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Effect of aquatic exercise on physical function and QOL in individuals with neurological disorder: A systematic review and meta-analysis

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ABSTRACT

Background: When applying aquatic exercise program to patients with neurological disorder, quality of life (QOL) can be changed by physical function or psychological improvement.
Methods: Cochrane Database, CINAHL, Embase, Google Scholar, PEDro, PubMed, ScienceDirect, and SCOPUS were used to systematically search for relevant studies published between January 1999 and June 2019. The study quality was determined using the Physiotherapy Evidence Database (PEDro) scale.
Results: Eight of the 326 retrieved articles met the inclusion criteria. The results of the studies led to a general consensus: physical education program increased balance and gait and decreased pain. QOL improved as physical health, mental health, and vitality recuperated.
Conclusions: The findings indicate that aquatic exercise program could be helpful when treating neurological disorders and should be considered as a means of reducing pain while increasing physical function and QOL in standard clinical research programs.

1. Introduction

Patients with neurological disorder have limitation of body movement, disability, and decreased quality of life (QOL) (Adamson et al., 2015; Odabaş and Uca, 2018; Wong et al., 2017). Moreover, they develop sensory, gait, balance, cognitive, and perceptual deficits as well as anxiety and depression (Amtmann et al., 2018; Rahman et al., 2008). In some cases, they have dementia with aging, increased dependency in daily activities with terminal illness, and even death due to respiratory problems (Boentert et al., 2017). Therefore, primary physical exercise is necessary for patients with neurological disorder and improves the overall health condition for QOL (Maher et al., 2017; McDonnell et al., 2011; Portugal et al., 2013; Zheng et al., 2016).

Aquatic exercise is a method that improves the physical function and QOL of patients with neurological disorders (Kargarfard et al., 2012, 2018). For example, patients with Parkinson's disease can develop fatigue in a bent posture and a short stride of unbalance (Carroll et al., 2017; Intzandt et al., 2018; Volpe et al., 2017). In addition, many aquatic exercises have been performed for relief of symptoms of multiple sclerosis such as limb weakness, paralysis, tremor, and muscle spasms (Roehrs, 2004). In the water, falling speed is slower than that on land, so it can be applied to exercise with more stability (Oh et al., 2015). In addition, aquatic exercise can reduce stiffness and increase muscle strength, agility, and fine motor control in children with cerebral palsy (CP) (Adar et al., 2017). Aquatic exercise can be psychologically beneficial to patients with neurological disorder, with physical benefits as well as stability and enjoyment (Carroll et al., 2017). Especially, in spasticity, which is a characteristic of patients with central nervous system injuries, aquatic exercise can be an intervention that can reduce abnormally increased muscle tone and muscle contraction due to hyperactivity of the stretch reflex (Marinho-Buzelli et al., 2015).

Therefore, when applying aquatic exercise to patients with neurological disorder, QOL can be changed by physical function. However, it is necessary to summarize clinical guidelines in terms of physical, psychological, and social impacts on the daily life of patients with neurological disorder. We will review recent trends and examine how the application of aquatic exercise affects balance ability, and QOL of patients with neurological disorder.

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2. Methods

2.1. Search strategy

Cochrane Database, CINAHL, Embase, Google Scholar, PEDro, PubMed, ScienceDirect, and SCOPUS were used to systematically search for relevant studies published between January 1999 and June 2019. The following search terms were used: “aqua exercise,” “aquatic exercise,” aquatic therapy,” “balance,” “balance ability,” “hydro,” “hydrotherapy,” “neurological disorder,” “physical activity,” “physical function,” “water exercise,” “water therapy,” and “quality of life.” The study quality was determined using the Physiotherapy Evidence Database (PEDro) scale (de Morton, 2009). This study was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Moher et al., 2009).

2.2. Eligibility criteria

2.2.1. Types of studies

We included original articles and excluded reviews, books, book chapters, conference papers, articles in press, editorials, notes, short surveys, and erratum.

2.2.2. Inclusion and exclusion criteria

The inclusion criteria of Participants, Interventions, Comparisons, Outcomes, and Study design (PICOS) were as follows:

P: Adults aged 18 years or older who presented with fibromyalgia, hemiplegia, multiple sclerosis, and Parkinson's disease and those aged between 4 and 18 years who had cerebral palsy.

I: Aquatic exercise for neurological disorder.

C: Aquatic exercise alone, conventional exercise versus aquatic exercise.

O: Primary outcomes include changes in QOL and balance; secondary outcomes include changes in pain and physical activity.

S: Randomized controlled trials and pilot studies.

The exclusion criteria were studies of musculoskeletal diseases, skin disorders, and bladder or bowel incontinence.

2.2.3. Types of interventions

2.2.3.1. Main program of aquatic exercise. Pool temperature range: 28–33 °C; Type I, general exercise (warm up with walking, upper and lower body stretches, cardiovascular exercise, trunk stretches, gait re-education, cool down) (Adar et al., 2017; Carroll et al., 2017; Kargarfard et al., 2012; Roehrs, 2004); Type II, Ai Chi (Kurt et al., 2018; Pérez de la Cruz S, 2018); Type III, Halliwick and Ai Chi (Eyvaz et al., 2018).

