

Research Paper



Aquatic and Kinetic Chain Exercises for Rehabilitation of Chronic Non-specific Low Back Pain

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ABSTRACT

Objectives: Chronic non-specific low back pain (CNSLBP) considerably influences individuals' daily activities. Aquatic exercise (AE) is used for musculoskeletal rehabilitation. This study aimed to examine the effects of open and closed kinetic chain (CKC) exercises in water on range of motion (ROM) and balance in men with CNSLBP.

Methods: A three-arm randomized controlled trial (RCT) assigned 60 men with CNSLBP to open-chain AEs (OCAEs), closed-chain AEs (CCAEs), and a control group (n=20 each). The intervention groups exercised for eight weeks, three sessions per week. The outcomes were ROM, dynamic balance, and pain.

Results: The study's findings showed that OCAE and CCAE improved ROM, dynamic balance, and pain. The results showed a significant difference between the OCAE, CCAE and control groups in left ROM ($F=11.447$, $P<0.001$, $\eta^2=0.367$), right ROM ($F=14.806$, $P<0.001$, $\eta^2=0.343$), pain ($F=112.386$, $P<0.001$, $\eta^2=0.801$), dynamic balance (anterior) ($F=6.065$, $P<0.004$, $\eta^2=0.178$), and dynamic balance (posterior-lateral) ($F=7.204$, $P<0.002$, $\eta^2=0.204$), dynamic balance (posterior-medial) ($F=3.964$, $P<0.005$, $\eta^2=0.124$).

Discussion: The OCAE and CCAE groups improved in ROM, dynamic balance, and pain compared to the control group. AE can be considered a supplementary program to rehabilitation protocols for individuals with CNSLBP.

Keywords:

Aquatic exercise (AE), Pain, Balance, Non-specific chronic back pain

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Highlights

- Balance indicators are essential factors in the rehabilitation of low back pain.
- Adding AE to conventional training can improve strength and balance.
- AE is more effective than traditional protocols

Plain Language Summary

One of the primary causes of disability, healthcare utilization, and work absenteeism worldwide is low back pain (LBP). A reduced range of motion (ROM) in the lumbar region is often observed in individuals with chronic LBP. Previous studies have highlighted the importance of improving ROM in patients with chronic LBP to enhance their physical capabilities and alleviate pain symptoms. Interventions targeting flexibility and ROM in the lumbar region significantly manage chronic LBP and improve overall functionality and well-being. Open-chain aquatic exercises (OCAE) and closed-chain aquatic exercises (CCAЕ) have gained remarkable attention as valuable and efficient rehabilitation techniques. A closed kinetic chain (CKC) takes place when the foot supports weight on the ground, stabilizing the distal part of the lower limb. In contrast, an open kinetic chain (OKC) occurs when the distal segment is movable and not anchored. Among the patients with LBP, it was suggested to apply aquatic exercise (AE) as an adjunct therapy for dynamic balance, ROM, pain reduction, and LBP rehabilitation.

Introduction

Low back pain (LBP) is a critical global public health issue with a negative impact on quality of life (QoL) and a remarkable social and economic burden [1]. Epidemiological research has revealed that LBP affects 43%-83% of individuals across various societies [2, 3]. Approximately 70%-85% of individuals experience LBP in their lifetime [2, 3]. LBP is one of the primary causes of disability, healthcare utilization, and work absenteeism worldwide [2]. This problem has been reported to be the second most common reason for medical visits, the third most common reason for surgeries, and the fifth most common reason for hospitalization [3]. According to the [World Health Organization \(WHO\)](#) statement, LBP is one of the top ten high-impact conditions and can be experienced during daily life activities, with negative impacts on health, QoL, and daily activities [4].

