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Original Article

Physiotherapy Section

Long-term Efficacy of Aquatic Therapy on Balance and Gait in Older Adults: A Randomised Clinical Trial

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ABSTRACT

Introduction: Balance and gait issues significantly contribute to fall-related injuries in older adults. Aquatic therapy interventions, such as Clinical Ai Chi (CAC), Water-Specific Therapy (WST) and the Bad Ragaz Ring Method (BRRM), have shown short-term benefits in enhancing balance and gait. Nevertheless, it is uncertain whether these improvements can be maintained over a longer duration.

Aim: To assess the long-term effectiveness of CAC, WST and BRRM in preserving balance and gait improvements 12 months after the intervention, with an emphasis on functional outcomes and the reduction of falls.

Materials and Methods: This randomised clinical study was conducted at Bangalore, Karnataka, India which involved 69 participants who completed an initial eight weeks of intervention. The sustainability of the eight-week intervention's impact on balance and gait was evaluated over 12 months, with periodic assessments using the Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Functional Reach Test (FRT), Timed Up and Go (TUG) test and Balance Confidence Scale (BCS). Data were gathered through clinical assessments, self-reported fall records and mobility diaries. Statistical analysis involved repeated measures Analysis of Variance (ANOVA) and post-hoc comparisons to investigate temporal trends and differences between groups.

Results: A 12-month follow-up revealed that the CAC group maintained clinically significant improvements in BBS (p-value <0.01) and DGI (p-value <0.012) scores. The WST group exhibited a delayed but progressive improvement in FRT and TUG scores, indicating sustained long-term benefits. However, the BRRM group showed only marginal improvements, which diminished over time. Furthermore, the CAC group reported significantly fewer self-reported falls compared to both the WST and BRRM groups (p-value <0.05), and participants in the CAC group also expressed increased confidence and improved mobility in their daily activities.

Conclusion: The study confirms the long-term efficacy of CAC in sustaining balance and gait improvements, reducing fall risk and enhancing confidence among older adults. WST showed delayed but beneficial effects, while BRRM exhibited limited long-term impact. Future research should explore tailored aquatic therapy protocols to maximise long-term benefits for diverse populations.

Keywords: Ageing, Gait disorders, Hydrotherapy, Postural balance, Rehabilitation

INTRODUCTION

Falls and balance impairments are among the most critical health challenges faced by the ageing population [1]. With age, the risk of experiencing gait instability and diminished balance increases substantially, often leading to severe injuries, reduced mobility and a diminished quality of life [2]. This issue is compounded by the associated psychological effects, such as the fear of falling, which can further restrict participation in daily activities and exacerbate the physical decline observed globally [3]. Therefore, the development and evaluation of effective interventions to manage these risks are essential for promoting healthy ageing and preserving independence in older adults.

General exercises for older adults often face limitations due to the physical and physiological changes associated with ageing. Reduced muscle strength, joint stiffness and chronic health conditions may hinder the ability to perform conventional exercises effectively [4]. Moreover, exercises that do not target specific functional needs, such as balance or gait training, may fail to address the primary risks of falls and mobility impairments [5]. Adherence to exercise routines is another significant hurdle, with factors such as a lack of motivation, fear of injury and accessibility to appropriate facilities impacting consistency [6,7]. Social isolation and a lack of professional supervision can further diminish engagement, reducing the potential benefits of exercise programmes [8].

Aquatic therapy provides a distinct advantage over conventional exercises for older adults by leveraging the unique properties of water [9,10]. The buoyancy reduces stress on the joints, allowing for low-impact movement that minimises pain and the risk of injury [11]. Resistance from water enhances muscular strength and stability without requiring heavy weights, which can be intimidating or unsafe [12]. Hydrostatic pressure improves circulation and proprioception, promoting balance and mobility [13]. Unlike conventional exercises that often demand high levels of coordination and strength, aquatic therapy offers a supportive environment for gradual improvement. This makes it particularly suitable for older adults with mobility limitations, chronic conditions, or a fear of falling [14].