2.2.3.2. Details of intervention content. 1) The aquatic exercise program consisted of 30 sessions (n = 17, in swimming pool at 33 °C, five times per week for six weeks) (Adar et al., 2017). 2) The aquatic exercise program consisted of 20 sessions (n = 20, in swimming pool at 33 °C (with a variation of less than 0.5 °C, twice a week, during the 10-week duration; swimming pool: 20 × 6 m, with a depth of 110 cm; water temperature was 33 °C with a variation of less than 0.5 °C) and the ambient temperature was 27.5 ± 1 °C) (Pérez de la Cruz S, 2018). 3) In the aquatic exercise program consisted of 18 sessions, 3 per week for six weeks in a swimming pool at 33 °C (Eyvaz et al., 2018). 4) In the aquatic exercise program consisted of a 1-h session 2 times per week for 12 weeks (n = 19, in swimming pool at 83–85°F) for progressive multiple sclerosis (Roehrs and Karst, 2004). 5) In the aquatic exercise program period of 8 weeks (n = 10, in swimming pool at 28–30 °C) for patients with multiple sclerosis (Kargarfard et al., 2012). 6) The aquatic exercise program (Ai Chi) period of 5 weeks (n = 20, in the 1.2-m-deep swimming pool at a temperature of 32 °C) for patients with Parkinson's disease (Kurt et al., 2018). 7) In the aquatic exercise program period of 6 weeks (n = 10, in the swimming pool: 12 m long and 6 m wide with a graded depth, varying from 0.6 to 1.30 m, 32 °C, air temperature was set at 31 °C) for people with Parkinson's disease (Carroll et al., 2017). 8) The aquatic exercise program consisted of 5 sessions per week (N = 15, in swimming, eight weeks) for correct posture deformities (Volpe et al., 2017).

2.2.4. Types of outcome

The studies were required to report pain, physical activity, and QOL as outcome measure. QOL were assessed by the fibromyalgia impact questionnaire, revised fibromyalgia impact questionnaire, Parkinson's disease questionnaire-39 (PDQ-39), pediatric QOL inventory (PedsQL)-CP, and Short Form-36 (SF-36).

2.2.5. Quality assessment

Two reviewers independently assessed the quality of all included studies, using the Down and Black quality index. The total score is 32. The quality scores were calculated and ranked on a four-category scale. PEDro scores were categorized as follows: 9–10, excellent; 6–8, good; 4–5, fair; and <4, poor (Eyvaz et al., 2018; Moseley et al., 2002). The risk of bias in each included study (selection bias, performance bias, detection bias, attrition bias, reporting bias) was assessed by two independent reviewers following the Cochrane Handbook for Systematic Reviews of Interventions (Higgins, 2011).

2.3. Data synthesis

Statistical analysis was performed using Review Manager Version 5.3 (RevMan, 2014) for risk of bias graph and summary.

3. Results

3.1. Study selection

Our literature search identified 803 potentially eligible studies, eight of which were ultimately included in our analysis. The procedure used to identify eligible studies is outlined in the PRISMA flow diagram (Fig. 1).

3.2. Quality assessment

All eight studies were evaluated using the PEDro scale, which consists of 8 eligibility criteria: random allocation, concealed allocation, baseline similarity, subject blinding, therapist blinding, assessor blinding, <15% dropout rate, intention-to-treat analysis, between-group statistical comparisons, inclusion of point estimates, and inclusion of variability measurements. Participants (n = 253) were consisted of CP (n = 32) (Adar et al., 2017), fibromyalgia (n = 20) (Pérez de la Cruz S, 2018), hemiplegia (n = 30) (Eyvaz et al., 2018), multiple sclerosis (n = 40) (Kargarfard et al., 2012; Roehrs, 2004), and Parkinson's disease (n = 131) (Carroll et al., 2017; Kurt et al., 2018; Volpe et al., 2017) (Table 1).

3.3. Risk of bias

The risk-of-bias graph (Fig. 2) and summary (Fig. 3) were included in all studies.

3.3.1. Selection bias

Random sequence generation is at high risk of bias in two studies (Adar et al., 2017; Roehrs, 2004). Six studies were as low risk

