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Comparison Of Aquatic and Land-Based Rehabilitation In Post-Stroke Patients For Balance and Gait: A Systematic Review

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COMPARISON OF AQUATIC AND LAND-BASED REHABILITATION IN POST-STROKE PATIENTS FOR BALANCE AND GAIT: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction. Cerebral vascular accidents (CVA), or stroke, can lead to impairments in strength, range of motion (ROM), balance, cognition, sensory integrity, and motor function. These several impairments all contribute to a decline in dynamic and static balance among stroke patients. Traditional rehabilitation for stroke involves land-based therapy (LB) techniques addressing impairments within each individual patient. Aquatic therapy (AQ) has also been utilized for rehabilitation in stroke and has been found to be beneficial among stroke patients. The purpose of this Systematic Review (SR) is to compare the effect of AQ and LB therapies on balance and gait. The rehabilitation programs consisted of neuromuscular and strength training.

Methods. The Databases searched included PubMed, Web of Science, PEDro, SAGE journals and Ebsco (Figure 1). We included Randomized Control Trials (RCTs) that compared LB with AQ therapy, or a combination of the two, on post-stroke patients. The main outcomes assessed include dynamic balance, static balance, and gait. We assessed the risk for bias using the PEDro Scale.

Results. A total of 10 RCTs were included in the analysis. For gait and balance, limited evidence was found showing that AQ can be used as an alternative to LB in the short-term. Most of the studies showed significant improvement from baseline when using aquatic therapy. However, in most studies no significant difference was found between the control and the intervention groups post-treatment.

Discussion. This SR suggests that AQ alone, or AQ+LB for post-stroke rehabilitation is adequate and effective in improving gait, static and dynamic balance in the short-term. Improvements in the within-group analysis were found in each article for at least one balance and gait outcome measure. Although improvements were found post-treatment, no group is superior when compared between each other. Rehabilitation plan of care should consist of two sessions per week for 4-to-8 weeks.

Limitations. Some of the limitations of this SR include: small sample size on the articles analyzed, reliance on outcome measures and heterogeneity of the studies.

Conclusion: This SR supports the use of Aquatic alone or in combination with Land-based in post-stroke rehabilitation since it proved to be an effective treatment approach for improving balance and gait. Future research should implement consistent methodology and follow up with long term outcomes to be able to extract more long-term conclusions.

INTRODUCTION

It has been reported that around 40% of post-stroke or, cerebrovascular accident (CVA) patients, experience falls within the first year. [1] Post-stroke patients show cognitive impairment and deficits in the sensory and motor system leading to a decrease in the strength and range of motion (ROM). Altogether can contribute to a reduction in the patient's function and put them at risk for falls. Postural control utilizes sensory, motor, and cognitive components for adequate balance and gait.[2] Interference among any of the components will create or cause deficits in static and postural stability, contributing to the increased risk of falls.[2]

In addition to the risk of falls, the impairments can affect the patient's functional status and ability to ambulate.[3] Post-stroke patients tend to present with a hemiparetic gait, which affects step length and stance phase.[3] In addition, spasticity and paresis are also present which contribute to the altered pattern.[3] Individuals may show limitations in hip and knee flexion and a tendency for excessive plantarflexion with diminished dorsiflexion.[3] If present, these joint impairments can have a negative effect on an individual's gait cycle that could lead to a loss of balance and place them at an increased risk for falls.[3] Consequently, this can affect an individual's activities of daily living (ADL) as well as their ability to participate in the community.[3]

Post-stroke rehabilitation plays an important role in improving and regaining functional status.[3] Traditional post-stroke Physical Therapy (PT) is typically land-based therapy (LB) and follows a sequential order focused on addressing the impairments seen among patients. Post-stroke LB is task-oriented and adapted based on the patient's disability.[3] PT traditionally consists of neuromuscular, strength and gait training. Although LB is important in post-stroke treatment, there may be a concern with increased stress on joints, musculature, and increased risk of fracture with falls in this patient population.[4]

Aquatic Therapy (AQ) allows individuals to be in a safer environment to relearn skills and retrain the body to restore optimal function.[5] Rehabilitation in the water can provide patients with a favorable environment by decreasing the demands on the body due to changes in the properties of buoyancy, viscosity, hydrostatic pressure, and thermodynamics.[3] These properties can decrease the gravity imposed on the muscles and joints. In addition, they provide resistance to the body as they go through the treatment and can provide the patient with somatosensory input to facilitate functional movements.[3,5] The combination of these properties can be advantageous for post-stroke patients because it allows them to be successful as they undergo rehabilitation.[3,5] It is critical for clinicians to understand how the properties of water work to maximize the results and improve the patient's quality of life.

The purpose of this Systematic Review (SR) is to compare the effects that aquatic and land-based therapy have on balance and gait for post-stroke individuals who participate in rehabilitation programs that focus on neuromuscular and strength training.

METHODS

Search strategy:

The Databases searched included PubMed,Web of Science, PEDro, SAGE journals and Ebsco (Figure 1). The search included articles published from 2008 to 2022. The terms search included: Chronic stroke, CVA, Rehabilitation, Land-based therapy, aquatic therapy, physiotherapy, balance and gait.

Study selection

Randomized controlled trials (RCTs) in English, or translated to English, that compared AQ and LB on gait and balance in chronic post-stroke patients were included. Studies that used strength and neuromuscular training as their interventions were included. Studies that looked at non-reliable outcomes were excluded. Studies that were non-peer-reviewed were excluded. A study that compared two different types of AQ was excluded.

Data extraction

The data extracted from each study included interventions, outcome measures and results. This data had to be reliable and valid for patients with post-stroke.

Quality assessment

The PEDro scale was used to evaluate the quality of these RCTs. Each study was given a score out of 10 points using this scale.

Data synthesis and analysis

Studies that met the inclusion criteria were scored using the PEDro scale to determine the quality and risk of bias of the study (Table 1). Furthermore, each study was analyzed based on the sample size, outcome measures and intervention (Table 2).

RESULTS

The initial literature search resulted in 2,643 articles which 27 were recognized as eligible based on the abstract articles. Of these, 17 were excluded based on accessibility, relatable outcome measures and non-peer-reviewed status. In the end, 10 articles were included in this SR (Figure 1). The outcomes assessed in this study include gait, dynamic balance and static balance. All of the studies included were RCTs.

