstring muscle of the affected side or unaffected side, to both velocities ($P > .05$).

Balance

Five randomised controlled trials assessed balance as an outcome.^{31,32,36,39,42} Balance was assessed by the Berg Balance Scale (0-56 points). The meta-analysis showed significant improvement in balance at 1.69 (95% CI: .9, 2.5; $N = 149$) for

Table 1. Study quality on the PEDro scale

Study	1*	2	3	4	5	6	7	8	9	10	11	Total
1. Chu et al, 2004 ¹⁹	✓	✓		✓			✓	✓		✓	✓	6
2. Aidar et al, 2007 ²⁰	✓	✓		✓				✓		✓	✓	5
3. Noh et al, 2008 ²¹	✓	✓		✓			✓			✓		4
4. Lee et al, 2010 ²²	✓	✓		✓				✓		✓	✓	5
5. Park et al, 2010 ²³	✓	✓		✓						✓	✓	4
6. Park et al, 2011 ²⁴	✓	✓		✓						✓	✓	4
7. Park et al, 2012 ²⁵	✓	✓		✓						✓	✓	4
8. Aidair et al, 2013 ²⁶	✓	✓		✓				✓		✓	✓	5
9. Han et al, 2013 ²⁷	✓							✓		✓	✓	3
10. Furnari et al, 2014 ²⁸		✓		✓			✓			✓	✓	5
11. Jung et al, 2014 ²⁹		✓		✓				✓		✓	✓	5
12. Park et al, 2014 ³⁰	✓	✓		✓				✓		✓	✓	5
13. Tripp et al, 2014 ³¹	✓	✓	✓	✓			✓	✓		✓	✓	7
14. Kim et al, 2015 ³²		✓		✓						✓	✓	4
15. Kim et al, 2015 (2) ³³		✓		✓						✓	✓	4
16. Zhu et al, 2016 ³⁴	✓	✓	✓	✓			✓	✓	✓	✓	✓	8
17. Zhang et al, 2016 ³⁵		✓		✓			✓	✓	✓	✓	✓	7
18. Kim et al, 2016 ³⁶		✓		✓						✓	✓	4
19. Matsumoto et al, 2016 ³⁷		✓		✓			✓	✓		✓	✓	6
20. Park et al, 2016 ³⁸	✓							✓		✓	✓	3
21. Chan et al, 2017 ³⁹	✓	✓		✓			✓			✓	✓	5
22. Han et al, 2018 ⁴⁰	✓	✓	✓	✓				✓		✓	✓	6
23. Aidar et al, 2018 ⁴¹	✓	✓		✓						✓	✓	4
24. Eyvaz et al, 2018 ⁴²	✓	✓	✓					✓		✓	✓	5

1: eligibility criteria and source of participants; 2: random allocation; 3: concealed allocation; 4: baseline comparability; 5: blinded participants; 6: blinded therapists; 7: blind assessors; 8: adequate follow-up; 9: intention-to-treat analysis; 10: between-group comparisons; 11: point estimates and variability.

*Item 1 does not contribute to the total score.

participants in the water-based exercise and land exercise group compared with the land exercise group (Fig 3A).

Gait Speed

Four randomised controlled trials assessed gait speed as an outcome.^{32,36,39,42} Due to the difference between the tests used in the assessment of gait, we performed a meta-analysis with the SMD. The meta-analysis showed a significant improvement in gait speed of .64 (95% CI: .3, .9; $N = 185$) for participants in the water-based exercise and land exercise group compared with the land exercise group (Fig 3B).

Mobility

Two randomised controlled trials assessed mobility as an outcome.^{32,36,39,42} Mobility was assessed by the Timed Up and Go test. The meta-analysis showed no significant improvement in mobility at -1.39 seconds (95% CI: $-2.91, .12$; $N = 125$) for participants in the water-based exercise and land exercise group compared with the land exercise group (Fig 3C).

Aerobic Capacity (Peak VO₂)

There were no randomized controlled trials of aerobic capacity as an outcome.

Functional Reach

Two randomised controlled trials assessed balance as an outcome.^{31,36} Functional reach was assessed by the Functional Reach Test. The meta-analysis showed significant improvement in functional reach at 2.1 cm (95% CI: 1.1, 3.0; $N = 50$) for participants in the water-based exercise and land exercise group compared with the land exercise group (Fig 3D).

Quality of Life

Two randomised controlled trials assessed Quality of life as an outcome^{37,42} by the Short Form Survey (SF-36). The eight domains of SF-36 reported were Physical functioning, Role limitations due to physical functioning, Role limitations due to emotional problems, Vitality, General Mental Health, Social Functioning, Bodily pain, and General health.

The meta-analysis showed not significant improvement in Physical functioning at 2.32 (95% CI: $-2.66, 7.3$; $N = 180$) and General Mental Health at 3.32 (95% CI: $-5.1, 11.71$; $N = 180$) for participants in the water-based exercise and land exercise group compared with the land exercise group (Fig 3E and F).