Studies indicate that a precise pathoanatomical diagnosis is only attainable in 8-15% of individuals with lower back pain. Consequently, most LBP cases are designated as chronic nonspecific lower back pain (CNSLBP), a classification denoting pain that persists for three months or more [5]. The main complaint of patients with CNSLBP when they visit a physician is movement restriction in the lumbar spine, which often contributes to discomfort and functional impairment. This exacerbates patients' daily activities and QoL [6]. Reduced ROM in

the lumbar region is often observed in individuals experiencing chronic LBP [7]. Previous studies have highlighted the importance of improving ROM in chronic LBP patients to enhance their physical capabilities and alleviate pain symptoms [8, 9]. Interventions targeting flexibility and ROM in the lumbar region significantly manage chronic LBP and improve overall functionality and well-being [10]. Limited ROM in patients with LBP changes the muscle sensitivity to tension, followed by pain sensation, which does not allow the muscles to reach their full ROM [11]. This changes the movement pattern and contraction of back muscles, which are the primary stabilizers of this region [12], thus leading to muscle imbalance and negatively affecting lumbopelvic stability [13].

Aquatic exercise (AE) is a valuable intervention for psychological problems (e.g. depression, stress, and anxiety) [14], and promotes overall well-being [15]. Immersing and performing physical exercises in water can improve mood, generate relaxation responses, improve well-being, and offer an opportunity to attend to the emotional aspects of rehabilitation [15]. The properties of water, such as buoyancy and support, can alleviate anxiety and promote a relaxed mental state [16].

Open-chain AEs (OCAEs) and closed-chain AEs (CCAЕs) have gained remarkable attention as valuable and efficient rehabilitation techniques [17]. Closed kinetic chain (CKC) happens when the foot supports

weight on the ground, stabilizing the lower limb's distal segment [18]. Conversely, an open kinetic chain (OKC) occurs when the distal section is movable [18]. OCAE and CCAE have both benefits and drawbacks in rehabilitation [18], and the decision to select between them depends on the treatment goals [19]. The CCAE offers advantages, such as heightened joint compressive forces, enhanced joint stability, lower shear forces, diminished acceleration forces, greater resistance, better proprioception, and superior dynamic stability [19]. Conversely, the benefits of OCAE include higher rotational and distraction forces, lower resistance forces, increased acceleration forces, enhanced joint and muscle mechanoreceptor deformation, enhanced concentric acceleration and eccentric deceleration forces, and increased backing for functional tasks [19]. A major benefit of AE for rehabilitation is the capacity to start treatments sooner than on land [14]. Earlier AE for chronic LBP patients can be helpful as buoyancy decreases pressure on the spinal column and hydrostatic pressure together with water temperature, improves balance, reduces pain, and prevents muscle atrophy [20]. AE is crucial for enhancing the QoL of individuals with LBP. They can be essential in comprehensive therapeutic programs for individuals [21]. It remains unclear how OKC and CKC exercises can be combined in rehabilitation programs for chronic LBP. Most studies have investigated the effects of performing these exercises on land, while few studies have been conducted for closed- and open-chain exercises in water [22]. Consequently, musculoskeletal and central nervous system (CNS) involvement should be considered when creating treatment plans. Considering this, a randomized controlled trial (RCT) was conducted to examine the possible advantages of incorporating aquatic therapy into the open and closed chain exercises within a comprehensive rehabilitation protocol for individuals with LBP. AE is recognized for its advantages in LBP; the question is whether balance and ROM change after AE. Therefore, this study aimed to investigate the effects of OCAE and CCAE on dynamic balance, ROM, and self-reported pain in male patients with CNSLBP.

Materials and Methods

Study design

This was a three-arm, double-blind RCT (blinding of evaluators and patients). To prevent patient bias, the participants in each group were also unaware of the other group's existence and the results of their tests until after the post-test stage. The trial adhered to the CONSORT 2010 guidelines to ensure methodological rigor and transparency [23].