Among the established methods in aquatic therapy are CAC, WST, and the BRRM. These techniques leverage structured exercises within an aquatic environment to enhance proprioception, muscular strength and coordination, which are fundamental in improving balance and gait stability. CAC is based on the principles of mindfulness, controlled breathing and gentle, flowing movements performed in warm water. It emphasises postural control, muscle relaxation and balance enhancement [15,16]. WST focuses on individualised, task-oriented exercises performed in water to improve functional movements. This therapy emphasises specificity, where exercises replicate daily activities or rehabilitative goals [17]. BRRM employs the use of floating devices, such as rings, to facilitate resistance-based exercises. It is grounded in the principles of Proprioceptive Neuromuscular Facilitation (PNF), utilising water resistance to improve strength, flexibility and coordination. The method involves passive and active movements tailored to individual needs, enhancing muscle re-education and functional recovery [18,19].

The short-term benefits of these aquatic therapy interventions are well-documented, but there is a paucity of evidence regarding their sustainability over longer periods. Most studies to date have focused on immediate or short-term improvements in balance and gait, often neglecting the critical question of whether these benefits endure beyond the intervention period [14,19]. Addressing this gap is crucial for developing long-term rehabilitation strategies and providing older adults with effective tools to maintain functional independence and reduce the risk of falls over time. The current study investigated the long-term efficacy of CAC, WST and BRRM in improving balance and gait stability in older adults. This study evaluates the sustainability of functional improvements 12 months postintervention.

MATERIALS AND METHODS

This study was a randomised clinical trial, employing a three-arm parallel-group design to compare CAC, WST and BRRM. Data were collected in Bangalore, Karnataka, from September 2022 to September 2024, with participant assessments at 4, 8, and 12 months after the intervention's completion. Assessments occurred at the research centre or participants' homes, depending on mobility and preference. Ethical clearance was obtained from the Assam Downtown University ethics committee (AdtU/Ethics/PhD Scholar/2021/062).

Inclusion criteria:

1. Elderly individuals aged over 60 years of both genders [20];
2. A history of balance impairment, with a BBS score <45 out of 56 [21];
3. A TUG score >13.5 seconds [22];
4. Subjects having one of the following, as reported: fear of falling, a history of at least one fall in the past two years, or a referral from a physician for balance issues.

Exclusion criteria:

1. Severe co-morbidities or progressive neurological diseases;
2. Contraindications to aquatic therapy;
3. Inability to participate in aquatic interventions due to hydrophobia or chlorine sensitivity.

Sample size calculation: From the initial sample of 69 participants used for the interventional study, 78% (54 individuals) were successfully contacted for all three follow-up assessments. To assess the adequacy of the sample size, a post hoc power analysis was conducted. Using an effect size (η^2) of 0.42 (large effect), an alpha (α) of 0.05, and a sample size per group of approximately 18 (CAC: 18, WST: 19, BRRM: 17), the analysis yielded a statistical power of 0.76 (76%), which is approaching the recommended threshold of 0.80 for adequate power.

Study Procedure

Each participant group received their assigned intervention based on the methodology described in the initial trial. Interventions were delivered by trained physiotherapists over eight weeks, followed by self-directed maintenance. In the CAC group, the exercises focused on postural control, muscle relaxation and balance improvement through slow, controlled aquatic movements [19]. In the WST group, the focus was on task-oriented exercises, including sagittal and transverse rotation control, balance challenges and obstacle negotiation [17]. The BRRM group utilised resistance-based patterns with participants supported by floating devices to improve strength and coordination [18].

Primary outcome measures: The BBS evaluates static and dynamic balance through 14 functional tasks, each scored from 0 to 4. A higher score (maximum: 56) indicates better balance and a lower risk of falls [23].

Dynamic Gait Index (DGI): This test evaluates gait adaptability under various conditions, with scores ranging from 0 to 24. Lower scores indicate a higher risk of falling [24].

Timed Up and Go Test (TUG): This test measures mobility and balance, with shorter completion times indicating better performance [25].

Secondary outcome measures:

Functional Reach Test (FRT): This test measures dynamic balance by assessing how far a person can reach forward while maintaining a fixed base of support. A reduced reach distance is associated with a higher risk of falls [26].

