Research Paper

Water Kinetic Exercises' Effects on Pain, Plantar Pressure, Disability, and Kinesiophobia in Chronic Low Back Pain: An Randomized Clinical Trail

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ABSTRACT

Purpose: One of the principal factors contributing to absenteeism in the workplace, high utilization of healthcare services, and filing of health insurance claims is chronic low back pain (CLBP). This study aimed to evaluate the influence of closed and open kinetic chain exercises in water on plantar pressure variables, pain, disability, and kinesiophobia in men with non-specific chronic LBP (NSCLBP).

Methods: Using a pre-post-test design, this randomized controlled trial included patients between the ages of 40 and 60 who had NSCLBP. The patients in the control group had a mean age of 50.4±5.43 years, while the mean ages of the patients in the open and closed kinetic chain hydrotherapy (HT) groups were 46.1±6.06 and 47.8±5.43, respectively. The results incorporated measurements of plantar pressure variables, pain, disability, and kinesiophobia using a plantar pressure device, the visual analog scale, the Oswestry disability index, and the Tampa Kinesiophobia scale (TSK). For eight weeks, the intervention groups adhered to the exercise routine. The group differences were compared using an analysis of covariance.

Results: There was a significant difference in reducing pain ($F2=112.386$, $P=0.001$, $\eta^2=0.801$), disability ($F2=31.581$, $P=0.005$, $\eta^2=0.253$), and kinsiophobia scores ($F2=110.700$, $P=0.001$, $\eta^2=0.798$) between the experimental groups, with a significant effect size. Additionally, significant effects of plantar pressure variables were observed on the following measurements: length of the minor axis (mm) ($F2=6.015$, $P=0.004$, $\eta^2=0.207$), length of the major axis (mm) ($F2=12.178$, $P=0.001$, $\eta^2=0.303$), sway area (mm²) ($F2=6.52$, $P=0.001$, $\eta^2=0.340$), path length of sway (mm) ($F2=6.52$, $P=0.048$, $\eta^2=0.129$), sway velocity (mm/s) ($F2=9.893$, $P=0.001$, $\eta^2=0.261$), standard deviation on the x-axis (mm) ($F2=9.21$, $P=0.001$, $\eta^2=0.248$), and standard deviation on the y-axis (mm) ($F2=18.599$, $P=0.001$, $\eta^2=0.399$).001, η². 248) on the y-axis(mm) ($F2=18.599$, $P=0.001$, $\eta^2=399$).

Conclusion: HT could potentially alleviate pain, disability, and kinesiophobia as it adjusts plantar pressure variables. The aforementioned outcomes highlight HT's therapeutic benefits for persistent lumbar pain and overall physical health enhancement.

Keywords:
Low back pain (LBP), Plantar pressure, Kinetic chain, Hydrotherapy (HT)

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Highlights

- Kinetic chain exercises and HT are beneficial for adults with CLBP because they reduce the intensity of the pain.
- Kinetic chain exercises and HT improve the disability and kinesiophobia of adults with CLBP.
- HT kinetic chain exercises improve plantar pressure variables in adults with CLBP.

Plain Language Summary

Chronic low back pain (CLBP) is a prevalent concern that results in absenteeism from work and increased utilization of healthcare resources. The groups undergoing the experimental interventions showed a substantial decrease in pain, disability, and kinesiophobia with a strong impact size. Moreover, notable distinctions were noted for the experimental groups' plantar pressure variables. It has been demonstrated that hydrotherapy (HT) improves the plantar pressure variables in people with CLBP. According to the study's findings, engaging in HT, specifically practicing kinetic chain exercises in water, significantly enhances plantar pressure variables. Engaging in recommended HT exercises over time allows individuals with CLBP to gain better control and adjustment of plantar pressure variables, which can lead to improved walking patterns and overall physical health. Additionally, due to its hydrostatic properties and viscosity, individuals can initiate HT exercises without experiencing pain or fear of movement.