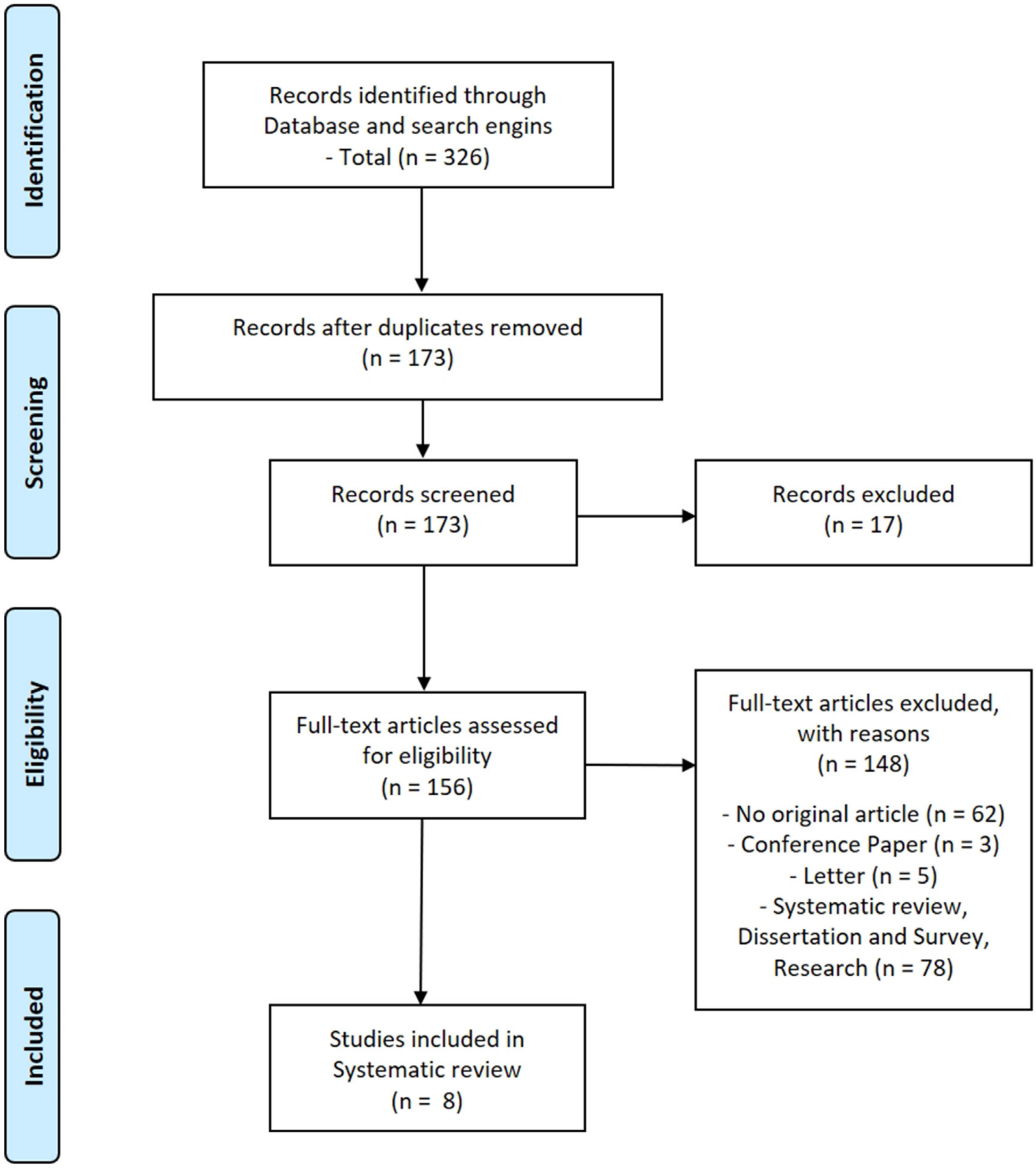

Fig. 1. Flow chart of study.

of random sequence generation (Carroll et al., 2017; Eyvaz et al., 2018; Kargarfard et al., 2012; Kurt et al., 2018; Pérez de la Cruz S, 2018). Allocation concealment is high risk of bias in 4 studies (Adar et al., 2017; Kurt et al., 2018; Pérez de la Cruz S, 2018; Roehrs, 2004). 4 studies were as low risk of allocation concealment (Carroll et al., 2017; Kargarfard et al., 2012; Kurt et al., 2018; Volpe et al., 2017).

3.3.2. Performance bias

Blinding of participants and personnel is high risk of bias in 5 studies (Eyvaz et al., 2018; Kurt et al., 2018; Pérez de la Cruz S, 2018; Roehrs, 2004; Volpe et al., 2017). 3 studies were as low risk of random sequence generation (Adar et al., 2017; Carroll et al., 2017; Kargarfard et al., 2012).

3.3.3. Detection bias

Blinding of outcome assessment is high risk of bias in 7 studies (Adar et al., 2017; Carroll et al., 2017; Eyvaz et al., 2018; Kurt et al., 2018; Pérez de la Cruz S, 2018; Roehrs, 2004; Volpe et al., 2017). 1 studies were as low risk of blinding of outcome assessment (Kargarfard et al., 2012).

3.3.4. Attrition bias

Incomplete outcome data is low risk of bias in 8 studies (Adar et al., 2017; Carroll et al., 2017; Eyvaz et al., 2018; Kargarfard et al., 2012; Kurt et al., 2018; Pérez de la Cruz S, 2018; Roehrs, 2004; Volpe et al., 2017).

3.3.5. Reporting bias

8 studies were as low risk of Selective reporting (Adar et al., 2017; Carroll et al., 2017; Eyvaz et al., 2018; Kargarfard et al., 2012; Kurt et al., 2018; Pérez de la Cruz S, 2018; Roehrs, 2004; Volpe et al., 2017).

Table 1
PEDro scale total scores of included studies.

PEDro Scale	Roehrs and Karst (2004)	Kargarfard et al. (2012)	Kurt et al. (2018)	Carroll et al. (2017)	Adar et al. (2017)	Volpe et al. (2017)	Pérez and Lambeck (2018)	Eyvaz et al. (2018)
Random allocation	NO	YES	YES	YES	YES	YES	YES	YES
Concealed allocation	NO	YES	YES	YES	NO	YES	NO	YES
Baseline comparability	YES	YES	YES	YES	YES	YES	YES	YES
Blinded subjects	NO	YES	NO	YES	YES	YES	NO	NO
Blind therapists	NO	NO	NO	YES	NO	NO	NO	NO
Blind assessor	NO	YES	NO	NO	NO	NO	NO	NO
Adequate follow up	NO	YES	NO	NO	NO	YES	YES	NO
Intention-to-treat-analysis	NO	YES	NO	YES	NO	NO	NO	NO
Between-group comparisons	YES	YES	YES	YES	YES	YES	YES	YES
Point estimates and variability	YES	YES	YES	YES	NO	NO	YES	No
Total score	3 (Fair)	9 (Excellent)	5 (Fair)	8 (Good)	4 (Fair)	6 (Good)	4 (Fair)	4(Fair)

YES: include criteria; NO: exclude criteria; PEDro: Physiotherapy Evidence Database.