Balance Confidence Scale (BCS): This scale assesses an individual's confidence in performing daily activities without losing balance or falling. On a scale of 0 to 100, higher scores indicate greater confidence and a lower fear of falling [27].

Self-reported fall records and mobility diaries were also collected during the follow-up period. Randomisation procedures from the initial trial were maintained, with participants remaining in their original groups. Outcome assessors were blinded to group assignments to reduce bias. Data collection was performed by trained physiotherapists, who visited participants at home or conducted evaluations at the research centre based on the participants' convenience. A standardised protocol was used to ensure consistency.

Adherence to self-directed maintenance was monitored through participant logs and follow-up phone calls. In this study, adherence was considered high when participants completed at least 75% of the recommended self-directed aquatic therapy sessions over the 12-month follow-up period. Participants were expected to perform at least three sessions per week as part of their self-directed maintenance programme, and high adherence was defined as completing at least nine out of 12 sessions per month, on average.

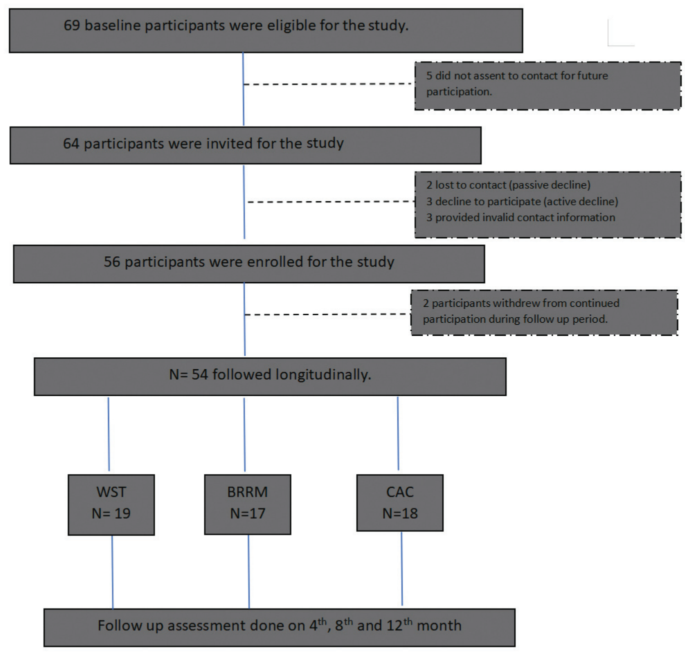
STATISTICAL ANALYSIS

Repeated measures ANOVA was used to evaluate changes over time for parametric data (FRT, TUG), while Friedman's repeated measures ANOVA was employed for Non parametric variables (BBS, DGI, and BCS). The between-group analysis was performed using one-way ANOVA for FRT and TUG, and Kruskal-Wallis tests for BBS, DGI, and BCS. Post-hoc analysis was conducted with Bonferroni adjustments to identify pairwise differences. Subgroup analysis was undertaken to evaluate differences based on adherence levels and assessment locations. Statistical significance was set at p-value <0.05. All analysis were performed using Statistical Package for the Social Sciences (SPSS) version 23.0.

RESULTS

Out of the 69 participants initially enrolled in the study, 54 (78.3%) completed all three follow-up assessments over the 12 months. Among the remaining 15 participants, losses occurred for the following reasons: seven did not consent to contact for future participation and were lost to follow-up (passive decline), three participants withdrew consent citing personal reasons, three participants were unresponsive despite multiple follow-up attempts, and two participants withdrew from continued participation during the follow-up. Participant distribution across the groups was as follows: CAC group: 18, WST group: 19, BRRM group: 17 participants completed all assessments [Table/Fig-1].

Recruitment for the follow-up study began in September 2022, and the study concluded in September 2024. Follow-up assessments were conducted at three intervals: the end of the 4th month (FU1), the 8th month (FU2), and 12 months (FU3) from the last intervention session of the previous phase. The baseline characteristics of the three groups (CAC, WST and BRRM) were well matched, showing no statistically significant differences in age, gender, Body Mass Index (BMI), recruitment time postintervention, or living situation.