Introduction

The prevalence of low back pain (LBP) has been highlighted by the World Health Organization (WHO) as a significant health concern, affecting individuals regularly and leading to a decline in their overall well-being and quality of life (QoL). Moreover, it can hinder their functional abilities, contributing to absenteeism in the workplace, early retirement, and in more severe instances, disabilities [1]. The prevalence of LBP in Iran ranges from 14.4% to 84.1% in various subsets of the population, such as working populations, pregnant women, and students, following world trends [2]. Regardless of the etiology, LBP ranks as the third most frequent contributor to morbidity and disability within the Iranian population aged 15–69 [2]. The reported annual incidence rate of LBP in Iran stands at 65%, affecting both males and females equally [3]. Studies have shown that the prevalence of LBP in Iranian men is approximately 27–28%, and varies depending on the type of population studied. Proper control and management of these forces are crucial for injury prevention and optimal performance [4]. Plantar variables, including foot pressure distribution and arch height, significantly affect individuals with LBP. Altered pressure patterns often arise as compensatory mechanisms to relieve discomfort but can lead to abnormal gait and increased strain on the lumbar spine [4]. Addressing these factors is essential for effective management of LBP [5, 6]. LBP is one of the disorders that disrupts the mechanical function of walking and alters ground reaction forces [5].

Studies have shown that the foot pressure pattern in individuals with LBP differs during standing and walking compared to healthy individuals, suggesting the presence of compensatory mechanisms to prevent pain [5]. The continuous activation of pain receptors in chronic LBP leads to changes in the cortical and subcortical regions of the brain [7]. This condition leads to disturbances in sensory and motor nerves, as well as changes in the neurochemical processes involved in the central nervous system's response to pain [7]. Moreover, the presence of chronic LBP in affected individuals causes changes in the deep sensory receptors of the spinal column, which can send inadequate and inaccurate messages about body position [8]. Consequently, this results in impaired muscle activation and reduced neuromuscular control, ultimately leading to altered movement patterns and disruption in the absorption of ground reaction forces, causing a general imbalance in both static and dynamic stability in these patients [9]. As a result, the foot pressure pattern in individuals suffering from LBP becomes disrupted [10]. During hydrotherapy (HT) sessions, changes in weight and load on the spine can be facilitated by changing the immersion level in water, allowing for an earlier start compared to dry land exercises [10]. HT for LBP initiates treatment interventions sooner than pain-free and dry land methods [11]. People with initiates exhibit changes in their motor control, characterized by a reduced range of motion of the pelvis, increased ground reaction force, and differences in walking speed and step length; thus, LBP significantly impacts walking ability [12]. Abnormal muscle recruitment and reduced neuromuscular control lead to spinal proprioception deficits [13]. Finally, this mechanism increases the loading speed and reaction force of the earth and decreases the absorption capacity [14]. Water offers more resistance compared to air because of its higher viscosity. This increased resistance can enhance sensory feedback and awareness, leading to improved stability for individuals [10]. Thus, HT is an active therapeutic method for improving balance because the unique properties of water reduce pressure on the spine, increase spinal stability, and aid in performing physical activities without pain [15]. Incorporating motion-based therapy into open/closed kinetic chain (O/CKC) exercises can improve spinal management for optimal trunk function [16].

HT, a therapeutic approach that involves exercises performed in water, has a significant impact on the kinetics of gait [17]. The characteristics of water, including buoyancy and resistance, create a distinctive environment conducive to enhancing gait mechanics and efficiency [17]. By reducing the impact on joints and providing support, HT allows individuals to practice walking patterns with less pain and stress on the body [18]. The resistance of water also helps strengthen the muscles involved in gait, leading to better control and coordination during walking [16]. In addition, multidirectional resistance in water can challenge balance and stability, further enhancing the overall quality of gait [19]. Incorporating HT into gait training can help individuals improve their walking abilities, increase muscle strength, and enhance overall mobility [18].

HT significantly influences kinetics in rehabilitation and movement therapy [20]. The unique properties of water, such as buoyancy and resistance, create an environment that can enhance the effectiveness of kinetic exercises [20]. By using water resistance, individuals can engage in controlled and stable movements, which can lead to improved muscle activation and coordination throughout the kinetic chain [21]. Additionally, the reduced impact on joints in water allows for smoother and more fluid movements, promoting proper alignment and biomechanics [21]. Incorporating HT into kinetic training can optimize muscle recruitment, movement efficiency, and overall functional performance, making it a valuable tool for improving movement patterns and enhancing physical rehabilitation outcomes [22]. Most studies that have been conducted on the use of kinetic chain exercises have focused on their effects on knee and hip joints on land or in water [22]. However, there has been limited research on the impact of these exercises on people with chronic LBP in water. The effects of these workouts on individuals with persistent back pain in the water have not been studied. Thus, the purpose of this research was to assess the effect of O/CKC exercises in water on plantar pressure variables, pain, and disability in males suffering from non-specific chronic LBP (NSCLBP).