The meta-analysis showed significant improvement in the domains of SF-36 such as Role limitations due

Table 2. Characteristics of the included studies

Study	Patients (N analysed, age, gender)	Intervention types	Outcome measures				Key findings
			Balance	Gait	Function	Quality of life	
1. Chu et al, 2004 ¹⁹	N = 12, 62.6 y, 91.6% male	Aerobic and stretching	BBS	Self-selected gait speed			The experimental group attained significant improvements over the control group.
2. Aidar et al, 2007 ²⁰	N = 28, 51.4 y, 67.85% male	Hydrokinesiotherapy				SF-36	In the evaluation between groups, there were significant differences in quality of life.
3. Noh et al, 2008 ²¹	N = 25, 63.9 y, 56% male	Halliwick and Ai Chi	BBS mtd-B	MMAS			Compared with the conventional therapy group, the aquatic therapy group attained significant improvements in balance and strength.
4. Lee et al, 2010 ²²	N = 34, 61.7 y, 47.05% male	Hydrokinesiotherapy (coordination, balance, endurance)	GBS				When the groups' static and dynamic balance was compared, the in-water training group showed significant improvements.
5. Park et al, 2010 ²³	N = 20, 55.25 y, 45% male	The treadmill inclination underwater		GA		SF-8	Participants in underwater group improved more than those in over-ground training in affect stance phase, affected weight bearing, and emotional aspect.
6. Park et al, 2011 ²⁴	N = 44, 53.8 y, 61.36% male	Nervous system exercise therapy underwater	POMA		JPS		There was more improvement in the aquatic exercise group than in the land exercise group in the joint position sense and mobility.
7. Park et al, 2012 ²⁵	N = 21, 55.25 y, 47.61% male	Aquatic treadmill walking			SPPB		Muscle strength showed a similar increase in both groups.
8. Aidair et al, 2013 ²⁶	N = 28, 51.4 y, 67.85% male	Aquatic exercise program				BDI TSAI	Significant differences were found in pre- and post-treatment values in the EG and between groups in the depression and state anxiety levels.
9. Han et al, 2013 ²⁷	N = 62, 56.3 y, 45.1% male	Proprioceptive exercise program in water	GBS BBS		JPS		The joint position sense test, sway area, and Berg Balance Scale showed there was more improvement in the underwater exercise group.
10. Furnari et al, 2014 ²⁸	N = 40, 70 y, 50% male	Hydrokinesytherapy	EB		BI FIM AS		After treatment, the patients undergoing hydrokinesytherapy showed a

Table 2. (Continued)

Study	Patients (N analysed, age, gender)	Intervention types	Outcome measures				Key findings
			Balance	Gait	Function	Quality of life	
11. Jung et al, 2014 ²⁹	N = 30, 70 y, 56.4% male	Obstacle training underwater	GBS				significantly greater improvement than those undergoing training. The static balance of the aqua group was significantly better than the land group.
12. Park et al, 2014 ³⁰	N = 20, 61.2 y, 55% male	Underwater treadmill gait program	BS-SD				The means of static and dynamic balance ability increased significantly in both groups, but there was no significant difference between groups.
13. Tripp et al, 2014 ³¹	N = 30, 64.9 y, 63.3% male	Halliwick-Therapy	BBS	FAC	FRT RMI BI		Compared to the control group, significantly more subjects in the Halliwick-Therapy group of the balance and of the functional gait than in the control group.
14. Kim et al, 2015 ³²	N = 20, 68.5 y, 50% male	PNF lower extremity patterns in water	BBS TUG OLST		FIM FRT		The between-group comparison, the experimental group was significantly difference from the control group.
15. Kim et al, 2015 (2) ³³	N = 20, 65 y, 50% male	PNF lower extremity patterns in water	BBS TUG	10MWT	FRT		On comparison between the groups, there were greater improvements in the experimental group.
16. Zhu et al, 2016 ³⁴	N = 28, 56.8 y, 78.5% male	Aquatic treadmill training	BBS TUG	2MWT	FRT		The improvement in the gait was significantly higher in the aquatic group than in the control group. Balance e-mobility were not statistically significant.
17. Zhang et al, 2016 ³⁵	N = 36, 55.5 y, 52.77% male	Aquatic therapy		FAC	MIVC MAS BI		Compared with the conventional intervention, the aquatic intervention resulted in significantly results were greater in aquatic group.
18. Kim et al, 2016 ³⁶	N = 20, 68.5 y, 50% male	Aquatic dual-task training	BBS TUG	10MWT FGA	SST		For intergroup comparison, the experimental group showed relatively more significant change in balance and gait assessment.
19. Matsumoto et al, 2016 ³⁷	N = 120, 62.8 y, 77.3% male	Water-based exercises	10MWT		MAS	SF-36	Improvements in 10MWT results, spasticity parameters, and QOL were

(Continued)

Table 2. (Continued)

Study	Patients (N analysed, age, gender)	Intervention types	Outcome measures				Key findings
			Balance	Gait	Function	Quality of life	
20. Park et al, 2016 ³⁸	N = 28, 44.2 y, 71.8% male	Halliwick, Watsu, and trunk exercise	MDT				greater in the experimental group than in the control group.
21. Chan et al, 2017 ³⁹	N = 25, 65 y, 51% male	Water-based exercises	BBS CBMT TUG	2MWT			Walking parameters significantly improved after the aquatic and land-based trunk exercise program.
22. Han et al, 2018 ⁴⁰	N = 20, 60.9 y, 60% male	Water-based aerobic exercise		6MWT	BI		The experimental group attained significant improvements over the control group.
23. Aidar et al, 2018 ⁴¹	N = 36, 52.2 y, 52.77% male	Aquatic physical activities	BBS TUG			BDI TSAI	The WBE group showed significant improvements when compared to the control group.
24. Eyvaz et al, 2018 ⁴²	N = 60, 58.4 y, 48.33% male	Water-based exercise + land-based exercise	TUG		FIM	SF-36	Experimental group improved measures of depression, anxiety trait, and anxiety state and in all tests related to functional capacity compared to control group.
							Post-treatment results showed significant improvements in all of the parameters in both groups, except in the quality of life.

