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BMC Sports Science, Medicine and Rehabilitation (2025) 17:9
https://doi.org/10.1186/s13102-024-01049-3

BMC Sports Science, Medicine and Rehabilitation

RESEARCH
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Comparative analysis of land-based vs. water-based balance training on quality of life and physical and psychological deficits in athletes with chronic ankle instability: a randomized controlled trial

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Abstract

Background Aquatic training is known for its effective and gentle rehabilitation benefits, but its impact on athletes with chronic ankle instability (CAI) remains underexplored. This study compares the effects of water-based and land-based balance training on functional performance, dynamic balance, fear of reinjury, and quality of life in athletes with CAI.

Methods Forty-one athletes with chronic ankle instability (CAI) were randomly assigned to water-based (WBBE, $n = 21$) or land-based (LBBE, $n = 20$) balance exercise groups, completing 24 sessions of 30–45 min over 8 weeks. Assessments before and after the interventions included functional ankle instability (CAIT), kinesiophobia (TSK-17), quality of life (SF-36), dynamic postural control (Y Balance Test), and functional performance (Figure-8 hop and single-limb side-hop tests). Perceived treatment effects were measured using the Global Rating of Change (GROC) post-intervention. Data were analyzed using mixed-design ANOVA ($P \leq 0.05$).

Results The statistical analysis of the study revealed no significant time × group interaction effects for CAIT scores, kinesiophobia scores, the Psychological Quality of Life (QoL) Component, or SEBT scores ($p > 0.05$). The LBBE group showed significant improvements in functional tasks, specifically in F8H and SLSH scores, compared to the WBBE group ($p < 0.05$), while the WBBE group had better outcomes in overall Quality of Life and the Physical QoL Component than the LBBE group ($p < 0.05$).

Conclusion Both land-based and water-based balance exercises benefit athletes with CAI, with land-based exercises improving functional performance and water-based exercises enhancing physical and overall Quality of Life. A flexible rehabilitation program combining both approaches can optimize recovery, addressing specific needs, even though no significant differences were found in ankle stability, kinesiophobia, psychological Quality of Life, and dynamic balance between the two methods.

Trial registration This study was prospectively registered with the University Hospital Medical Information Network Clinical Trial Registry under Clinical Trials UMIN000051746 on July 29, 2023.

Keywords Ankle injuries, Aquatic therapy, Postural balance, Hydrotherapy, Kinesiophobia

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Background

Chronic ankle instability (CAI) affects approximately 40% of individuals following an initial lateral ankle sprain, resulting in recurring instability, sensory deficits, joint laxity, pain, swelling, and impaired function [1]. The complex interplay of various factors—such as mechanoreceptor damage [2], balance disorder [3] and psychological burden of re-injury [4])—contributes to the challenges faced by athletes with CAI. This condition hampers athletic performance and significantly limits participation in daily activities, often leading to prolonged absences from training and competition [5–9]. Athletes experiencing CAI struggle with movements requiring rapid direction changes, jumping, and landing, increasing their vulnerability to additional injuries [8, 10, 11]. Moreover, the fear of re-injury can erode confidence and competitiveness, further impacting overall quality of life [4]. Therefore, effective management of CAI is crucial for preserving athletes' physical well-being and extending their athletic careers.

Despite the recognized prevalence of CAI and its adverse effects on athletic performance and quality of life, significant gaps remain in our understanding of effective rehabilitation strategies [12, 13]. Conservative interventions such as balance training, strength training, and multi-exercise programs form the cornerstone of treatment [12–14]; among these, balance training is particularly effective [13, 14] as it stimulates the ankle ligaments and joint capsules, enhancing motor sensory input and activating gamma motor neurons [15, 16]. While existing literature emphasizes the benefits of land-based balance exercises, there is a notable lack of research on the impact of aquatic environments on recovery outcomes for athletes with CAI participating in balance training. This gap is particularly relevant given the unique properties of aquatic training—such as buoyancy and hydrostatic pressure—which may provide distinct advantages over traditional land-based methods. Aquatic environments significantly reduce joint impact while promoting muscle engagement and strength [17], thereby enhancing functional training [1]. Additionally, the controlled setting of aquatic rehabilitation can alleviate fears of re-injury, a common barrier to effective recovery [4, 18–20]. Investigating the efficacy of water-based balance exercises could therefore provide valuable insights into optimizing recovery outcomes for athletes with CAI.

Several studies have demonstrated the effectiveness of aquatic training in enhancing mobility, muscle strength, and proprioception across various populations, including healthy individuals [21], those with knee osteoarthritis [22], elite athletes with Grade III ankle sprains [23], and patients recovering from ACL reconstruction [19]. However, its application in the context of CAI, especially among athletes, has not been thoroughly investigated. Given that aquatic training can enhance joint stability, facilitate muscle engagement, and alleviate the fear of re-injury [4, 18–20], it is essential to explore its specific impact on functional performance, dynamic balance, fear of reinjury, and overall quality of life in athletes with CAI. Addressing this information gap is vital for developing comprehensive rehabilitation protocols that optimize recovery outcomes and inform clinical practice.