3.4. Data extraction and analysis

The data were extracted from the included articles using a data extraction form (Table 2).

3.5. Outcomes of aquatic exercise

3.5.1. Overall neurological disorders

3.5.1.1. Balance. Three studies (Adar et al., 2017; Kurt et al., 2018; Volpe et al., 2017) have investigated the effect of aquatic exercise on balance between the aquatic exercise and control groups (Fig. 4). The heterogeneity test showed $I^2 = 95\%$ ($p < 0.01$), and a fixed-effect model was used. Results with SMD = −0.46 (95% CI: -3.84−2.93, $p = 0.79$) showed that aquatic exercise had a similar effect on balance between the aquatic exercise and control groups.

3.5.1.2. Quality of life. Six studies (Adar et al., 2017; Carroll et al., 2017; Eyvaz et al., 2018; Kargarfard et al., 2012; Kurt et al., 2018; Volpe et al., 2017) have investigated the effect of aquatic exercise on QOL between the aquatic exercise and control groups (Fig. 5). The heterogeneity test showed $I^2 = 100\%$ ($p < 0.01$), and a fixed-effect model was used. Results with SMD = −3.97 (95% CI: -14.04−6.10, $p = 0.44$) indicated that aquatic exercise had a similar effect on the QOL of the aquatic exercise and control groups.

3.6. Individual neurological disorders

3.6.1. Cerebral palsy

Significant improvements in most functional outcome measures in the two groups were shown. There were no significant differences in the percentage changes of the scores for functional outcome measures between both groups (Adar et al., 2017). However, aquatic exercise resulted in greater improvement in QOL scores than land-based exercises. Post-treatment ultrasonographic assessment of the spastic gastrocnemius muscle showed a significant improvement in the compressibility ratio in the aquatic exercise group. The modified Ashworth scale score of the spastic gastrocnemius muscle in patients with CP showed a negative and weak-to-moderate correlation with the compressibility ratio based on the ultrasonographic evaluation.

3.6.2. Fibromyalgia

There were significant improvements ($p < 0.05$) in pain perception, vitality, and mental health and perceived overall improvement in QOL (Pérez de la Cruz S, 2018).

3.6.3. Hemiplegia

Results of the functional independence measurement, Berg balance scale, and timed up and go test (except SF-36 pain parameter) were significant in both the water- and land-based

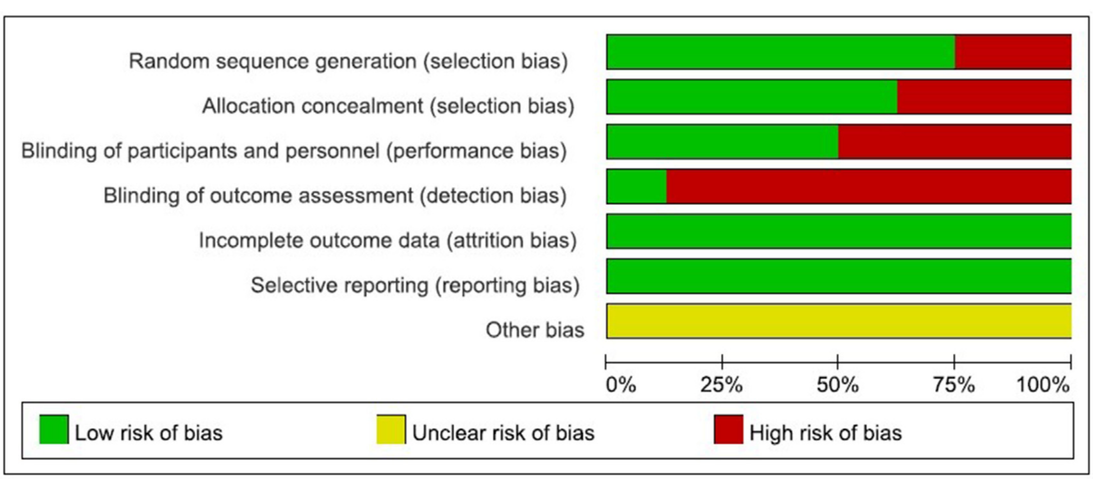

Fig. 2. Risk of bias graph.