Abbreviations: BBS, Berg Balance Scale; BDI, Beck depression inventory; BI, Barthel Index; BS-SD, balance system—SD; CBMT, community balance and mobility test; CMSA, Chedoke—McMaster stroke assessment; EB, electronic baropodometer; FAC, functional ambulation categories; FGA, functional gait assessment; FIM, functional independence measure; FRT, functional reach test; GA, gait analysis; GBS, good balance system; IMS, isokinetic muscle strengths; JPS, joint position sense; MAS, Modified Ashworth Scale; MDT, motor-driven treadmill; MIVC, maximum isometric voluntary contraction; MRS, Modified Ranking Scale; MS, muscle strength; MSAS, Modified Motor Assessment Scale; Mtd-B, mtd-balance; MW, maximal workload; OLST, One Leg Stand Test; PNF, proprioceptive neuromuscular facilitation; POMA, performance-oriented mobility assessment; QOL, quality of life; RMI, rivermead mobility index; SDB, static and dynamic balance; SF:36, 36-short form health survey; Sf-8, short form 8; SPPB, short physical performance battery; SSGS, self-selected gait speed; SST, Sit to Stand Test; TSAI, trace state anxiety inventory; TT, Tinetti Test; TUG, Timed Up and Go Test; WBE, water-based exercise; 2MWT, 2-Minute Walk Test; 6MWT, 6-Minute Walk Test; 10MWT, 10-Meter Walk Test.

Table 3. Characteristics of the WBE intervention in the trials included in the review

Study	Outcome measures	Intervention types	WBE intervention	Intensity/volume	Pool (depth/temp)	(× per wk)	Time (min)	Length (wk)
1. Chu et al, 2004 ¹⁹	VO2Max MW SSGS BBS MS	Arm function program	Stretching and aerobic warm-up 30 min of moderate to high aerobic activities Cool down and gentle stretching	50%-80% heart rate reserve ± 5 beats/min	Chest deep 26°C-28°C	3	60	8
2. Aidar et al, 2007 ²⁰	SF-36	No exercise	Warming out with walks Activities in the pool with walking exercises inside the pool, exercises with appliances, and swimming	-	15 cm -	2	45-60	12
3. Noh et al., 2008 ²¹	CMSA BBS Mtd-B MSASIMS	Conventional therapy Strengthening gait training	Warm-up in the water 40 minutes of the Halliwick and rounding and balancing according to the Ai Chi Cool-down	-	115 cm 34°C	3	60	8
4. Lee et al, 2010 ²²	GBS SDB	Land exercise	Warm-up Balance tasks, coordination, balance and muscular strength tasks Cool-down	Borg category scale 11 and 13	125-15 cm 25°C-28°C	3	50	12
5. Park et al, 2010 ²³	GA SF-8	Treadmill inclination was setting horizontally	The treadmill inclination was setting horizontally.	Speed was carried out maximum velocity within the limit of 2-4 m/s	Thoracic vertebrae 11 33°C-35°C	4	30	6
6. Park et al, 2011 ²⁴	JPS POMA	Conventional nervous system exercise therapy	Aerobic and balance exercises	-	Thoracic vertebrae 11 33°C-35°C	6	35	6
7. Park et al, 2012 ²⁵	SPPB	Aquatic treadmill walking	The treadmill inclination was setting horizontally.	Speed was carried out maximum velocity within the limit of 2-4 m/s	Thoracic vertebrae 11 28°C-30°C	4	30	6
8. Aidair et al, 2013 ²⁶	BDI TSAI	Not submitted to any kind of specific physical activity	Warm up Aerobic exercises exercise to calm return	Borg category scale 12-17	150 cm -	2	45-60	12
9. Han et al, 2013 ²⁷		The land exercise group used		-	110 cm 33,5°C	3	40	6

(Continued)

Table 3. (Continued)