This study aims to compare the effects of land-based and water-based balance training programs on functional performance, dynamic balance, fear of reinjury, and quality of life in athletes with CAI. We hypothesize that incorporating an aquatic environment into balance training would lead to significantly improved outcomes compared to traditional land-based exercises. By examining these variables, we seek to contribute to the understanding of effective rehabilitation strategies for athletes suffering from CAI, ultimately enhancing their recovery and long-term athletic performance.

Methods

Study design

This prospective randomized control trial (RCT) examined the effects of an 8-week intervention on performance, balance, and quality of life in participants assigned to water-based (WBBE) or land-based balance exercises (LBBE), with assessments conducted before and after the intervention (Fig. 1). The study adheres to CONSORT guidelines, and a completed checklist is provided as supplementary information (Supplementary Table 3).

Participants

Based on a previous study indicating a Cohen's d of 0.38 for the Cumberland Ankle Instability Tool [12], a sample size calculation using G*Power software (v.3.1.9.2) determined that 40 participants were needed for a repeated measures analysis of variance with an alpha of 0.05 and power of 0.90. Anticipating a 15% dropout rate as recommended by the International Ankle Consortium [10], 46 participants were enrolled between June 2018 and August 2018 through presentations at local community, public, and university clubs in Sanandaj, Iran.

The study included athletes aged 18 to 55 who had suffered a significant ankle sprain with inflammatory symptoms (e.g., pain and swelling) that led to at least one day of sports time loss within the 12 months before enrollment. Eligible participants had to report at least two episodes of ankle instability (e.g., giving way and recurrent sprains) for more than three months before enrollment and score 24 or below on the CAIT. Exclusion criteria involved positive ligamentous laxity confirmed by physiotherapist-administered anterior drawer and Talar tilt

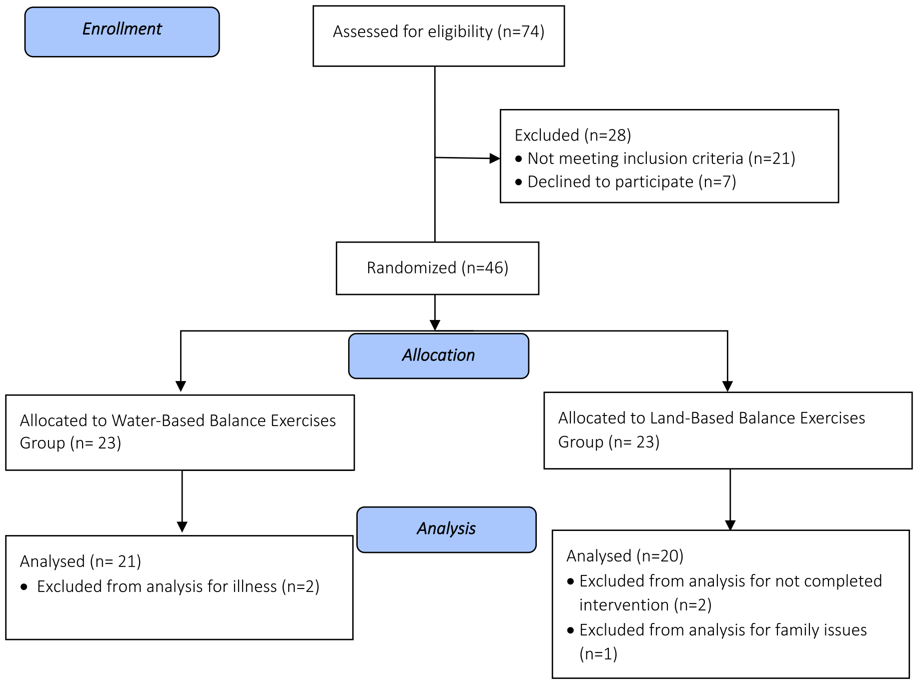

Fig. 1 Flowchart of the study design

tests, as well as a history of fractures or surgery in either lower extremity within 3 months before enrollment. Other exclusions encompassed participants with muscular, joint, or neurological conditions affecting lower limb function, those currently in ankle rehabilitation programs, and athletes with visual, vestibular, or cognitive deficits, aligning with recommendations from the International Ankle Consortium [10].

Randomization

After baseline testing, participants were randomly assigned to either the WBBE or LBBE group using a closed envelope technique with a 1:1 allocation ratio, while ensuring gender balance through block randomization with block sizes of 2 and 4. These block sizes were selected to effectively balance small sample sizes while minimizing assignment predictability. To maintain strict allocation concealment, group assignments were kept hidden from investigators, laboratory specialists, and data analysts by using sequentially numbered, opaque, tamper-evident sealed envelopes. An independent administrator, who was not involved in any other aspects of the study, managed the envelopes, which were opened only after participants completed all baseline assessments. This approach preserved the integrity of the study's randomization process.