[Table/Fig-1]: CONSORT flow diagram for enrolment and retention in the study phase.

This suggests that any observed differences in outcomes between the groups are likely due to the intervention itself, rather than pre-existing differences among the participants. The trial was completed as planned, with no interruptions. Baseline demographics for the three groups are summarised in [Table/Fig-2].

Characteristic	CAC (n=18)	WST (n=19)	BRRM (n=17)	p-value
Mean age (years)	67.4±4.5	68.1±5.0	66.8±4.8	0.82[a]
Gender (Male/Female)	12/6	11/8	12/5	0.84[b]
BMI (kg/m²)	25.2±3.1	24.8±3.5	25.0±3.2	0.93[a]
Average time taken for completion of the intervention (weeks)	11.8±0.49	10.2±1.17	14.2±0.77	0.31[a]
Living situation	15 Independent	16 Independent	14 Independent	0.76[b]

[Table/Fig-2]: Demographic data of the three groups at the time of recruitment for follow-up.
a: ANOVA analysis; b: Chi-square analysis

The within-group analysis revealed a progressive decline in balance and gait performance across all intervention groups over 12 months. However, the CAC group demonstrated the slowest rate of decline, suggesting better retention of functional improvements. The WST group showed moderate retention, whereas the BRRM group exhibited the fastest decline, indicating lower sustainability of benefits [Table/Fig-3].

Between-group analysis [Table/Fig-4] revealed significant differences, with CAC consistently outperforming WST and BRRM across all time points (p-value <0.05). The sustained effectiveness of CAC suggests that its structured, mindfulness-based approach promotes long-term adherence and functional retention. WST showed moderate benefits, while BRRM had the least lasting impact. These results highlight the varying long-term efficacy of different aquatic therapy techniques for balance and gait stability.

No serious adverse events were reported during the follow-up period. Minor complaints included mild muscle soreness (n=6) and temporary fatigue (n=4), both of which resolved spontaneously.

Adherence to the prescribed aquatic therapy programme varied across the three intervention groups. CAC demonstrated the highest adherence, with 15 out of 18 participants (83.33%) completing at least 75% of the prescribed sessions, and an average participation rate of 3.6±0.83 sessions per week. WST showed moderate adherence, with 15 out of 19 participants (78.95%) meeting the high adherence criteria, averaging 3.2±0.67 sessions per week. BRRM had the lowest adherence, with only 12 out of 17 participants (70.59%) maintaining high adherence, and an average participation rate of 2.8±0.64 sessions per week. The most commonly reported barriers to adherence in the BRRM group were fatigue and difficulty maintaining consistency, whereas participants in the CAC group reported greater motivation and comfort with the exercises, leading to higher participation rates.

Self-directed logs: Participants submitted self-directed exercise logs during follow-up, which showed that CAC participants engaged in an average of 3.6±0.83 sessions per week, compared to 3.2±0.67 in WST and 2.8±0.64 in BRRM. This difference was statistically significant (p-value=0.012).

Dropout analysis: Adherence was also a factor in attrition. Of the 15 participants who did not complete the study, 9 (60%) were from the BRRM group, citing difficulty in maintaining self-directed