Study	Outcome measures	Intervention types	WBE intervention	Intensity/volume	Pool (depth/temp)	(× per wk)	Time (min)	Length (wk)
10. Furnari et al, 2014 ²⁸	JPS GBS BBT MRS BI FIM MAS TT EB	balance mats in an exercise treatment Warm-up Lower and upper extremity strengthening, postural control exercise, gait training	The water exercise group used balance exercise in the pool Warm-up Halliwick method, Ai Chi method, Strength exercises using water resistance Cool-down	The degree of difficulty was reviewed weekly.	115 cm 33°C-34°C	3	60	8
11. Jung et al, 2014 ²⁹	GBS	Obstacle training	Warm-up Obstacle training Cool-down	-	110 cm 33°C-35°C	3	40	12
12. Park et al, 2014 ³⁰	BS-SD	Postural control, gait training, and balance training, muscular strength training, FES was applied to the upper and lower extremities	Warm-up Main exercise Cool-down exercises	The initial was set at 36% of each subject's ground gait speed. (increased in increments of by .1 m/s)	Xiphoid process 34°C	5	30	4
13. Tripp et al, 2014 ³¹	BBS FRT FAC RMI BI	Standard physiotherapy	Halliwick-Therapy	-	Different water depths -	3	45	2
14. Kim et al, 2015 ³²	BBS TUG FRT OLST FIM	PNF lower extremity patterns	PNF lower extremity patterns in water (supine posture)	-	110 cm 31°C-33°C	5	30	6
15. Kim et al, 2015 (2) ³³	BBS FRT 10MWT TUG	Neurodevelopment treatment	Neurodevelopment treatment + PNF lower extremity patterns in water (supine posture)	The movement was maintained for 10 s each One set included 10 movements	100 cm 32°C-34°C	5	30	6
16. Zhu et al, 2016 ³⁴		-	Aquatic treadmill training	-		5	45	4

Table 3. (Continued)

Study	Outcome measures	Intervention types	WBE intervention	Intensity/volume	Pool (depth/temp)	(× per wk)	Time (min)	Length (wk)
17. Zhang et al, 2016 ³⁵	BBS FRT 2MWT TUG	Standard physiotherapy Daily life activity training directed at each individual's functional impairment and limbs exercises Treadmill exercise	Warm-up Halliwick method and limbs exercises, treadmill exercise underwater	15-30 s and was performed for 10 repetitions	140 cm 34°C-36°C	5	40	8
	MIVC MAS FAC BI				Xiphoid process 37°C-38°C			
18. Kim et al, 2016 ³⁶	BBS SST 10MWT TUG FGA	Neurodevelopment therapy	Neurodevelopment therapy + aquatic dual-task training	-	100 cm 32°C-34°C	5	30	6
19. Matsumoto et al, 2016 ³⁷	10MWT MAS Sf-36	ROM exercises, muscle strengthening basic activity training usual gait	Warm-up and flexibility exercises Endurance and strength exercises based on walking Cool-down	-	Xiphoid process 30°C-31°C	2	30	12
20. Park et al, 2016 ³⁸	MDT	The trunk exercises, bridge exercises, diagonal reaching exercises, abdominal hollowing, and quadruped exercises	Halliwick, Watsu, and trunk exercise	-	Xiphoid process 30°C	3	30	4
21. Chan et al, 2017 ³⁹	BBS CBMT TUG 2MWT	Land therapy	Land therapy + balance and stretching exercises, endurance training	-	34°C	2	30	6

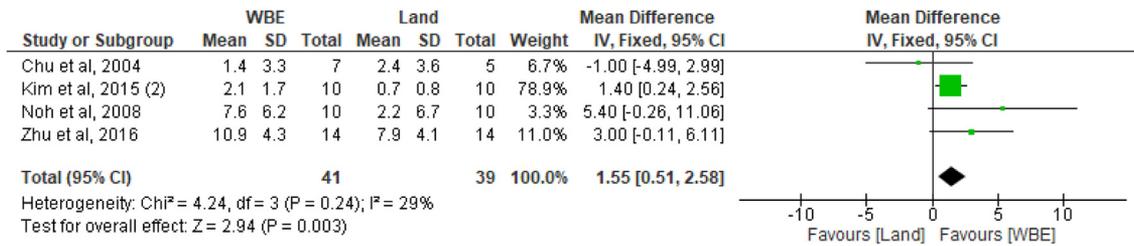
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Table 3. (Continued)

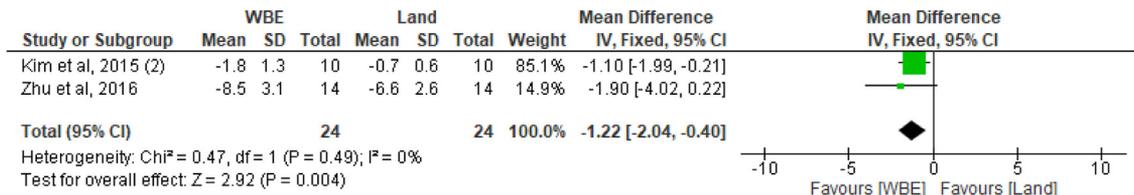
Study	Outcome measures	Intervention types	WBE intervention	Intensity/volume	Pool (depth/temp)	(× per wk)	Time (min)	Length (wk)
22. Han et al, 2017 ⁴⁰	6MWT BI	Warm-up Aerobic activity Cool-down	Aquatic treadmill	50%-85% of HR reserve;	External buoyancy 30°C-33°C	5	50	6
23. Aidar et al, 2018 ⁴¹	BBS TUG BDI TSAI	Control group was not submitted to any kind of specific physical activity	Warm-up Aerobic training Cool-down.	Omni Resistance Exercise Scale	Breast level water 27°C	2	45-60	12
24. Eyvaz et al, 2018 ⁴²	TUG FIM SF-36	Warm-up range of motion, strengthening, trunk mobility and balance exercises, and walking training; Cool-down	Warm-up; strengthening, balance, coordination exercises. Walking in the pool, climbing up and down stairs and squatting. Cool-down	-	27°C	3	60	6