Outcomes

Functional ankle instability, kinesiophobia, quality of life, dynamic postural control, functional performance, and perceived treatment effects were evaluated, as described below, in two phases: before (from August 6 to August 19, 2023) and after (from October 16 to October 26, 2023) an 8-week intervention. This evaluation involved participants from both the land-based and water-based balance exercise programs conducted at Mehr Sports Hall in Sanandaj, Iran.

Functional ankle instability was evaluated using the CAIT, a nine-item questionnaire that measures ankle instability during both sports and daily activities. CAIT scores range from 0 to 30, with lower scores indicating greater severity of ankle instability. In this study, a score below 24 was used as the threshold for identifying ankle instability [24].

Kinesiophobia, or fear of movement, was assessed with the Tampa Scale for Kinesiophobia (TSK-17), a 17-item scale where each item is rated on a 4-point Likert scale from "strongly disagree" to "strongly agree." The total score ranges from 17 to 68, with higher scores reflecting greater levels of kinesiophobia [25].

Quality of life was measured using the Short Form-36 Health Survey (SF-36), which assesses eight health domains split into physical and mental components. The physical component includes physical functioning

(10 items), role limitations due to physical problems (4 items), bodily pain (2 items), and general health perception (5 items). The mental component covers vitality (4 items), social functioning (2 items), role limitations due to emotional problems (3 items), and mental health (5 items). The total score ranges from 0 to 100, with higher scores indicating better health status [26].

The Global Rating of Change (GROC) was used to gauge participants' perceived treatment effects. This 15-point scale ranges from "totally worse" to "totally better," with "no change" in the middle. Higher ratings signify improvement, while lower ratings indicate a decline in health [27].

Dynamic postural control was assessed using the Y Balance Test. Participants stood on their injured leg at the center of a grid formed by three tape measures extending at 120° angles. They maintained a one-legged stance with eyes open and hands on hips while extending their non-stance leg to reach the furthest point along each tape measure. Reach distances were standardized based on leg length, measured from hip to ankle. Three trials were conducted in each direction with a 10-second break between trials, and the best result was used for analysis [15].

Functional performance was evaluated using the Figure-8 hop test (F8H) and the single-limb side-hop (SLSH) test. The F8H required participants to hop on their injured leg as quickly as possible through a figure-8 course marked by cones over a 5-meter distance, with total time recorded using a handheld stopwatch. The shortest time was used for the analysis [8]. In the SLSH, participants performed 10 lateral hops on their injured leg over a 30-cm distance as quickly as possible [28].

Interventions

Both the aquatic and land groups participated in a balance training program designed to be identical for both groups. This program was adapted from established balance protocols that have been shown to effectively reduce the incidence of ankle sprains, alleviate residual complaints, and improve postural control [12, 15, 16, 29]. The included exercises and progression scheme are presented in Table 1and Supplementary Table 1 and 2, with a more detailed description available in Supplemental File 1. The program required participants to complete 24 sessions over 8 weeks, each lasting 30–45 min. Sessions began with a 5-minute warm-up (jogging and jumping

Table 1 Balance program exercise

Group A: Single-Leg Stance Exercise	**Group E: Single-Leg Hop Exercise**
• Firm Surface, Eyes open, arms extended outward • Firm Surface, Eyes open, arms crossed over chest • Firm Surface, Eyes closed, arms extended outward • Firm Surface, Eyes closed, arms crossed over chest • Foam pad, Eyes open, arms extended outward • Foam pad, Eyes open, arms crossed over chest • Foam pad, Eyes closed, arms extended outward • Foam pad, Eyes closed, arms crossed over chest	• Firm Surface, Eyes open, arms extended outward, 50 cm distance forward • Firm Surface, Eyes open, hands on the pelvis, 50 cm distance forward • Firm Surface, Eyes open, arms extended outward, 30 cm distance sideways Firm Surface, Eyes open, hands on the pelvis, 30 cm distance sideways
Group B: Crossed-Leg Sway Exercise	**Group F: Single-Leg Tuck Jump Exercises**
• Firm Surface, Eyes open, arms extended outward • Firm Surface, Eyes open, hands on hips • Firm Surface, Eyes closed, arms extended outward • Firm Surface, Eyes closed, hands on hips • Foam pad, Eyes open, arms extended outward • Foam pad, Eyes open, hands on hips • Foam pad, Eyes closed, arms extended outward • Foam pad, Eyes closed, hands on hips	• Firm Surface, Eyes open, arms extended outward **Group G: Throw/Catch a Ball Exercises** • Firm Surface, Eyes open, Unilateral • Foam Pad, Eyes open, Unilateral
Group C: Single-Leg Squat Exercise	**Group H: Modified Y Balance Exercise**
• Firm Surface, Eyes open, arms extended outward • Firm Surface, Eyes open, hands on hips • Firm Surface, Eyes closed, arms extended outward • Firm Surface, Eyes closed, hands on hips • Foam pad, Eyes open, arms extended outward • Foam pad, Eyes open, hands on hips • Foam pad, Eyes closed, arms extended outward • Foam pad, Eyes closed, hands on hips	• Firm Surface, Eyes open, arms extended outward, in all directions • Firm Surface, Eyes open, hands on the pelvis, in all directions • Foam Pad, Eyes open, arms extended outward, in all directions • Foam Pad, Eyes open, hands on the pelvis, in all directions
Group D: Heel Raise Exercise	**Group I: 3-Way Single-leg Romanian Deadlift Exercises**
• Firm Surface, Eyes open, bilateral • Foam pad, Eyes open, bilateral • Firm Surface, Eyes open, unilateral • Foam pad, Eyes open, unilateral	• Firm Surface, Eyes open, arms extended outward, in all directions