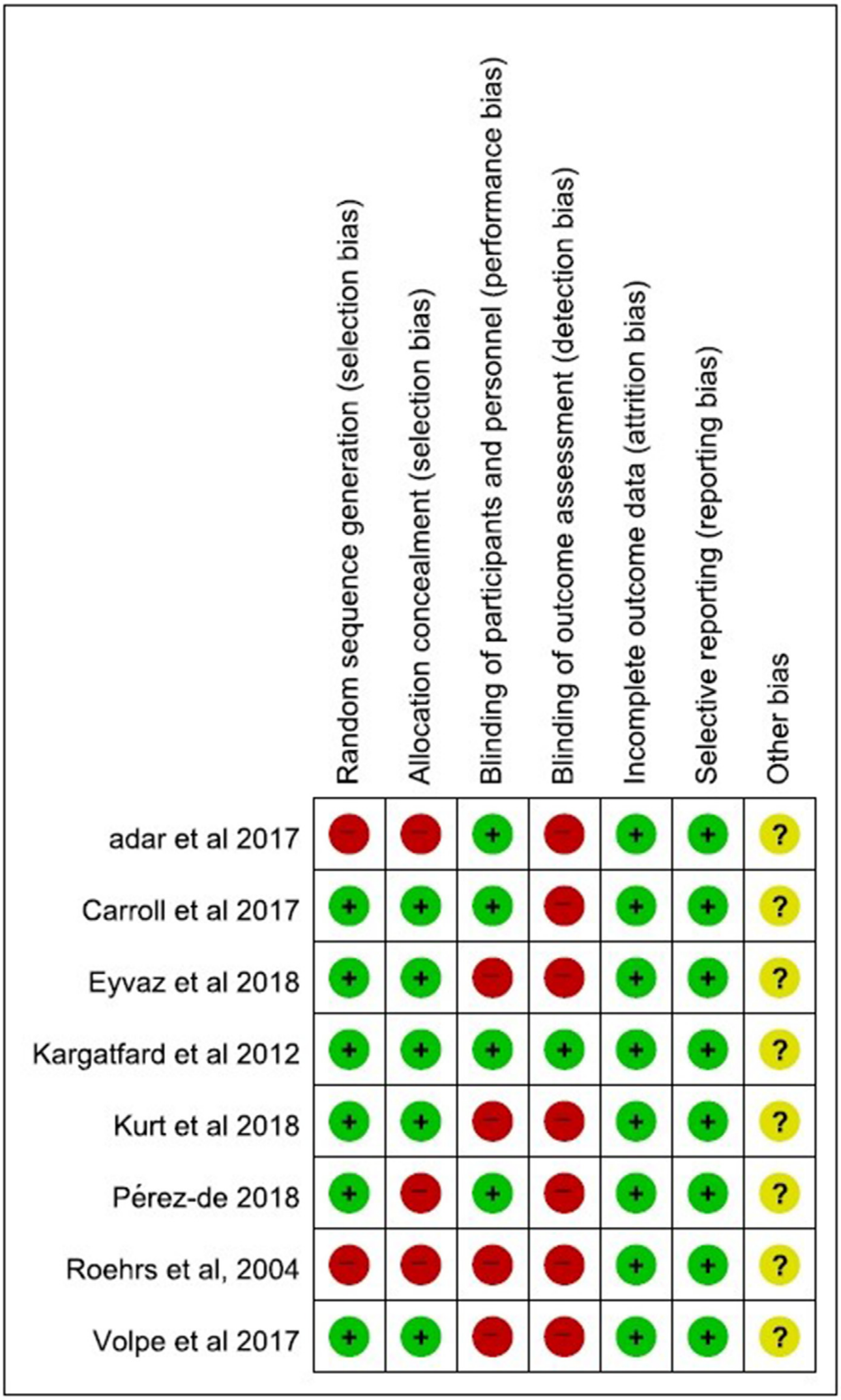

Fig. 3. Risk of bias summary.

groups. The SF-36 score was higher in the water-based group than in the land-based group, and the BBS score was significant in the water-based group (Eyvaz et al., 2018).

3.6.4. Multiple sclerosis

1) Significant improvements in the QOL domains of social functioning and fatigue were observed in the exercise participants (Roehrs, 2004). Barriers limiting exercise adherence included physical and psychological symptoms, transportation difficulties, and availability of a significant other to assist in the program.
2) The another study finding are based on 21 patients (10 from the exercise group and 11 from the control group) who had available data on outcomes. There was no significant difference between the two groups at baseline (Kargarfard et al., 2012). The aquatic exercise group showed significant improvements in fatigue and subscores of Health-Related Quality of Life (HRQOL) after 4 and

Table 2
Characteristics of included studies.