Abbreviations: BBS, Berg Balance Scale; BDI, Beck depression inventory; BI, Barthel Index; BS-SD, balance system—SD; CBMT, community balance and mobility test; CMSA, Chedoke—McMaster stroke assessment; EB, electronic baropodometer; FAC, functional ambulation categories; FGA, functional gait assessment; FIM, functional independence measure; FRT, functional reach test; GA, gait analysis; GBS, good balance system; IMS, isokinetic muscle strengths; JPS, joint position sense; MAS, Modified Ashworth Scale; MDT, motor-driven treadmill; MIVC, maximum isometric voluntary contraction; MRS, Modified Ranking Scale; MS, muscle strength; MSAS, Modified Motor Assessment Scale; Mtd-B, mtd-balance; MW, maximal workload; OLST, One Leg Stand Test; PNF, proprioceptive neuromuscular facilitation; POMA, performance-oriented mobility assessment; QOL, quality of life; RMI, rivermead mobility index; SDB, static and dynamic balance; SF:36, 36-short form health survey; Sf-8, short form 8; SPPB, short physical performance battery; SSGS, self-selected gait speed; SST, Sit to Stand Test; TSAI, trace state anxiety inventory; TT, Tinetti Test; TUG, Timed Up and Go Test; WBE, water-based exercise; 2MWT, 2-Minute Walk Test; 6MWT, 6-Minute Walk Test; 10MWT, 10-Meter Walk Test.

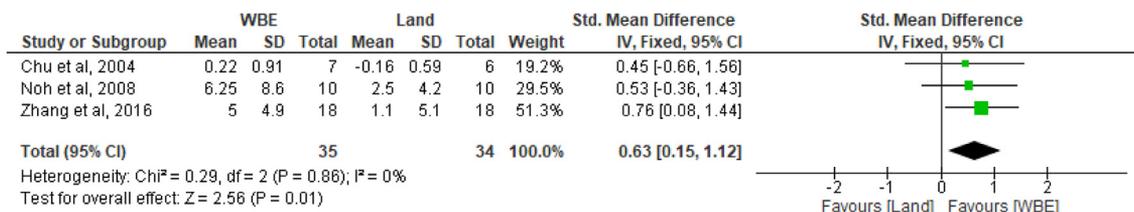
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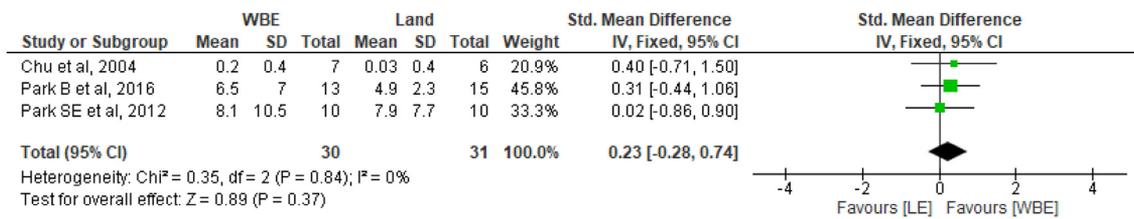
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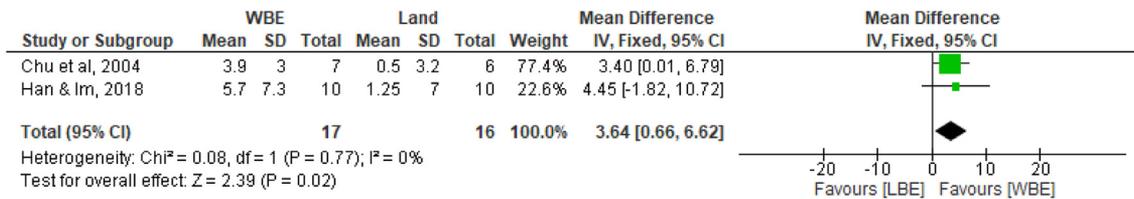
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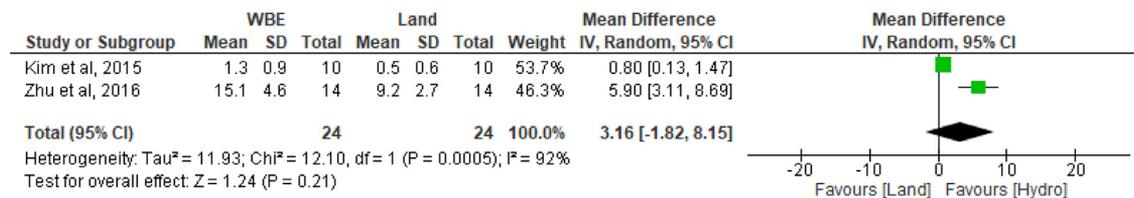
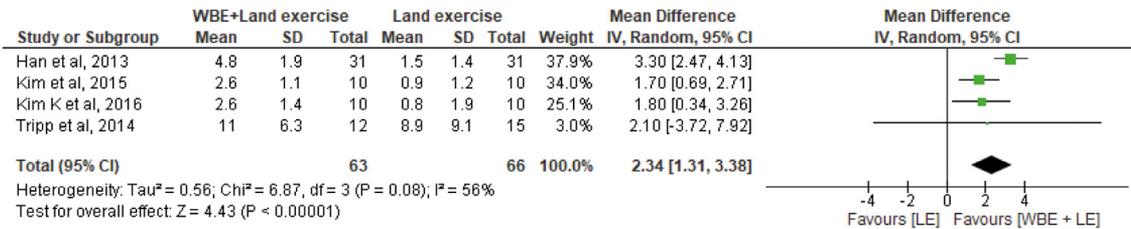
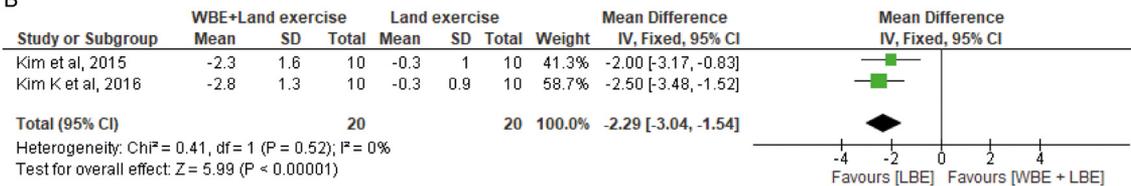