Participants

Participants in this study were men aged 40-60 years who had been diagnosed with CNSLBP by a spine specialist, they freely participated in the trial. They were assigned at random using sequentially numbered opaque sealed envelopes to hide their allocation, divided into three groups using software that generates random numbers: OCAE (n=20), CCAE (n=20), and a control group (n=20). In this random allocation method, based on the sample size, each of the randomly produced sequences was recorded on a card, which was then put into one of the prepared envelopes. Finally, after the evaluation, each patient opened one of the envelopes to specify their group. The minimum sample size was calculated utilizing G*Power software, version 3.1.9.2 (effect size=0.8, $\alpha=0.05$, and power of the test=0.95) for multivariate analysis of variance, one-way analysis of variance (ANOVA) test, and analysis of covariance (ANCOVA) (demographic information). The study included 86 men with LBP, of whom 18 were eliminated because they did not meet the inclusion criteria. Additionally, eight participants did not adhere to the rehabilitation process. Finally, based on the inclusion and exclusion criteria, 60 participants were chosen to make up the statistical sample. Ultimately, there were 20 patients with CNSLBP in the OCAE group, 20 in the CCAE group, and 20 in the control group (Figure 1). All patients had CNSLBP, which was confirmed by a neurosurgeon. The inclusion criteria included being aged 40-60, having a history of pain for over 12 weeks, and having no history of spinal surgery or hip replacement. The exclusion criteria included pain in other body parts, involvement in therapeutic activities, sciatic pain, lower and upper limb deformities, physiotherapy use throughout the past 12 months, and spondylolysis and respiratory problems [24]. The experimental groups performed CKCE and OKCE for eight weeks, three sessions per week, while the control group received no intervention. Patients were instructed not to inform the evaluators about their group assignments to preserve blinding. The participants were provided with an explanation of the processes and goals. Under the Declaration of Helsinki, all participants and/or their legal guardians provided informed consent before participating in the study and, when appropriate, before information or photos were published in an online open-access publication [25]. Ethical approval was obtained from the Ethics Committee of Bu-Ali Sina University for this study. The study was registered at the Iranian Registry of Clinical Trials (IRCT).