Quality Assessment

Description of the studies

Overall, 10 studies were included in this SR. Three of the studies compared LB with AQ. Five of the studies compared LB with AQ and LB. Two of the studies consisted of three groups in which they compared results between LB alone, AQ alone, and Aquatic Therapy and Land-Based Therapy (AQ+LB) combined. The inclusion and exclusion criteria of each study are listed in Table 2 of the appendix,

Aquatic vs Land-based therapy (AQ vs LB)

Zhu et al performed a study where 28 patients were randomly allocated into two groups using random numbers in sealed envelopes.[6] Both of the groups, LB and AQ, performed a rehabilitation program consisting of stretching, strengthening, balance, coordination and treadmill walking on land or in the water respectively.[6] The AQ group showed significant improvements in walking ability when compared to the LB group which was measured by the 2-Minute Walk Test (2MWT) (p<0.01).[6] They also found that the AQ group had significant effects on static balance as measured by the Berg's Balance Scale (BBS) (p<0.05) and Functional Reach Test (FRT) (p<0.05) when comparing pre- and post-treatment.[6] The AQ group revealed significant improvements in the FRT (p<0.01) when compared to the LB group.[6] Significant improvements were also found in the Timed Up and Go (TUG) test after 4 weeks of treatment (p<0.05) in the within-group analysis post-treatment.[6] However, there was no significant difference after treatment between the AQ and LB groups in the TUG test.[6] This study supports the use of AQ to improve balance and gait, in patients recovering from a stroke.

In 2019, Saleh, Rehab, and Aly randomly allocated 50 post-stroke patients into two groups using a permuted block randomization.[4] The LB group performed dual task training on land while the AQ performed the same tasks in a pool.[4] They participated in therapy 3 times a week for 6 weeks. After 6 weeks of treatment, the authors found that AQ and LB both showed a significant improvement in walking speed, step length of the affected and non-affected limb, and support time on the affected side (p<0.05).[4] They also found that both the AQ and LB groups had a significant decrease (p<0.01) in stability when measured by the Overall Stability Index (OASI), Anteroposterior Stability Index (APSI) and Mediolateral Stability Index (MLSI).[4] In addition, they found the AQ group had a significant decrease (p<0.05) in all three parameters when compared to the LB group.[4] The results of the study support the use of AQ in chronic stroke patients. However, it should be carefully applied to the population because the sample was not a random sample when the subjects were selected.

Noh, Lim, Shin and Paik performed a RCT using a blocked randomization method to allocate post-stroke subjects into two groups (LB and AQ).[7] Both groups underwent therapy for 8 weeks consisting of 1 hour sessions 3 days/week.[7] The AQ group performed rehabilitation consisting of Halliwick and Ai Chi Methods in order to improve balance while the LB group performed strengthening and balance exercises on land.[7] After 8 weeks, they found significant improvements in the BBS for the AQ group (p=0.012) but not for the LB group in the within group comparison.[7] Furthermore, when comparing both groups post-treatment, the AQ group showed significant increase in BBS scores when compared to the LB group (p< 0.05).[7] These Results suggest that AQ consisting of Halliwick and Ai Chi methods can be effective in improving static balance post-stroke. However, the study scored a 5 on the PEDro scale, placing it at a high risk for bias.

Land-based vs Aquatic +Land-based (LB vs AQ + LB)

In 2016, Kim, Lee, and Kim performed a RCT with 20 post-stroke patients divided into two groups.[8] Both groups underwent Neurodevelopmental Training for 30 minutes a day, 5 times per week for 6 weeks.[8] The AQ + LB group underwent an additional 30 minutes of training 5 times per week for 6 weeks, consisting of dual-task Aquatic Therapy.[8] After 6 weeks of training, the LB group and AQ+LB group both showed a significant improvement in the 10-Meter Walk test (10MWT)($p<0.05$) when compared within groups.[8] The AQ+LB group also showed significant difference post-treatment when compared to the LB group ($p<0.05$) in the 10MWT.[8] They also analyzed static balance through the FRT and BBS, and concluded that both groups showed significant improvement in the within groups comparison ($p<0.05$).[8] When compared to the LB group, the AQ+LB group showed significant difference in the FRT and BBS ($p<0.05$).[8] Lastly, they used the Functional Gait Assessment (FGA) to measure Dynamic Balance and found a significant difference between groups ($p<0.05$), with the AQ+LB group showing a significant increase when compared to the LB group ($p<0.05$).[8] These results, support the use of AQ in combination of LB in order to improve balance and gait. However, the study was found to be "fair" in the PEDro scale (4) indicating a risk for bias within the results. Furthermore, the experimental group underwent an additional 30 minutes of PT 3 times a week which could explain the results of this study.

Tripp and Krakow conducted a study containing a total of 27 post-stroke patients assigned to the Halliwick-Therapy group (AQ+LB) versus conventional physiotherapeutic group (LB).[9] The participants were randomly allocated through pre-filled envelopes that contained numbers.[9] The AQ+LB group consisted of exercising rotational control and locomotion with different variations of intensity.[9] The AQ+LB group underwent AQ three times per week and LB two times per week for five weeks.[9] The LB group received standard physical therapy that consisted of different treatment concepts for two weeks, 5 times per week.[9] In Trip and Krakow's post-treatment analysis, they found significant difference ($p<0.1$) of improvement for the

AQ+LB group when assessing functional gait ability measured through the Functional Ambulation Category (FAC).[9] Tripp and Krakow utilized the BBS and found clinically significant improvements in both AQ+LB and LB groups ($p<0.05$) after treatment.[9] The AQ+LB group found significant improvement BBS scores when compared to the LB group post-treatment ($p<0.05$).[9] These results support the utilization of AQ in combination with LB in chronic post-stroke rehabilitation.

Park, Lee, Lee and Lee conducted a study comparing the effects of AQ+ LB with LB alone on 30 randomly allocated post-stroke patients.[10] The AQ+LB group consisted of AQ and LB each for 30-minutes a day, 5 times a week for 4 weeks and a LB group which performed LB 30-minutes twice a day, 5 times a week for 4 weeks.[10] Both AQ and LB interventions consisted of trunk and postural control exercises focused on observing improvements in balance and trunk control outcomes. Following the 4 weeks, they utilized a shortened version of the BBS, known as a 3-level Berg Balance Scale (BBS-3L), and found significant difference ($p<0.001$) in the BBS-3L after 4 weeks of therapy in both the AQ+LB and LB groups. [10] They also found both groups to significantly improve the FRT ($p<0.05$) post-treatment.[10] Additionally, when comparing post treatment values between both groups, the AQ+LB group found significant difference in the BBS-3L and FRT ($p<0.05$) when compared with the LB group supporting the use of a combined AQ and LB interventions.[10] The study was found to be "good" when appraised for bias using the PEDro Scale, scoring a 6, indicating a decreased risk for bias within the results.