Participants		Intervention			Comparisons	Outcomes	
Article	Sample characteristics	Education program session	Details of intervention content	Measurements	Education program, Mean age (SD)	Result	Dropout
Adar et al. (2017)[18]	Cerebral palsy (N = 32)	30 sessions five times per week for 6 weeks	Water temperature: 33 °C	1. Primary outcomes 1)MAS score 2)TUG score 3)GMFM score 4)WeeFIM score 5)Gastrocnemius thickness 6)Fascicle length 7) Pennation angle 8) Compressibility ratio 2. Quality of life 1) Child Self Report-PedsQL score 2) Parent Report-PedsQL score	1) Aquatic education program group (N = 17): 10.1 (2.4) 2) Land-based education program group (N = 15): 9.3 (1.9)	1. Primary outcomes 1) MAS score - Not significant in both groups 2) TUG score - Not significant in both groups 3) GMFM score - Not significant in both groups 4) WeeFIM score - Not significant in both groups 5) Gastrocnemius thickness - Not significant in both groups 6) Fascicle length - Not significant in both groups 7) Pennation angle - Not significant in both groups 8) Compressibility ratio - Not significant in both groups 2. Quality of life 1) Child Self Report-PedsQL score - Not significant in both groups 2) Parent Report-PedsQL score - Not significant in both groups	No
Pérez and Lambeck (2018)[23]	Fibromyalgia (N = 20)	20 sessions twice a week during the 10-week duration with 45-min sessions	Swimming pool: 20 × 6 m, with a depth of 110 cm Water temperature: 33 °C (with a variation of less than 0.5 °C) ambient temperature : 27.5 ± 1 °C	1. Pain 1) VAS score 2. Quality of life 1) SF-36 score	1) Ai chi education program group: 61.45 (4.62)	1. Pain 1) VAS score - Significantly different between pre- and post-intervention ($p < 0.001$) 2. Quality of life 1) SF-36 score - Significantly different between pre- and post-intervention in terms of physical function, bodily pain, general health, vitality, social function, and mental health ($p < 0.05$)	No
Eyvaz et al. (2018)[24]	Hemiplegia (N = 60)	40-min training program (range of motion exercise, strengthening exercises, trunk mobility exercises, balance exercises, and walking training) for 1 h per day for five sessions for 6 weeks	Water temperature: 33 °C	1. Primary outcomes 1) BBS score 2) FIM score 2. Secondary outcomes 1) SF-36 score	1) Water-based education program group (N = 30): 58.5 (6.27) 2) Land-based education program group (N = 30): 58.3 (5.43)	1. Primary outcomes 1) BBS score - Significantly different between pre- and post-treatment in both groups ($p < 0.001$) 2) FIM score - Significantly different between pre- and post-treatment in both groups ($p < 0.001$) 2. Secondary outcomes 1) SF-36 score - Significantly different between pre- and post-treatment in both groups ($p < 0.05$)	No
Rochr and Karst (2004)[16]	Multiple sclerosis (N = 19)	1-h session two times per week for 12 weeks	Water temperature: 83 −85°F	1. Quality of life 1) SF-36 score 2) MSQLI score	Aquatic intervention: Women = 50.4 (10.8), Men = 52.7 (9.1)	1. Quality of life 1) SF-36 score - Significantly different only in terms of social function between pre- and post-intervention ($p = 0.015$) 2) MSQLI score - Significantly different in terms of MFIS and MSSS scores between pre- and post-intervention ($p \leq 0.05$) - Not significant in terms of PES, SSS, BLCS, BWCS, IVIS, PDQ, and MHI scores between pre- and post-intervention ($p < 0.05$)	No
Kargarfard et al. (2012)[11]	Multiple sclerosis (N = 21)	Supervised aquatic education program in a swimming pool (three	Water temperature: 28 −30 °C	1. Fatigue 1) MFIS score 2. Quality of life	1) Aquatic education program	1. Fatigue 1) MFIS score	No

Table 2 (*continued*)

Participants		Intervention			Comparisons	Outcomes	
Article	Sample characteristics	Education program session	Details of intervention content	Measurements	Education program, Mean age (SD)	Result	Dropout
	IG = 33.7 ± 8.6 CG = 31.6 ± 7.7	times a week, each session lasting 60 min for 8 weeks)		1) HRQOL score	training group (N = 10): 33.7 (8.6) 2) Control group (N = 11): 31.6 (7.1)	- Significantly different in terms of overall MFIS score (physical, psychosocial, and cognitive) between pre- and post-interventions ($p < 0.05$) 2. Quality of life 1) HRQOL score - Significantly different in terms of physical and mental function based on MSQOL-54 scores ($p < 0.001$). Not significantly different in terms of cognitive and sexual function	
Kurt et al. (2018)[22]	Parkinson's disease (N = 40)	60-min sessions five times a week for 5 weeks (a total of 25 sessions)	Water temperature: 32 °C Water depth: 1.2 m	1. Primary outcomes 1) Dynamic balance score 2) BBS score 3) TUG score 4) UPDS-III score 2. Secondary outcomes 1) PDQ-39 score	1) Ai Chi education program group (N = 20): 62.41 (6.76) 2) Land-based education program control group (N = 20): 63.61 (7.18)	1. Primary outcomes 1) Dynamic balance - Significantly different in the Ai Chi group ($p < 0.001$) 2) BBS score - Significantly different in terms of dynamic balance in the BBS group ($p < 0.001$) 3) TUG score - Significantly different in terms of dynamic balance in the TUG group ($p < 0.001$) 4) UPDS-III score - Significantly different in terms of dynamic balance in the UPDS-III group ($p < 0.001$) 2. Secondary outcomes 1) PDQ-39 score - Significantly different in terms of PDQ-49 scores in the Ai Chi group ($p < 0.001$)	No
Carroll et al. (2017)[15]	Parkinson's disease (N = 18)	45 min twice a week for 6 weeks	Water temperature: 32 °C Air temperature: 31 °C Water depth: 12 m long and 6 m wide with a graded depth, varying from 0.6 to 1.30 m	1. Gait variability 1) Step length 2) Step time 3) Step width 2. Secondary outcomes 1) UPDRS III score 2) FOGQ score 3) PDQ-39 score	1) Aquatic education program group (N = 11): 69.5 (67.71 −71.75) 2) Land-based education program group (N = 10): 74 (67–77)	1. Gait variability 1) Step length - Not significantly different in both groups ($p < 0.05$) 2) Step time - Not significantly different in both groups ($p < 0.05$) 3) Step width - Not significantly different in both groups ($p < 0.05$) 2. Secondary outcomes 1) UPDRS III - Significantly different in terms of UPDRS III scores in both groups ($p < 0.05$) 2) FOGQ - Not significantly different in terms of step width in both groups ($p < 0.05$) 3) PDQ-39 - Not significantly different in terms of step width in both groups ($p < 0.05$)	No
Volpe et al. (2017)[14]	Parkinson's disease (N = 30)	One of two 8-week treatment sessions	Water temperature & depth: No information	1. Primary outcomes 1) UPDRS score 2) BBS score 3) ABC score 4) TUG score 5) FES score 2. Quality of life and pain 1) PDQ-39 score	1) Water-based group: (N = 15), 70.6 (7.8) 2) Non-water-based: group (N = 15), 70 (7.8)	1. Primary outcomes 1) UPDRS score - Significantly different in both groups (8 and 16 weeks) ($p < 0.05$) 2) BBS - Significantly different in both groups (8 and 16 weeks) ($p < 0.05$) 3) ABC - Significantly different in both groups (8 and 16 weeks) ($p < 0.05$) 4) TUG	No