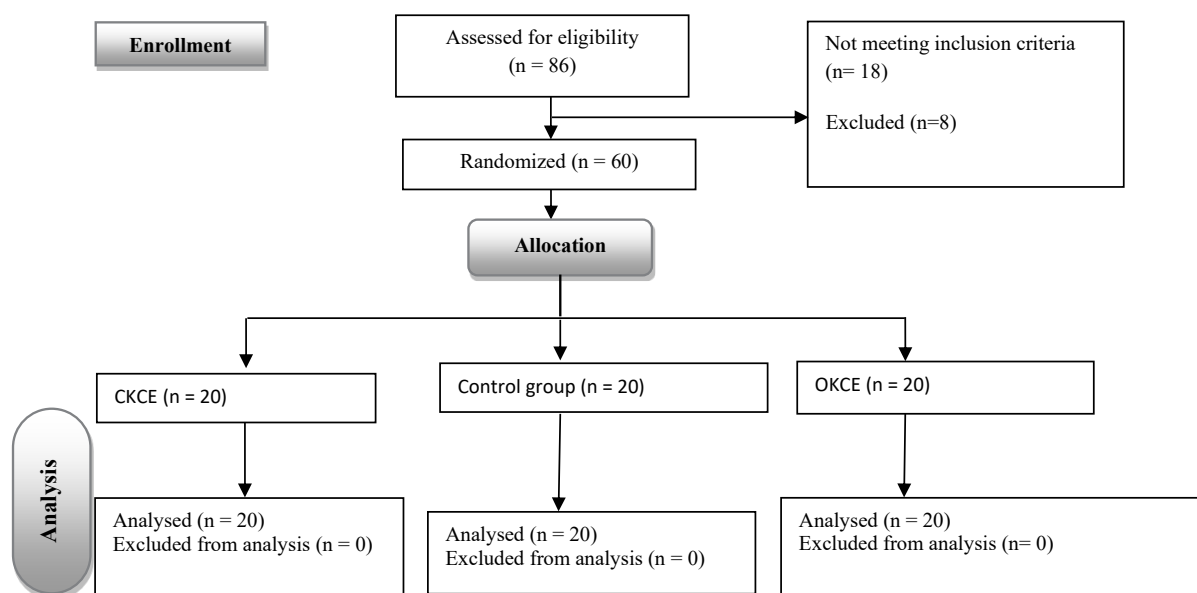


Figure 1. The subjects' CONSORT flow diagram

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Experimental intervention

After evaluating the listed variables, exercises were performed for eight weeks in two stages. The first stage (first four weeks) aimed to familiarize participants with water, examine breathing patterns, train and perform breathing correctly, use swimming in a pool to strengthen the transverse abdominal muscles and multifidus, and maintain proper posture and breathing throughout daily activities (Table 1). The second stage (last four weeks) comprised functional progress and aimed to enhance endurance and muscle strength by incorporating a resistance threshold into the exercises (Table 2). A hydrotherapy specialist and researcher supervised all exercise sessions conducted three times a week. Each session lasted approximately 60 minutes, starting with five minutes of general warm-up followed by 50 minutes of core workouts. OCAE group exercises, such as the abdominal drawing-in maneuver, are specifically intended to activate the deep core stabilizers, the transverse abdominis and multifidus muscles. In the deep water, the following exercises were performed using pool noodles (for support) and theraband (for resistance): Leg abduction and adduction, which involve moving the legs apart and together with the knees extended; and hip flexion and extension, which consist of bending and straightening the thigh at the hip while in a floating position. The CCAE group was trained in proper breathing techniques and performed core-stabilizing exercises. These included a supported half-squat against the pool wall with feet on the floor to target the transverse abdominis and multifidus muscles. The program included various walk-

ing drills: Forward, backward, and sideways with long steps and extended knees, along with single-leg balance practice that involved moving the other leg forward and back, ending with five minutes of cooling (stretching exercises). The training regimen expanded in volume, intensity, duration, and repetition over successive weeks (Tables 1 and 2). The CCAE group exercised in shallow water, while the OCAE group used noodles in deep water (supervised by a lifeguard) (depth to chest area). The protocols for both groups were performed by a skilled physiotherapist specializing in hydrotherapy [6, 19, 26].

Range of motion (ROM)

This study assessed the ROM of the lumbar region through left and right lateral trunk flexion. During the test, the individual stands comfortably and bends to the left or right by lowering their hand along the side of the leg, and the distance from the middle fingertip to the ground was measured (Figure 1). The validity and reliability were found to be high for left and right lateral flexion (intraclass correlation [ICC]: 0.985; 95% CI, 0.969%, 0.993%) [27].

Y-dynamic balance

The Y test is a reliable method for evaluating dynamic balance. It has been reported that this test's reliability coefficient is (0.91-0.99). In this test, the subject stands with the dominant leg in the middle (Y angle between the arms: 135°, 90°, and 135°). The participant is instructed to reach with the opposite foot's toes in three direc-

Table 1. Phase's first exercises from weeks 1 to 4

Time, Repetition, Duration	Closed Chain Exercise Group	Open Chain Exercise Group
Orientation: 10 min familiarization with the pool environment, floor, changing areas, and safety rules.		
Warm-up: 3 min in shallow water: Stepping forward, backward, and side-to-side with arm movements.		
Each stretch was 15 s long and repeated twice.	Static stretching of major muscles: Quadratus lumborum, piriformis, iliopsoas, and hamstrings.	
5 min	Instruct and practice proper breathing techniques.	Instructions and practice of proper breathing techniques using noodles for support in deep water.
10 s×3	Activities include leaning against the pool's edge and positioning your legs on the ground in a half-squat stance to strengthen your multifidus and transverse abdominal muscles.	Exercises involving noodles, a half-squat position, and resting against the pool wall in the deep end to activate the transverse abdominal and multifidus muscles.
3×12 m	Moving forward while keeping the knees extended.	Using noodles in the deep section while bending and opening the thighs with an extended knee.
3×12 m	Taking large strides backward.	Making big steps back. Employing noodles in the deep section, move in reverse (similar to biking).
3×12 m	Taking large strides when walking side by side.	Noodles on the deep side are used to adduct and abduct the legs with extended knees.
3×10 s	Thigh flexion and extension while standing on one leg with the knee flat.	Using noodles in the deep region, flex and extend the thigh in a floating position.
Cooling (5 minutes) Strolling in the shallow water while stretching the upper and lower body muscles.		

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tions (anterior, posterolateral, and posteromedial) while maintaining balance on one leg. The participant was kept balanced, the supporting foot's heel was kept from lifting off the ground, the reaching toes made slight contact with the ground without bearing weight, and the foot was brought back to its standing posture without making contact. They did not implement these cases; it was considered an error, and the test was repeated after a two-minute rest. Balance scores were normalized based on leg length (the separation between the medial malleolus and the anterior superior iliac spine when supine), and the final test score was the average of three repetitions [14, 28].