Figure 2. (A) Water-based exercise versus land exercise: Berg Balance Scale (BBS). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (B) Water-based exercise versus land exercise: time up and go (TUG). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (C) Water-based exercise versus land exercise: muscle strength. Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (D) Water-based exercise versus land exercise: gait speed. Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (E) Water-based exercise versus land exercise: aerobic capacity (Peak VO₂). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (F) Water-based exercise versus land exercise: functional reach. Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

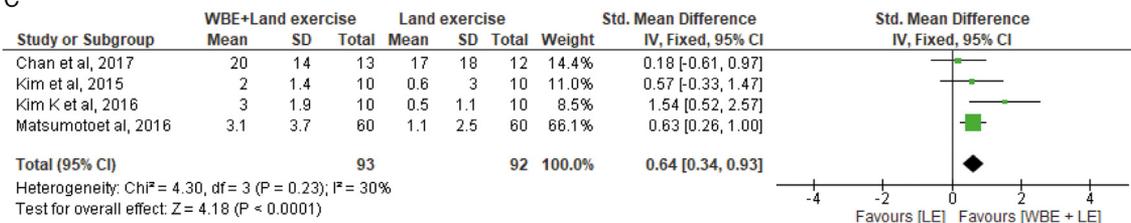
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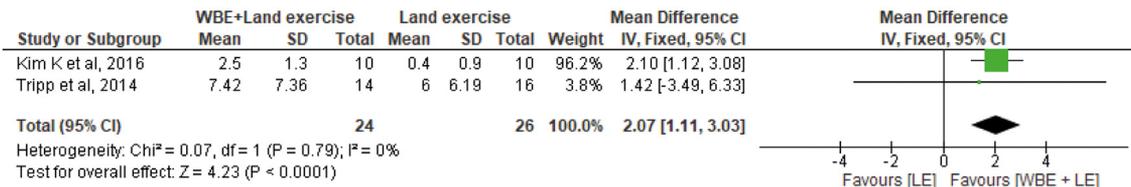
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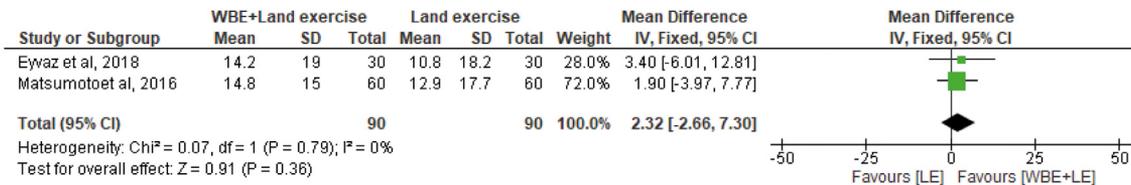
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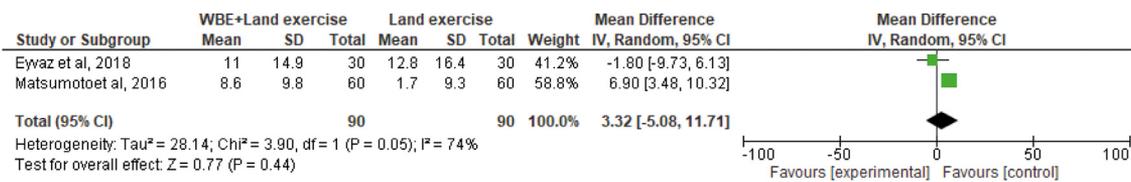


Figure 3. (A) Water-based exercise and land exercise versus land exercise: Berg Balance Scale (BBS). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (B) Water-based exercise and land exercise versus land exercise: time up and go (TUG). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (C) Water-based exercise and land exercise versus land exercise: gait speed. Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (D) Water-based exercise and land exercise versus land exercise: functional reach. Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (E) Water-based exercise and land exercise versus land exercise: quality of life (physical functioning). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (F) Water-based exercise and land exercise versus land exercise: quality of life (role limitations due to emotional problems). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (G) Water-based exercise and land exercise versus land exercise: quality of life (role limitations due to physical functioning). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (H) Water-based exercise and land exercise versus land exercise: quality of life (role limitations due to emotional problems). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013. (I) Water-based exercise and land exercise versus land exercise: quality of life (vitality). Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