(*continued on next page*)

Table 2 (*continued*)

Participants		Intervention			Comparisons	Outcomes	
Article	Sample characteristics	Education program session	Details of intervention content	Measurements	Education program, Mean age (SD)	Result	Dropout
						- Significantly different in both groups (8 and 16 weeks) ($p < 0.05$) 5) FES - Significantly different in both groups (only 8 weeks) ($p < 0.05$) 2. Quality of life and pain 1) PDQ-39 - Significantly different in both groups (only 8 weeks) and in the water-based group alone (only 16 weeks) ($p < 0.05$)	

ABC, activities-specific balance confidence; BBS, berg balance scale; BLCS, bladder control scale; Bowel control scale, BWCS; FES, fall efficacy scale; FIM, functional independence measurement; FIQ, fibromyalgia impact questionnaire; FIQR, revised fibromyalgia impact questionnaire; GMFM, Gross Motor Function Measure; HRQOL, Health-Related Quality of Life; IVIS, impact of visual impairment scale; MAS, Modified Ashworth Scale; MFIS, modified fatigue impact scale; MHI, mental health inventory; MSSS, modified social support survey; MSQLI, multiple sclerosis quality of life inventory; PedsQL, pediatric quality of life inventory; PDQ-39, Parkinson's disease questionnaire-39; PedsQL-CP, pediatric quality of life inventory-cerebral palsy; PDQ, Perceived deficits questionnaire; PES, pain effects scale; Sexual satisfaction scale, SSS; SF-36, Short Form-36; TUG, timed up and go test; UPDRS, unified Parkinson's disease rating scale; VAS, visual analog scale; WeeFIM, wee functional independence measure.

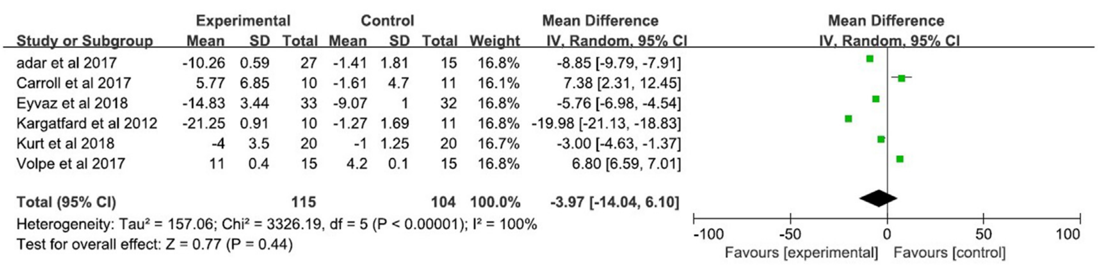

Fig. 4. Meta-analysis of difference in Balance between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of freedom.

8 weeks compared with the control group. Results obtained from the intention-to-treat analysis were consistent with those of the per-protocol analysis.

3.6.5. Parkinson's disease

1) Although patients in both groups showed significant improvement in all outcome variables, improvement in dynamic balance was significantly greater in the Ai Chi group ($p < 0.001$), as shown in the Berg Balance Scale ($p < 0.001$), Timed Up and Go Test ($p < 0.002$), Parkinson's Disease Questionnaire-39 ($p < 0.001$), and Unified Parkinson's Disease Rating Scale-III ($p < 0.001$) (Kurt et al., 2018).
2) People in the aquatic therapy group and usual care group showed similar small improvements in gait variability (Carroll et al., 2017). The aquatic therapy group showed greater improvements in disability than the usual care group ($p < 0.01$). No differences between groups or over time were identified for freezing of gait or QOL. Aquatic therapy sessions were safe and enjoyable with no adverse events.
3) After the treatment, only subjects with Parkinson's disease randomized to water-based treatment showed a significant improvement in trunk posture with a significant reduction in cervical flexion (water-based group, $-65.2°$; non-water-based group, $+1.7°$), dorsal flexion (water-based group, $-22.5°$; non-water-based group, $-6.5°$), and lateral inclination of the trunk (water-based group, $-2.3°$; non-water-based group, $+0.3°$) (Volpe et al., 2017). Both groups presented significant improvements in the secondary clinical outcomes without between-group differences.
4) The results showed a significant effect on time of a high effect which indicates that the VAS scores ($F = 1.3$; $p < 0.001$), Five time ($F = 1.8$; $p = 0.001$), and Get up and Go ($F = 1.7$; $p < 0.001$)