Lee, Im, Kim and Han conducted a RCT assessing the effects of an underwater treadmill program compared to a land-based aerobic program following 4-weeks of intervention.[11] A total of 18 post-stroke subjects were analyzed in the AQ group and 14 post-stroke subjects in the LB group at the end of the 4-weeks.[11] Both groups within the study received physical therapy and occupational therapy throughout their respective programs making the analysis an AQ+LB compared to the control of LB alone.[11] It is important to note that although they assessed isometric strength of the paretic limb, this SR focused on the balance outcomes assessed pre and post-intervention. They found a significant increase in BBS scores within the AQ+LB group ($p<0.01$), however, there was no significant difference when a between group analysis was performed ($p=0.07$).[11] These findings suggest there was no significant impact in balance between AQ+LB and the LB group and both can be implemented yielding positive outcomes for balance as reported by the significant increase in BBS scores post-intervention. The study was found to be "good" when appraised using the PEDro scale, which scored a 7, indicating a low risk for bias.

Eyvaz, Dundar and Yasil had a total of 60 post-stroke participants in their study.[5] This yielded two groups, comparing AQ+LB versus LB alone.[5] The AQ+LB group had AQ three times per week with LB two times per week for a total of 6 weeks.[5] The LB group received treatment five times per week for 6 weeks.[5] Both groups in this study incorporated range of motion, strengthening, trunk mobility, balance, and gait training in their sessions according to their desired environment.[5] All participants were randomly allocated to their respective group through an envelope method.[5] The study found both groups to make significant improvements ($p<0.001$) in the TUG after 6 weeks of therapy, with no significant difference between groups post-treatment.[5] The study found significant improvements in the BBS ($p<0.001$) after treatment in both the AQ+LB and LB groups after 6 weeks of rehabilitation.[5] However, contrary to the prior studies, the LB group revealed a significant difference in the BBS when compared to the AQ+LB group after treatment following an intergroup analysis ($p<0.05$).[5] Even though both groups had rehabilitation five times a week, the results can be explained by the fact that the LB group conducted specific balance training five times a week when compared to two times a week for the AQ+LB group.[5] Furthermore, the LB group had a significantly lower BBS score at baseline allowing for a larger opportunity for improvements to be observed than the AQ+LB group.

Land-based vs Aquatic vs Aquatic +Land-based (LB vs AQ vs AQ+LB)

Perez-de la Cruz (2021) had an RCT with three possible group assignments for its post-stroke participants.[1] The study divided the groups into an experimental group (AQ), control group (LB), and combined (AQ+LB).[1] There were a total of 45 participants that were randomly allocated through unmarked envelopes with a 33% chance of belonging to either group.[1] All groups received a total of two sessions per week for 12 weeks (24 sessions total).[1] The AQ group focused on utilization of an Ai Chi program during their sessions.[1] The LB group incorporated exercises that focused on balance, proprioception, muscle relaxation, stretching, and activities of daily living (ADL) tasks.[1] The AQ+LB group focused their interventions alternating between Ai Chi and land based activities such as those stated previously.[1] Perez-de la Cruz (2021) utilized the TUG to analyze dynamic balance.[1] A significant improvement was found after 12 weeks of treatment in the TUG scores for the AQ+LB group ($p<0.01$) when compared to the LB group.[1] This group maintained the improvements 1-month post-treatment.[1] The AQ group also showed improvements in TUG scores post-treatment; however, they did not demonstrate a significant difference.[1] These results suggest that AQ in supplementation with LB can help reduce the risk for falls when using the TUG to quantify it.

Perez-de la Cruz (2020) investigated 40 post-stroke patients randomly allocated into three groups. The three groups created were LB group, AQ group, and AQ+LB group.[3] The researchers divided all participants using random numbers that were in sealed envelopes.[3] The participants engaged in 24 sessions, with two sessions per week for a total of 12 weeks.[3] Ai Chi was incorporated into the AQ group for specific water based interventions.[3] In regards to LB, the patients went through a series of proprioception, muscle relaxation, muscular stretches, ADL tasks, and balance interventions.[3] A combination of the Ai Chi program and LB mentioned above were used in the AQ+LB group.[3] Perez-de la Cruz (2020), evaluated gait and dynamic balance through the Tinetti Performance Oriented Mobility Assessment (POMA).[3] The investigators found that the AQ group and AQ+LB group significantly improved their Tinetti POMA scores after 12 weeks of treatment and 1-month after the initial 12 weeks of treatment ($p<0.05$), while the LB group did not yield significant results.[3] However, it was not specified whether the gait section of the Tinetti POMA yielded significant difference between groups alone.[3] It was also found that only the AQ group and the AQ+LB group significantly improved their 360 degree rotation test ($p<0.05$), while the control group showed no significant improvement.[3] The improvements found within the AQ and AQ+LB group remained following 1-month post treatment.[3] The study used an ANOVA tests to analyze the data, further statistical analysis should be done to specify where the significant difference was. These findings suggest that the incorporation of AQ promotes balance outcomes as observed by the significant improvements found and retention of improved results at 1-month follow up.