Outcomes	Parametric data						
	Group	Baseline	4 months (Mean±SD)	8 months (Mean±SD)	12 months (Mean±SD)	p-value	Effect size (η²)
TUG (s)	CAC	10.7±2.9	12.3±1.1	12.6±1.2	12.9±1.3	0.124	0.3
	WST	12.6±3.0	13.2±1.4	13.6±1.5	14.0±1.6	0.031	0.25
	BRRM	11.8±.8	14.0±1.4	14.6±1.5	15.0±1.6	0.01	0.15
FRT (cm)	CAC	24.6±4.7	22.7±3.6	21.9±3.8	21.2±3.9	0.021	0.32
	WST	23.9±4.2	21.4±3.3	20.3±3.5	19.5±3.6	0.011	0.28
	BRRM	21.8±3.7	20.2±3.6	18.9±3.8	18.1±3.9	0.01	0.18
Outcome measure	Non parametric data						
	Group	Baseline	4 months median (Percentile)	8 months median (Percentile)	12 months median (Percentile)	p-value	Effect size (ε²)
BBS	CAC	50 (47-53)	46 (44-47)	45 (43-46)	44 (42-45)	0.012	0.33
	WST	45 (42-48)	44 (42-45)	43 (41-44)	42 (40-43)	0.001	0.26
	BRRM	44 (42-45)	43 (41-44)	41 (39-42)	40 (38-41)	0.001	0.16
DGI	CAC	19 (18-20)	19 (18-20)	18 (17-19)	17 (16-18)	0.01	0.31
	WST	18 (17-19)	17 (16-18)	16 (15-17)	15 (14-16)	0.001	0.24
	BRRM	18 (17-19)	16 (15-17)	15 (14-16)	14 (13-15)	0.001	0.14
BCS	CAC	85 (81-88)	84 (82-86)	82 (80-84)	80 (78-82)	0.01	0.29
	WST	82 (80-84)	82 (80-84)	79 (77-81)	76 (74-78)	0.01	0.22
	BRRM	79 (77-81)	78 (76-80)	74 (72-76)	71 (69-73)	0.01	0.19

[Table/Fig-3]: Within-group analysis using repeated measures ANOVA for parametric data and Fredmans repeated measures analysis for non parametric data.

Parametric data						
Outcome	Time point	CAC (Mean±SD)	WST (Mean±SD)	BRRM (Mean±SD)	p-value	Effect size (η^2)
TUG (s)	Baseline	10.7±2.9	12.6±3.0	11.8±.8	0.016	0.43
	4 months	12.3±1.1	13.2±1.4	14.0±1.4	0.013	0.3
	8 months	12.6±1.2	13.6±1.5	14.6±1.5	0.010	0.25
	12 months	12.9±1.3	14.0±1.6	15.0±1.6	0.001	0.22
FRT (cm)	Baseline	24.6±4.7	23.9±4.2	21.8±3.7	0.015	0.38
	4 months	23.9±4.2	21.4±3.3	20.2±3.6	0.014	0.32
	8 months	21.8±3.7	20.3±3.5	18.9±3.8	0.001	0.28
	12 months	21.2±3.9	19.5±3.6	18.1±3.9	0.001	0.2
Non parametric data						
Outcome measure	Time point	CAC Median (Percentile)	WST Median (Percentile)	BRRM Median (Percentile)	p-value	Effect size (ε^2)
BBS	Baseline	50 (47-53)	45 (42-48)	44 (42-45)	<0.01	0.42
	4 months	46 (44-47)	44 (42-45)	43 (41-44)	<0.01	0.33
	8 months	45 (43-46)	43 (41-44)	41 (39-42)	<0.05	0.26
	12 months	44 (42-45)	42 (40-43)	40 (38-41)	<0.05	0.22
DGI	Baseline	19 (18-20)	18 (17-19)	18 (17-19)	<0.05	0.39
	4 months	19 (18-20)	17 (16-18)	16 (15-17)	<0.01	0.31
	8 months	18 (17-19)	16 (15-17)	15 (14-16)	<0.05	0.24
	12 months	17 (16-18)	15 (14-16)	14 (13-15)	<0.05	0.20
BCS	Baseline	85 (81-88)	82 (80-84)	79 (77-81)	<0.01	0.31
	4 months	84 (82-86)	82 (80-84)	78 (76-80)	<0.01	0.29
	8 months	82 (80-84)	79 (77-81)	74 (72-76)	<0.05	0.22
	12 months	80 (78-82)	76 (74-78)	71 (69-73)	<0.05	0.2

[Table/Fig-4]: Between-group analysis using One-way ANOVA for parametric data and Kruskal Walis test for non parametric data.

exercises, as this technique required therapist assistance—this was a primary reason for withdrawal.

Maintenance over time: The study observed a gradual decline in adherence across all groups over the 12-month follow-up, but this decline was least pronounced in the CAC group (n=1, 13% reduction) compared to WST (n=4, 20%) and BRRM (n=5, 29%).