jacks) and included stretching exercises. Almost all exercises were performed unilaterally (tested ankle), and progression consisted of variation in arm position, visual control, and surface material [15, 29]. At the start of the training, participants were briefed on the exercises and given an instruction booklet with detailed guidelines to ensure proper execution of the exercises. For the aquatic training group, exercises were conducted in a pool that accommodated participants of varying heights. The subjects in the WBBE group performed exercises without footwear, while those in the LBBE group wore athletic footwear. This approach was employed to replicate the real-world conditions that athletes commonly experience during land-based training. By ensuring that participants wore appropriate footwear, we aimed to preserve ecological validity in the land-based environment, where balance exercises are typically performed while wearing shoes. This strategy enhances the relevance of our findings to actual athletic performance. Based on participant feedback, exercises were individually adapted for increasing difficulty. If a participant struggled with an exercise and touched the ground three or more times, they repeated the previous level until they succeeded. One investigator supervised both training sessions, and a lifeguard was present during the aquatic sessions for safety. Participants were required to keep a diary to document their compliance and any comments. Participants who missed fewer than 5 sessions (20% of the total) completed the final assessment again following the interventions.

Statistical analyses

The researchers employed IBM SPSS Statistics software version 26.0 (IBM Corp., New York, USA) for data analysis, presenting results using mean with standard deviation, frequency with percentages, and mean differences with 95% confidence intervals. Normality and variance homogeneity were assessed using the Shapiro-Wilk and Levene's tests, respectively. To evaluate the effects of LBBE versus WBBE on dependent variables, separate 2×2 mixed-model ANOVAs were conducted, with groups (land-based and water-based exercises) and time (baseline and posttest) as factors. Post hoc tests were performed as needed, maintaining a significance level of 0.05 for all analyses. To better understand the range of training gains, Cohen's d_z was used, with effect sizes categorized as trivial (0.01–0.20), small (0.21–0.50), medium (0.51–0.80), and large (>0.81).

Results

A total of 46 athletes with CAI participated in the study, with 23 assigned to the WBBE group and 23 to the LBBE group (Table 2). Five participants were excluded due to missing more than three training sessions, illness, or family issues—two from the WBBE group and three from the LBBE group (Fig. 1). Both groups demonstrated high adherence rates, with an overall attendance of 98% (approximately 99% for the WBBE group and 97% for the LBBE group). Ultimately, forty-one athletes completed the study and were included in the final statistical analysis.

The repeated-measures ANOVA did not reveal significant time × group interaction effects for CAIT scores ($p < 0.05$), indicating that the WBBE group did not improve CAIT scores more than the LBBE group at the post-test. However, large effect sizes were observed, with Cohen's d_z values of 1.54 for the WBBE group and 0.95 for the LBBE group, respectively, indicating substantial improvements in both groups over the 8-week study period (Table 3; Fig. 2).

Similarly, no significant time × group interaction effect was found for kinesiophobia scores ($p < 0.05$), suggesting that the WBBE group did not show greater reductions in kinesiophobia than the LBBE group at the post-test. Nevertheless, large effect sizes were observed, with Cohen's

Table 2 Demographics and clinical characteristics of participants by groups

Variables	WBBE Group ($n = 21$)	LBBE Group ($n = 20$)	t-value	*p*-value
Gender (men/ women)	11 / 10	10 / 10	-	-
Age (years)	32.9 ± 9.6	29.7 ± 8.9	1.1	0.3
Weight (kg)	78.9 ± 18.4	79.5 ± 10.9	0.13	0.9
Height (cm)	174.9 ± 8.2	176.0 ± 8.6	0.6	0.5
Body Mass Index (kg/m^2)	25.6 ± 4.8	25.7 ± 4.5	0.1	0.9
Affected Side (left/right/bilateral)	4 / 14 / 3	3 / 15 / 2	-	-
Target Side (dominant/nondominant)	16 / 5	14 / 6	-	-
Injury History (months)	8.2 ± 1.7	8.8 ± 2.0	1.00	0.30
Time Since First Sprain (years)	1.7 ± 1.1	1.9 ± 1.1	0.46	0.65
Time Since Last Sprain (months)	6.2 ± 2.2	6.9 ± 2.5	0.84	0.40

Data are presented as mean ± standard deviation (mean ± SD) or frequency

Table 3 Repeated measure ANOVA results for ankle instability, Fear of Movement, functional performance, and dynamic Postural Control