Materials and methods

Study design

This double-blind, randomized controlled trial with a pre-post-test design assessed males with NSCLBP. In blocks 4 and 6, the randomized codes were produced using Random Allocation software, version 1.0. Allocation concealment was ensured through the use of sealed envelopes that were sequentially numbered. An unbiased researcher, not involved in data collection, opened and sequentially distributed these envelopes to patients. The patients were randomly assigned to three groups: Control (20 patients), closed kinetic chain exercises (CKCE) (20 patients), and open kinetic chain exercises (OKCE) (20patients). Patients were kept blind to their group assignment during the study, and they were instructed to keep their group assignment concealed from the assessors. Participants received detailed instructions about the research goals and methods before the study. Consent was given voluntarily by all participants and/or their legal guardians in compliance with the Helsinki Declaration [23].

Sample size

The sample size was determined using G*Power software, version 3.1 considering a power of 0.8, a significance level of 0.5, and an effect size of 0.8 [17].

Recruitment and participants

Sixty male patients aged 40 to 60 years (mean age, 48.1±5.97), all approved by a neurosurgeon, participated in this randomized controlled trial. For eight weeks, the experimental groups underwent kinetic chain exercises three times weekly. The control group received no intervention (Figure 1). The inclusion criteria were a history of discomfort lasting more than 12 weeks, an age range of 40 to 60 years, and the absence of any prior hip or spine surgery. Exclusion criteria included pain in other areas, participation in therapeutic exercises, sciatic pain, lower and upper limb deformities, the use of physiotherapy within the last year, spondylolysis, neuromuscular disorders, and respiratory problems [24].

Intervention

HT intervention

Following the evaluation of the previously mentioned parameters, an eight-week HT program was initiated. This program included three sessions per week, each lasting 60 minutes, and was conducted by a skilled aquatic sports therapist. Each session began with a 5-minute warm-up, followed by 50 minutes of motor chain exercises, and concluded with a 5-minute cool-down. At Bu-Ali Sina University in Hamadan, a specialist guided the OKCE group through noodle-assisted aquatic therapy in the deep end of the swimming pool, supervised by four lifeguards. Earlier research suggested that the exercise programs for these groups included increases in volume, intensity, duration, and repetition rates (Table 1). Prior to the assessments, participants engaged in a 6-minute warm-up, consisting of 3 minutes of general warm-up activities and 3 minutes of stretching exercises. The foot pressing model, FDMeS, from Zebris Co., Germany, was used to measure gait variables, and the Win FDM-S stance software, version 01.02.09 was utilized for data analysis. The subjects were instructed to stand and then walk normally over a pressure distribution device [25]. They were asked to take one step in the middle of the device, and the data were recorded. The subjects were required to follow the path while walking in a regular pattern. The criteria examined included the total stance time (contact time), the maximum number of vertical forces of the first, depth, and second components, and the time required to reach these components (Figure 2) [26, 27]. After collecting data from the plantar pressure device, the components of the ground reaction force were normalized by dividing the body weight of the individuals. The results were then expressed as a multiplier of the body weight. These variables were calculated using the average data obtained from three successful walking iterations. The normalized ground reaction force components provided valuable insights into the distribution of pressure and weight during walking, allowing for a more in-depth analysis of gait patterns and potential areas of improvement [28] (Table 2).

Outcome measures

Plantar pressure variables

For the evaluation of plantar pressure, we utilized a Zebris plantar pressure device (intraclass correlation coefficient [ICC]=0.91). The patient stood barefoot with their eyes open on the designated area of the platform, ensuring that both feet were positioned correctly. The feet and ankles were maintained in a neutral position, with the patient's hands positioned alongside the trunk. To reduce disturbances to the vestibular system and avoid head movements, the patient was instructed to concentrate on a 10 cm diameter marker located on the wall, 2 meters away. Each test was performed three times within a 30-second duration, allowing for a 2-minute rest interval between each trial. The plantar pressure data were evaluated using Win FDM-S software, version 01-02-09 (Figure 2), [29-31].

Pain

Pain evaluation was carried out using a 10-centimeter visual analog scale (VAS). This scale is utilized to gauge how individuals perceive pain, with participants indicating their pain intensity by marking a point within the scale's prescribed range. In the current study, individuals with pain scores above four were included [32, 33].