DISCUSSION

This SR, based on ten RCTs, aimed to compare the effectiveness of using Aquatic Therapy (AQ) on post-stroke patients. The studies suggest that using all three (LB, AQ, or AQ+LB) types of rehabilitation are effective in improving gait and balance. A common denominator between all studies is that sessions lasted between four to eight weeks with at least two sessions per week. A prior meta-analysis in 2020, found AQ to be useful in post stroke patients in improving balance and gait, but did not directly compare it to LB.[12]

Gait

Stroke affects gait amongst various variables including: temporal, spatial, symmetrical, and kinematical. A narrative review conducted by Balaban and Tok found that gait deviations arising from stroke are defined as a hemiplegic gait.[13] The hemiplegic gait is characterized using the variables described above and all exhibit unique presentations based on the affected individuals' impairments.[13] Balaban and Tok identified the main deficit after a stroke is a slower gait velocity due to individuals having lower extremity weakness and poor motor control.[13] One of the studies that was analyzed showed improvements in walking speed, bilateral step length, and support time after 6-weeks of treatment inferring that AQ or LB could be beneficial to address some of the impairments observed after a stroke.[4] In addition, muscle strength and motor control therapy can be utilized to make an impact on these components and allow for an increase in velocity and a decrease in abnormal movements. [13]

Neuroplasticity is an important process that can help aid in the increase of motor function for individuals after a stroke.[14] The gold standard for post-stroke rehabilitation still remains as a combination of broad aerobic exercise and task oriented activities to allow for neuroplasticity to occur.[14] There is data on animal models that demonstrate molecular pathways being activated during post-stroke rehabilitation that consisted of aerobic training, and task specific exercises.[14] When the rodents participated in motor training, angiogenesis occurred, while skill specific training caused synaptogenesis, and synaptic potentiation which leads to anatomical and physiological changes.[14] When these molecular pathways activate not only does neurogenesis occur, but learning and memory effects take place as well.[14] Clinically, neurological rehabilitation specialized therapy that focuses on motor impairments allows for the process of neuroplasticity to take place which permits individuals to improve their gait.[14] AQ can be utilized for individuals who are not physically able to make use of the mechanics that are required for balance and gait during LB. All of the studies took into consideration how the properties of water will play a role in several aspects of gait such as velocity, overall mechanics, and distance, with the results of this SR showing compatibility.

When comparing AQ and LB, and the effect that each of those interventions have on individuals during post stroke rehabilitation, the studies within this SR found significant differences in several different components of gait. Zhu et al found that there was a significant difference in walking ability when individuals participated in AQ therapy compared to LB therapy which was measured with the 2MWT.[6] Even though the 2MWT is clinically used to evaluate cardiovascular endurance, these results show that AQ can be useful in improving the patient's ability to walk longer distances in the same period of time.

When comparing two groups that consisted of LB vs AQ+LB, the studies within the SR found significant differences in gait velocity, and functional gait ability when comparing these groups alongside each other. Tripp and Krakow found that individuals who participate in AQ+LB, while utilizing the Halliwick Concept in AQ, showed a significant improvement in one's functional gait ability when compared to just LB alone which was measured through the FAC.[9] Another study directly measured gait velocity through the 10MWT agreed with this conclusion since it was found that gait velocity increased in individuals who participated in LB alone, as well as a combination of AQ+LB.[8] These findings suggest that a combination of both AQ+LB for post stroke rehabilitation is adequate to help increase gait velocity and gait functionality.

When taking into consideration three different groups involving LB vs AQ vs AQ+LB, Perez-de la Cruz (2020) evaluated the gait of individuals through the use of the Tinetti POMA to be able to look at the effects of all the groups.[3] Perez-de la Cruz (2020) found that individuals who participated in AQ and a combination of AQ+LB, were able to significantly improve their Tinetti POMA scores post treatment as well as 1 month after their treatment.[3] Although an improvement was noted in these two groups, it was not specified if the gait section of the Tinetti POMA revealed a significant difference between both of these groups.[3]

The findings of this SR suggest that AQ alone, or a combination of both AQ+LB for post-stroke rehabilitation is suitable for individuals to improve their overall gait since every article that assessed a gait outcome, demonstrated improvements post-treatment. However, AQ or AQ+LB cannot be found superior to LB alone based on these results.

Balance

Balance training is a crucial component in stroke rehabilitation due to the impairments caused by motor and sensory dysfunction through the central nervous system. Pathways within the central nervous system allow for the generation of movement through the activation of motor fibers innervated by efferent fibers and provide sensory input from receptors through afferent fibers. Collectively both efferent and afferent fibers provide input and output for proper static and dynamic balance. The properties of water were considered within all the studies included in this SR and results were mixed regarding the beneficial effects they have on static balance. Zhu et al found improvements within the AQ regarding static balance measured by the BBS and FRT.[6] These findings were supported by the thermal effects water contains physiologically within the body through the expansion of blood vessels, increased relaxation of musculature, and decrease of sensitivity to pain and muscle spasms.[6] A couple of studies conducted by Noh, Lim, Shin, and Paik and Eyvaz, Dundar, and Yasil also found significant improvements in static balance measured by the BBS within the aquatic groups and stated properties of water such as buoyancy, thermal physiological effects, and implementation of Ai Chi techniques to contribute towards the improvements of static balance.[5,7] BBS is a valid and reliable outcome measure widely used to quantify static balance in stroke rehabilitation.[15] Due to this, a conclusion can be drawn from the results that AQ can be an effective treatment in improving static balance; however, the sample sizes for both of these studies were fairly small.

When incorporating a combination of AQ+LB as an intervention, the studies included in this SR found significant improvements in both static and dynamic balance measures when compared to LB. Kim, Lee, Kim found increases in FRT and BBS scores following a 6-week program utilizing a combination of AQ+LB interventions.[8] Lee, Im, Kim and Han and Park, Lee, Lee and Lee both found significant improvements in BBS scores following 4-weeks of intervention; however, Lee, Im, Kim and Han utilized an aquatic treadmill program where the participants lower extremities were submerged only rather than utilizing a pool to perform aquatic dual-task exercises.[8,11] This suggests that a combination of AQ+LB can lead to functional gains in balance outcome measures as it could be theorized that this could be due to the viscosity of the water. Kim, Lee, Kim found significant improvement in FGA values following a 6-week program for subjects within the AQ+LB intervention group, indicating functional gains in both dynamic balance and gait.[8] Postural and functional exercise in the aquatic environment promote motor control and are further enhanced with increased strength of the trunk and balance on land.[10]

When analyzing 3 groups consisting of: LB vs AQ vs AQ +LB; improvements in both dynamic and static balance were found in AQ+LB group compared to LB or AQ groups alone.[1,3]

Perez-de la Cruz (2020) and Perez-de la Cruz (2021), found significant improvement in both 360 degree rotation test and BBS values in AQ+LB with improvements also shown in the AQ, although it was not statistically significant.[1,3] Perez-de la Cruz (2020) also evaluated dynamic balance via the Tinetti POMA and found significant improvement in the AQ+LB group, whereas no significant improvement was found in the AQ or LB groups alone.[3] Perez-de la Cruz (2021) utilized the TUG for evaluation of fall risk and found significant improvements in the AQ+LB group, with improvements also noted in the AQ group that were not statistically significant.[1] These findings suggest that although improvements occurred with the utilization of AQ alone, the combination of both AQ+LB interventions can yield a further increase in outcomes. Although the TUG does not directly measure dynamic balance, it can be used as a good predictor for fall risk that can be utilized in clinical practice. The use of the aquatic interventions provide a safe and stable environment for individuals who have difficulty with balance and gait. Utilization of the principles of water provide for improved translation of postural support and progressive weight bearing when transitioning to a land environment.[11] The findings from the studies within this SR in combination with the principles of neuroplasticity support that AQ can provide for an increase in functional gains, which are later reinforced through land-based interventions.