Variables	Time	WBBE group (n = 21)	LBBE group (n = 20)	Between-group difference Mean (95%CI)	Group effects		Time effects		Group × Time effects	
					F	p	f	p	f	P
Functional ankle instability (0 to 30)	Pretest	18.2 ± 3.5	16.9 ± 4.8	1.3 (−1.4 to 3.9)	0.67	0.42	81.1	< 0.001	0.33	0.57
	Postets	23.3 ± 3.0	21.4 ± 4.5	1.9 (−0.5 to 4.3)						
Fear of movement (17 to 68)	Pretest	36.1 ± 3.0	35.9 ± 3.5	0.3 (−1.7 to 2.4)	0.61	0.4	68.5	< 0.001	1.4	0.2
	Postets	29.3 ± 3.9	30.8 ± 3.1	−1.5 (−3.7 to 0.8)						
Quality of life										
Physical component score (0–100)	Pretest	63.9 ± 13.9	66.4 ± 14.4	−2.5 (−11.5 to 6.4)	0.05	0.8	45.6	< 0.001	9.0	0.01*
	Postets	75.0 ± 12.5	70.7 ± 12.7	4.3 (−3.7 to 12.3)						
Mental component score (0–100)	Pretest	66.9 ± 10.8	67.1 ± 12.7	−0.2 (−7.6 to 7.3)	3.0	0.6	116.1	< 0.001	3.9	0.06
	Postets	79.6 ± 9.2	75.9 ± 9.3	3.8 (−2.1 to 9.7)						
Total QoL score (0–100)	Pretest	65.4 ± 9.4	66.8 ± 10.2	−1.4 (−7.5 to 4.8)	0.3	0.6	140.0	< 0.001	12.0	< 0.001*
	Postets	77.3 ± 8.5	73.3 ± 7.7	4.1 (−1.1 to 9.2)						
Functional performance										
Figure-of-8 hop (S)	Pretest	16.6 ± 3.1	16.3 ± 2.6	0.4 (−1.4 to 2.2)	0.5	0.5	268.2	< 0.001	5.9	0.02*
	Postets	15.4 ± 2.8	14.6 ± 2.4	0.8 (−0.8 to 2.5)						
Lateral Hopping (S)	Pretest	16.9 ± 3.0	17.1 ± 2.9	−0.26 (−2.1 to 1.6)	0.02	0.9	107.2	< 0.001	4.2	0.04*
	Postets	15.6 ± 2.7	15.3 ± 2.6	0.34 (−1.3 to 2.0)						
Dynamic postural control										
Anterior reach (% LL)	Pretest	67.2 ± 6.6	65.9 ± 6.5	0.7 (−3.5 to 4.9)	0.06	0.8	93.9	< 0.001	2.3	0.14
	Postets	70.3 ± 6.9	70.8 ± 7.6	−0.6 (−5.1 to 3.9)						
PM reach (% LL)	Pretest	97.5 ± 7.2	96.3 ± 5.6	1.2 (−2.9 to 5.3)	0.05	0.8	109.0	< 0.001	2.1	0.12
	Postets	105.6 ± 5.5	107.0 ± 6.4	−1.4 (−5.0 to 2.4)						
PL reach (% LL)	Pretest	89.3 ± 5.7	92.6 ± 8.4	−3.3 (−8.4 to 0.3)	3.0	0.09	160.1	< 0.001	0.20	0.6
	Postets	98.1 ± 6.8	102.1 ± 7.0	−4.0 (−8.4 to 1.8)						
Composite score (%LL)	Pretest	84.5 ± 4.6	84.9 ± 3.6	−3.3 (−7.9 to 1.3)	1.0	0.3	319.2	< 0.001	3.4	0.07
	Postets	90.8 ± 4.5	92.7 ± 3.5	−4.0 (−8.4 to 0.4)						

Data are presented as mean ± standard deviation (mean ± SD) or frequency

Abbreviations; WBBE Water-based balance exercises, *LBBE* Land-based balance exercises