Disability

The oswestry disability index (DOI), consisting of ten items with six subcategories each, was used to assess disability. The disability levels were categorized as lower (scores of 25), moderate (scores of 25-50), severe (scores of 50-75), and acute (scores of 75-100) [34].

Tampa scale for kinesiophobia (TSK)

The TSK was employed to evaluate the fear of movement during both the pre-test and post-test assessments. This questionnaire includes 11 items, with participants directed to answer each item based on their genuine feelings. Responses are rated using a four-point Likert scale, where a score of one is assigned to "I strongly disagree," and a score of four is given to "I strongly agree" [28].

Statistical analysis

We evaluated the homogeneity of variance using the Levene test and assessed the normal distribution of the data with the Shapiro-Wilk test. Before performing a two-way repeated measures ANOVA to examine the effect of the intervention on plantar pressure variables, pain, and disability, these exploratory tests were carried out. In the one-way ANOVA, the effect size of the group×time interaction was assessed using the partial eta squared (η^2_p) measure. Our analysis was carried out with a significance threshold of $P<0.05$, and group differences were assessed using the analysis of covariance (ANCOVA) [34]. Data analysis was performed using SPSS software, version 26.

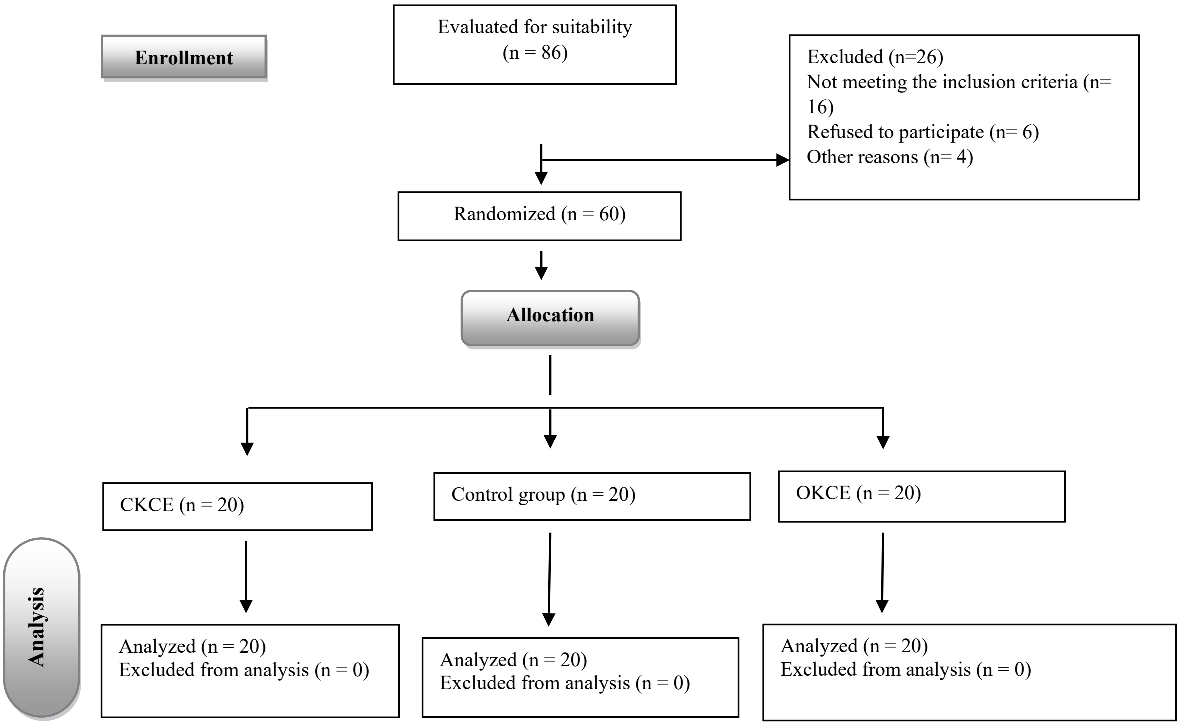

Figure 1. The CONSORT flow diagram of the study

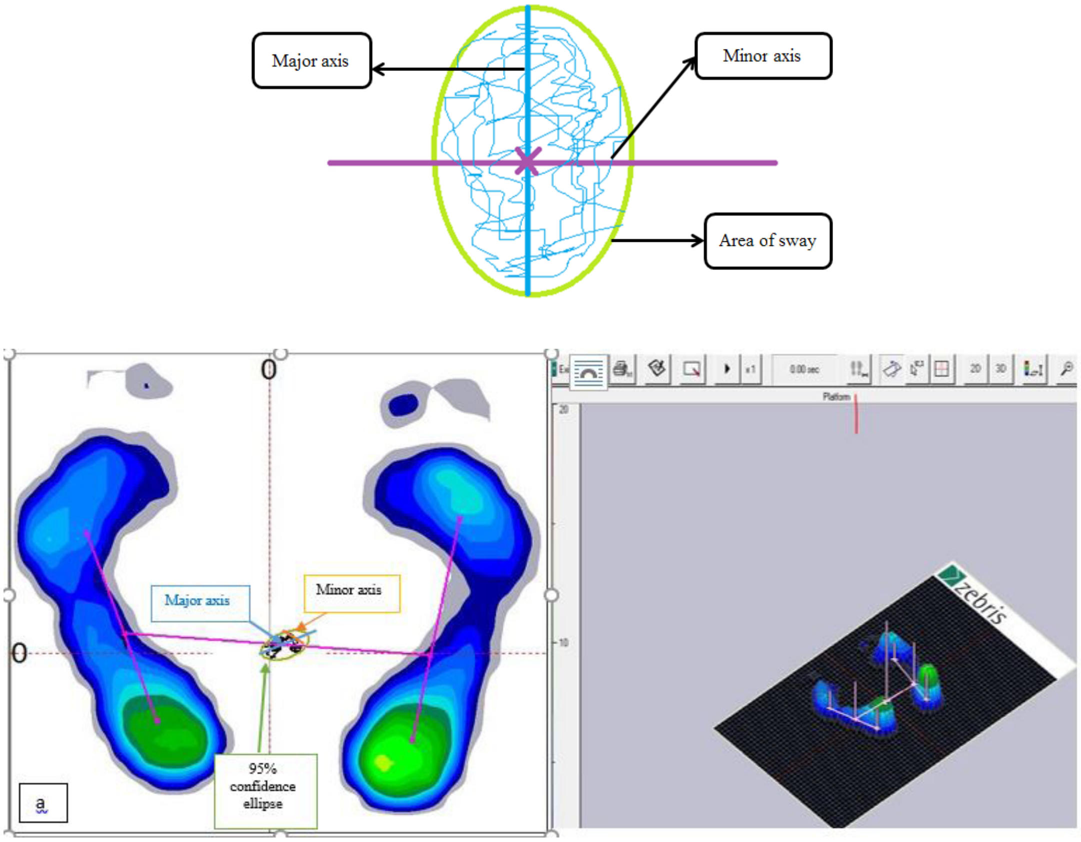

Figure 2. COP sway, the 95% confidence ellipse, and the average force distribution along with the 95% confidence ellipse

Table 1. Exercise program for CKCE

Duration, Repetition, and Time	Content
Familiarization with the process of entering the aquatic facility (including flooring and changing areas), along with an introduction to the pertinent rules, regulations, and the indoor aquatic environment, will be conducted for a duration of 10 minutes.	