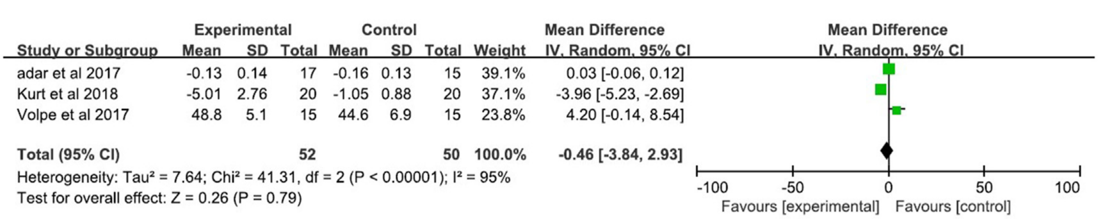

Fig. 5. Meta-analysis of difference in QOL between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of free.

significantly decreased in time, independent of the treatment group [12]. In contrast, no significant differences were found in the results shown on the PDQ-39 scale, with changes only in the section of social support ($p < 0.001$; $F = 18.63$).

4. Discussion

The purpose of this study was to determine the effect of aquatic exercise on the pain, physical activity, and QOL of patients with neurological disorder. In our study, patients were divided based on the neurological disorder, namely, CP, fibromyalgia, hemiplegia, multiple sclerosis, and Parkinson's disease.

4.1. Cerebral palsy

Patients with CP had improved daily and school activity, movement and balance, pain, and eating activity (Adar et al., 2017). However, fatigue, speech and communication, and eating activity were reduced (Lee et al., 2011). Especially, it is important to improve eat activity for body growth in CP (Kukke et al., 2016). The improvement in movement and balance was a positive aspect. The psychological aspect and stability will also improve due to decrease of fall and sway during gait. However, speech and communication did not improve. Therefore, it would be good if there is a program that can help in the communication of participants in underwater games to help in the growth of the child.

4.2. Fibromyalgia

Patients with fibromyalgia had decreased pain and increased perception (Pérez de la Cruz S, 2018). Vitality and mental health in the QOL improved. Fibromyalgia causes chronic pain in soft tissues such as muscles, joints, ligaments, and tendons and may reduce serotonin metabolism in the central and the autonomic nervous systems. Especially, rehabilitation and exercise on land can provide treatment in local areas, but the underwater environment can be beneficial to the whole body that can be applied simultaneously through water turbulence and viscosity.

4.3. Hemiplegia

The aquatic exercise group with hemiplegia had better quality of life and balance than the land-based exercise group (Eyvaz et al., 2018). Clinically, hemiplegia patients need to prevent falls that help to water environment in resistance, viscosity etc. In addition, water environment may help provide an opportunity for more movements during the reduction of ground reaction force in patients with hemiplegia (Chan et al., 2017).

4.4. Multiple sclerosis

Patients with multiple sclerosis had improved mental and social function (Roehrs, 2004). Fatigue and pain were also reduced. Motor and sensory impairments in these patients are basically accompanied by pain and sensory disturbances such as movement disorders with fatigue, numbness, tingling sensation, and burning sensation. However, these symptoms may be alleviated, and social function may be restored with increase in mental function. However, patients with multiple sclerosis are sensitive to temperature, which should be adjusted.

4.5. Parkinson's disease

The QOL of patients with Parkinson's disease increased with social support (Carroll et al., 2017; Kurt et al., 2018; Volpe et al., 2017). Dynamic balance increased, and gait time and pain decreased. Particularly, the increase in dynamic balance seems to be significant in patients with Parkinson's disease whose balance and gait ability are weakened by body freezing and general walking. However, studies on substantial physical improvement such as resting tremor, pill-rolling tremor, rigidity, and sleep disturbance in the water are also needed for Parkinson's disease. One of the suggestions is to modify land-based exercise like dance practice (Delabary et al., 2018) in water for local muscle activation and enjoyment of patients with Parkinson's disease.

4.6. Limitations of the study

The limitations of this study were inadequacy and variation in the overall diseases of the subjects. Further detailed qualitative research is needed to evaluate the details of the QOL, such as activities of daily living and instrumental activities of daily living, of patients with neurological disorders.

5. Conclusion

This study aimed to systematically review the effect of aquatic exercise on the balance rehabilitation, and QOL of patients with neurological disorder. The findings presented indicate that aquatic exercise could be helpful in improving neurological disorders and should be considered as a means of reducing pain while increasing balance ability and QOL in a standard clinical research program.

5.1. Clinical relevance

Aquatic exercise is recommended within a 12-week program, 2 or more times a week, 45–60 min (28–33 °C) for the physical function and quality of life to neurological patients. It needs to from general exercise in the water to Ai Chi and Halliwick, special treatments are required in stages. However, depending on the patient's condition, considering the characteristics and age of each disease, a treatment strategy appropriate to the situation is required.

CRediT authorship contribution statement

Sejun Oh: Conceptualization, Writing - original draft, Methodology, Software, Validation. **SangHeon Lee:** Writing - review & editing.

Declaration of competing interest

No conflict of interest was reported for this study.

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