DISCUSSION

This study addresses a critical gap in the long-term evaluation of aquatic therapy interventions, specifically CAC, WST and BRRM, for improving balance and gait stability in older adults. While prior studies have predominantly focused on short-term outcomes [19,28,29], few have examined the sustainability of these improvements over extended periods [30,31]. Moreover, the majority of these studies [15,18] involved neurological patients or discussed only one specific type of aquatic therapy technique while comparing it with other standard protocols.

Aquatic therapy provides a multisensory environment that enhances neuromuscular control, which is crucial for balance rehabilitation. The viscosity of water creates controlled resistance, allowing for gradual strength progression without abrupt movements that could destabilise gait [32]. Furthermore, warm water immersion reduces muscle stiffness and spasticity, improving joint mobility and coordination [33]. The cognitive engagement required in water-based exercises also enhances motor learning, promoting long-term balance adaptation [34].

This longitudinal analysis, conducted over 12 months, provides valuable insights into the retention of functional benefits following three different types of aquatic therapy interventions. The novelty lies in its comparative framework, assessing three distinct aquatic therapy approaches using rigorous methodology, which includes blinded outcome assessors, standardised protocols, and repeated measures across critical time points. Additionally, the study incorporates a robust evaluation of adherence and self-directed maintenance—aspects often overlooked in rehabilitation research.

In comparison with previous research, the findings of this study align with and expand upon existing literature in several key areas, particularly regarding which type of aquatic therapy intervention benefits the elderly in terms of balance, confidence and gait performance [14,35]. Studies by Becker BE and Turner AJ et al., have underscored aquatic therapy's ability to improve balance and mobility in older adults and have explained how this can lead to a significant reduction in falls [35,36]. This study corroborates those findings, demonstrating that all three interventions yielded significant short-term improvements in balance and functional mobility.

Consistent with the work of Mao W et al., which highlighted the benefits of CAC for postural control among patients with peripheral neuropathy [37], this study found CAC to outperform WST and BRRM at all time points among the elderly, indicating its superior retention of balance and gait improvements. In the review of previous research, it was noted that WST is also referred to as Halliwick's therapy, or more generally, as aquatic therapy [38]. There is very little research documented on WST, which showed moderate retention of functional gains, particularly in task-specific movements. This can be explained by the fact that variations in the environment for functional performance might have led to poor translation of pool performances to real-life situations. Furthermore, the majority of previous studies were conducted on stroke or cerebral palsy patients who had a much poorer prognosis [38,39].

While prior work by Sekome K and Maddocks S, emphasised short-term functional improvements, this study was among the few to provide a detailed year-long follow-up, shedding light on the temporal degradation of benefits among the geriatric population with balance disturbances [40]. The role of adherence emerges as pivotal; as pointed out by Collado-Mateo D et al., this study isolated CAC as one aquatic therapy intervention with higher adherence rates and better outcomes, indicating the influence of user-friendly and less physically demanding protocols of CAC that suit the elderly population [6].

Limitation(s)

The 21.74% attrition rate may introduce bias, as those who dropped out could have exhibited different outcomes compared to completers. Additionally, the modest sample size (n=54) limits the generalisability of the findings. Self-reported logs may be prone to recall bias, which could impact the accuracy of adherence data. Variability in assessment settings (home versus research centre) may also introduce measurement imprecision. The use of multiple outcome measures increases the risk of Type I errors, despite Bonferroni adjustments.

The findings demonstrate high applicability to community-dwelling older adults with balance impairments. The inclusion of diverse aquatic therapy methods broadens the relevance to populations with varying functional needs. However, the single-location study design and reliance on specific inclusion criteria limit external validity. Consequently, the study's outcomes are most applicable to older adults with mild to moderate mobility impairments who have access to aquatic therapy facilities.

CONCLUSION(S)

Aquatic therapy in the form of CAC demonstrated the greatest effectiveness, highlighting the critical role of adherence in maintaining functional improvements. Future studies should explore the use of wearable technology or telerehabilitation to monitor adherence and provide immediate feedback in self-managed aquatic therapy. Additionally, research should examine the benefits of combining aquatic and land-based exercises to improve programme accessibility and outcomes.

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