Warm-up 3 min	Participants will engage in forward and backward walking, including lateral steps to both the right and left, while performing arm movements that adhere to the principles of coordination in the shallow area of the pool. This involves moving back and forth and stepping sideways while coordinating arm movements in the shallow section of the pool.
Each stretch of 15 seconds in two repetitions	Stretching protocols will be administered to target the primary muscle groups of the human body, with particular emphasis on the hamstrings, iliopsoas, piriformis, and quadratus lumborum.
5 Min	An assessment of respiratory patterns, along with training in optimal breathing techniques, will be conducted.
10s×3	Exercises designed to activate the transverse abdominal muscles and multifidus may be executed from a semi-squat position while maintaining contact with the pool wall, with the feet resting on the pool floor. Exercises designed to activate the transverse abdominal muscles and multifidus may be executed from a semi-squat position while maintaining contact with the pool wall, with the feet resting on the pool floor.
3×12 m	Progressing forward while extending the knee.
3×12 m	Ambulating in reverse with elongated strides.
3×12 m	Lateral ambulation with extended steps.
10s×3	Assuming a single-leg stance with a straight knee, incorporating flexion and extension of the thigh.
Cooling down (5 min) Stretching exercises aimed at the upper and lower body musculature and continued ambulation within the shallow region of the pool.	

PHYSICAL TREATMENTS

Results

Demographic details, including age, height, weight, and BMI (P>0.05) are included in Table 3. Age, weight, height, and BMI did not differ statistically significantly across the groups (P>0.05).