Limitations of the study

The risk for bias on the studies analyzed varied between the studies according to their PEDro score. The scores ranged from 4-8 with a median of 7/10. The lack of patient and therapist blinding was the most common methodological flaw, which is nearly impossible to account for in these types of studies. Therefore, the methodological quality should not be accounted as a major limitation. The relatively small sample sizes in most studies does have an effect on the internal validity of the studies analyzed and increasing the likelihood of a type 2 error (Table 2). Another limitation of the studies considered, was that none of the articles assessed for changes longer than 4 months with four of the studies only reporting results no longer than 4-weeks post treatment. Therefore, the true long-term outcomes of AQ cannot be drawn based on these results.

The studies analyzed used some of the most common outcome measures used in rehabilitation such as the BBS, TUG, 2MWT and others. Although these studies have shown to be good predictors in balance, some of the results may not directly translate to a clinical scenario. In other words, a post stroke patient may show significant improvements in an outcome but may still be at risk for falls.

The heterogeneity of subjects also varied in age amongst which can be an important component contributing to recovery. The type of stroke and specific area of the brain affected were not discussed within each study and could have provided valuable information towards effective intervention, rather the paretic side was included in most studies with also differentiation between hemorrhagic and ischemic lesions. The use of different interventions amongst each study also provided for variability of intervention and contributed to the heterogeneity as a whole. Each study utilized their own aquatic and land-based interventions tailored to address the subjects' impairments found. As there is no such standardized method for treating patients who have suffered stroke due to the multitude and variability of patient presentation that can be encountered and clinician preference.

Despite the limitations, many strengths exist within the studies analyzed. Only one of the articles did not retain at least 85% percent of their subjects (Table 1). The BBS was used for 8 out of the 10 studies which is a reliable outcome measure used to assess an individual's static balance and is widely used in stroke rehabilitation.[15]

CONCLUSION

Our SR showed evidence that supports the use of aquatic therapy, alone or in combination with land-based therapy, as an effective treatment for improving balance and gait in post-stroke patients. Clinicians can use AQ as an alternative intervention when patients cannot tolerate full-sessions of LB since the pool does provide the patient with a more friendly environment due to the properties previously mentioned. As such, clinicians should utilize a firm base of clinical reasoning and evidence-based practice tailored to their patients' impairments and presentation when deciding to utilize AQ or LB intervention. Future research should be done with consistent methodology and with long-term outcomes to be able to draw more reliable conclusions.

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APPENDIX:

Figure 1. PRISMA Diagram

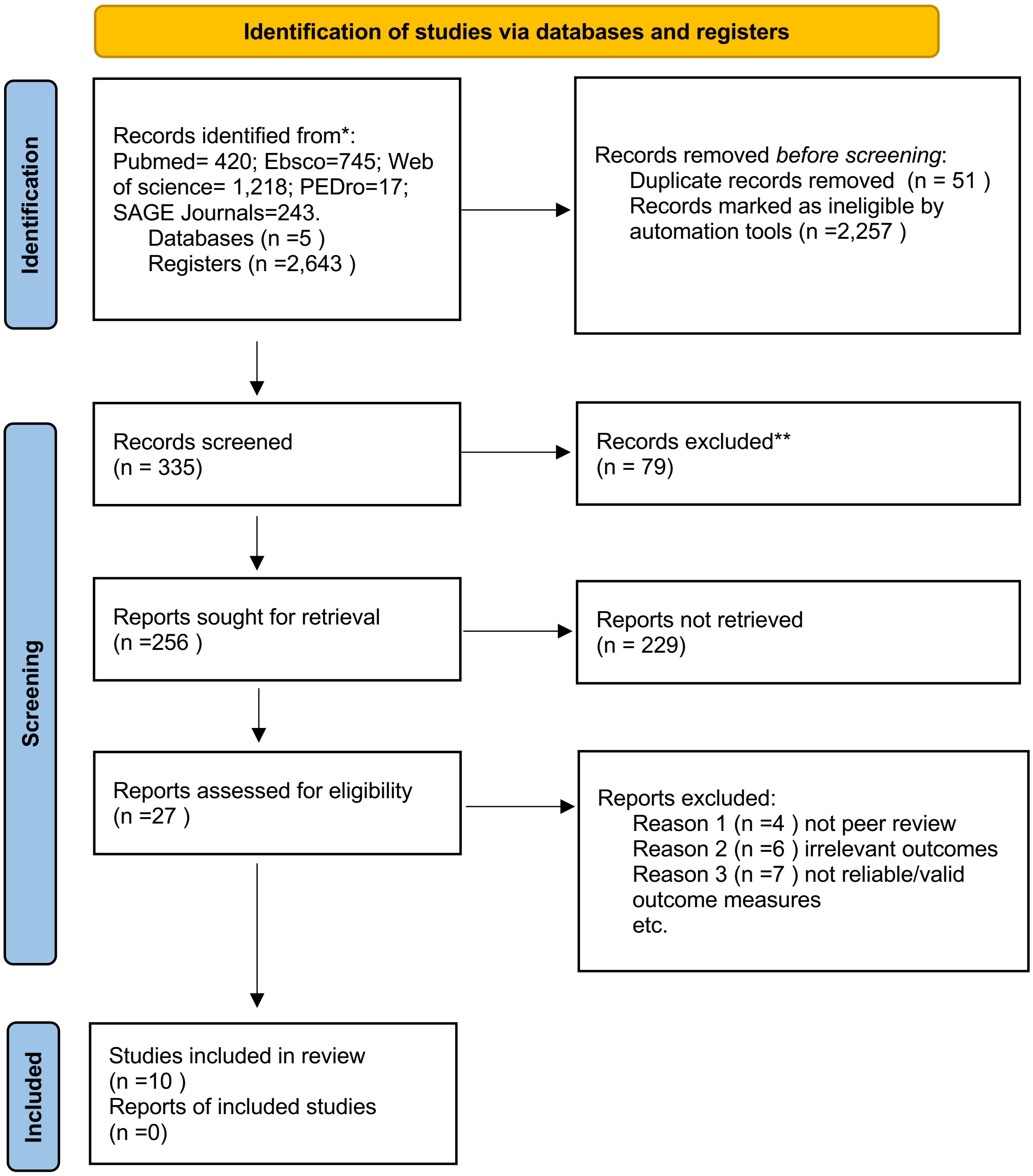

Figure 2. PEDro Scale

PEDro scale

1. eligibility criteria were specified	no ❑ yes ❑ where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no ❑ yes ❑ where:
3. allocation was concealed	no ❑ yes ❑ where:
4. the groups were similar at baseline regarding the most important prognostic indicators	no ❑ yes ❑ where:
5. there was blinding of all subjects	no ❑ yes ❑ where:
6. there was blinding of all therapists who administered the therapy	no ❑ yes ❑ where:
7. there was blinding of all assessors who measured at least one key outcome	no ❑ yes ❑ where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no ❑ yes ❑ where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	no ❑ yes ❑ where:
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ❑ yes ❑ where:
11. the study provides both point measures and measures of variability for at least one key outcome	no ❑ yes ❑ where:

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

Table 1. Appraisal table per PEDro Scale

Study	Score	1	2	3	4	5	6	7	8	9	10	11		Overall appraisal
Eyvaz, Dundar, Yesir (2018)	5	1	1	1	0	0	0	0	1	0	1	1	Fair	Include
Kim, Lee, Kim (2016)	4	0	1	0	0	0	0	0	1	0	1	1	Fair	Include
Lee, Im, Kim, Han (2018)	7	1	1	1	1	0	0	1	1	0	1	1	Good	Include
Noh, Lim, Shin, Paik (2008)	5	1	1	0	1	0	0	1	0	0	1	1	Fair	Include
Park, Lee, Lee, Lee (2019)	6	1	1	1	1	0	0	0	1	0	1	1	Good	Include
Perez-De La Cruz (2020)	8	0	1	1	1	0	0	1	1	1	1	1	Good	Include
Perez-De La Cruz (2021)	8	1	1	1	1	0	0	1	1	1	1	1	Good	Include
Saleh, Ibrahim, Aly. (2019)	7	1	1	1	1	0	0	0	1	1	1	1	Good	Include
Temperoni, et al. (2020)	8	1	1	1	1	0	0	1	1	1	1	1	Good	Exclude
Tripp , Krakow (2013)	7	1	1	1	1	0	0	1	1	0	1	1	Good	Include
Zhu et al. (2015)	8	1	1	1	1	0	0	1	1	1	1	1	Good	Include

PEDro Scale: 1. Eligibility; 2. Randomization; 3. Concealed allocation; 4. Baseline Comparability; 5. Blind Subjects; 6. Blind therapists; 7. Blind assessors; 8. Measurement of at least 85% of the subjects; 9. Intention to treat; 10. Between-group statistical analysis; 11. Point measures and measures of variability. *Eligibility was not included in composite score

Table 2. Summary Table: Articles Summaries.

STUDY	QUALITY ASSESSMENT (PEDro Score)	NUMBER OF PARTICIPANTS	PARTICIPANT DEMOGRAPHICS	EXPERIMENTAL GROUP INTERVENTIONS (S)	CONTROL/COMPARISON GROUP INTERVENTION (S)	RESULTS
Eyvaz, Dundar, Yesir (2018)	5	IG=30 CG=30 Lost 5 during treatment	-Poststroke patients (at least 6 months) -Diagnosed with hemiplegia -50 to 85 years of age	-3days/week for 6 weeks -Pool was 33℃ -Consisted of strengthening and balance exercises -Control intervention was applied 2days/week for 6 weeks	-5days/week for 6 weeks -Consisted of ROM, strengthening, balance, trunk mobility, and gait training exercises	-The IG reported statistically significant improvements in the vitality parameter of the SF-36 (p=0.015) when compared to the CG. -The CG reported statistically significant improvements in the BBS (p=0.04) when compared to the IG
Kim, Lee, Kim (2016)	4	IG=10 CG=10	-6-month history of a stroke diagnosis -All subjects scored >24 points on the mini-mental state examination -Able to walk >10 m -No visual field effects/handicap	-Both groups did neurodevelopmental treatment -Received aquatic dual-task training for 30 minutes a day, 5 days a week, for 6 weeks	-Both groups did neurodevelopmental treatment for 30 minutes a day, 5 days a week, for 6 weeks	-Intragroup comparison, the IG had significant change post intervention in all gat and balance tests (p<0.05) -intergroup comparison, the IG had relatively more significant chant post intervention in all balance and gait assessment tests (p<0.05) -Overall aquatic dual task training has a positive effect on stroke patients improving their balance and gait
Lee, Im, Kim, Han (2018)	7	IG=19 CG=18	- First ever primary ischemic or hemorrhagic stroke that was confirmed through CT scan and MRI - The time interval between stroke and recruitment to the study was less than or equal to 3 months	- All patients underwent conventional rehabilitation therapy that included PT and occupational therapy for 4 weeks - PT included postural control balance training, gait training for 5x a week, 1x per day, for 30 minutes - Occupational therapy included facilitation of fine motor and sensory motor recovery for 5x per week, 1x per day, for 30 minutes - Aquatic therapy was performed on a motorized aquatic treadmill 5x per week, 1x per day, for 30 minutes	- All patients underwent conventional rehabilitation therapy that included PT and occupational therapy for 4 weeks - PT was same as IG - Occupational therapy was the same as IG - Control group underwent a land based aerobic exercise using upper and lower body ergometers 5x per week, 1x per day, for 30 minutes.	- Results in the Aquatic therapy group (IG) showed significant improvements in peak oxygen consumption (P = 0.02), maximal isometric strength of the bilateral knee extensors (P < 0.01) and paretic knee flexors (P = 0.01), FMA (P = 0.03), FMA-LL (P = 0.01), BBS (P = 0.01), K-MBI (P < 0.01), and EQ-5D index (P = 0.04) after treatment in the aquatic therapy group - Between both groups, only a significant difference was found in maximal isometric strength in the knee extensors (P = 0.03) and flexors (P = 0.04)