Pain

A visual analog scale (VAS) measuring 10 centimeters was used to quantify pain perception. Participants were asked to indicate their pain level by marking a scale within this range. Pain intensity was measured on a scale of 0 (no pain) to 10 (worst pain) [29, 30].

Statistical analysis

Data pertaining to all three groups were collected in the pre-test, post-test, and statistical analysis was then carried out to examine how CKCE and OKCE affected

study indicators. The Shapiro-Wilk test was used to assess the η^2 normal distribution of data related to variables and demographic characteristics, and the Levene test was used to assess the homogeneity of variances. Analysis of variance (ANOVA) was used to compare the pre-test values of groups, the t-dependent test to examine intra-group differences, and the ANCOVA method was used to compare the post-test values between groups with effect size analysis. Data were analyzed using SPSS software, version 26. The significance level was set at 0.05 ($P < 0.05$). The effect of the interventions was considered using eta coefficients (η^2): Low (0.01), medium (0.06), and large (0.14).

Results

Demographic characteristics, such as age, height, weight, and body mass index (BMI), were reported as Mean±SD ($P > 0.05$) (Table 3). At baseline, no statistically significant differences were observed between the groups regarding demographic characteristics (age, weight, height, BMI) or outcome measures (ROM, dynamic balance, and pain), ($P > 0.05$ for all) (Table 3).

Table 2. Progress and functional phase exercises: Week 5-8

Time, Repetition, Duration	Closed Chain Exercise Group	Open Chain Exercise Group
Warm-up 3 min Progressing	Walking forward, backward, and side-to-side in the shallow water while making coordinated arm movements.	
Each stretch was 20 s long and repeated twice.	Stretching methods for the primary muscles of the body, such as the quadratus lumborum, piriformis, iliopsoas, and hamstring.	
3×15 s	Activities include pushing against the pool wall and positioning the legs on the ground in a half-squat stance to engage the multifidus and transverse abdominal muscles.	Activities to activate the transverse abdominal muscles and multifidus using noodles while maintaining a half-squat stance and leaning against the pool wall in the deep section.
4×12 m	Utilizing a theraband, the legs are moved in and out with the knee straight.	Utilize noodles in the deep section and a Theraband to perform leg adduction and abduction with a straight knee.
4×12 r	Shoulder flexion and extension while in a half-squatting position.	Shoulder flexion and extension while in a half-squat stance with noodles in the deep section.
4×12 m	Using a theraband to walk backwards.	Racing backward with a theraband while utilizing noodles in the deep section.
4×12 m	Using a theraband, adduction and abduction of the legs were performed with the knee extended.	Using noodles in the deep area and a theraband, adduction and abduction of the legs with an extended knee.
3×12 r	While positioned in a half-squat, perform horizontal abduction and adduction of the legs using a theraband stretcher.	Using a theraband around the legs, executing horizontal abduction and adduction while performing a half-squat with two noodles in the deep area.
Cooling (5 minutes)		
Strolling in the shallow water while stretching both the upper and lower body muscles		

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Table 3. Descriptive statistics of participants and the result of one-way ANOVA test (n=20)

Variables/Groups		Mean±SD			F	P
		CKCE	OKCE	Control		
Age (y)		46.10±6.06	47.80±5.43	50.43±5.41	2.791	0.070
Height (cm)		174.98±6.47	172.12±8.34	174.24±6.27	3.93	0.065
Weight (kg)		82.91±8.07	78.70±11.61	76.60±9.70	0.176	0.839
BMI (kg/m²)		25.88±2.51	25.72±2.25	24.78±1.80	1.61	0.208
ROM_R		47.45±4.55	46.25±5.19	45.65±2.99	0.888	0.417
ROM_L		47.15±4.53	46.70±5.49	46.25±4.47	2.66	0.078
Y-balance (cm)	Anterior	15.60±1.42	15.52±1.31	15.54±0.98	0.571	0.538
	Posterior lateral	14.60±1.47	14.53±1.84	14.35±1.35	2.083	0.134
	Posterior medial	12.60±1.42	12.51±1.18	12.56±1.83	0.463	0.632
Pain		6.60±1.3	5.9±1.75	6.05±0.83	1.61	0.209

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Abbreviation: CKCE: Closed chain kinetic exercise; BMI: Body mass index; ROM_R: Range of motion right; ROM_L: Rang of motion left.