Pain and disability

There was a significant difference (P<0.05) in the participants' levels of pain, disability, and Kinesiophobia between the CKCE and OKCE groups, according to the statistical analysis utilizing paired t-tests. The scores of

Table 2. Exercise program for OKCE

Duration, Repetition, and Time	Content
Familiarization with the procedures for entering the aquatic facility (including flooring and changing room protocols), along with an introduction to the established rules, regulations, and the controlled indoor environment of the pool for 10 minutes.	
Warm-up 3 min	Walking back and forth while moving arms from side to side in the shallow part of the pool.
Each stretch lasts 15 seconds and is performed for two repetitions	Implementation of stretching protocols specifically designed to target the primary muscle groups of the human body, with a distinct focus on the hamstrings, iliopsoas, piriformis, and quadratus lumborum.
5 min	Assessment of respiratory patterns, coupled with training and the correct application of breathing techniques utilizing aquatic noodles in the deeper section of the pool.
10s×3	Engaging in exercises incorporating the use of noodles, adopting a semi-squat posture, and leaning against the pool wall in the deeper zone, which can effectively stimulate the transverse abdominal muscles and multifidus.
3×12 m	Flexion and extension of the thighs with a straight knee while utilizing noodles in the deeper section of the pool.
3×12 m	Reverse racing motions (analogous to cycling) employing noodles in the deeper area of the pool.
3×12 m	Adduction and abduction of the legs with a straight knee using noodles in the deeper section of the pool.
10s×3	Noodles are positioned floating in the deep thigh region for flexion and extension.
Cooling phase (5 min) Execution of stretching exercises targeting both the upper and lower muscle groups of the body, combined with ambulation in the shallower section of the pool.	

PHYSICAL TREATMENTS

Table 3. Demographic characteristics of the participants (n=60)

Variables	Mean±SD			F	P
	CKCE Group (n=0)	OKCE Group (n=20)	Control Group (n=20)		
Age (y)	46.1±6.06	47.806±5.43	46.1±6.06	2.791	0.070
Height (cm)	174.98±6.47	172.12±8.34	174.98±6.47	3.93	0.065
Weight (kg)	78.7±11.61	84.83±10.21	78.7±11.61	0.176	0.839
BMI (kg/m²)	28.32±11.4726	28.24±3.46	28.32±11.4726	1.61	0.208

CKCE: Closed kinetic chain exercise; OKCE: Open kinetic chain exercise; BMI: Body mass index. PHYSICAL TREATMENTS

the control group were not substantially different before and after the intervention (P>0.05) (Table 4). Additionally, the ANOVA results revealed significant reductions in disability (F2=9.138, P=0.001, η^2=0.253), pain (F2=112.386, P=0.001, η^2=0.801), and kinesiophobia (F2=110.700, P=0.001, η^2=0.798) scores among the experimental groups, indicating a large effect size (Table 5).

Plantar pressure variables

The results of ANCOVA showed that the experimental groups had a significant difference in the plantar pressure variables, including the length of the minor axis (mm) (F2=6.015, P=0.004, η^2=0.207), length of the major axis (mm) (F2=12.178, P=0.001, η^2=0.303), sway area (mm²) (F2=6.52, P=0.001, η^2=0.340), the path length of sway (mm) (F2=6.52, P=0.048, η^2=0.129), sway velocity (mm/s) (F2=9.893, P=0.001, η^2=0.261), standard deviation on the x-axis (mm) (F2=9.21, P=0.001, η^2=0.248), and standard deviation on the y-axis (mm) (F2=18.599, P=0.001, η^2=0.399) (Table 5).

Discussion

This double-blind randomized controlled trial assessed the effect of O/CKC exercises in water on plantar pressure variables, pain, and disability in men with chronic LBP. Our findings revealed a significant improvement in plantar pressure variables within the experimental groups compared to the control group. As a result, our initial hypothesis was confirmed. Previous research has indicated that people who suffer from LBP may experience motor disorders in other parts of their body while performing motor tasks [35]. For example, LBP can reduce the intensity of muscle activity in the lower extremities during walking and standing and can also decrease the ground reaction force rate of loading [36, 37]. The observed effects highlight potential differences in movement patterns among individuals with LBP during standing, particularly concerning their lower extremities, compared to those without such pain. This may increase the risk of lower extremity injuries [38, 39]. Several studies have shown that the lack of coordination in the lumbar region, especially during sudden movements, can result in musculoskeletal injury. To better understand spinal movement patterns and the relationship between kinetic and kinematic changes in individuals with chronic LBP, postural compensatory strategies can be used [17, 39]. As a result, it is conceivable that people with LBP improve their control of movements by walking more slowly and carefully, allowing for greater safety when facing deviations [18].