*Significant between group changes

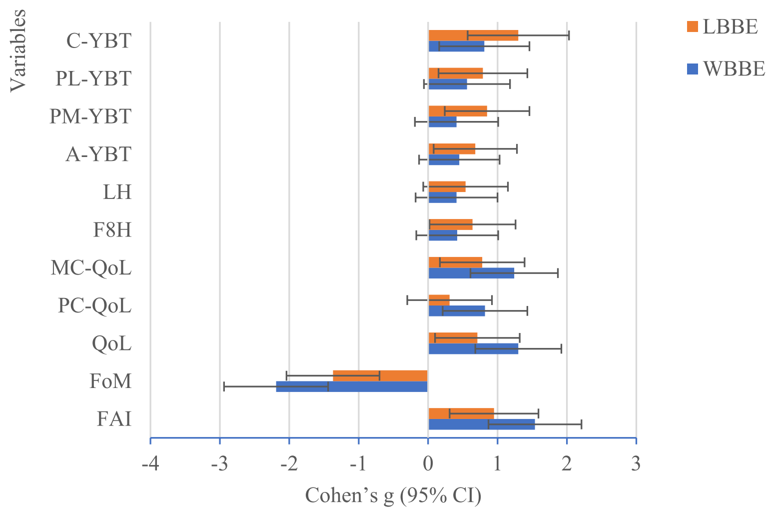

Fig. 2 Graph of Cohen's g effect sizes for changes from pre- to the follow-up survey of outcomes for water-based balance exercises (WBBE) and land-based balance exercises (LBBE) groups. Abbreviations used in the graph are as follows: FAI; functional ankle instability, FOM; fear of movement, PC-QoL; physical component of QoL, MC-QoL; mental component of QoL, F8H; Fig. 8 hop test, LH; Lateral hoping, A- YBT; anterior reach distance of Y balance test, PM-YBT; posterior medial reach distance of Y balance test, PL-YBT; posterior-lateral reach distance of Y test, C-YBT; composite score of Y balance test

d_z values of −2.19 for the WBBE group and − 1.37 for the LBBE group, indicating significant reductions in kinesiophobia for both groups over the study period (Table 3; Fig. 2).

The study found significant time × group interaction effects for overall Quality of Life (QoL) ($p=0.001$) and the Physical QoL Component ($p=0.01$), but not for the Psychological QoL Component ($p=0.06$). The WBBE group demonstrated the greatest improvements in overall QoL and the Physical QoL Component, although it did not have a significant advantage in the Psychological QoL Component compared to the LBBE group. Specifically, the LBBE group had an effect size of 0.71 for overall QoL, with 0.31 for the Physical QoL Component and 0.78 for the Psychological QoL Component. In contrast, the WBBE group exhibited greater effect sizes: 1.3 for overall QoL, 0.82 for the Physical QoL Component, and 1.24 for the Psychological QoL Component, indicating substantial improvements in both QoL components (Table 3; Fig. 2).

The ANOVA did not reveal significant interaction effects for the YBT composite score ($p=0.16$) or its reach components: anterior ($p=0.14$), posteromedial (PM) ($p=0.12$), and posterolateral (PL) ($p=0.7$). These results suggest that the WBBE group did not achieve significantly greater improvements in dynamic balance compared to the LBBE group. The LBBE group demonstrated an effect size of 1.3 for the YBT composite score, with specific gains reflected in effect sizes of 0.68 for the anterior reach, 0.85 for the PM reach, and 0.79 for the PL reach. In comparison, the WBBE group's effect sizes were 0.81 for the composite score, 0.45 for the anterior reach, 0.41 for the PM reach, and 0.56 for the PL reach (Table 3; Fig. 2).

However, the study found significant improvements in the Lateral Hopping score ($p=0.04$) and figure-of-8 hop score ($p=0.02$) for the WBBE group compared to the LBBE group. The effect sizes clearly indicated that the LBBE group achieved a greater reduction in test execution time from pre-test to post-test, with values of −0.64 for the Lateral Hopping score and − 0.54 for the figure-of-8 hop score. In contrast, the WBBE group exhibited smaller effect sizes of −0.41 for the Lateral Hopping score and − 0.42 for the figure-of-8 hop score, respectively (Table 3; Fig. 2).

Discussion

The study found that athletes with CAI experienced significant improvements in ankle stability, fear of movement, quality of life, dynamic balance, and functional performance following either WBBE or LBBE). The moderate to large effect sizes from the pretest to the posttest indicate that both interventions led to clinically meaningful changes. Although no significant differences were observed between WBBE and LBBE regarding ankle stability, fear of movement, psychological QoL, or dynamic balance, the LBBE group demonstrated notable improvements in functional performance tests such as the Figure-of-8 hop and lateral hopping, while the WBBE group showed better outcomes in overall and physical QoL.

This suggests that both modalities are effective but may offer distinct advantages for different outcomes.

Contrary to our study's findings, Sadaak, AbdElMageed [23] reported that a four-week aquatic therapy program significantly outperformed traditional physiotherapy for elite athletes with Grade III ankle sprains, leading to faster recovery, improved pain management, enhanced dynamic balance, and better overall athletic performance. Athletes in the aquatic therapy group returned to sports nearly three weeks earlier than those undergoing land-based exercises, indicating a shift towards functional, exercise-based rehabilitation over conventional immobilization. In contrast, Kim, Kim [30] found that both aquatic and land-based exercises produced similar reductions in pain and improvements in static and dynamic stability for elite athletes with Grade I or II ankle sprains. The contradictory results may stem from the fact that participants in the studies by Sadaak, AbdElMageed [23] and Kim, Kim [30] had acute ankle sprains, which do not fully capture the challenges of CAI. Additionally, the chronic nature of CAI may lead to long-term adaptations that traditional self-report questionnaires cannot adequately assess, which could explain the absence of significant differences between groups. Moreover, the effectiveness of aquatic versus land-based exercises may vary based on the type of injury, its severity, and specific outcomes. Ultimately, our findings indicate that while each exercise type offers unique benefits, neither consistently outperforms the other across all measured outcomes. For instance, Roth, Miller [21] noted that both land-based and water-based exercises are effective for static and dynamic balance in healthy individuals. Our study aligns with this by showing that each exercise environment offers unique benefits specific to different aspects of physical and functional performance.