*Significant difference between groups (P<0.05).

Pain

The statistical analysis results using paired t-tests showed a significant difference in pain levels between the participants in the CCAE and OKCE test groups ($P<0.05$). This suggests that CCAE and OCAE may be more effective in alleviating pain in individuals with CNSLBP. No significant difference was observed in scores in the control group between the pre-and post-tests ($P>0.05$) (Table 4). Additionally, ANCOVA revealed a substantial effect size with a significant difference in pain levels among the groups ($F_2=112.386$, $P=0.001$, $\eta^2=0.801$). This finding supports the efficacy of exercise interventions in reducing pain and highlights the potential for implementing CCAE and OCAE as a therapeutic approach for patients with CNSLBP.

ROM

The results of the statistical analysis using paired t-tests showed a significant difference in right and left ROM before and after the intervention in the CKCE and OKCE test groups ($P<0.05$). This indicates that both exercise modalities effectively enhance mobility among individuals with CNSLBP. No significant difference was observed in scores in the control between the pre- and post-tests ($P>0.05$) (Table 4). In addition, the ANCOVA test indicated a small effect size significant difference between CCAE and OCAE groups with the control group in left ROM ($F_2=11.447$, $P=0.001$, $\eta^2=0.29$), right ROM ($F_2=14.806$, $P=0.001$, $\eta^2=0.343$)

(Table 5). These findings indicate a substantial effect of both exercise interventions on improving ROM. Post-hoc test for ANCOVA showed the difference between the control group and the CCAE and OCAE groups for right ROM ($P<0.001$ for both) and left ROM ($P=0.001$ and 0.002 , respectively). Also, no significant difference was observed between the CCAE and OCAE groups. These results underscore the efficacy of incorporating both CCAE and OCAE into rehabilitation protocols for patients with CNSLBP, as they contribute to improved mobility and functional outcomes. Future studies should examine the causes and long-term impacts of these advancements.

Dynamic balance

The results of the statistical analysis using paired t-tests showed a significant difference in dynamic balance (anterior), dynamic balance (posterior-lateral), and dynamic balance (posterior-medial) between the participants in the CCAE and OCAE test groups ($P<0.05$). This indicates that both exercise modalities positively influence dynamic balance, a critical component in functional mobility for individuals with chronic CNSLBP. No significant difference was observed in scores in the control group between the pre- and post-tests ($P>0.05$) (Table 4). ANCOVA indicated a small effect size significant difference between CCAE and OCAE groups and control group for dynamic balance (anterior) ($F_2=6.065$, $P=0.004$, $\eta^2=0.178$), and dynamic balance (posterior-lateral) ($F_2=7.204$, $P=0.002$, $\eta^2=0.204$), dynamic bal-

Table 4. Descriptive statistics (Mean $\pm$ SD) and T-dependent test (n=20)

Variables		Control			OKCE			CKCE		
		Pre-test	Post-test	P	Pre	Post-test	P*	Pre-test	Post-test	P*
	Pain	6.00±0.83	6.50±1.00	0.214	5.9±1.75	1.65±1.22	0.001	6.60±1.3	1.07±1.23	0.001
	ROM_R	45.65±2.99	45.60±2.98	0.33	46.25±5.19	51.00±4.61	<0.001	47.45±4.55	53.00±5.94	<0.001
	ROM_L	46.25±4.47	46.05±4.38	0.33	46.70±5.49	51.20±5.34	<0.001	47.15±4.53	52.70±6.97	<0.001
Y-balance (cm)	Anterior	15.54±0.98	15.50±1.05	0.214	15.52±1.31	19.85±1.15	<0.001	15.60±1.42	19.50±1.76	<0.001
	Posterior lateral	14.35±1.37	14.85±1.63	1	14.50±1.87	18.35±1.53	<0.001	14.60±1.47	18.87±1.82	<0.001
	Posterior medial	12.56±1.83	12.95±1.54	0.376	12.51±1.18	16.50±1.35	<0.001	12.60±1.42	16.52±1.36	<0.001

Abbreviation: CKCE: Closed chain kinetic exercise; ROL_R: Rang of motion right; ROM_R: Range of motion right; ROM_L: Rang of motion left.