Studies investigating the standing pattern of patients with NSCLBP have shown an increase in the activity of the vertebral column straightener muscle and a decrease in the reverse rotation between the pelvis, back, and thoracic spine [28]. Furthermore, in contrast to those without pain, those with LBP often increase their stride rate rather than their stride length when instructed to walk faster [40]. The findings of this study support previous research by Delitto et al. [37], Alaca et al. [38], Pires et al. [39], Yalfani et al. [17], and Khojastehpour et al. [40], which suggests that a stable spine can lead to better body mechanics while standing, particularly for individuals who experience back pain. When the hip, knee, and ankle joints deviate from their normal positions, it can cause an uneven distribution of force and impair everyday functioning in the body [37-40, 17]. Weakness or improper muscle function can cause instability, leading to excessive pressure on the joint and further irritation [35]. On the other hand, in patients with NSCLBP, plantar pressure distribution is higher in the forefoot than in the hindfoot [39]. In general, patients with NSCLBP often use ankle strategies for postural control. Consequently, the ankle strategy increased the center of pressure deflection forward, thereby increasing the load on the forefoot [18].

Table 4. The results of paired-samples t-test regarding standing on both feet

Variables	Group	Mean±SD		P
		Pre-test	Post-test	
Pain	Control	6.3±0.978	6.5±1	0.214
	CKCE	6.5±1.46	2.07±1.23	0.001*
	OKCE	5.95±0.6	1.65±1.22	0.001*
Disability	Control	49.3±10.9	49±59.9	0.982
	CKCE	43.1±10.06	29.1±9.51	0.001*
	OKCE	49.3±10.9	31.5±7.84	0.001*
Kinsiophobia	Control	28.45±3.61	28.3±4.15	0.905
	CKCE	28.3±3.67	17.1±3.85	0.001*
	OKCE	29.65±3.61	15.75±2.29	0.001*
Length of minor axis (mm)	Control	8.86±2.18	8±1.77	0.162
	CKCE	7.57±1.62	9.95±2.96	0.002*
	OKCE	9.32±5	11.39±5.24	0.001*
Length of major axis (mm)	Control	7.57±1.62	9.95±2.96	0.135
	CKCE	14.08±4.44	15.87±7.44	0.001*
	OKCE	18.98±13.5	10.24±3.25	0.001*
Sway area (mm^2)	Control	96.4317±64.26	109.12±53.95	0.833
	CKCE	99.76±51.04	96.31±48.28	0.004*
	OKCE	124.85±188.5	43.376±21.25	0.001*
Path length of sway (mm)	Control	153.51±46.99	152.29±48.18	0.329
	CKCE	168.99±84.99	119.51±58.7	0.025*
	OKCE	195.22±101.66	104.63±55.88	0.002*
Sway velocity (mm/s)	Control	10.33±5.1	10.06±5.4	0.329
	CKCE	10.94±5.54	17.86±4.04	0.014*
	OKCE	13.62±6.82	8.54±3.1	0.003*
SD on x-axis (mm)	Control	9.25±4.03	9.2±4.9	0.924
	CKCE	9.64±5.62	5.08±4.53	0.001*
	OKCE	9.57±5.10	5.6±4.3	0.001*
SD on y-axis (mm)	Control	16.52±10.72	15.01±9.81	0.329
	CKCE	21.07±9.18	11.14±7.84	0.001*
	OKCE	19.22±15.36	6.62±5.08	0.001*

PHYSICAL TREATMENTS

CKCE: Closed kinetic chain exercise; OKCE: Open kinetic chain exercise.

*Significant difference between groups (P<0.05).