Performing balance exercises in water and on land offers unique advantages due to the distinct properties of each environment, resulting in different impacts on quality of life and functional performance for individuals with ankle instability. Water-based exercises use buoyancy to reduce joint stress, making movements easier and enhancing comfort while also promoting muscle strengthening and proprioceptive training with minimal injury risk. This low-impact setting leads to improved physical health and higher scores in both overall and physical quality of life. Conversely, land-based exercises provide greater specificity and variability by closely mimicking real-life movements, thereby enhancing skills related to hopping and lateral movements crucial for daily activities and sports. Consequently, while water-based exercises mainly improve quality of life, land-based training more effectively boosts functional performance.

The CAIT is specifically designed to assess the subjective symptoms of CAI [24]. Given that CAI lacks an objective criterion standard test, such as a positive MRI, patient-reported questionnaires like the CAIT are crucial for accurately quantifying the severity and impact of this condition on individuals [3, 24]. The International Ankle Consortium endorses the CAIT for use in CAI research, where it serves as an inclusion criterion, a descriptive tool, and a patient-reported outcome measure [10]. A score increase of ≥ 3 points on the CAIT has been established as the minimum threshold for clinically meaningful improvement [31]. In our study, the LBBE group showed a 27.94% improvement (5.1 points), and the WBBE group exhibited a 26.25% improvement (4.5 points), both exceeding this threshold. These improvements are comparable to those reported in previous studies, such as a 5.1-point increase after 6 weeks of strength training and a 4.2-point increase following a 6-week balance training program [32]. Similarly, Cain, Ban [33] reported a 4.42-point increase in CAIT scores for participants undergoing resistance band training and a 5.8-point increase for those using a BAPS board training program.

Kinesiophobia, an exaggerated fear of movement and anticipation of pain, can significantly impair an athlete's strength, postural control, and movement patterns, increasing the risk of re-injury [34]. This condition is especially prevalent in individuals with CAI, who tend to exhibit higher levels of kinesiophobia than healthy individuals, negatively impacting their muscles, proprioception, and postural control [25]. In our study, both LBBE and WBBE groups showed significant within-group reductions in kinesiophobia, with scores decreasing by 18.9% in the WBBE group and 14.2% in the LBBE group. The minimal detectable change (MDC) for TSK-17 in individuals with musculoskeletal pain is 13% [34], meaning that any reduction beyond this threshold reflects a meaningful decrease in kinesiophobia for the study participants. Consistent with our study, other research has demonstrated that six weeks of strength and balance training can effectively reduce TSK scores by 7.8% and 15.8%, respectively [32]. Although there was no significant difference between the two groups in reducing kinesiophobia, the results suggest that both types of balance training are effective. This highlights the importance of balance training, particularly in enhancing balance, in mitigating the fear of movement associated with FAI.

CAI is associated with reduced health-related quality of life (HRQOL), as evidenced by lower scores on the Short Form-36 (SF-36) [5, 6]. Using multidimensional HRQOL tools like the SF-36 helps clinicians better incorporate patient perspectives into rehabilitation and outcome evaluations [7]. Specifically, in our study, the LBBE group saw a 9.76% increase in overall QoL, with a 6.43% improvement in the Physical QoL Component and 13.04% in the Psychological QoL Component. In contrast, the WBBE group exhibited greater increases: an 18.21% improvement in overall QoL, 17.37% in the Physical QoL Component, and 18.97% in the Psychological QoL Component.

Functional performance tests are dynamic evaluations used to assess overall lower body function, incorporating key components such as muscular strength, neuromuscular coordination, and joint stability, all of which can be impacted by joint injuries [8, 11]. These tests, including hopping tasks, are cost-effective, easy to administer, and valuable for tracking patient progress in both clinical and field settings [11]. Over 8 weeks, the LBBE group demonstrated greater improvements compared to the WBBE group, with reductions of 10.8% (1.85 s) in Lateral Hopping time and 10.4% (1.69 s) in Figure-of-8 Hop time, versus 7.4% (1.25 s) and 7.8% (1.26 s) reductions in the WBBE group, respectively. Both intervention groups exceeded the proposed MDC scores for the side-hop (0.97 s) and Figure-of-8 hop tests (0.98 s) [33]. Previous studies also highlight the effectiveness of such training [32, 33]. Park, Oh [32] reported that 6 weeks of strength and balance training reduced Lateral Hopping time by up to 1.3 s and Figure-of-8 hop test time by up to 1.0 s, while another study [27] found that 4 weeks of Resistance Band training resulted in reductions of 1.13 s in Lateral Hopping time and 0.77 s in Figure-of-8 hop test time [33].