*Significant difference between groups ($P<0.05$).

Table 5. ANCOVA results for outcome measuring

Variables	F	DF	Men Squares	Sum of Squares	Partial Eta Squared	P*	Control vs OKCE**	Contrl vs CKCE**	CKCE vs OKCE	
Pain	112.386	2	132.386	264.013	0.801	0.001	P<0.001	P<0.001	0.884	
ROM_R	14.806	2	215.575	431.149	0.343	0.001	P<0.001	P<0.001	0.768	
ROM_L	11.447	2	197.628	395.256	0.290	0.001	P<0.001	P<0.001	0.815	
Y-balance (cm)	Anterior	6.065	2	1.819	3.638	0.178	0.004	P<0.001	P<0.001	0.941
	Posterior lateral	7.204	2	2.190	4.381	0.205	0.002	P<0.001	P<0.001	0.822
	Posterior medial	3.964	2	1.193	2.386	0.124	0.005	P<0.001	P<0.001	0.873

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Significant difference between CKCE, OKCE and control groups ($P<0.05$); **post-hoc indicates significant difference between study groups ($P<0.05$).

ance (posterior-medial) ($F=3.964$, $P=0.005$, $\eta^2=0.124$) (Table 5). These results indicate that CKCE and OKCE significantly enhanced dynamic balance compared to no intervention, with the effect sizes suggesting a meaningful clinical impact. Post-hoc test for ANCOVA showed a difference between the control and CKCE and OKCE groups for dynamic balance (anterior) ($P<0.004$ for both), dynamic balance (posterior-lateral) ($P<0.002$ for both), and dynamic balance (posterior-medial) ($P<0.004$ for both). These findings underscore the importance of incorporating CCAE and OCAE into rehabilitation programs for patients with CNSLBP, as both interventions significantly enhance dynamic balance, which is crucial for preventing falls and improving functional mobility. Future studies should explore the long-term effects of these interventions and their implications for broader rehabilitation strategies.

Discussion

This RCT investigated the effects of AE combined with OKC and CKC exercises on dynamic balance, pain, and ROM in men with CNSLBP. This study aimed to investigate the effect of OCAE and CCAE on dynamic balance, ROM, and self-reported pain in men with CNSLBP. The findings demonstrated that dynamic balance was enhanced by both training program types in the anterior, posterior-lateral, and posterior-medial postural control indices. Additionally, no significant difference was observed in the effectiveness of OCAE and CCAE in posterolateral, posteromedial, pain, and ROM indices. Therefore, AE for eight weeks seems useful for reducing the pain of patients with CNSLBP. These results are consistent with those of Yalfani et al. (2020), Brech et al.

(2012), Khodaveisi et al. (2008) and Aluko et al. (2013), who have shown the beneficial effects of rehabilitation exercises in lowering pain levels in patients with CNSLBP [27, 31-36].

Dynamic balance is essential for functional mobility and is often compromised in individuals with CNSLBP [34-36]. The enhancement in anterior balance indicates improved forward stability, which is crucial for activities, such as walking, running, and reaching [37, 38]. CCAE and OCAE improve balance through several mechanisms. Both modalities enhance proprioceptive feedback by activating sensory receptors that provide information about body position and movement, improving body awareness and spatial orientation [39, 40]. The CCAE emphasizes weight-bearing movements that engage stabilizing muscles, while the OCAE utilizes the buoyancy of water to promote muscle coactivation and coordination without impacting the joints [11, 41]. These exercises also enhance neuromuscular control through repetitive practice and reflexive responses to perturbations, while building muscle strength and endurance [42]. Additionally, a safe aquatic environment reduces the risk of injury, allowing individuals to practice dynamic movements that mimic daily activities, ultimately fostering better balance and functional mobility, especially in those with CNSLBP [6, 43].