Noh, Lim, Shin, Paik (2008)	5	IG=13 CG=12	-Participants had a stroke at least 6 months prior -Unilateral limb weakness due to stroke -Ability to walk independently (with or without assistive) -No significant musculoskeletal problems due to outside reasons from the stroke	-Aquatic therapy group had Ai Chi and Halliwick methods consisting of balance and weight bearing exercises. -1 hour, 3x per week, 8 weeks	-Consisted of conventional therapy performing gym exercises -1 hour, 3x per week, 8 weeks	-The IG had significant improvements in Berg Balance Scale scores, knee flexor strength and, forward and backward weight bearing abilities ($p<0.05$) -Remaining measures did not experience significant difference between IG and CG
Park, Lee, Lee, Lee (2019)	6	IG=14 CG=15	-Chronic stroke (>6 months after stroke) -Ability to walk 10m with or without the use of AD -Ages 42 to 70 years	-PT for 30 minutes a day, 5 times a week for 4 weeks combined with AQ 30 minutes a day, 5 times a week for 4 weeks -Land-based trunk exercises in supine and sitting positions -Aquatic trunk exercises consisting of SRC, TRC, LRC, and BIS	-PT for 30 minutes, twice a day, 5 times a week for 4 weeks -Land-based trunk exercises in supine and sitting	-The IG reported statistical significant improvements in K-TIS and PASS-3L when compared to the CG ($p<0.05$) -The IG reported statistically significant improvements in BBS-3L and FRT distance compared to the CG ($p<0.05$) -The IG reported statistically significant improvement in MBI scores when compared to the CG ($p<0.05$) -Both IG and CG reported statistically significant improvements in K-TIS, PASS-3L, BBS-3L, FRT distance, and MBI scores at 4 weeks
Perez-De La Cruz (2020)	8	PT=14 AQ=13 AQ+PT=13	-Poststroke patients (at least 1 year before start of PT) -Ability to walk 10 m with an AD or with another person -Aged between 35-71 years	-AQ: 45-min group session twice a week for 12 weeks. Consisting of aquatic exercises known as Ai-Chi Therapy. -AQ+PT: Alternate dry land therapy sessions and aquatic chi therapy.	-Twice a week for 12 weeks for 45-50 min each. -Each session consisted of strength, flexibility, aerobic and coordination training with warm-up and cool down period	-After twelve weeks, Combined and experimental group were significantly better than the dry-land therapy group ($p<0.01$) in the VAS scale, CS-30 and 360° turn. - Improvements were also noted in the Tinetti scale in all groups but it was not significant.
Perez-De La Cruz (2021)	8	PT=17 AQ=15 AQ+PT=13	-Poststroke patients (>1 year) -Ability to walk independently for 10m with or without an AD -MAS score of less than or equal to 2 -Ages 24-71 years	-AQ group:24 sessions of Ai Chi lasting 45 minutes twice a week for 12 weeks -AQ+PT group: 24 sessions of alternating PT on dry land and Ai Chi in a pool for 45 minutes twice a week for 12 weeks	-PT group: 24 sessions of PT on dry land for 45 minutes twice a week for 12 weeks -Exercises included gait, trunk mobility, strength, aerobic, balance, proprioception, and stretching	- At 12 weeks, scores for the BBS, FTSTS, tandem stance test and TUG improved significantly in the AQ+PT group ($p<0.01$) when compared to the PT group. -Improvements were also found in the AQ group, but no statistical value was noted
Saleh, Ibrahim, Aly. (2019)	7	IG= 25 CG= 25	-Stroke patient based on clinical assessment of neurologist and radiological components of MRI and computed axial tomography -age ranged from 45 to 55 years -duration of illness from 6 months to 1 year	-Aquatic group received motor dual task training 3 days per week for six weeks -Each training session lasted 45 minutes (5 min warmup, 25 min main exercises of motor dual	-Land group received motor dual task training 3 days per week for six weeks -Each training session lasted 45 minutes (5 min warmup, 25 min main exercises of motor dual	- In both groups, all outcomes post treatment showed a significant improvement ($P < 0.05$). - In patients who received the motor dual task training in water in comparison to patients treated on land, there was a significant improvement in terms of overall stability index ($P = 0.02$), anteroposterior stability index ($P = 0.03$), mediolateral stability index ($P = 0.002$), walking speed ($P = 0.01$), step length of the

			-muscle tone of affected lower limb has score on MAS between 1 to 1+ -Brunnstrom stage 4 lower limb -Ability to walk 10 meters without assistive device	task training, and 5 mins of cool down)	task training, and 5 mins of cool down)	affected limb (*P* = 0.03), step length of the non-affected limb (*P* = 0.01), and time of support on the affected limb (*P* = 0.002).
Temperoni, et al. (2020) *	8	CG:15 IG:13	-Post-CVA patients (within 6 months) -Unilateral hemiplegic -25 to 80 years of age	-2 days /week, 4 weeks of sequential preparatory approach therapy	-2 days /week, 4 weeks of standard aquatic therapy	-The IG was statistically significantly better after treatment in the BBS (p=0.02) and SS-QOL(p<0.01). - Both treatments found significant differences in improvement of MAS Score (p<0.01).
Tripp, Krakow (2013)	7	CG= 16 IG=14	-Post-CVA patients at least 2 weeks post onset -Ability transferring from one chair to another independently or with assistance of one person	-Three 45-minute aquatic therapy sessions + two 45 conventional therapy sessions per week for 2 weeks.	- Five 45-minute sessions of aquatic therapy for two weeks. -Conventional physiotherapy consisting of mobility and treadmill training.	-The IG had significant improvements in the BBS compared to the CG (p<0.05). - Functional gait ability was significantly better in the IG compared to the CG (p<0.1).
Zhu et al. (2015)	8	IG = 14 CG = 14	-Stroke that occurred more than 6 months prior to being recruited for the study -Patient is able to move at least 10 m with the help of an assistive instrument or another individual -Patient can tolerate interventions and evaluations -Patient can follow two-step verbal commands	-Stretching of all joints and major muscle groups occurred on land -Aquatic exercises were performed in a pool (strengthening exercises, balance/coordination exercises, and aquatic treadmill exercises) -Cool down consisted of stretching, deep breathing, and floating -Sessions lasted 4 weeks, 45 minutes per session, and 5x per week	-Stretching of all joints and major muscle groups occurred on land -Land based exercises were performed (strengthening exercises, trunk mobility exercises, and treadmill training) -Cool down consisted of stretching all joints and major muscle groups	-In each group, with 4 weeks of treatment BBS, FRT, TUG, and 2MWT improved significantly (P < 0.05) - Mean improvement of the FRT and 2MWT were significantly higher in the aquatic group compared to the control group (P < 0.01)