Individuals with CAI experience balance deficits due to a compromised sensorimotor system, which limits their ability to quickly adapt to external forces [9]. This condition, though originating from a ligament injury, leads to broader systemic changes that slow the neuromuscular system's response, increasing susceptibility to instability. In our study, both intervention groups surpassed the MDC scores proposed by Cain, Ban [33] for medial (5.05%), posteromedial (6.58%), and posterolateral (7.04%) reach directions. The LBBE group achieved a 9.2% increase in the composite score, with improvements of 4.7% in the anterior reach, 11.1% in the posteromedial reach, and 10.2% in the posterolateral reach, while the WBBE group showed a 7.4% increase in the composite score, with 3% in the anterior reach, 8.2% in the posteromedial reach, and 9.9% in the posterolateral reach. In line with our study, Cain, Ban [33] reported that participants in the resistance band training group experienced substantial increases in reach distances, with 14.1% in the anterior direction, 15.2% in the posteromedial (PM) direction, and 15.2% in the posterolateral (PL) direction and the BAPS board training group showed more modest improvements, with increases of 1.0% in the anterior reach, 10.0% in the PM reach, and 9.5% in the PL reach.

Strength and limitations

When interpreting the results of this study, several limitations must be considered. The focus on athletes may limit the generalizability of the findings to the broader population with CAI. Potential confounding factors, a short follow-up duration, and reliance on self-reported outcomes could introduce measurement bias and impact result accuracy and generalizability. Future research should investigate the long-term effects of aquatic therapy on functional outcomes, such as preventing recurrent sprains, and explore the benefits of combining aquatic therapy with other interventions, like neuromuscular training. Additionally, further studies are needed to evaluate the duration of balance improvements post-training. Addressing sample size and cultural factors is crucial for enhancing the validity and applicability of study findings. Participant blinding was not feasible due to the study's design, which may have led to biased outcome assessments. Ethical concerns about withholding therapeutic interventions led to the exclusion of a control group, limiting comparisons between water-based and land-based balance exercises against rest. As a result, the effects of different exercise environments on ankle stability, fear of movement, psychological quality of life, and dynamic balance remain speculative, and no definitive conclusions can be drawn about the superiority of water-based versus land-based balance exercises compared to rest. To strengthen the findings of this study, it is recommended to incorporate additional assessments, such as electromyography (EMG) and three-dimensional motion analysis, which could offer a more comprehensive understanding of the functional improvements and neuromuscular adaptations associated with CAI following water-based versus land-based balance exercises. Additionally, this study did not consider limited dorsiflexion range of motion during gait as a potential risk factor for recurrent ankle sprains in individuals with CAI within the inclusion and exclusion criteria [35]. Future research should evaluate and control for dorsiflexion range of motion, as its limitations may influence the outcomes of balance training interventions and the risk of recurrent injuries in this population.

Practical implications

The study's findings offer valuable insights for tailoring rehabilitation strategies for CAI. Both water-based and land-based balance exercises demonstrate effectiveness in improving ankle stability, fear of movement, quality of life, and functional performance. Clinicians can use this information to design personalized rehabilitation programs that align with individual patient goals—whether it's enhancing overall quality of life or focusing on functional performance. Water-based exercises can be particularly beneficial for reducing joint stress and boosting quality of life, while land-based exercises might be more effective for improving specific functional skills. Additionally, addressing kinesiophobia through these exercise modalities can significantly support recovery and prevent re-injury. Overall, incorporating these findings into practice can help optimize rehabilitation outcomes and ensure a comprehensive approach to managing CAI.

Conclusion

The study concludes that both water-based and land-based balance exercises effectively enhance ankle stability, fear of movement, quality of life, dynamic balance, and functional performance in individuals with CAI. Although no significant differences were found between the two modalities regarding ankle stability, psychological QoL, or dynamic balance, each type of exercise offered distinct benefits: land-based exercises led to greater improvements in functional performance, while water-based exercises provided more substantial enhancements in overall and physical QoL. These findings indicate that either exercise type can be advantageous depending on the specific outcomes desired. The study highlights the value of a flexible, individualized rehabilitation approach and emphasizes the importance of including balance training—whether land-based or water-based—in CAI rehabilitation programs to address kinesiophobia and optimize recovery outcomes.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-024-01049-3.

Supplementary Material 1.

Acknowledgements

The authors would like to thank all the participants who contributed to this study.

Authors' contributions

AN and KA conceptualized the original idea and designed the study. KA conducted the literature review and data collection. AN handled data analysis, interpretation, and statistical analysis. KA drafted the manuscript and AN reviewed and edited it.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to privacy concerns regarding the research participants, the data are not publicly available.

Declarations

Ethics approval and consent to participate

This study adhered to ethical guidelines, with all participants providing informed consent after being fully informed of the study's purpose and procedures. Confidentiality was maintained, and participants could withdraw at any time. They were also offered access to the study's results if requested. The Ethics Committee of Shahrood University of Technology (IR.SHAHROODUT.REC.1403.023) approved, and the study was registered with the University Hospital Medical Information Network Clinical Trial Registry (UMIN000051746) on July 29, 2023. The researchers followed the principles outlined in the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 28 August 2024 Accepted: 30 December 2024
Published online: 20 January 2025

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