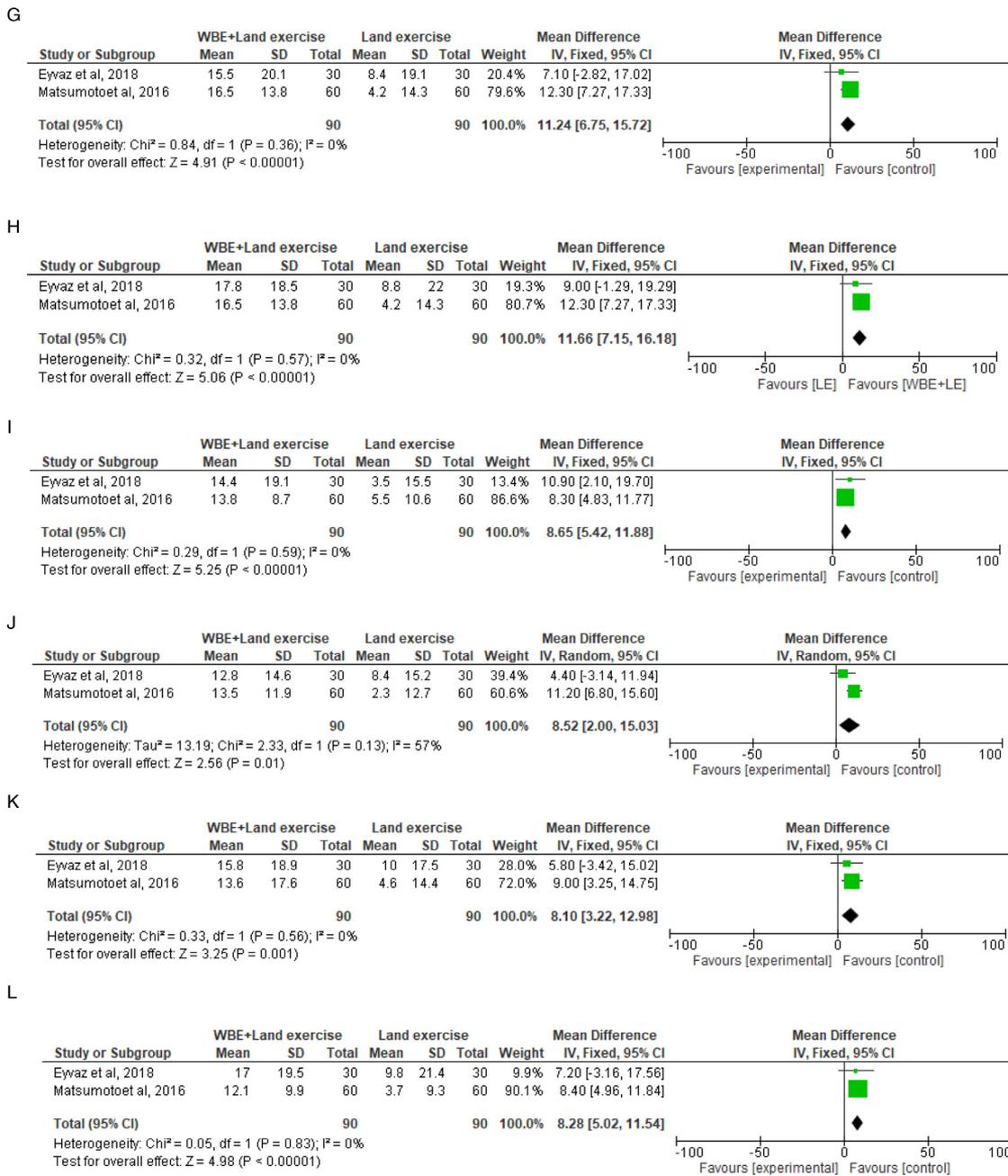


Figure 3. Continued

to physical functioning at 11.24 (95% CI: 6.75, 15.72; N = 180), Role limitations due to emotional problems at 11.66 (95% CI: 7.15, 16.18; N = 180), in Vitality at 8.65 (95% CI: 5.42, 11.88; N = 180), General Mental Health at 8.52 (95% CI: 2.0, 15.0; N = 180), Social Functioning at 8.10 (95% CI: 3.22, 13.0; N = 180), and Bodily pain at 8.28 (95% CI: 5.0, 11.5; N = 180) for participants in the water-based exercise and land exercise group compared with the land exercise group (Fig 3G-J, L, and M).

Water-Based Exercise and Physical Therapy Versus Land Exercise and Physical Therapy

Balance

Only 1 study assessed balance as an outcome.²⁷ Balance was assessed by the Berg Balance Scale (0-56 points). The Water-Based Exercise and Physical Therapy group and Land Exercise and Physical Therapy group showed a significant increase in Berg Balance Scale (P < .05), but the

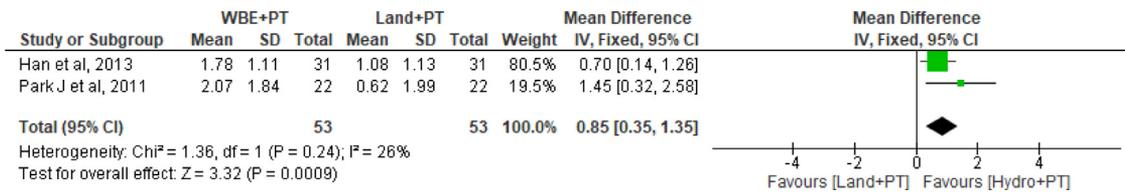


Figure 4. Water-based exercise and physical therapy versus land exercise and physical therapy: joint position sense. Review manager (RevMan). Version 5.2 The Cochrane Collaboration, 2013.

change was greater in the underwater exercise group than the land group (3.33; $P < .05$).