The significant reduction in pain reported by participants in both exercise groups underscores the therapeutic potential of these interventions. The AE alleviates pain through the buoyancy effect, which reduces mechanical stress on the spine and surrounding musculature [24, 44]. Similarly, AE may enhance pain relief by promoting muscle strengthening and improving functional move-

ment patterns, contributing to better spinal stability and reduced discomfort during daily activities [5]. AE, such as that performed in the OCAE and CCAE groups, has been shown to alleviate pain through several mechanisms. The buoyancy effect of water plays a crucial role in this process [11, 41, 45]. By reducing the gravitational load on the body, buoyancy minimizes mechanical stress on the spine and surrounding musculature [46, 47]. This allows individuals to engage in movements that might otherwise exacerbate pain on land [48, 49]. The hydrostatic pressure of water also promotes circulation, which can improve the way nutrients and oxygen reach tissues while making it easier to eliminate waste products from metabolism [11, 50, 51]. This improved circulation decrease inflammation and muscle soreness, reducing pain [48, 53]. In summary, the pain reduction observed in this study highlights the efficacy of both aquatic and CKC exercises as therapeutic interventions for individuals with CNSLBP. The unique properties of AE, combined with the strength-building focus of CCAE, create a comprehensive approach to pain management. Together, these modalities alleviate pain and empower individuals to regain control over their physical functions and improve their overall well-being.

The enhancement in trunk lateral flexion ROM was a pivotal finding of this study, as an increased ROM is critical for the execution of daily activities and preservation of overall functional independence. The buoyant properties of OCAE allow individuals to achieve a greater ROM without the gravitational constraints typically encountered on land [51, 53]. Studies have shown that AE can increase flexibility and improve overall physical function in CLBP patients [21, 24, 26, 54]. This unique environment facilitates stretching and mobility exercises that may be challenging for individuals with pain or stiffness, promoting greater flexibility and functional capacity [12, 55]. In contrast, the superior effectiveness of CCAE in improving ROM can be attributed to its targeted focus on strengthening the musculature involved in lateral flexion and spinal stabilization [25]. By enhancing both muscular strength and endurance, CCAE contributes to improved flexibility and mobility in the lumbar region, enabling participants to perform lateral movements with greater efficiency and reduced discomfort. Furthermore, the integration of both OCAE and CCAE within rehabilitation protocols is substantiated by neurophysiological evidence indicating that distinct sensory modalities elicit different neural processes [43]. This suggests that the synergistic combination of OCAE and CCAE may optimize neuromuscular adaptations, thus enhancing overall rehabilitation outcomes [39, 49, 56]. This dual approach is likely to improve propriocep-

tion, coordination, and muscle activation patterns, which are essential for effective balance and pain management [11, 57]. Consequently, this comprehensive methodology holds significant potential for improving functional performance and enhancing the QoL of individuals with CNSLBP. Furthermore, AE regulates neuromuscular postural control to a stable state, which is essential for improving muscle function. The exercises offered in this study seem to target neuromuscular issues related to CNSLBP, potentially resulting in enhanced ROM, pain relief, and dynamic balance. These findings have implications for health organizations to implement AE programs to improve mental health in patients with LBP.

Conclusion

This study showed that aquatic therapy positively affects dynamic balance, pain, ROM, and mental health in patients with CNSLBP. The primary objective of aquatic therapy is to instruct patients to utilize water as a supplementary treatment for recovering patients with LBP. Therefore, aquatic therapy can play a role in patient recovery. Healthcare professionals, including doctors, physiotherapists, and occupational therapists, can incorporate open and CKC exercises in water into a thorough therapeutic program for patients with LB.

Limitation

Our study has several limitations that should be acknowledged: the absence of female participants, the lack of long-term follow-up, potential selection bias, and the omission of a comparator group involving land-based exercises. Furthermore, the uncontrolled variables of participants' age and BMI may influence the results and restrict how widely the results can be used.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of [Bu-Ali Sina University](#), Hamadan, Iran (Code: IR.BASU.REC.1401.026). The study was registered at the [Iranian Registry of Clinical Trials \(IRCT\)](#), Tehran, Iran (Code: IRCT20230430058033N1).

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Authors' contributions

Conceptualization and study design, Hossein Ashoury; Drafting of article: Hossein Ashoury and Ali Yalfani; Critical revision: Hossein Ashoury and Masoud Azizian; monitoring progress: Ali Yalfani; Data analysis, interpretation and final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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