Table 5. ANCOVA results for outcome measurement

Variables	F	DF	Men Squares	Sum of Squares	Power	η^2_p	P
PAIN	112.386	2	132.386	264.013	1	0.801	0.001*
Disability	31.581	2	1643.122	3286.244	1	0.53	0.001*
Kinsiophobia	110.700	2	32.658	65.317	1	0.798	0.001*
Length of minor axis (mm)	6.015	2	57.253	114.556	0.874	0.207	0.004*
Length of major axis (mm)	12.178	2	270.47	540.94	0.994	0.303	0.001*
Sway area (mm^2)	6.52	2	17760.557	35521.113	0.893	0.189	0.003*
Path length of sway (mm)	6.52	2	17760.557	35521.113	0.893	0.129	0.048*
Sway velocity (mm/s)	9.893	2	100.764	201.529	0.979	0.261	0.001*
SD on x-axis (mm)	9.21	2	109.062	218.123	0.97	0.248	0.001*
SD on y-axis (mm)	18.599	2	669.112	1338.225	1	0.399	0.001*

*Significant difference between groups (P<0.05).

PHYSICAL TREATMENTS

In the domains of pain and disability index, the experimental group showed a notable improvement compared to the control group. According to Monticone et al. [41], Tavakoli et al. [42], and Yalfani et al. [17], significant improvements were observed in pain levels and disability index in patients with chronic LBP who underwent exercise. The aforementioned studies showed that exercise improves disability, and reduces pain in patients with chronic LBP, which is consistent with our findings [41, 42, 17]. Research has indicated that NSCLBP is linked to dysfunction and weakness in the abdominal muscles, along with alterations in walking variables [40]. For example, Carayannopoulos et al. stated that therapeutic exercises in water led to a significant reduction in pain and disability and a significant improvement in walking parameters in the experimental group. HT is a helpful form of treatment for patients with chronic LBP and can help alleviate muscle tension, reduce pain, and relieve stiffness in the back [14]. Additionally, the buoyancy of the water can help reduce pressure on the joints and spine, allowing patients to perform exercises that may be difficult or painful on land [24]. Many patients find relief and improved mobility through regular HT sessions [43]. In this regard, Baena et al. concluded that the aquatic environment itself helps relieve pain, increase blood flow, and block pain receptors, in addition to removing stimulants and creating the possibility for the stimulation and secretion of endorphins, all of which are mechanisms of pain reduction in people with back pain [29]. It is clear that the severity of pain determines disability in these patients; therefore, it can be concluded that along with the reduction of pain, disability is also reduced [15]. In addition, Khojastehpour et al. and Cuesta-Vargas et al. showed that practicing in a water environment led to a significant reduction in pain in people with CLBP, which reduced the severity of their disability [40, 43].

Maintaining pelvic and lumbar stability is essential for balancing forces in the vertebrae, pelvis, and motor chains, ultimately enabling proper limb movement [40]. Weakness or improper muscle function can cause instability, leading to excessive pressure on the joints and further irritation [40]. Proper control and absorption of these forces during physical activities are particularly crucial for injury prevention [44]. The formula for the rate of load indicates that an increase in Earth's reaction force peak also results in a corresponding increase in the rate of load [29]. The groups that participated in both O/CKC exercises in water showed an improvement in neuromuscular control in the lumbar and pelvic areas. This improvement helps distribute forces to the lower limbs, thus reducing the pressure on the lumbar and lower limbs, and ultimately reducing the ground reaction force and load levels in these individuals. Consequently, as HT exercises serve to improve limb movement control and lessen the strain on the lower limbs and vertical reaction force, they can be a useful therapeutic choice for people with chronic LBP. These exercises can aid in the recovery process for individuals with chronic LBP by potentially decreasing the reaction force and load during walking. However, the study had some limitations that future researchers should consider. The initial statistical sample solely comprised male individuals experiencing nonspecific chronic LBP. Second, the study solely focused on the effects of kinetic chain exercise programs on vertical component of ground reaction force (VGRF) and rate of loading in NSCLBP, neglecting other variables related to walking in this condition. Finally, there was a lack of long-term follow-up in the study.

Conclusion

The results highlight the significant effects of HT for men with chronic LBP. The plantar pressure variables can be efficiently changed by both O/CKC exercises in water. Moreover, HT can manage pain and disability in this specific group of individuals. Given these outcomes, it is recommended that healthcare professionals, including physicians, physiotherapists, and occupational therapists, incorporate both closed and open kinetic chain exercises into HT for chronic LBP patients.

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.1402.011), which complies with the 2008 Helsinki Declaration's tenets. The informed consent of the patients was obtained prior to any data collection. Moreover, this study was registered by the Iranian Registry of Clinical Trials (IRCT), Tehran, Iran (Code: IRCT20190129042534N1).

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Authors' contributions

Each author contributed equally to the preparation of this paper.

Conflict of interest

The authors declared no conflict of interest.

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