Joint Position Sense

Two randomised controlled trials assessed joint position sense as an outcome.^{24,27} Joint sense position was assessed by the joint position sense test. The meta-analysis showed significant improvement in joint position sense at .85 (95% CI: .35, 1.35; $N = 106$) for participants in the water-based exercise and physical therapy group compared with the land exercise and physical therapy group (Fig 4).

GRADE assessments

Water-Based Exercise Versus Land Exercise

The GRADE assessments are presented in Summary of Findings Table (Supplementary File 2). The quality of evidence for the outcomes balance, mobility, muscle strength, and aerobic capacity, were determined to be moderate. The quality of evidence for the outcome functional reach was determined to be very low.

Water-Based Exercise and Land Exercise Versus Land Exercise

The GRADE assessments are presented in Summary of Findings Table (Supplementary File 3). The quality of evidence for the outcomes mobility, gait, functional reach, and quality of life, were determined to be moderate. The quality of evidence for the outcome balance was determined to be low.

Discussion

In the present systematic review, our meta-analysis indicates that water-based exercise was more effective than land exercise for improving muscle strength, balance, mobility, aerobic capacity, and joint position sense in post-stroke persons. Moreover, combined water-based exercise and land exercise was more effective than land exercise for improving balance, mobility, gait, functional reach and quality of life, and joint position sense. In addition, individual studies suggested that water-based exercise contributes to an improvement in the levels of both depression when compared with a nonexercising control group.

Impairment of both mobility and balance are the most common reasons for a person with stroke to seek rehabilitation assistance initially. Water-based exercises have been used in rehabilitation programmes, especially when exercising under normal conditions of gravity is difficult and painful.⁴³ The fear of falling can be a barrier to balance training on land. In addition, a common belief is that water is a suitable environment for people who are unable or unwilling to train effectively on land.⁴⁴ Thus, exercise in an underwater environment can help poststroke persons by providing a low-risk exercise environment that supports their body and reduces their fear of falling.^{45,46} Individual studies demonstrate that both the land group and the water group significantly improved their mobility, balance, and muscle strength. However, water-based exercise was more effective.

Another important factor that favours exercise in water is that poststroke persons support most of their weight in the nonparetic causing postural asymmetry, reducing safety and increasing the fear of falling.⁴⁵ Thus, exercises in water reduce this asymmetry and lessen persons with stroke fear of falling thereby achieving greater participation and completion of the proposed exercises.⁴⁵⁻⁴⁷

This systematic review is important because it analysed water-based exercise alone or combined with land exercise as a potential intervention in the neurological rehabilitation of poststroke persons. Moreover, functional recovery through the improvement of both mobility and balance is a high priority in the healthcare system since it can also enable independence of poststroke persons.⁴⁸

This finding is important because it shows that water exercises can have additive effects and enhance the recovery of these persons. The combination of exercises in land and water can promote the specific gains made in each environment. Water-based exercises are considered more advantageous since they enable equal weight bearing by the lower extremities, may facilitate motor activity, and may encourage the strengthening of weakened muscles because of the natural resistance of water. In contrast, the difficulties in performing exercise on land are closer to performing their daily functional activities.⁴⁹

In addition to significant improvements in the outcome variables of mobility and balance, no negative side effects of water-based exercise have been reported in the included studies.

Our data are not consistent with findings from other systematic reviews. Mehrholz et al⁹ concluded that there is a

lack of hard evidence for water-based exercises and that the evidence from randomised controlled trials so far does not confirm or refute that water-based exercises after stroke might help to reduce disability after stroke. Marinho-Buzelli et al¹⁰ included randomised and nonrandomised studies with individuals with multiple sclerosis, Parkinson's disease, and stroke. After analysis of individual studies, the authors concluded that there is insufficient evidence to show water exercise is superior to land exercise to improve mobility in individuals with a neurological condition. However, including nonexperimental and/or quasi-experimental studies, the confidence in the results used was reduced.

Further research needs to be conducted to determine the best underwater exercise to improve functioning and quality of life poststroke. More powerful studies need to be completed with an increased number of participants so results can be generalised to the entire stroke population.

Conclusions

There is moderate quality evidence that water-based exercise versus land exercise should be considered an effective method of improving muscle strength, balance, mobility and aerobic capacity in poststroke persons. Whereas water-based exercise and land exercise versus land exercise showed improvement in the balance, gait speed, mobility, functional reach, and quality of life. Water-based exercise and physical therapy versus land exercise and physical therapy has improved the Joint Position Sense.

More well-designed, randomised controlled trials are necessary to determine the most appropriate methods and specifications (water temperature, depth, exercise intensity, and water-based intervention duration) to tailor water-based exercise to particular characteristics of a person subgroup.

Conflict of Interest

The authors declare that they have no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.jstrokecerebrovasdis.2019.104341](https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.104341).

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