Abbreviations: AD=Assistive Device; AQ=Aquatic Therapy; BBS=Berg Balance Scale; BBS-3L=3 Level Berg Balance Scale; CG=Control Group; CS-30=30s Chair Stand Test; CVA=Cerebrovascular Accident; EQ-5D=Quality of Life; FMA=Fugl-Meyer Assessment; FMA-LL=FMA lower limb; FRT=Functional Reach Test; IG=Intervention Group; K-MBI=Korean version of the Modified Barthel Index; K-TIS=Korean version Trunk Impairment Scale; MBI=Modified Barthel Index; PASS-3L=3 Level Postural Assessment Scale for Stroke; PT=Physical Therapy; SF-36=Short Form 36 Assessment Questionnaire; TUG=Timed up and go; 2MWT=2 Minute Walk Test; VAS=Visual Analog Scale; * Excluded due to methodology.

Table 3. Summary of Results

STUDY	COMPARISON(S)	INTERVENTIONS	OUTCOMES	WITHIN GROUPS. RESULTS	BETWEEN GROUPS RESULTS
Zhu et al (2015)	AQ vs LB	Both groups underwent 45-minute sessions, 5 days/week for 4 weeks. .	2MWT BBS FRT TUG	AQ group showed significant improvements in all outcome measures post-treatment ($p<0.05$).	-2MWT and FRT: AQ>LB ($p<0.05$) -BBS and TUG: no sig diff.
Saleh, Rehab, and Aly (2019)	AQ vs LB	Both groups underwent therapy 3 times/week for 6 weeks	Walking Parameters OASI APSI MLSI	-Both groups had a sig improvement in Walking Parameters ($p<0.05$). -Both groups had a significant decrease ($p<0.01$) in OASI, APSI and MLSI.	-OASI, APSI,MLSI: AQ>LB ($p<0.01$) -Walking parameter: No significant difference
Noh, Lin, Shin, Paik (2008)	AQ vs LB	Both groups underwent therapy for 8 weeks consisting of 1-hour sessions 3 days/week. Ai chi and Halliwick was used on AQ.	BBS	-They found significant improvements in the BBS for the AQ group ($p=0.012$) -No sig improvements for LB group.	-AQ group showed significant increase in BBS scores when compared to the LB group ($p<0.05$).
Kim, Lee, and Kim (2016)	LB vs AQ + LB	Both groups underwent Neurodevelopmental Training for 30 minutes a day, 5 days/ week for 6 weeks. AQ + LB group had an additional 30 minutes of training per session consisting of dual-task AQ.	10MWT BBS FRT FGA	-Significant improvement in both groups in 10-MWT , FRT and BBS($p<0.05$).	-AQ+LB>LB: Sign improvements in 10MWT, FRT, BBS and FGA ($p<0.05$). .
Tripp and Krakow (2013)	LB vs AQ + LB	-LB: Five 45-minute sessions of LB for two weeks. -AQ+LB: 3 45-minute AQ sessions + two 45 LB sessions per week for 2 weeks.	FAC BBS	-Sig improvement in FAC in the AQ+LB group ($p<0.1$) - Both groups found sig improvement in BBS ($p<0.05$).	- AQ+LB>LB in BBS ($p<0.05$)
Park, Lee, Lee and Lee (2019)	LB vs AQ + LB	-LB: 30 minutes, twice a day, 5 times a week for 4 weeks -AQ+LB: 30 minutes a day, 5x/ week for 4 weeks combined with AQ 30 minutes a day, 5 times a week for 4 weeks	BBS-3L FRT	-Significant difference ($p<0.001$) in the BBS-3L and FRT after 4 weeks of therapy in both groups.	-AQ+LB >LB: significant difference in the BBS-3L and FRT ($p<0.05$).
Lee, Im, Kin, Han (2018)	LB vs AQ + LB	-LB: aerobic exercise using upper and lower body ergometers 5x per week, 1x per day, for 30 minutes. -AQ+LB: AQ was performed on a motorized aquatic treadmill 5x per week, 1x per day, for 30 minutes; PT included postural control balance training, gait training for 5x a week, 1x per day, for 30 minutes	BBS	-Sig increase in AQ+LB group ($p<0.01$),	-No significant difference between groups

Eyvaz, Dundar and Yasil (2018)	LB vs AQ + LB	AQ +LB: 3 days/week of AQ and 2 days/week of LB x 6 weeks of AQ. LB: 5 days/week x 6 weeks	TUG BBS	Both groups made significant improvements post-treatment (*p*<0.001) in the BBS and TUG.	TUG: no sig diff. BBS: LB>AQ+LB (*p*<0.05)
Perez-de la Cruz (2021)	LB vs AQ vs AQ+LB	-LB group: 24 sessions of PT on dry land for 45 minutes 2x/ week for 12 weeks -AQ group:24 sessions of Ai Chi lasting 45 minutes 2x/ week for 12 weeks -AQ+PT group: 24 sessions of alternating PT on dry land and Ai Chi in a pool for 45 minutes 2x/ week for 12 weeks	TUG	-Only AQ+LB showed significant improvements post-treatment (*p*<0.01).	-Only AQ+LB showed sign increase over the LB group (*p*<0.01). -AQ showed improvements but not significant.
Perez-de la Cruz (2020)	LB vs AQ vs AQ+LB	-LB : 2x/ week for 12 weeks for 45-50 min each. -AQ: 45-min group session 2x/ week for 12 weeks. Consisting of aquatic exercises known as Ai-Chi Therapy. -AQ+PT: Alternate dry land therapy sessions and aquatic chi therapy.	Tinnetti POMA 360 Rotational Test	-AQ and AQ+LB showed sign improvements 12 weeks pos-treatment and 1 month post for both outcomes (p<0.05).	-AQ and AQ+LB> LB in 360 rotation test (*p*<0.01).

Abbreviations: AQ=Aquatic Therapy; LB: Land-Based Therapy; BBS=Berg Balance Scale; BBS-3L=3 Level Berg Balance Scale; FRT=Functional Reach Test; FAC=Functional Ambulation Category; TUG=Timed up and go; 2MWT=2 Minute Walk Test.